The Effects of Kinesio Taping on Biomechanical and Clinical Outcomes in Runners with and without Iliotibial Band Syndrome

by

Pongchai Watcharakhueankhan

A thesis submitted in partial fulfilment for the requirements for the degreeof Doctor of Philosophy at the University of Central Lancashire

January 2023

STUDENT DECLARATION

Type of Award Doctor of Philosophy

School Sport and Health Sciences

I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the University or other academic or professional institution.

I declare that no material contained in the thesis has been used in any other submission for an academic award and is solely my own work.

No proof-reading service was used in the compilation of this thesis.

Signature of Candidate: P. Watcharakhueankhan

Print name: Pongchai Watcharakhueankhan

ACKNOWLEDGEMENTS

The success of this PhD journey could not be completed without the extensive support and assistance from many individuals.

First of all, I would like to express my sincere gratitude and deepest appreciation to Professor Jim Richards, my major advisor, who was my inspiration during almost 4 years, always kindly supporting and supervising me with excellent guidance, invaluable advice, offering encouragement and all problems solving throughout the study, and taught me how to be a good researcher. I also would like to thank Dr. Graham Chapman, my second supervisor, for his valuable suggestions, kind support, excellent constructive comments, who taught me a critical thinking process and how to be a professional researcher, and helping and encouraging me throughout this journey. Aforementioned gratefulness also widely to the Allied Health Research Unit team at UCLan, Jessie, Lauren, and Ambreen, and my PhD friends for their support and friendship.

My expression of thanks also extends to you; Dr. Prasert, Dr. Sunee, Dr. Komsak, Dr. Tossaphon, Dr. Weerawat, Dr. Wattana, Dr. Chutima, my friends, senior and junior colleagues and staff in the Faculty of Physical Therapy, Mahidol University for their encouragement, great suggestions, cheerfulness and kind support. Moreover, my special thankfulness and deepest appreciation are extended to all my research participants both in the UK and Thailand for their excellent cooperation. Additionally, my sincere thanks are also extended to the Faculty of Physical Therapy, Mahidol University and my sponsorships; Ministry of Science and Technology, Thailand for financial support throughout the PhD study.

Finally, special thanks are delivered to my family, especially my wife and mother. During the PhD journey, there were several periods that I found very stressful and I could not have completed this work without them. Thank you for your love, warmest encouragement and understanding, especially during those periods when we were far apart from each other. And I wish this PhD award to be the best thing that represents my thankfulness to all of them.

ABSTRACT

Iliotibial band syndrome (ITBS) is a common repetitive injury in long-distance runners. Symptoms can lead to significant pain, functional impairment, and inability to participate in sporting activities such as running. Kinesio Taping (KT) is frequently used in the management of lower limb injuries and has been shown to improve pain, function, and running performance. However, the details of such effects remain unclear, with various hypothesised effects including; limiting the range of motion, improvements in strength and joint stability, and facilitation of muscle activity. Evidence suggests that Kinesio tape with tension (KTT) can improve abnormal biomechanics, change lower limb muscle activity and decrease pain compared to no tape or sham tape conditions and has been proposed as a potential treatment for ITBS. To date, no study has evaluated the effects of KT in runners with ITBS. Therefore, the purpose of this thesis was to investigate the effects of the application of KT on the biomechanics of running and clinical outcomes in runners with and without ITBS.

Initially the immediate effects of KT on kinematic, kinetic and EMG parameters in the lower limb; along with perceived comfort, stability of the knee joint, and running performance were recorded in 20 UK healthy participants (10 males and 10 females) and 20 Thai healthy participants (10 males and 10 females), aged between 18 and 45 years. Three conditions were tested; No Tape (NT) followed by a randomised order for Kinesio Tape with Tension (KTT), and Kinesio tape with No Tension (KTNT). The KTT consisted of three taping techniques; inhibition, space correction, and functional correction, which were applied over the ITB covering the TFL, at the lateral epicondyle of the femur, and over the thigh, respectively. The KTNT condition consisted of the same three layers of KT as in the KTT condition and was applied without tension with the participant positioned in a neutral lower limb position. Comparisons of peak hip, knee angles and moments, and EMG were analysed during the stance phase of running. The results from the healthy studies showed that this KT technique appeared to increase peak hip external rotation in both the UK and Thai healthy cohorts. Additionally, there was a decrease in peak hip internal rotation angle in the Thai healthy participants, and there was a trend towards a decrease in peak hip adduction and internal rotation angle in the UK healthy participants. Furthermore, TFL activity showed a decrease with KTT

compared with NT, and Gmax activity reduced with KTNT when compared with NT in the UK healthy participants. Whereas the Thai healthy participants showed Gmax activity decreased with KTNT compared with NT, and there was a trend toward a decrease in TFL activity in the KTT condition compared to the NT condition. These results suggest that a significant change in biomechanics of running and muscle activity can be achieved with the application of KT, with the greatest effect seen with the application of KT with tension, with no participants reporting any negative important changes in comfort and perception of stability of the knee joint, although two individuals in the KTT condition reported a clinically important negative change on running performance in the UK participants, with one in the KTT indicating a clinically important negative effect on comfort and running performance.

The last study was a randomised controlled trial that was conducted on 40 Thai participants with ITBS (20 in KTT group and 20 in KTNT group). The peak hip, knee angles and moments, EMG, hip abductor and external rotator muscle strength, and TFL muscle and iliotibial band (ITB) length were measured at pre-tape and immediate-post tape. Clinical outcome measures; Numerical Pain Rating scale (NPRS), Knee Injury and Osteoarthritis Outcome Score (KOOS), Tampa Scale for Kinesiophobia (TSK), Global Rating of Change (GROC), perceived comfort, stability of the knee joint, and running performance were measured across 7 days. Significant increases were seen in peak hip external rotation in the KTT group, with a significant decrease in average TFL muscle activity, but no main effect for group was seen. In addition, KTT group demonstrated significantly decreased peak knee external rotation moments compared to KTNT group immediate post-taping, with no significant differences between groups was seen for pre-tape. Moreover, there was a significant increase for TFL and ITB length in both KTT and KTNT groups and a decrease in the average Gmax, Gmed, and VM muscle activity. Furthermore, a significant decrease for peak Gmed muscle activity was seen in females in both groups. Participants in the KTT group reported improvements in NPRS, all domains of KOOS, GROC, and also no participant reported any negative important changes in perceive comfort, stability of the knee joint, and running performance after using KT, but no significant effects were seen for TSK.

This work provides new insights and data to support the use of KT to change running biomechanics previously associated with ITBS, with the greatest effect seen with the application of KT with tension, with important improvements in all clinical outcome measures except TSK. However, the majority of the changes were small when considering the variability in the biomechanical and EMG measurements, suggesting that there was little difference between the KTT and KTNT interventions. The clinical implications should be interpreted carefully along with the clinician's experience and expertise. Further work is required to explore the longer-term effects on the biomechanical and clinical outcome measures using KT with and without tension in the management of ITBS.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
ADL	Activities of Daily Living
ASIS	Anterior Superior Iliac Spine
C3D	Document format specific to C-Motion (Visual 3-D)
CAST	Calibrated Anatomical System Technique
EMG	Electromyography
Gmax	Gluteus Maximus
Gmed	Gluteus Medius
GROC	Global Rating Of Change
HDD	Hand-Held Dynamometer
ICC	Intraclass Correlation Coefficient
ITB	Iliotibial Band
ITBS	Iliotibial Band Syndrome
KOOS	Knee Injury and Osteoarthritis Outcome Score
KT	Kinesio Tape
KTNT	Kinesio Tape with no Tension
KTT	Kinesio Tape with Tension
LFE	Lateral Femoral Epicondyle
LSD	Least Significant Difference
MCIC	Minimal Clinical Important Change
MCID	Minimum Clinical Important Difference
MCL	Medial Collateral Ligament
MCT	McConnell Taping
MT	Mulligan Taping
NPRS	Numeric Pain Rating Scale
NT	No tape
PAR-Q+	Physical Activity of Readiness Questionnaire
PFP	Patellofemoral Pain
PSIS	Posterior Superior Iliac Spine
RCT	Randomised Control Trial

RM ANOVA	Repeated Measures Analysis of Variance
ROM	Range of Motion
SDC	Smallest Detectable Change
sEMG	Surface Electromyography
SLS	Single-Leg Squat
TFL	Tensor Fascia Latae
TSK	Tampa Scale for Kinesiophobia
VAS	Visual Analogue Scale
VL	Vastus Lateralis
VM	Vastus Medialis

CHAPTER 1 INTRODUCTION

Iliotibial band syndrome (ITBS) is a common repetitive injury in long-distance runners (Taunton et al., 2002b). Epidemiological studies have reported that incidence ranges from 1.6% to 12% of all lateral knee symptoms in runners (Lavine, 2010, Ellis et al., 2007, Messier et al., 1995). The recent systematic review of running-related musculoskeletal injuries in runners reported that incidence ranges from 3.4% to 15.7%, and the prevalence ranges from 2.2% to 17.4% of all symptoms in runners (Kakouris et al., 2021). Persistent symptoms, slow healing, and a high rate of recurrence makes ITBS a frustrating injury for runners, doctors, physiotherapists, and clinicians. In addition, these injuries may lead to significant pain, functional impairment, and time-off running participation (Beals and Flanigan, 2013).

The two theories which potentially explain the mechanisms of ITBS are friction and compression. The friction theory considers that the iliotibial band (ITB) glides over the lateral femoral epicondyle (LFE) during the first 25 degrees to 30 degrees of knee flexion causing irritation of the ITB or its bursa at foot strike and during the early stance phase of running (Orchard et al., 1996). The friction of the ITB is caused while moving into knee flexion and extension in the impingement zone coupled with internal rotation movement of the tibia. The compression theory considers the cause of pain through ITB inflammation associated with compression of the adipose tissue located between the ITB and distal femur just proximal to the LFE as the knee internally rotates during knee flexion, caused through the entheseal traction and repeated compression of the neurovascular rich, periepicondylar fatty tissue (Fairclough et al., 2006). During initial loading in stance phase, the knee increases its movement from extension to flexion. Compression of the ITB causes an impingement against the LFE at 30 degrees of knee flexion (Fairclough et al., 2006, Ekman et al., 1994). The knee is flexed to approximately 21 degrees during initial contact (Swanson and Caldwell, 2000), the ITB is located anteriorly to the LFE, and the ankle is supinated. During early midstance and throughout loading response, the ankle is in a pronated position, the tibia rotates internally, the knee joint flexes to 30 degrees, and the ITB translates posteriorly to the LFE. From early midstance and continuing into terminal stance phase the ankle then resupinates, the

tibia rotates externally and the knee re-extends (Levangie and Norkin, 2011). An abnormally high tension of the ITB could be the contributing factor in the high compression between the ITB and the LFE, which appears to be associated with the development of ITBS (Fairclough et al., 2006, Ekman et al., 1994).

There are many factors that influence the development of ITBS. The major extrinsic risks of ITBS may include worn out running shoes, training program errors, running at a too higher pace or high weekly mileage, and running on an uneven or slippery surface (van Poppel et al., 2021). Intrinsic risk factors can also influence the ability to absorb ground reaction forces, therefore placing more stress on the knee joint including movement into knee varum, rearfoot and forefoot varum, and pes cavus or high arch. Moreover, a prominent LFE, tightness of the ITB and tensor fascia latae (TFL), and weakness of the gluteus medius (Gmed) (Baker and Fredericson, 2016, Fredericson et al., 2000) and hip external rotators (Noehren et al., 2014). Inadequate warm-up before practice or play have also been suggested as intrinsic risks. Furthermore, in runners with tightness and weakness in the knee extensors, an excessive lateral tracking of the patella and decreased deceleration forces during flexion may occur, which could lead to increased stress on the lateral stabilizing structures of the knee joint (Messier et al., 1995, Worp and Maarten, 2012, Baker and Fredericson, 2016). Previous research has shown that runners with ITBS demonstrated abnormal running biomechanics with increased hip and knee internal rotation and adduction compared to healthy participants (Noehren et al., 2007, Noehren et al., 2014).

Various treatments have been suggested for ITBS including; manual adjustments to the ankle and foot, patella alignment, massage therapy or foam roller for myofascial release, use of ultrasound and electrical muscle stimulation to restore normal muscle tone and decrease inflammation. Moreover, strength training for the Gmed, gluteus maximus (Gmax) and quadriceps, as well as stretching the hamstrings, quadriceps, adductors, ITB, and external rotators of the thigh have also been suggested (Strauss et al., 2011, Menetrey and Fritschy, 1999, Kvist and Jarvinen, 1982). In addition, changing running shoes every 300-500 miles of use is recommended (Barber and Sutker, 1992), and an increase in training volume should not be increased by more than 10% per week (Buist

et al., 2008). Despite this, runners with ITBS still suffer from chronic severe pain and face a long rehabilitation time which can affect the career of professional athletes, and no clear guidelines exist for the management of ITBS.

Kinesio Taping (KT) is a common treatment technique in physical therapy and rehabilitation, which was developed in Japan by Kase and has become increasingly popular for use in musculoskeletal problems (Zhang et al., 2019, Campolo et al., 2013, Mackay et al., 2020). Although, the therapeutic effects of KT are still not clear, it is hypothesised that the therapeutic effects of KT include; reduced local edema, improvements in blood circulation by facilitating muscle activity, providing a sensory stimulus to the skin, muscle, or fascial structures, and limiting the range of motion of the affected tissues (Kase et al., 2003). It is claimed that the elastic nature of KT can generate stretch and recoil of the skin and superficial tissues during movement, resulting in mechanical deformation and stimulation of low-threshold mechanoreceptors in the skin, fascia, Golgi tendon organs and skeletal muscle spindles (Della Croce et al., 2005, Lim and Tay, 2015, Williams et al., 2012, Montalvo et al., 2014, Mostafavifar et al., 2012). In addition, it is claimed that the activation of mechanoreceptor peripheral afferents with low thresholds when using KT results in the inhibition of nociceptive transmission through pain gate control theory (D'Mello and Dickenson, 2008). Previous studies have demonstrated that Kinesio Tape with tension (KTT) can alter abnormal biomechanics and decrease pain through the stimulation of the mechanoreceptors within the skin compared to no tape or sham tape conditions (Kakar et al., 2020, Mackay et al., 2020, Song et al., 2015, Song et al., 2017). Therefore, there is potential that KTT may help the associated abnormal ITBS biomechanics by increasing the hip external rotation and abduction, decreasing hip internal rotation or adduction, decreasing knee internal rotation movement, and decreasing TFL muscle activity during the stance phase of running, which may be associated with improvements in clinical outcome measures.

Kinesio Taping is a common technique and has been proposed for the management of ITBS, and has been purported to work through a combination of muscle inhibition, mechanical correction through the use of tension within the tape, and space correction which is defined as increasing the space between the skin and muscle (Kase et al., 2003).

It has been suggested that this may enable runners with ITBS to keep running after applying KT. However, scientific evidence to support these statements is limited. A systematic review of KT indicated that KT was more effective compared to active or sham taping, while the differences were small and may not be clinically important, furthermore many of the trials were of low quality (Parreira Pdo et al., 2014). To date, no study has evaluated the effects of KT in runners with ITBS. Therefore, the purpose of this thesis is to investigate the effects of the application of KT on running biomechanics in healthy runners and biomechanical and clinical outcomes in runners with ITBS.

1.1 Thesis structure

The thesis consists of seven chapters.

Chapter 1 – Introduction

This provides a brief description of ITBS, which is followed by an overview of the epidemiology of ITBS, factors influencing the development of ITBS, the treatment and management of individuals with ITBS using KT, and highlights how the current thesis will contribute to knowledge in this field.

Chapter 2 – Literature review

This review presents literature concerning; the anatomy and function of the ITB and muscles associated with the ITB, epidemiology of ITBS, mechanisms of injury, risk factors, and clinical assessment. In addition, the current management strategies used for individuals with ITBS including taping and the mechanisms of taping will be considered. The biomechanical measurements and clinical outcome measures for the management of individuals with ITBS used in this thesis conclude this chapter. The aims, objectives and hypotheses of this thesis are then covered.

Chapter 3 – General methods

This chapter presents information regarding the instrumentation and general methods used across the different studies in this thesis. This includes calibration protocols, equipment specifications and sampling frequencies, biomechanical models, EMG

protocols, taping methods, running biomechanics tests, and data processing techniques. Justification for the selection of the subjective feedback questionnaires; perceived comfort, stability of the knee joint, and running performance assessments are also provided.

Chapter 4 – The immediate effects of kinesio taping on running biomechanics, muscle activity, and perceived changes in comfort, stability and running performance in UK healthy runners

This chapter explores the effect of KTT and KTNT on lower limb running biomechanics, lower limb muscle activity and perceived comfort, stability and running performance compared to no tape in UK healthy participants.

Chapter 5 – The immediate effects of kinesio taping on running biomechanics, muscle activity, and perceived changes in comfort, stability and running performance in Thai healthy runners

This chapter explores the effect of KTT and KTNT on lower limb running biomechanics, lower limb muscle activity and perceived comfort, stability and running performance compared to no tape in Thai healthy participants.

Chapter 6 – The effects of kinesio taping on running biomechanics, muscle activity, and clinical outcome measures in runners with iliotibial band syndrome: a randomised controlled trial

This chapter reports a randomised controlled trial (RCT) which investigated the short-term effect of KT in Thai runners with ITBS in a group of receiving KTT and a group receiving KTNT, emphasising the biomechanical and clinical effects of KTT and KTNT in individuals with ITBS, and comparisons between the two groups.

Chapter 7 – Synthesis and conclusion

This chapter provides the general discussion and clinical implication, highlights the contributions to knowledge, as well as the limitations and recommendations for future research, and final conclusions.

CHAPTER 2 Literature Review

2.1 Iliotibial band syndrome

2.1.1 Anatomy and function of the Iliotibial band

The Iliotibial band (ITB) or iliotibial tract is a lateral fascia which is formed by the tensor fascia latae (TFL) and gluteus maximus (Gmax) muscles. Its origin is at the iliac crest and continues downward to the lateral side of the thigh passing over the lateral femoral epicondyle (LFE), and inserts at the Gerdy's tubercle on the anterolateral aspect of the tibia, as illustrated in Figure 2-1 (Joshua, 2005, Baker and Fredericson, 2016). There are two regions of ITB that are identifiable; a proximal 'tendinous' part and over the LFE and a 'ligamentous' part between the LFE and Gerdy's tubercle. The superficial aspect of the ITB attaches to the fascia of the vastus lateralis (VL) muscle, linking the intermuscular septum to the linea aspera on the posterolateral aspect of the femur (Joshua, 2005). The other attachments of the ITB include the biceps femoris muscle, lateral patellar retinaculum, the patella through the epicondylopatellar ligament, the patellar retinaculum (iliopatella band), and the patellar tendon which help the lateral stabilization of the knee joint (Kaplan, 1958, Fairclough et al., 2006). The iliopatella band connects the anterior aspect of the ITB and femur to the lateral side of the patella, with the function being to decelerate the medial glide of the patella as the knee flexes (Terry et al., 1986). Additionally, there are bursa that is fluid sac located between the ITB and greater trochanter, and between the ITB and LFE. The bursa's function is to decrease and prevent friction between the ITB and greater trochanter, and between the ITB and LFE. There is a layer of adipose tissue between the tendon and the insertion area which consist of fat, blood vessels, nerves, and Pacinian corpuscles (Fairclough et al., 2006).

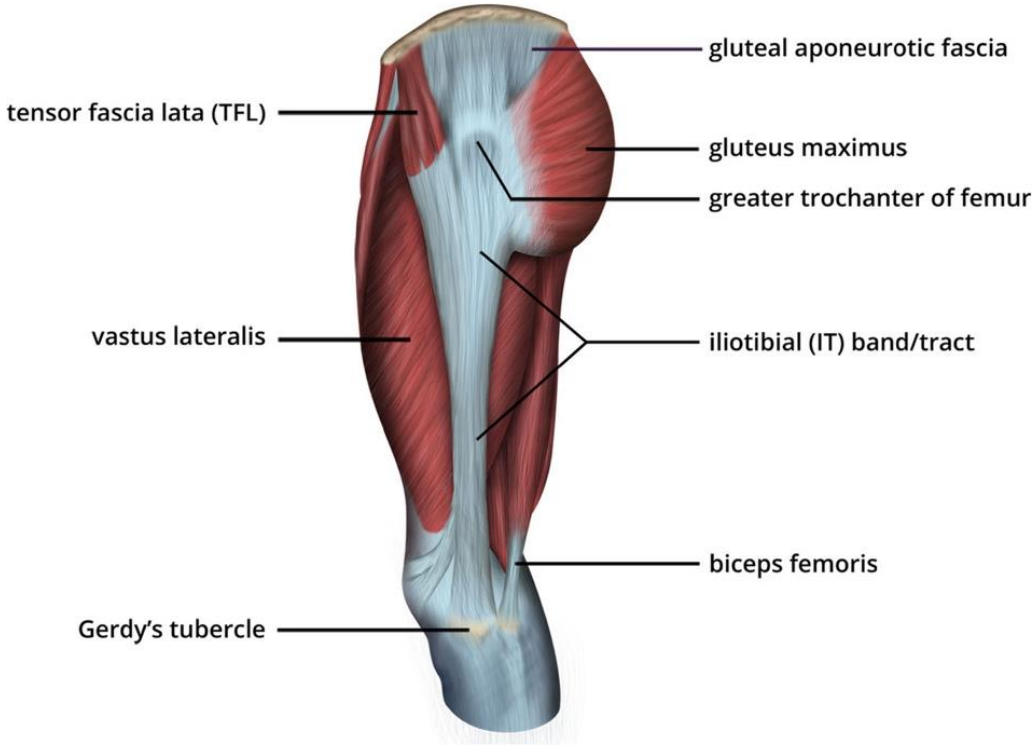


Figure 2-1 The lateral view of the thigh demonstrating the ITB and important adjacent landmarks (Flato et al., 2017).

There are three muscles of importance associated with the ITB which can be seen in Figure 2-1. Firstly, the Gmax, the largest muscle of the gluteal muscles which is a quadrangular shape. The origin of this muscle is the crest of the ilium, the posterior surface of the lower part of the sacrum, the base of the spine, and the coccyx, the aponeurosis of the erector spinae (lumbodorsal fascia), the sacrotuberous ligament, and the fascia covering the gluteus medius (gluteal aponeurosis). The main function of Gmax is hip extension but also stabilizes the knee and hip joints via the ITB (Richard et al., 2009, Agur et al., 2017). Secondly, the TFL, which is a lateral thigh muscle with an origin at the external surface of the iliac crest from the anterior superior iliac spine to the tuberculum of iliac crest, inserts into the ITB and runs inferior to attach at the tibia. The TFL muscle helps to stabilise the knee in extension, and abducts and rotates the hip joint internally (Richard et al., 2009, Agur et al., 2017). The relationship of Gmax and TFL is at the proximal part of the ITB, which provides an insertion for the Gmax in the posterior portion and TFL in the anterior portion which acts as a lateral hip stabiliser by resisting hip adduction (Joshua, 2005, Strauss et al., 2011). Finally, the gluteus medius (Gmed), is one of three gluteal muscles which originates from the outer surface of both

the anterior and posterior gluteal lines of the ilium and attaches to the lateral surface of the greater trochanter of the femur. Although, Gmed does has no connection to the ITB, the main function is to abduct and externally rotate the hip which acts as a main hip stabiliser (Richard et al., 2009, Agur et al., 2017). The distal part of the ITB acts as a stabiliser for the lateral aspect of the knee joint and attaches to both the distal femur and the proximal tibia (Terry et al., 1986). Moreover, when the knee flexes less than 30 degrees, the ITB also functions as a knee extensor, but at angles greater than 30 degrees of flexion it works as a knee flexor, and as the knee increases into flexion the ITB moves more posteriorly to the lateral femoral epicondyle that can help to resist tibia internal rotation (Strauss et al., 2011, Amis, 2017). In addition, the ITB helps stability and resists the large knee abduction moments (Hamill et al., 2008), and overuse such as long-distance running or cycling can trigger ITB injuries.

2.1.2 Epidemiology

Iliotibial band syndrome (ITBS) is one of the most common overuse injuries in long-distance runners, commonly presenting as pain on the lateral side of the knee (Taunton et al., 2002a, van der Worp et al., 2012). Similarly, ITBS can be seen in cyclists and has been reported to account for 15% to 24% of all overuse injuries in cyclists (Farrell et al., 2003, Holmes et al., 1993), and is also commonly reported in athletes participating in field hockey, tennis, soccer, rowing, skiing, and triathlons (Messier et al., 1995, Tuite, 2010, Lavine, 2010, Rumball et al., 2005, Devan et al., 2004). The reported incidence of ITBS ranges from 1.6% to 12% of lateral knee symptoms in runners (Ellis et al., 2007, Messier et al., 1995, Lavine, 2010) and 22.2% of all injuries of the lower extremity (Fredericson et al., 2000). Kakouris et al. (2021) reported that incidence of ITBS ranges from 3.4% to 15.7%, and the prevalence ranges from 2.2% to 17.4% of all symptoms in runners in a systematic review of running-related musculoskeletal injuries.

Many studies have explored the prevalence of ITBS and associated running injuries. Noehren et al. (2007) reported an ITBS incidence rate of 16% from 400 runners over four years in the University of Delaware community. Taunton et al. (2002a) reported 63 cases of ITBS in 926 males and 105 cases in 1,076 females, indicating a prevalence of 6.8% in

males and 9.8% in females. This showed a higher incidence of ITBS compared with previous reported data from the Allan McGavin Sports Medicine Centre, with 4.3% reported in 1981 (Clement et al., 1981), 7.5% in 1991 (Macintyre et al., 1991) and 8.4% in 2000. Furthermore, Tenforde et al. (2011) surveyed 442 female and 306 male high school athletes aged 13 to 18 years old and reported a prevalence of ITBS of 7% in females and 5% in males. From these data on the incidence and prevalence of ITBS, this can be considered a common lower limb injury especially in runners. In order to provide the most appropriate management and treatment for individuals with ITBS, a greater understanding of the potential mechanisms of injury is required.

2.1.3 Mechanisms of injury

The mechanisms of ITBS injury are important for its prevention and management. There are two contrasting theories which potentially explain the mechanisms of ITBS which involve the compression and friction of the impingement at around 30 degrees of knee flexion. The friction theory is a traditional concept and it was believed that the ITB glides over the LFE during the first 25 degrees to 30 degrees of knee flexion causing irritation of the ITB or its bursa during repetitive activities such as cycling or running (Orchard et al., 1996, Fredericson and Wolf, 2005, Bonaldi et al., 1998). Orchard et al. (1996) described an impingement zone as an area of friction on the ITB and LFE that occurs at 30 degrees of knee flexion, or slightly below, at foot strike and during the early stance phase of running. The friction of the ITB is caused while moving into knee flexion and extension in the impingement zone coupled with the internal rotation of the tibia and an increase in the tension of the VL, bicep femoris, TFL and iliotibial tract. During this period, the TFL and Gmax muscles work eccentrically causing the leg to decelerate, generating tension in the ITB. If the tension in the Gmax or TFL increase, this will cause an increase in tension in the ITB and cause friction between the ITB and the LFE (Orchard et al., 1996, Kirk et al., 2000). Figure 2-2 presents a representation of the friction and impingement model of ITBS.

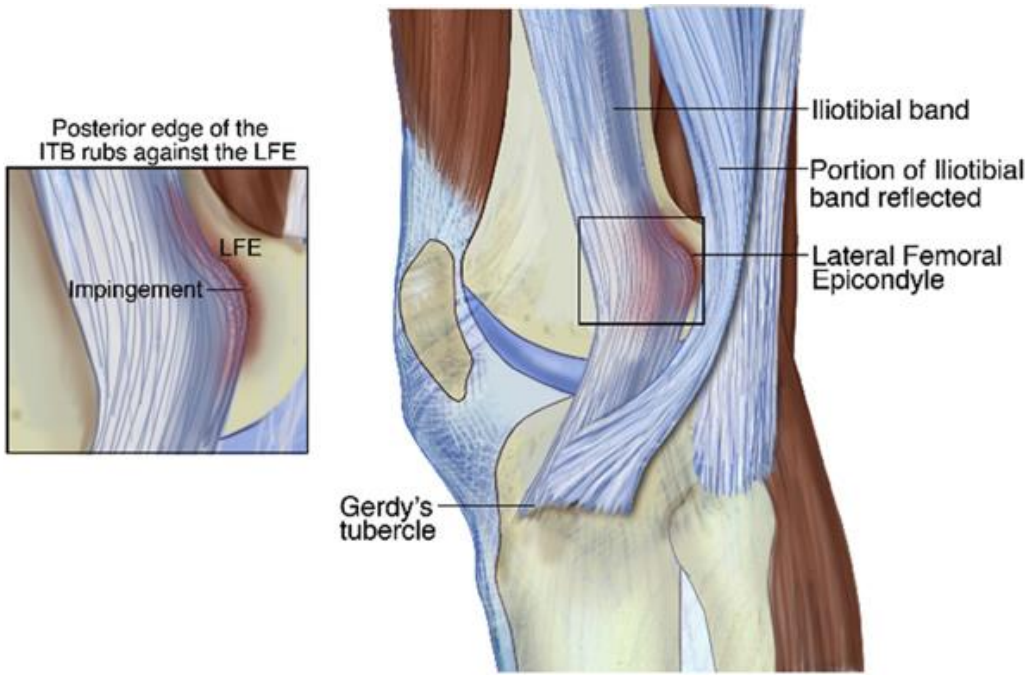


Figure 2-2 Friction and impingement model. ITB, iliotibial band; LFE, lateral femoral epicondyle (Baker and Fredericson, 2016).

In contrast to the compression model, Fairclough et al. (2006) hypothesised that friction is not the cause of ITBS as the ITB insertion is deeply and strongly into the LFE. Fairclough and colleagues highlighted that ITBS occurs at 30 degrees of knee flexion through a compression mechanism, suggesting that the cause of pain and inflammation of ITBS is from the compression of the adipose tissue onto the LFE as the knee internally rotates during knee flexion. Therefore, ITB may be more likely to be associated with the compression of the fat pad and Pacinian corpuscle onto the ITB, rather than through repetitive friction as the knee flexes and extends. Therefore, Fairclough and colleagues concluded that ITBS is not a friction syndrome, but it is a result of entheseal traction and repeated compression of the neurovascular rich, periepicondylar fatty tissue located between the ITB and distal femur just proximal to the LFE. Figure 2-3 presents the enthesopathy and compression model of ITBS.

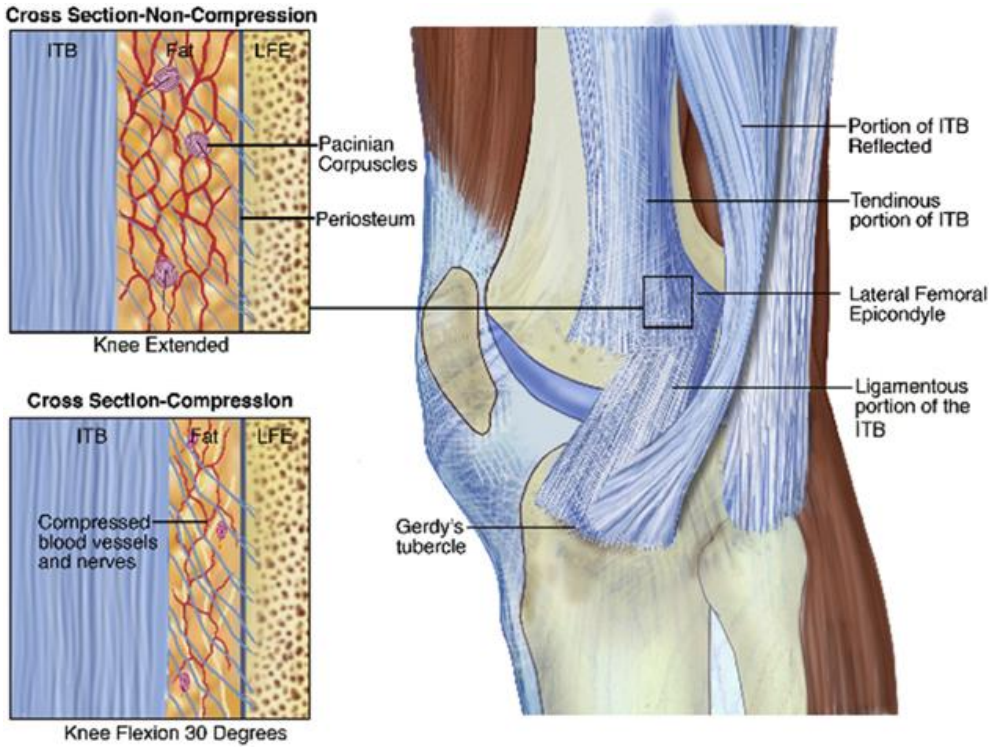


Figure 2-3 Enthesopathy and compression model. ITB, iliotibial band; LFE, lateral femoral epicondyle (Baker and Fredericson, 2016).

Jelsing et al. (2013) suggested that there is an overlap between the two theories. They studied the ITB movement relative to the LFE as a function of knee flexion in both non-weight-bearing and weight-bearing positions using sonographic evaluation in five male and 15 female asymptomatic recreational runners. They measured the distance between the anterior fibres of the ITB and the LFE in full extension, 30° of knee flexion, and 45° of knee flexion. The measurements were investigated on both knees in the supine (non-weight-bearing) and standing (weight-bearing) positions. The results of this study revealed the anteroposterior motion of the ITB relative to the LFE during knee flexion and extension from 0° to 30° and 45° of knee flexion. Although these findings showed that the posterior fibres of the ITB movement were difficult to analyse because of stronger blending into the fascia, Jelsing and colleagues stated that by 30° of knee flexion, the posterior ITB moved over the LFE in a posterior direction. As a result, during knee flexion, the posterior free edge of the ITB comes into contact with and passes over the LFE. These findings support the study by Orchard et al. (1996), who demonstrated that the posterior fibres was seen to be anterior to the lateral condyle of the femur in full knee extension in six out of 11 cadaver knees. Therefore, both Orchard et al. (1996)

and Jelsing et al. (2013) support the concept of a friction and impingement zone, and the unique posterior fibre attributes of the ITBS.

2.1.4 Risk Factors

Risk factors provide runners and therapists with precautions to raise awareness which aim to reduce the chances of developing ITBS. There are many influencing factors that have been suggested to be associated with the development of ITBS which include both intrinsic and extrinsic risk factors (Baker et al., 2011).

2.1.4.1 Intrinsic risk factors

Anatomy or alignment of the lower extremity is one intrinsic risk factor that needs to be considered. Malalignment of the knee, ankle or foot can trigger the symptoms of ITBS as these can all change the tension within the ITB. The presence of genu varum, excessive internal rotation of the tibia, rearfoot and forefoot varum, pes cavus or high arch, prominence of the LFE have all been highlighted as having a possible association with ITBS (Joshua, 2005, Noble, 1980, Ferber et al., 2010b, Noehren et al., 2007). Taunton et al. (2002a) studied a retrospective case-control analysis of 2002 running injuries and reported differences in lower limb alignment in 164 individuals with ITBS including; 33% of cases presenting with varus knee alignment, 15% of cases showing valgus knee alignment, 15% of cases showing pes planus, 7.3% of cases showing pes cavus, and 10.4% of cases showing a large leg length discrepancy. McNicol et al. (1981) studied 52 athletes with ITBS and found that 55% had mild-to-severe knee varus, and 8% had mild knee valgus, 90.4% had functional overpronation and 13% had leg-length discrepancies. The increased foot pronation or rearfoot eversion may increase tibial internal rotation which in turn may elongate and increase the tension in the ITB. This is in contrast with Messier et al. (1995) who showed that there was no significant difference in leg-length between ITBS and a control group. Everhart et al. (2019) studied the relationship between LFE morphology and ITBS in 75 ITBS cases and 75 matched controls using knee magnetic resonance imaging. They found that the height of the LFE in ITBS cases was significantly higher than the control group suggesting a higher LFE could increase the tissue compression of the posterior ITB over the LFE. Jelsing et al.

(2014) used sonography in 12 unembalmed cadaver knees after injecting saline solution to create an effusion, then monitored below the ITB at the LFE at 0 degrees, 25 degrees, and 45 degrees of knee flexion. All knees demonstrated fluid deep and anterior to the ITB in both knee flexion and extension. They concluded that a lateral synovial recess extending deep to the ITB insertion maybe a source of lateral knee pain syndromes, including ITBS.

Based on the anatomy, the tightness of Gmax, quadriceps, ITB and lateral retinaculum may contribute to abnormal and excessive tensioning of the ITB (Stecco et al., 2013). This unusual tension of the ITB may be related to hypertonicity of the Gmax muscle and an increased activation of the TFL and Gmax muscle (Stecco et al., 2013), and rapid rate of loading of the ITB (Hamill et al., 2008, Meardon et al., 2012). However, the tightness within the TFL muscle or ITB was the most common issue found in individuals with ITBS (Joshua, 2005, Falvey et al., 2010, Baker and Fredericson, 2016). The TFL tightness is one of the primary risk factors of ITBS as it attaches to the ITB (Baker et al., 2011, Richard et al., 2009). Miller et al. (2007) reported that runners with ITBS had a tighter ITB than control runners using the Ober's test. This finding was similar to Noehren et al. (2014) who showed a reduced ITB length in a ITBS group compared to a control group. In addition, Foch et al. (2015) found that there was a decrease in the ITB flexibility in runners currently suffering from ITBS compared to runners previously suffering from ITBS when compared with healthy controls.

The tightness in the TFL can increase the tension in the ITB that could be a contributing factor of the high compression against the LFE, which could lead to the development of ITBS (Fairclough et al., 2006). The tightness in the TFL, which attaches to the ITB, can result in changes to running biomechanics. The TFL has several functions including hip abduction, flexion and internal rotation (Richard et al., 2009). Tightness in the TFL can cause hip internal rotation, which is a commonly reported presentation in runners with ITBS (Baker and Fredericson, 2016). This is supported by Noehren et al. (2014) who reported that runners with ITBS had significantly greater hip internal rotation during early stance. They suggested that this may be due to various factors such as tightness in the TFL, weakness in the hip abductors, or altered neuromuscular control. The

reductions in the tightness of the TFL may help to improve the symptoms of ITBS by improving hip muscle control. However further work is required to investigate if different interventions can reduce TFL tightness, improve flexibility and symptoms in runners with ITBS.

Muscle weakness, especially hip abductor muscle weakness or Gmed weakness is one of the main risk factors of ITBS (Fredericson et al., 2000, Noehren et al., 2007). Fredericson et al. (2000) stated that the strength in the hip abductors in the affected leg was lower when compared with their unaffected leg in runners with ITBS. Moreover, Foch et al. (2015) compared the isometric hip abductor strength between an ITBS group and healthy control group and found significantly weaker hip adductors in runners previously suffering from ITBS compared to runners currently suffering from ITBS and healthy controls. Furthermore, a systematic review found a relationship between hip abductor strength and injury in long-distance runners, and demonstrated that hip abductor muscle weakness is common among runners with ITBS (Mucha et al., 2017). Moreover, if hip abductor weakness is present, it can result in changes in running biomechanics in individuals with ITBS (Baker et al., 2011). In addition, previous studies have reported weakness in the external rotators in runners with ITBS which can increase the load on the ITB (Noehren et al., 2014). Baker and Fredericson (2016) suggested that the hip abductor or external rotator weakness may lead to an increased hip adduction and internal rotation angle during the stance phase of running, and lead to an increased valgus force at the knee thus increasing the strain of the ITB and compressing the tissues beneath.

Runners who have developed ITBS have been reported to have an increased hip adduction angle and knee internal rotation, and may therefore have an increased compression force from the ITB on the LFE (Noehren et al., 2007). Noehren et al. (2007) compared the lower extremity kinematics and kinetics of female runners who had developed ITBS to healthy runners. They reported that female runners who develop ITBS had a greater hip adduction angle compared to healthy runners. However, Brown et al. (2019) indicated that ITBS runners showed a decrease in the Gmed muscle activity at initial median frequency values (an indicator of fatigue resistance) suggestive of fatigue,

but muscle onset activation timing did not differ between ITBS and control groups for the Gmed muscle. They stated that there was no gross strength impairments of the Gmed muscle in female runners with ITBS, but did demonstrate a lower resistance to fatigue. The increase muscle strength or endurance in the hip abductor or Gmed may help to improve the symptoms of ITBS. However further work is required to investigate if different interventions can increase hip abductor or external rotator strength, and improve the symptoms in runners with ITBS.

Sex differences is one of the intrinsic risk factors that should be considered as differences in the skeletal alignment of the lower limb exists between the two sexes, which may lead to variations in gait patterns. For healthy runners, previous studies studying sex differences in running biomechanics have reported that there was a difference in running biomechanics between healthy male and female runners (Ferber et al., 2003, Nigg et al., 2012). No significant differences have been reported in the sagittal plane kinematics for the hip, knee, and ankle between healthy male and female runners (Ferber et al., 2003, Chumanov et al., 2008, Nigg et al., 2012, Sakaguchi et al., 2014). However, several studies have reported greater frontal and transverse plane kinematics for the hip and knee angles in female compared with male runners (Chumanov et al., 2008, Ferber et al., 2003, Sakaguchi et al., 2014, Nigg et al., 2012). Ferber et al. (2003) demonstrated that female recreational runners exhibited a significantly greater peak hip adduction, hip internal rotation and knee abduction angle compared to male runners. This is supported by Chumanov et al. (2008) who showed that females presented greater peak hip internal rotation and adduction angle during stance of running compared to males. Nigg et al. (2012) reported that healthy female runners have a greater hip and knee adduction in the stance phase when compared to healthy male runners. Similarly, Sakaguchi et al. (2014) reported that female runners demonstrated significantly greater peak knee abduction, hip adduction and internal rotation angles.

When considering the clinical implication of increased range of motion (ROM) of females compared to males, it may be plausible to prescribe different levels of intervention for females compared to males. Females may require greater KT tension in order to increase

the stimulation of the mechanoreceptors, enhancing proprioception in order to alter their abnormal running mechanics. However, care must be taken as an excessive increase in KT tension may cause skin irritation. To the author's knowledge, no research has examined specific interventions for male and female runners with ITBS and as a result, future research may want to examine the effect of altering KT tension in males and females to determine any differential effect on lower limb running mechanics.

When considering the differences in joint moments between sexes in healthy runners, Ferber et al. (2003) demonstrated that female runners were slightly greater hip flexion and produced a great hip extension moment but showed similar knee joint moment in sagittal plane, and there was a similar in the frontal and transverse planes for hip and knee joint moments in female runners compared to male runners. In contrast, Vannatta and Kernozek (2021) showed that males produced reduced peak hip abduction and external rotation moments than females while there was no difference in hip extension moment between male and female runners. In addition, Sinclair and Selfe (2015) indicated that females showed significantly greater peak knee extension and abduction moments compared to males during running.

There are only a limited number of studies that examined sex differences and muscle activities between healthy male and female runners. Previous studies showed that healthy female runners have a greater Gmax muscle activity during the stance phase compared to healthy male runners, but no differences were seen in Gmed muscle activity between sexes (Chumanov et al., 2008, Willson et al., 2012).

When considering individuals with ITBS, many of the previous studies investigated ITBS in females (Noehren et al., 2007, Ferber et al., 2010b, Foch and Milner, 2013) or mixed-sex runners (Grau et al., 2011), even though 50% to 81% of the ITBS population are male runners (van der Worp et al., 2012). There was only one study demonstrated sex differences in ITBS. Phinyomark et al. (2015) studied the differences between males and females in gait kinematics in runners with ITBS, and between healthy runners compared with their ITBS counterparts. In addition, the result of this study showed that female ITBS runners exhibited significantly greater hip external rotation compared with male

ITBS and female healthy runners. However, there is still a lack of information on the differences in biomechanical presentation between male and female runners with ITBS. This highlights the importance of considering sex differences when exploring the differences between healthy individuals and those with ITBS.

Biomechanical risk factors during running have been reported, including proximal, distal and local factors with respect to location of ITBS pain. Proximally, the ITB acts as a hip stabilizer on the lateral side resisting hip adduction (Fredericson et al., 2000). Because of the ITB's attachment to the pelvis and femur, increased hip adduction angles have been proposed as an aetiologic factor for ITBS as it could potentially lead to increased strain in the ITB (Ferber et al., 2010a, Ferber et al., 2010b, Noehren et al., 2007). Some studies have explored the relationship between dynamic alignment in the lower extremities and ITBS (Foch and Milner, 2013, Shen et al., 2021). Shen et al. (2021) studied the effects of running biomechanics on the occurrence of ITBS in male runners during an eight-week running programme. They found that the ITBS group showed greater anterior pelvic tilt and hip flexion angle than the control group. They indicated that ITBS might be related to the lack of timely gait adjustment, excessive trunk inclination, and anterior pelvic tilt angle. The increased anterior pelvic tilt angle may be due to the hip flexor musculature tightness, such as iliopsoas and TFL, or the surrounding anterior hip capsular and ligamentous structures (Schache et al., 2000). Foch and Milner (2013) studied the frontal plane running biomechanics of 17 female runners with previous ITBS, and 17 healthy control participants. The result showed that runners with previous ITBS exhibited similar peak trunk lateral flexion, peak contralateral pelvic drop, peak hip adduction, and peak external knee adduction moment compared with controls. They indicated that frontal plane pelvis and trunk motion may not be associated with ITBS.

Local factors associated with ITBS include an impingement zone between 20-30 degrees of knee flexion which may cause a compression between the LFE and the ITB (Orchard et al., 1996). However, Orchard et al. (1996) reported that there were no differences in knee flexion at foot strike or peak knee flexion on the affected side in individuals with ITBS compared to the unaffected leg. In addition, Noehren et al. (2007) showed no

differences in knee flexion/extension patterns in runners who had ITBS compared to healthy controls. This would suggest that the cause of pain and discomfort associated with ITBS is unlikely to be due to differences in sagittal plane biomechanics. With attachments of ITB at the LFE and the Gerdy's tubercle, the ITB is likely strained with an increase in internal rotation of the knee. The strain of the ITB may contribute to the development of ITBS (Fredericson et al., 2000, Baker and Fredericson, 2016, Aderem and Louw, 2015). This was supported by Noehren et al. (2006) who showed that runners who have a history of ITBS had a significantly higher knee internal rotation compared to a healthy control group. The combination of greater knee internal rotation angle and an associated high external rotation moment could place greater demands on the ITB which could contribute to ITBS.

It is also important to consider distal factors, including ankle and foot biomechanics, which may contribute to the presentation of ITBS. The increase in rearfoot eversion may be a risk factor of ITBS as this produces an increase in tibia internal rotation, and consequently places an excessive tensile force on the ITB, which has been shown to be a contributing factor in ITBS (Ferber et al., 2010b). In addition, the excessive internal rotation of tibia was explained in the linkage between the occurrence of ITB injury and in-toeing during stance phase (Reischl et al., 1999). However, a systematic review did not contain any prospective studies that demonstrated differences in rearfoot eversion angles between healthy matched controls and runners with ITBS (Louw and Deary, 2014). Miller et al. (2007) demonstrated that runners with ITBS during a run to fatigue test showed a greater rearfoot inversion angle at heel strike compared to a healthy control group. In addition, Grau et al. (2008b) found that individuals with ITBS had a reduced inversion angle at heel strike compared to a healthy control group, however there was no significant difference in peak rearfoot eversion between the ITBS and the control group. In 2006, Noehren et al showed that runners with a history of ITBS had reduced peak rearfoot eversion, although this is in contrast to the findings of Messier et al. (1995) who showed no significant difference in rearfoot mechanics while running between runners with a history of ITBS and healthy controls. In addition, Noehren and colleagues (2007) reported that the rearfoot eversion was similar between a healthy and

ITBS group. These contrasting findings highlight that the link between the distal mechanisms and ITBS is still unclear and needs further study.

The proximal, local, and distal biomechanical risk factors during running are important considerations in ITBS, however, there are many research studies which have considered the biomechanics in runners with ITBS, which have mostly highlighted the importance of the frontal and transverse plane biomechanics (Noehren et al., 2007, Ferber et al., 2010b, Miller et al., 2007, Orchard et al., 1996). Orchard et al. (1996) stated that the mechanics in the coronal and transverse planes may show a greater number of biomechanical risk factors related to ITBS compared to the sagittal plane. In addition, when considering the running phase of study, some studies state that we should study the full gait cycle as understanding the movement in swing phase (Foch and Milner, 2013, Shen et al., 2021), although pain associated with ITBS often occurs in the stance-phase of running, hence the majority of ITBS research only studied the stance-phase, especially the deceleration phase (Noehren et al., 2007, Ferber et al., 2010b, Foch et al., 2015).

There are many studies that have reported on the biomechanics of ITBS. Noehren et al. (2007) hypothesised that ITBS runners would reveal an increase in the peak hip adduction, knee internal rotation, rearfoot eversion angle, but would not show any differences in knee flexion at heel strike. Moreover, the ITBS group were predicted to have greater hip abduction, knee external rotation, and rearfoot inversion moments. A total of 400 participants were recruited over a period of four years, of whom 18 developed ITBS. The results showed that those who developed ITBS revealed significantly greater hip adduction and knee internal rotation compared to the control group. However, they presented similar rearfoot eversion and knee flexion angles, and no differences in joint moments were seen when compared with the control group. This supports the hypotheses that frontal and transverse plane kinematics play an important role, and appear to be a risk factor contributing to the presentation of ITBS in female runners, particularly greater hip adduction and knee internal rotation angle. Similarly, Ferber et al. (2010b) studied competitive female runners with a history of ITBS. They investigated 35 females, who had a past history of ITBS and 35 females, matched for age

and running distance, with no previous knee-related musculoskeletal injuries as the control group. The results showed atypical hip and knee kinematics, evidenced by significant increases in the peak hip adduction and peak knee internal rotation angles, and greater rearfoot invertor moments in the stance phase in the ITBS group compared to the control group. Miller et al. (2007) examined eight runners with a history of ITBS compared to eight control participants during an exhaustive run. The result of this study demonstrated that runners with ITBS showed greater internal rotation of the tibia, and a greater knee flexion angle at heel strike, with participants with ITBS reporting an average of 43.8 degrees compared with 36.5 degrees in the control group. This indicated that the sagittal plane as well as the frontal and transverse planes may be important in the presentation of ITBS. Additionally, the result showed a greater foot inversion angle with 3.3 degrees seen in the participants with ITBS and -9.5 degrees in the control group, and a maximum knee internal rotation velocity of 16.4 degrees/s in the participants with ITBS compared with 10.3 degrees/s in the control group. Grau et al. (2011) reported the kinematics in a group of 18 participants with ITBS and 18 participants in a healthy control group. They indicated that runners with ITBS demonstrated significantly lower hip adduction and frontal hip ROM than the control group. Noehren et al. (2014) studied runners with ITBS compared to the control healthy group. They found that runners with ITBS had a significantly greater hip internal rotation and greater knee adduction angle compared to the control group. Foch et al. (2015) examined the associations between ITB injury status and running biomechanics by determining the lower extremity and trunk biomechanics during running in 27 female runners who were currently suffering from ITBS, previously suffering from ITBS, and a control group. They found a significant increase in the trunk ipsilateral flexion in runners currently suffering from ITBS compared to runners previously suffering from ITBS and healthy controls. Additionally, they stated that participants currently suffering from ITBS may lean forward more at the trunk in the stance limb which may be related to a decline in flexibility within the iliotibial band. Hamill et al. (2008) analysed the mechanical strain in the ITB as a possible causative factor in the progression of ITBS. The magnitude strain of ITB, ITB strain rate, and duration of impingement was calculated using a model for the lower extremity. Hamill and colleagues found that there was a significant increase in the strain rate in the ITBS group compared to the control group, which was also higher in the affected leg of

the ITBS group compared to the unaffected leg. However, there were no significant differences in strain magnitudes and in the duration of impingement between the ITBS and control groups.

In summary, there are many intrinsic risk factors that can contribute to ITBS including anatomy or alignment of lower extremity, sex differences, muscle tightness, muscle weakness, biomechanics of running. Figure 2-4 presents the summary diagram of intrinsic risk factors of ITBS in runners. However, there are extrinsic risk factors that can contribute runners to ITBS that should be considered.

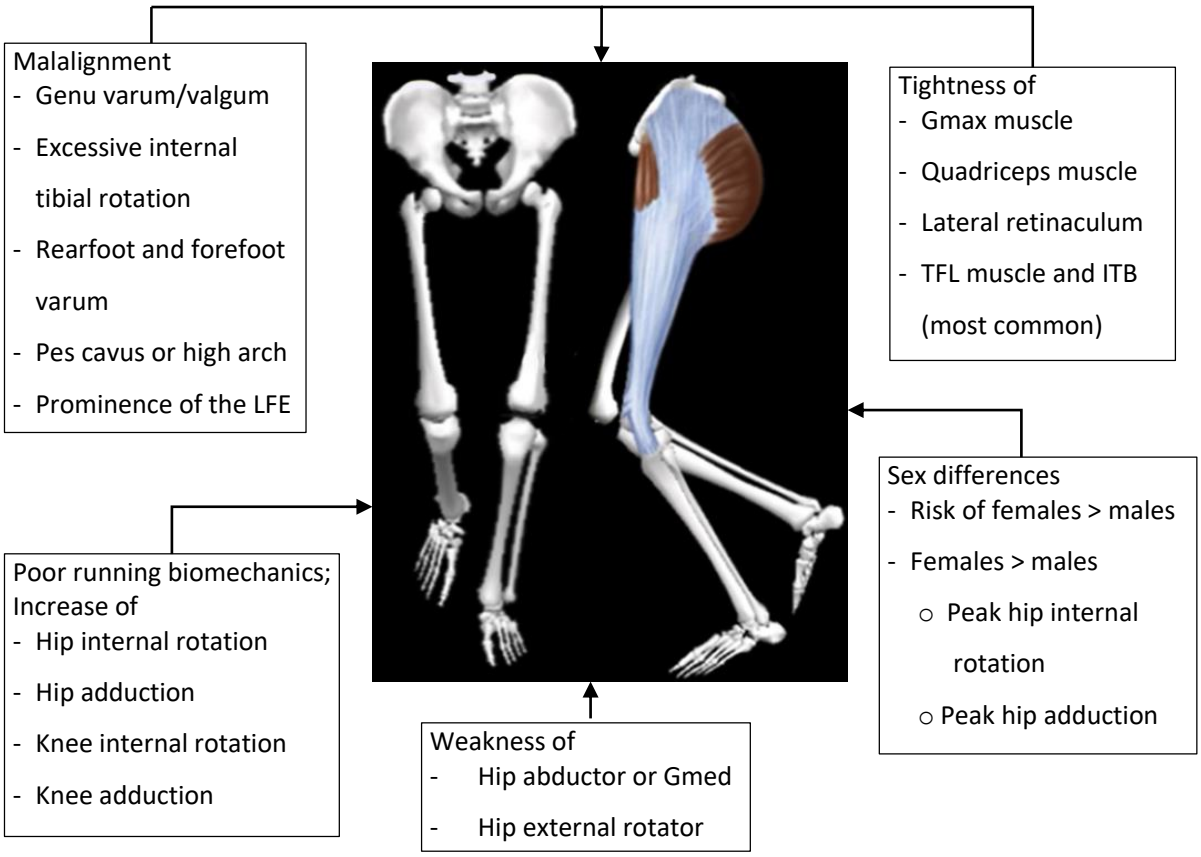


Figure 2-4 Summary diagram of intrinsic risk factors of ITBS in runners (Image modified from Baker and Fredericson, 2016).

2.1.4.2 Extrinsic risk factors

Extrinsic risk factors may include; worn-out running shoes, training program errors, running too fast, high weekly mileage, and running on an nonstandard surface (David and Peter, 1994). When considering the condition of running shoes, it has been reported that after 300 to 500 miles these lose approximately 50% of their ability to offer

adequate impact absorption of ground reaction forces (Messier et al., 1995). This may result in greater forces at the hip, knee, and ankle joints which may be responsible for injuries in these joints and surrounding musculature. Training program errors include rapid increasing the running distance, increase the incline/decline of running, and increasing running speed to soon, which have all been reported to be associated with the occurrence of ITBS. McNicol et al. (1981) reported that 22 from 52 cases of athletes with ITBS could be attributed to training errors. Therefore, it is recommended that increases in running distance during training should not exceed 5 to 10% per week due to the adaptation of muscle, tendons, ligaments and bone needing a gradual increase in load (Joshua, 2005, Tenforde et al., 2011, Messier and Pittala, 1988). It has been reported that too high a running speed is a common risk factor in runners, leading to lower extremity muscle fatigue and injury (Joshua, 2005, Noble, 1980). Additionally, the type of surface may increase the chance of injury by putting excess strain on the lateral aspect of the knee (Strauss et al., 2011, McNicol et al., 1981), and downhill running has been reported to decrease the knee flexion and increase the knee joint force around the impingement zone and has therefore been reported as a risk factor for ITBS (Orchard et al., 1996).

2.1.5 Clinical Assessment and Diagnosis of ITBS

The diagnosis of ITBS in runners is based on the history, signs, and presentation of symptoms. Patients usually present with localised pain to the lateral aspect of the knee in the early stage, especially in the region of the distal ITB between the LFE and its insertion on the Gerdy tubercle. There is often an onset of symptoms during repetitive flexion-extension exercises such as running and cycling. In the worst cases the symptoms may also present at rest, but it is more common after running distances such as 5-20 kilometres or when running downhill (Strauss et al., 2011, Khaund and Flynn, 2005).

Assessments for the presence of ITBS have used several tests including the Noble's compression test and Ober's test (Fredericson and Wolf, 2005, Noehren et al., 2007, Foch et al., 2015, Ferber et al., 2010b). The Noble's or Noble's compression test was developed by Clive Noble and is used to confirm the presence of ITBS (Noble, 1979). To

perform this test, the patient lies either supine or on their non-injured side or they can stand (modified). The patient then bends their knees 90 degrees whilst the therapist applies pressure to the lateral epicondyle or 1 to 2 cm proximally, the patient then slowly extends their knees. A positive test is confirmed if the patient is in pain at 30 degrees of knee flexion over the lateral epicondyle, and this pain is the same as they experience when running (Noble, 1979). This impingement zone of the ITB at 30 degrees of knee flexion was first reported by Orchard et al. (1996) and later described by Fairclough et al. (2006).

The Ober's test is a common test used in ITBS which assesses the tightness of the ITB and TFL muscle (Kendall et al., 2005). In addition, this test can be used in research by using an inclinometer for measurement which improves the intra-rater reliability. Reese and Bandy (2003) studied the intra-rater reliability of the Ober test and the modified Ober test for the assessment of ITB flexibility using an inclinometer to measure the hip adduction angle in sixty-one participants. The result showed that there were high intraclass correlation coefficient (ICC) values for the intra-rater reliability, with 0.90 for the Ober test and 0.91 for the modified Ober test.

There are potentially different diagnoses for other lateral knee pain pathologies which should be considered due to the many structures around the lateral aspect of the knee joint, and these could result in misdiagnosis by the therapist. Therapists should therefore consider other lateral knee pain problems such as lateral meniscus tears, lateral retinaculum, popliteus and bicep femoris tendinopathy, and myofascial pain, degenerative joint disease, patellofemoral pain (PFP), referred pain from lumbar spine, stress fractures, superior tibiofibular joint sprain and lateral collateral ligament sprain (Grau et al., 2011, Khaund and Flynn, 2005, Taunton et al., 2002a). Therefore, differential diagnosis of ITBS from other lateral knee pain presentations is important and can help therapist in the management of these conditions.

2.1.6 Management of ITBS

There are several treatments that are recommended for ITBS which include both non-surgical and surgical options. Non-surgical management has been shown to be effective in athletes returning to sport within six to eight weeks with no long-term sequelae at a rate between 81% and 100% (Lavine, 2010, Bolia et al., 2020). However, surgery was recommended after non-surgical techniques had been explored in individuals who still experience pain and functional limitations. Individuals who have not responded to non-surgical management for more than six months, would potentially benefit from surgery (Strauss et al., 2011, Bolia et al., 2020). However, this thesis focuses on a particular non-surgical option, therefore, this section of the literature review will concentrate on the non-surgical management of ITBS.

Non-surgical management is usually the primary treatment for ITBS (Lavine, 2010, Baker and Fredericson, 2016). Physical therapy is important in the management of ITBS. This not only uses physical therapy modalities, but also manual therapy and exercise interventions which are often combined to try and achieve successful rehabilitation outcomes. Various treatments of manual and exercise therapy have been suggested for ITBS including manual mobilization to the ankle and foot, and patella alignment may also contribute to lengthening the ITB and alleviate symptoms (Strauss et al., 2011). In addition, massage therapy and foam roller treatments have been reported to help patients for myofascial release and reduction of soft-tissue adhesions in the ITB (Winslow, 2014). In addition, the Gmed, Gmax, quadriceps, and core muscles strength training exercises have been suggested as preventive treatments for ITBS as well as stretching of the hamstrings, quadriceps, adductors, ITB, and external rotators of the thigh (Menetrey and Fritschy, 1999, Kvist and Jarvinen, 1982, Strauss et al., 2011, Baker and Fredericson, 2016). Furthermore, improvements in neuromuscular control have been reported to enhance movement patterns during eccentric muscle contractions and functional movement patterns in the treatment of ITBS (Fredericson and Weir, 2006, Fredericson and Wolf, 2005).

The treatment depends on the severity and whether the patient is in the acute (inflammatory phase, 3 days–1 week), subacute (3 days–2 weeks), or recovery phase

(more that 2 weeks). The main goal of treatment in the acute phase is a controlling of inflammation and pain relief. If patients have inflammation, ice and anti-inflammatory medications can be used to relieve symptoms. In addition, treatment modalities including therapeutic ultrasound, laser, phonophoresis, electrical stimulation, iontophoresis, and transcutaneous nerve stimulation have been used to alleviate pain, restore normal muscle tone and decrease inflammation (Fredericson et al., 2000, Baker and Fredericson, 2016).

Patient education and activity modification have been reported to be the most important treatments for ITBS (Fredericson and Weir, 2006), with rest from the provocative activity until the pain has resolved often being suggested (Fredericson and Wolf, 2005). In addition, the therapist should suggest other activities that do not aggravate the pain such as swimming, yoga or walking to allow patients to maintain physical fitness (Fredericson et al., 2000, Baker and Fredericson, 2016).

Some patients who have moderate or severe pain are often prescribed oral nonsteroidal anti-inflammatory drugs (NSAIDs), and/or corticosteroid injections which can reduce the acute inflammatory response and can reduce pain levels in ITBS (Gunter and Schwellnus, 2004). However, it has been reported that NSAIDs alone are ineffective in relieving the symptoms of ITBS, although NSAIDs when combined with other non-surgical modalities can be beneficial in short-term treatment (1-7 days) (Ellis et al., 2007).

In the sub-acute phase, the main goal is still to reduce pain and inflammation, if patients still have inflammation. However, if patients are pain free, stretching and soft tissue mobilization to reduce myofascial adhesions is recommended (Fredericson and Wolf, 2005). One intervention for ITBS which has received some attention is stretching exercises which have been recommended within rehabilitation programs (Baker et al., 2011, Richard et al., 2009). Falvey et al. (2010) reported that stretching may have some effects, and may help to reduce the tension within the ITB which inserts into the TFL. Fredericson et al. (2000) used stretching of the TFL in the rehabilitation program in an attempt to release the tension within the ITB. They stated that this could help patients to reduce their symptoms by reducing the tension within the ITB, which in turn may help

to reduce the friction between the ITB and the LFE and/or the Gerdy tubercle. Fredericson et al. (2002) compared the relative effectiveness of three common standing stretches for the ITB in healthy runners by estimating the ITB length/change in length using a motion capture system. This study demonstrated that all three stretching methods lead to a statistically significant lengthening of the ITB relative to baseline measurements. However, this study estimated changes in length from angular changes and did not directly measure ITB length. Therefore, this might not represent the real changes in ITB length. Nevertheless, the stretching of the TFL and ITB is often considered essential in ITBS rehabilitation programs (Fairclough et al., 2006) and may reduce the friction between the ITB and the LFE during the flexion and extension of the knee joint (Joshua, 2005), which may in turn reduce pain and inflammation.

Reductions in the tightness may lead to an increase in TFL flexibility (Fredericson et al., 2002). This may change the biomechanics of running in individuals with ITBS producing an increased hip external rotation. Although the increase of TFL flexibility can reduce the tension in the ITB (Fredericson et al., 2002), successful rehabilitation may require other treatments to correct running biomechanics for effective longer-term treatments of runners with ITBS, one such treatment that has been considered is hip abductor strengthening (Fredericson et al., 2000).

The last stage is the recovery phase, when the patient is efficient in performing the stretching program without pain, strengthening is added to the rehabilitation program (Lavine, 2010). In this phase, with muscle strengthening and return to sport being the main goals. The strengthening of the Gmed and other muscles around the hip joint are key, and individuals should be pain free (Fredericson et al., 2000).

The Gmed exercise is a common exercise in ITBS rehabilitation that can help to decrease pain and improve the clinical symptoms of ITBS. Several studies support increasing Gmed strength to alleviate the symptoms for individuals with ITBS (Fredericson et al., 2000, Beers et al., 2008). Beers et al. (2008) reported that there was a significant difference in hip abductor strength between the affected and unaffected leg before starting a rehabilitation program. This difference in hip abductor strength between the

affected and unaffected leg was reduced after hip abductor strengthening in a six-week rehabilitation program in nine individuals with ITBS. However, the strengthening exercise of Gmed should be applied appropriately without pain according to the stage of rehabilitation with the emphasis of improving triplane motion and integrated functional movement patterns (Fredericson and Weir, 2006, Joshua, 2005). Furthermore, rehabilitation programs should not only include Gmed strengthening but also other techniques when considering runners with ITBS, as not all runners show a clinical improvement in symptoms (Fredericson and Weir, 2006). Fredericson et al. (2000) highlighted that following a six-week hip abductor strengthening program, 90% (22 of 24 runners) of the ITBS runners were pain free and returned to running. After rehabilitation, there was an increase in hip abductor torque of 34.9% in female and 51.4% in male runners with ITBS. After six-weeks of rehabilitation, 22 out of 24 of the runners with ITBS were pain free during all exercises and were able to return to running, and at 6-months follow-up there were no reports of any recurrence of ITBS.

Studies exists supporting the effect of Gmed strengthening on the biomechanics of running in individuals with ITBS (Schreiber and Louw, 2011). Schreiber and Louw (2011) investigated a six-week program of Gmed strengthening in runners with ITBS and found that there was a decrease of hip adduction angle on the affected side at 30^{o} of knee flexion during heel strike. In contrast, Willy and Davis (2011) demonstrated that a rehabilitation program which included hip strengthening and single leg squat (SLS) progression training did not change the abnormal biomechanics of running but improved only SLS movements. They suggested that hip strengthening and SLS progression training alone cannot change the differences seen in running biomechanics associated with ITBS.

Typically, the management of individuals with ITBS is to focus on specific stretching exercises on the ITB, TFL, and the strengthening of the hip abductor muscles to prevent excessive adduction and internal rotation of the hip (Baker and Fredericson, 2016, Baker et al., 2018). However, several studies have shown that a combination of treatments is more beneficial for runners with ITBS (Fredericson et al., 2000, Beers, 2008, Ferber et al., 2010b). The combination of increasing flexibility of the TFL and the ITB with the

strengthening of the hip abductors has been reported to be the best treatment for ITBS. Nevertheless, there are other risk factors that need to be considered including; educating regarding running shoes, the correct running technique and progression of running distances. For example, changing running shoes every 300-500 miles of use is recommended (Barber and Sutker, 1992), and total mileage should not be increased by more than 10% per week (David and Peter, 1994).

2.1.6.1 Summary of management

There are many treatments for ITBS such as increasing flexibility of the TFL and the ITB, strengthening of the hip abductors. However, other impairments such as malalignment of the foot or the knee have been reported through physical examination, which may still need to be addressed. Many risk factors have been reported to contribute to ITBS; including worn-out running shoes, training program errors, rapid increase the running distance or high frequently a week, and running on an irregular surface (David and Peter, 1994). Therefore, clinical examination is key to determine the impairments so that the correct treatment approach can be provided. One such treatment that has been suggested to change alignment and improve symptoms during running is taping.

2.2 Taping

2.2.1 Rigid (athletic) taping

Rigid taping is a non-elastic tape and is primarily used to support injured structures and limit potentially harmful ROM. This is purported to enhance repair and recovery, allowing pain-free functional movement, resumption of activities, control of swelling, and pain reduction (Hewetson et al., 2010). Taping can be applied to any part of the body which depends on the objective, whilst still allowing the individual to participate in the athletic activity (Cupler et al., 2020). There are various methods of rigid taping that are available such as McConnell and Mulligan. Each of these taping techniques has been associated with specific therapeutic mechanisms.

McConnell taping (MCT) is a rigid tape technique aim to create a mechanical realignment of the patella in the intertrochlear groove in one specific direction so that the patella

bone can move freely without contacting other parts of the femur during knee movement, and thus decreasing pain (Campolo et al., 2013, Callaghan et al., 2008), Figure 2-5. MCT has been reported to reduce anterior knee pain, regulate the pulling force of the patella in the mediolateral direction, improve knee joint alignment and facilitate the vastus medialis (VM) (Campolo et al., 2013). In addition, a significant increase in knee proprioception has been reported when using MCT in people with poor proprioceptive ability in both healthy individuals (Callaghan et al., 2002), and patients with PFP (Callaghan et al., 2008).

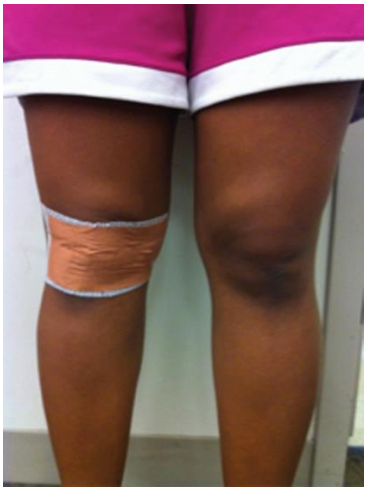


Figure 2-5 McConnell Taping Technique Application (Campolo et al., 2013).

Mulligan taping (MT) is a rigid strap method applied in a spiral line around the knee without contacting the patella (Hing et al., 2020), Figure 2-6. This method has been theorized to indirect alter patellar tracking by increasing the tibia internal rotation relative to the femur or by externally rotating the femur during weightbearing (Mackay et al., 2020). MT is used as a supplement to the Mulligan mobilization with movement, which is a manual technique applying force to a joint and sustained in a specific pain free direction in order to allow painless motion of a previously painful joint (Logan et al., 2017). After applying the Mulligan mobilization, the MT is applied in the same direction. It is believed that this will extend the usefulness of mobilization with movement after the end of the treatment session (Hopper et al., 2009).

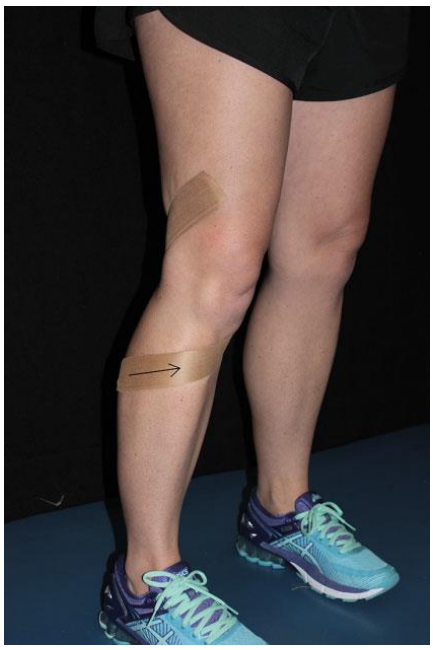


Figure 2-6 Mulligan taping (Mackay et al., 2020).

2.2.2 Kinesio Taping (KT)

Kinesio Taping (KT) was developed in the 1970's by Dr. Kenzo Kase, a chiropractor and acupuncturist. This is an elastic therapeutic tape, commonly known by the brand names which include; Kinesio Tex tape, Kinesiology Tape, Rock tape, SpiderTech, and many more. KT has become popular in the treatment of musculoskeletal and neurological conditions, as well as paediatric patients and athletes in various sports (Kase et al., 2003). The common characteristics of KT include a waterproof hypoallergenic porous cotton fibre strip with a medical-grade acrylic adhesive (Williams et al., 2012).

The main difference between rigid athletic tape and KT tape is the elasticity, with KT taping being able to be stretched to 140% of its original length (Kase et al., 2003). Various effects of KT have been reported including; increasing local blood flow (Woodward et al., 2015, Liu et al., 2020), reducing local edema (Donec and Kriščiūnas, 2014), reductions in pain (Lee et al., 2016, Anandkumar et al., 2014), increasing joint ROM and flexibility (Farquharson and Greig, 2015, Lee et al., 2016, Yoshida and Kahanov, 2007), improve strength and stability (Kim et al., 2015, Anandkumar et al., 2014), and improvements in joint position sense (Seo et al., 2016). Additional characteristics of KT include properties that are intended to imitate human skin (Firth et al., 2010). Moreover, the thickness of

KT is nearly the same as the epidermis of the skin which can help to avoid too much sensory stimuli when applied on the skin (Firth et al., 2010).

The repetitive nature of running requires a minimal restriction; therefore, KT appears to be useful when considering running due to its ability to stretch. Since the main mechanism of ITBS has been identified as the tightness of TFL and ITB, and greater hip adduction and hip internal rotation, it would be logical to consider KT from this perspective, which has been reported to correct the abnormal biomechanics, decrease tightness and pain through the stimulation of the mechanoreceptors within the skin (Song et al., 2015, Song et al., 2017). Figure 2-7 presents the known mechanisms of injury in runners with ITBS and the theorised changes associated with KT application.

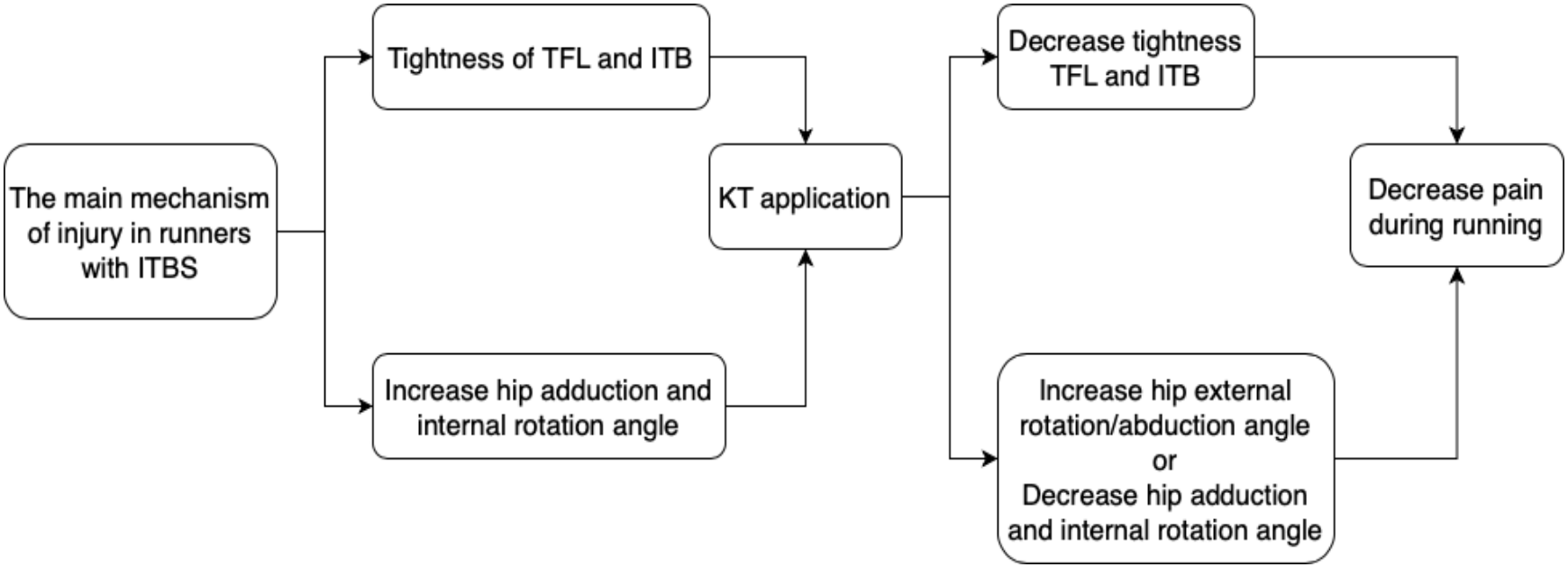


Figure 2-7 The mechanisms of injury which have been associated with runners with ITBS and the potential benefits of KT.

There are many techniques of KT which can be applied depending on the clinical examination and assessment of therapists. Firstly, muscle inhibition technique, this technique used for decreasing muscle spasms or muscle hyper tone or overused muscles by applying KT from the insertion to the origin of the muscle. It has been suggested that KT's recoil effect may induce motor neuron inhibition by stretching the Golgi tendon organ located at the distal ends of the muscles (Yeung and Yeung, 2016). This technique may be helpful in decreasing the tension or tightness and associated pain in the TFL and ITB which is present in people with ITBS. This is supported by Davison et al. (2016) who considered the use of an inhibitory technique using KT and reported that the majority of participants had a reduction in average gastrocnemius muscle activity during a single leg vertical jump after inhibition technique application. In addition, Öztürk et al. (2016) investigated inhibitory KT technique in patients with active upper trapezius myofascial and KT exhibited statistically significant improvements in pain and upper trapezius muscle strength. Secondly, a muscle facilitation technique has also been reported in the literature to manage muscle weakness or hypotonia by applying KT from the origin to the insertion of the muscle (Rajasekar et al., 2018).

The effect of both muscle inhibition and facilitation KT on muscle strength has also been explored. Rajasekar et al. (2018) used a facilitation technique directly to the Gmed and found this was able to correct exaggerated dynamic knee valgum and improve hip abductor strength. In addition, Słupik et al. (2007) investigated the effect of KT on changes in the tone of the VM muscle during isometric contractions. The result showed that there was an increase VM muscle activity after 24 hours of KT use, and this effect was maintained for 48 hours following removal of the tape. There was a decrease in muscle tone to the baseline value, which was observed during the fourth day with the KT applied. They indicated that this may have resulted from the time of the application of KT being shorter than previously believed. However, previous research in healthy participants has also showed no significant changes in maximal quadriceps strength immediately after application of inhibition, facilitation, or sham KT (Vercelli et al., 2012). Poon et al. (2015) also showed no significant differences in quadriceps peak torque between facilitative KT, sham KT, and NT taping and concluded that KT did not facilitate muscle performance. Yam et al. (2019) performed a meta-analysis on the effects of KT on lower limb muscle strength and functional performance during single leg hop and

vertical jump height. They concluded that KT can improve lower limb muscle strength in people with musculoskeletal disorders, but the use of KT in healthy populations was not supported. The variations in the findings highlight that both the muscle inhibition and facilitation techniques require more research, especially when considering different patient groups.

The mechanisms of KT also include the mechanical technique which aims to provide a correction through positional stimulation through mechanoreceptors in order to adjust posture. This technique aims to inhibit pathological movements, activate muscles and maintain an active ROM (Han et al., 2015, Lyman et al., 2017). This technique is similar to the functional correction technique that is used to assist or restrict movement by stimulating the sensory system. This can help to improve the direction of movement (Song et al., 2015, Song et al., 2017), and has been reported to increase hip external rotation and abduction angles which can help to correct abnormal running biomechanics in people with ITBS(Mackay et al., 2020).

The space correction KT technique was claimed that has a lifting effect to reduce pressure, resulting in a reduction of pressure between the ITB and lateral femoral epicondyle, and lead to decrease pain associated with the ITB insertion at the LFE in people with ITBS (Kase et al., 2003). Previous studied have shown that the space correction technique can increase the patellofemoral joint space in healthy adults, when assessed using diagnostic ultrasound to measure; the patellofemoral joint space, the skin and the superficial patella distance, and the skin and the patellar tendon distance (Lyman et al., 2017). Lyman et al. (2017) found an increase in the distance between the patella and the medial femoral condyle, but saw no increases in the distance from the skin to the superficial aspect of the patella nor to the patellar tendon.

There are several reported physiological effects of KT which include the stimulation of the cutaneous afferent and motor nerves which are part of the somatic nervous system, and the stimulation of peripheral nerves has been shown to stimulate excitability in the motor cortex (Ridding et al., 2000). Therefore, a tactile proprioceptive input through the stimulation of cutaneous mechanoreceptors may be able to enhance the muscle performance through changes in motor unit recruitment controlled by the motor cortex

(Pamuk and Yucesoy, 2015). When using KT over a long period, stimulation of cutaneous receptors may become saturated over time and therefore any enhanced proprioception may gradually diminish due to the skin's adaptation to the stimulation provided (Lee and Lee, 2015), therefore in order to provide effective skin stimulation the therapist may require to reapply the KT with the appropriate amount of tension (Kim and Lee, 2015).

Any pain reductions resulting from KT application may be associated with gate control theory. Gate control theory of pain was first proposed by (Melzack and Wall, 1965) to explain how the stimulation of non-painful sensations such as touch, pressure, and vibration can help to reduce pain sensation. Pain comes from the stimulation of afferent input of nociceptors and travels to the brain through small sensory nerve fibres. In contrast, non-painful sensations are transmitted to the brain through large sensory nerve fibres. The gate control theory describes the reduction of pain as a closed gate due to the transmission of non-painful sensations, whilst an open gate has been described as the transmission of painful sensations (Moayedi and Davis, 2013). When there is more activation of the large sensory nerve fibres associated with non-painful sensations in comparison to small sensory nerve fibres associated with painful sensations, this has been described as a closed gate as the large sensory nerve fibres can help to block or diminish the pain signals from the small sensory nerve fibres (Coffey and Mahon, 1982).

When considering KT, it is plausible to suggest that the KT application can 'pull' the skin, which can induce the "closing of the gate" and may possibly provide pain relief. It has been suggested that KT over the skin stimulates the mechanoreceptors of the skin and may help to reduce pain by increasing afferent feedback through the large sensory nerve fibres to the central nervous system which may reduce the afferent feedback of pain transmitted by small sensory nerve fibres (Thelen et al., 2008, Pamuk and Yucesoy, 2015). However, previous studies have not been able to confirm if KT can provide effective pain reduction according to gate control theory (Kakar et al., 2020, Song et al., 2017, Park et al., 2019).

2.2.3 Taping and ITBS

There have been a number of studies that have examined the effect of taping on knee and hip biomechanics, muscle activity, and clinical outcome measures. However, there are limited studies that have examined the effect of taping in individuals with ITBS. Hickey et al. (2016) determined whether MT technique alters the level of knee pain and changes the lower limb biomechanics during SLS in adult females with PFP. They found that MT was able to reduce knee pain and peak hip internal rotation, resulting in early activation of the Gmed compared to the NT condition. Similarly, Mackay et al. (2020) considered KT and rigid tape using MT in female patients with PFP. They reported that both rigid tape and KT significantly reduced pain during a pain provocative task; running and SLS when compared to the NT condition. However, KT was perceived to be more comfortable than rigid tape. In addition, both rigid and KT showed an increase in the knee internal rotation angle at initial contact during the running task and at the onset of knee flexion during the SLS task, and greater peak knee internal rotation during both the running and SLS tasks. Therefore, from this study, both rigid and KT taping methods were shown to reduce pain and change lower limb biomechanics, but KT may be chosen clinically for comfort reasons.

Other rigid taping techniques have been shown to change hip movement. Masters et al. (2018) used a hip taping technique that consisted of an abduction component of rigid tape and with an additional external rotation component of rigid tape, with the purpose of mechanically restricting hip adduction and internal rotation movement. They compared the hip taping technique to sham tape and NT in female runners who had excessive functional knee valgus on hip and knee kinematics. The results showed that hip taping significantly reduced the hip adduction and internal rotation angles in stance phase compared to sham tape and NT. Furthermore, hip taping significantly increased knee adduction, internal rotation, flexion, and reduced peak knee flexion angles, compared to NT. Therefore, hip taping appears to be able to help functional knee valgus correction and reduce excessive hip motion and also improve knee kinematics in the frontal and transverse planes.

Song et al. (2017) investigated the effects of femoral rotational KT taping on task performance, dynamic postural control, and pain during the Star Excursion Balance Test

in patients with PFP compared to healthy controls. They applied a piece of I-shaped KT anchoring at the inferior-medial aspect of the thigh and used a standardized rotational pulling force with a 20% to 25% stretch of tape on the thigh. The result showed that femoral rotational taping increased the maximum excursion distance, decreased hip adduction excursion and reduced pain in the PFP group. Therefore, femoral rotational taping could be used in the management of young female patients with PFP. This is similar to the findings of Song et al. (2015) who explored the effects of femoral rotational KT on the hip and knee joint kinematics, muscle activation, and pain between participants with PFP and a control group during SLS. The result showed that both femoral rotational and sham taping applications reduced the pain in the PFP group. In addition, femoral rotational tape significantly shifted the patella into a more posterior and distal position in the PFP group compared with NT or sham tape. However, there was no significant difference for muscle activity for Gmax, Gmed, and rectus femoris.

Although the studies by Song et al used femoral rotational KT tape, they use only one technique with one line of KT. However, they did not study in running biomechanics that maybe need more one technique or one line of KT to encourage to change the running biomechanics. Guner et al. (2015) compared the effects of KT with facilitation and inhibition techniques on knee kinematics and kinetics during walking in healthy participants. The results showed that both KT techniques had no effect on the knee joint ROM in the sagittal plane. The facilitation KT did show a significant decrease in knee external flexion moments during the early stance phase and an increase in the knee external extension moment during the mid-stance phase. In addition, the inhibition KT showing an increase in knee external flexion moment. They concluded that the facilitation KT technique can influence the terminal stance phase of walking and inhibition KT technique can influence the terminal swing phase when compared to a NT. Rajasekar et al. (2018) determined whether KT over Gmed can correct exaggerated dynamic knee valgum and improve hip abductor strength when compared to sham KT. Athletes with dynamic knee valgum performed a drop jump test and the Donnatelli Drop Leg Test. This showed that immediately after the application of KT, dynamic knee valgum significantly reduced dynamic knee valgum but this was not maintained to the third day. In addition, there was a significant increase in Donnatelli Drop Leg Test, which is a measurement of Gmed strength, immediately and on the third day of wearing KT. This

indicates that Gmed strength is increased immediately in the KT group and was maintained to the third day.

Some studies have reported no significant differences in lower limb biomechanics when using KT. Howe et al. (2015) compared the effects of MT and KT with NT on hip and knee kinematics and kinetics during running in female healthy recreational runners. The result showed that there was no difference between MT, KT and NT for hip and knee angles. However, there was an overall main effect of tape on peak hip and knee moments during running. The pairwise comparisons showed that MT produced a significantly lower knee extensor moment compared with KT and no tape, and MT reduced the hip flexor moment and hip extension moment when compared with KT and no tape. No significant differences were seen for peak hip and knee kinematics and kinetics between KT and NT. Similarly, Hendry et al. (2015) investigated the effects of KT, MT and NT on knee and hip kinetics during three landing positions in ballet dancers. They found a significant reduction in peak posterior knee shear forces, and hip peak posterior, medial, and lateral shear forces in the MT condition compared with NT when landing in the “first position”. Therefore, MT appears to support the knee and hips, but the KT does not seem to change the joint stability.

Although there is evidence that MT using rigid tape helps joint stability, consideration around the practical use of MT especially during running is needed. KT has been reported to be more comfortable than MT applied with rigid tape (Mackay et al., 2020). Mackay et al. (2020) investigated female patients with PFP who performed a self-selected pain provocative task, a SLS and a running task, while wearing MT applied with rigid and KT tape with a 100% stretch. KT and rigid tape both showed a significant increase in hip external rotation angle at initial contact during running and a decreased transverse hip ROM compared to NT. In addition, both rigid and KT showed a good level of perceived comfort, but KT was significantly more comfortable than rigid tape. It has been suggested that the greater comfort observed when wearing KT is due to its mechanical properties (Tunakova et al., 2017). Rigid tape is created with a strong rayon backing and a rubber zinc oxide adhesive, while KT is an elastic adhesive tape which is a highly elastic cotton woven fabric (Tunakova et al., 2017, Masters et al., 2018). Furthermore, stretchy cotton materials are known to work ideally with the skin's natural

elasticity, therefore, KT has been associated with fewer skin allergies than rigid tape (Song et al., 2015). When considering the amount of stretch, Mackay et al. (2020) used KT at 100% of stretch but the general clinical guideline of KT is to use less stretch to reduce any irritation on the skin, especially during running (Andrýsková and Lee, 2020). In addition, there was little evidence to support the efficacy and effectiveness of different application tensions of KT tape.

To the author's knowledge, there is a lack of research on the effect of KT on the biomechanics in runners with ITBS. However, Kase previously proposed the use of KT for ITBS using a combination of techniques including inhibition, mechanical correction with tension, and space correction (Kase et al., 2003). Kase claimed that these techniques will assist in inflammation reduction and decreased tension in the ITB. Moreover, other techniques were suggested for ITBS including fascia correction or combination of fascia correction and muscle inhibition, however all these techniques are largely anecdotal with little data to support their use or details of the application tension used.

2.3 Clinical Outcome Measures

To determine clinical importance or clinical significant, there are two terms involved; the minimum clinically important change (MCIC) and the minimum clinically important difference (MCID) (Togo et al., 2011). MCIC is defined in this thesis as the threshold when change from baseline (pre-tape) is considered as clinical meaningful within group of participants with ITBS following a treatment intervention. MCID is defined in this thesis as the threshold when a minimum difference in score between two treatment intervention groups as clinical meaningful (Togo et al., 2011).

2.3.1 Numeric Pain Rating Scale (NPRS)

The NPRS is one of the most commonly used pain scales which was designed to help assess the extent of pain an individual is experiencing, and to improve communication regarding pain with clinicians. The most common NPRS scale used is an 11-point scale from 0-10 with 0 equalling no pain and 10 equalling the worst pain possible. The scale typically uses a horizontal line and can be administered in written or verbal form. The patient is asked about the intensity of the pain experienced and a particular time frame

or descriptor is established. Furthermore, in a systematic literature review by Hjermstad et al. (2011), they concluded that a NPRS is an applicable measure of pain intensity in almost all settings.

The NPRS has been shown to have high correlations with other pain assessment tools in several studies (Jensen et al., 1986, Kremer et al., 1981). The NPRS had moderate to high test-retest reliability, varying from 0.67 to 0.96 (Kahl and Cleland, 2005) and had a convergent validity when correlated with the Visual Analogue Scale (VAS), which ranged from 0.79 to 0.95 (Good et al., 2001). In clinical trials the NPRS has been demonstrated to be more reliable than the VAS (Ferraz et al., 1990). A two-point reduction in NPRS has been reported as a MCIC in chronic pain patients (Farrar et al., 2001). In addition, Michener et al. (2011) reported a 2-pointMCID for NPRS in patients with shoulder pain. Similarly, Childs et al (2005) used NPRS in low back pain patients, they explored the resulting changes in NPRS scores, which were compared to patient improvements in pain after physical therapy using a 15-point Global Rating of Change scale. They concluded that clinicians can be confident that a 2-point change on the NPRS represents a clinically meaningful change (Childs et al., 2005).

2.3.2 Knee Injury and Osteoarthritis Outcome Score (KOOS)

There are many questionnaires that can be used to assess knee pain or injury including the Oxford Knee Score, Lower Extremity Functional Scale, Western Ontario and McMaster Universities Arthritis Index, and The Knee injury and Osteoarthritis Outcome Score (KOOS). The choice of questionnaire depends on the purpose and design of the study.

The KOOS questionnaire was developed in the 1990s as an instrument to assess patients' perceptions of their knee pain for both short- and long-term assessment following knee injury. The KOOS is patient-administered, the format is user-friendly and it takes about 10 minutes to complete. There are five separate domains scored from 42 question items: pain (9 items), symptoms (7 items), activities of daily living (ADL) (17 items), function in Sport and Recreation (5 items), and knee-related quality of life (4 items) (Roos and Lohmander, 2003). The KOOS questionnaire uses Likert scales in all items which have five answers from 0 (No problems) to 4 (Extreme problems) and the sum of

the items included is computed with each of the five scores. A normalised score, 100 representing no symptoms and zero representing extreme knee problems, is calculated for each subscale. KOOS subscale scores can be accumulated and averaged as the primary outcome. The five individual KOOS subscale scores can be used as a secondary outcome for clinical interpretation.

KOOS is a popular questionnaire tool for knee injury. Khadavi et al. (2015) showed the reduction in the knee pain parameters of the KOOS when applying knee bracing. Sinclair (2016) investigated the effects of a 10-week foot strike transition in habitual rearfoot runners with PFP and found improvements in the pain, sport, function and daily living KOOS subscales. Sinclair et al. (2016) used KOOS to assess a knee brace intervention on self-reported knee pain in recreational athletes. The MCIC is now recommended to be 8-10 points out of 100. However, the current understanding is that MCIC is related on factors such as patient group, intervention, and time to follow-up. This thesis used the Thai version of KOOS which has been shown to have a high reliability (ICC = 0.78-0.82) for the pain and activity daily living domains and acceptable reliability (ICC = 0.71-0.72) for the sport and recreation and quality of life domains, while for symptoms a lower but still acceptable ICC = 0.45 has been reported. Cronbach's alpha for internal consistency reliability from all domains was 0.9. The Thai version of KOOS has been previously used in a clinical study as a self-reported functional outcome after a 4-week home-based exercise program in people with knee OA (Chaipinyo and Karoonsupcharoen, 2009). It has also been used to assess the functional outcome after autologous chondrocytes implantation for traumatic cartilage defects of the knee (Kasemkijwattana et al., 2009b, Kasemkijwattana et al., 2009a).

2.3.3 Tampa Scale for Kinesiophobia (TSK)

Kinesiophobia is defined as an irrational and debilitating fear of physical movement and as a result of a feeling of vulnerability to painful injury or reinjury after recovery (Kori, 1990). The phenomenon of post-injury has later also been described as fear of movement/re-injury, and refers to an idea of having a vulnerable, easily harmed body, and that movement may cause re-injury (Vlaeyen et al., 1995a). Kinesiophobia leads to decreased motion and often perpetuates a cycle of pain and disuse that may result in a chronic pain syndrome and decreased physical function, negatively affecting an

individual's quality of life, psychological and physical health (Vlaeyen et al., 1995b, Lethem et al., 1983). After injury, athletes within one study reported a fear and insecurity towards returning to the sport in which they experienced their injury (Heijne et al., 2008).

The Tampa Scale of Kinesiophobia (TSK) was developed by Miller and colleagues in 1991 to assess the subjective rating of fear of movement. The TSK is now widely used to assess the fear of movement in musculoskeletal injuries and pain for both chronic and acute conditions (Miller et al., 1991) including low back pain and fibromyalgia (Roelofs et al., 2004, Goubert et al., 2004), osteoarthritis (Heuts et al., 2004), traumatic neck pain (Nederhand et al., 2004), burn pain (Willebrand et al., 2006), and sports injury (Kvist et al., 2005).

The TSK is a 17-item self-rated questionnaire using a 4-point Likert scale regarding specific situations, performance, the fear of re-injury and activity avoidance. In addition, the TSK can be useful in measuring unhelpful feelings and beliefs about pain in individuals with chronic pain. The range of scores of TSK are from 17 to 68, with higher scores indicating greater amounts of kinesiophobia (Pool et al., 2009). The final TSK score is formed by adding the points from all 17 items. A score of 37 or over is considered as a high score, which indicates a high degree of kinesiophobia (Vlaeyen et al., 1995a), while scores below that are considered as having a low degree of kinesiophobia. Huang et al. (2019) studied the reproducibility, responsiveness and validation of the Japanese version of TSK (TKS-J) in patients with ACL injuries and found that there were no floor or ceiling effects in the TSK-J scale. The MCIC and MCID were 0.8 and 1.3, respectively, and the smallest detectable change (SDC) in the TSK-J scale was 7.6 for individuals, and 1.2 for groups (Huang et al., 2019). However, some studies have reported the SDC of TSK for patients with acute low back pain as 9 (Ostelo et al., 2007) and 8 for patients with chronic back pain (Lüning Bergsten et al., 2012). In the Finnish version of TSK, the test-retest reliability (ICC) for the paper and computer versions were 0.887 and 0.877 respectively which are both excellent (Koho et al., 2014). There was a predictive validity in the moderate correlation coefficient with a physical performance test (Roelofs et al., 2004) with a moderate concurrent validity, ranging from r(s) =0.33 to 0.59 (Swinkels-Meewisse et al., 2003). The Thai version of TSK has been reported to be easily

understood and completed within six minutes. The Thai version of TSK has been reported to show a good internal consistency (α = 0.90) and high test-retest reliability (ICC = 0.934). Additionally, there were high correlations and convergent validity with the VAS, Western Ontario and McMaster Universities Osteoarthritis Index, and State-Trait Anxiety Inventory (r = 0.741, 0.856, and 0.817), respectively (Areeudomwong and Buttagat, 2017).

TSK has been used as a questionnaire to assess taping in various studies. Alahmari et al. (2020) showed no significant differences in immediate and short-term effects between dynamic taping (one band of elastic tape) and KT in kinesiophobia. Kurt et al. (2016) used the TSK to evaluate the short-term effects of KT in patients with PFP and found significant improvements in TSK in the KT group compared to placebo KT group.

Harput et al. (2016) investigated the effects of a knee brace and KT on functional performance and self-reported function in individuals six months after anterior cruciate ligament reconstructed who desired to return to their pre-injury activity levels. They concluded that both knee brace and KT have a positive effect on individuals after anterior cruciate ligament reconstructed and may help to reduce the kinesiophobia when returning to pre-injury activity levels, with the knee brace appearing to provide the participants better knee function compared to KT. Castro-Sánchez et al. (2012) investigated the effect of KT over the lumbar spine with chronic non-specific low back pain compared to sham tape and found that TSK did not show any statistically significant difference between the groups at one week or four weeks.

2.3.4 Global Rating Of Change (GROC) scale

The Global Rating of Change (GROC) scale provides a measure of self-perceived change in health status. The main purpose of GROC is to allow patients or study participants to indicate whether their condition has improved or deteriorated or stayed the same, and to quantify the magnitude of that change over time (Jaeschke et al., 1989). GROC scales are commonly used in both clinical practice and research settings as a clinical outcome measure (Bobos et al., 2019). There are several different names for this scale (Kamper et al., 2009), including; Global Perceived Effect Scale (Stewart et al., 2007), Transition Ratings (Guyatt et al., 2002, Hillen et al., 2003), and Patient Global Impression of Change

(Dworkin et al., 2005), but all these essentially measure the same thing. GROC scales consist of ordered categories which may have different ranked point scale with 15-, 11- and 7-point scales being most common, however 3- and 5-point scales have also been reported, Table 2-1. The usual structure of GROC is the use of a middle '0' score corresponding to 'no change', with negative values representing magnitudes of deterioration while positive values indicate improvement (Kamper et al., 2009).

Table 2-1 Previously reported GROC point scales.

GROC Range	Study
3-point scales	Bendig (1954), Jaeschke et al. (1989)
5-point scales	Crossley et al. (2004), Collins et al. (2009), Monticone et al. (2018), Monticone et al. (2015)
7-point scales	Farrar et al. (2001), Björklund et al. (2017), Guzy et al. (2013), Jorritsma et al. (2012), Ngo et al. (2010)
11-point scales	Costa et al. (2008), Stewart et al. (2007), Stewart et al. (2003), Pengel et al. (2004), Ferreira et al. (2009), Watson et al. (2005), Kamper et al. (2010)
15-point scales	Collins et al. (2009), Piva et al. (2009), Stratford et al. (1996), Burns et al. (2011), Cleland et al. (2007), Jaeschke et al. (1989), Cleland et al. (2006), Cleland et al. (2008), Cook et al. (2014), Farooq et al. (2017), Shaheen et al. (2013)

While there is little compelling evidence of the optimal number of point scales of GROC, a greater number of response categories have been reported to produce reliable and stable results (Preston and Colman, 2000). A comparison of a 7-point and 15-point scales found no significant difference in performance of the two scales in terms of their responsiveness (Kamper et al., 2010), with the most commonly used being 15-point scales. Bobos et al. (2019) performed a systematic review with meta-analysis and meta-regression to explore the psychometric properties of the GROC scales in patients with neck disorders by searching four databases (MEDLINE, EMBASE, CINAHL, SCOPUS) until February 2019. The most commonly reported GROC scale was a 15-point scale for six studies with the most frequent used '−7 (a very great deal worse) to 0 (about the same)

to +7 (a very great deal better)'. A 7-point scale was reported in five studies, 11-point and 5-point scales were reported in two studies and a 9-point scale in one study.

When considering the reliability and validity of GROC scales, the test-retest reliability of GROC has been reported to be high (ICC = 0.9) (Costa et al., 2008), and showed a high face validity between GROC and patient ratings of the importance of change (Pearson's r = 0.90), ICC = 0.74 between clinician and patient-rated GROC (Watson et al., 2005). On an 11-point GROC scale, a change of 2 points or more may be considered a clinically meaningful change (Kamper et al., 2009). For a 15 point (–7 to +7) scale, Stratford et al. (1994), reported MCIC was 5; an important improvement was +5 or more, with a deterioration defined as –5 or less. This was based on a meaningful improvement or deterioration based on a clinical observation of whether patients with lower change scores continued to seek treatment.

2.4 Biomechanics and muscle activity measurements during running

Biomechanics and muscle activity measurements in running are key to help researchers and therapists understand running injuries such as ITBS. In addition, this can help our understanding of the risk factors and the different methods of injury management (Harrast, 2020). Biomechanical and muscle activity measurements are important tools that can be used to assess the efficacy of interventions, however there are important factors that should be considered such as sampling frequency, marker sets, anatomical models, and signal processing.

2.4.1 Kinematic measurements in the assessment of running injuries

Running analysis can use a single camera or multiple cameras for two or three-dimensional movement analysis (Sorenson et al., 2015). Two-dimensional (2D) video systems are portable, time and cost effective, and require little training (Munro et al., 2012). In addition, video evaluations can be done within a clinical setting and the results can be easily presented with the sagittal and frontal planes being the most commonly examined. However, risk factors for knee injury can occur in the sagittal, frontal, and transverse planes (Vannatta et al., 2020). In addition, one factor that must be considered is that 2D kinematic measurement are unable to measure rotation movement such as

hip external and internal rotation (Schurr et al., 2017). Therefore, laboratory three-dimensional (3D) motion capture systems are considered the "gold standard" in the assessment of biomechanical risk factors (Munro et al., 2012). These systems are reliable for many functional tasks and can accurately determine multi-planar and multi-dimensional kinematics (Nakagawa et al., 2014, Ford et al., 2007, Clansey et al., 2012, Verheul et al., 2017), and provides an objective measure of multi-planar biomechanical risk factors that can contribute to running injuries (Maykut et al., 2015). Previous work has highlighted the clinical implications of the frontal and transverse plane kinematics include hip adduction and abduction angles, hip internal and external rotation angles, knee abduction and adduction angles, and knee internal and external rotation angles with regards to rehabilitation and injury prevention in runners (Baker and Fredericson, 2016).

2.4.2 Kinetic measurements in the assessment of running injuries

Force measurements are essential for understanding human movement, and a common laboratory-based approach is the use of force platforms in order to assess the external forces generated by athletes. When an object or limb contacts the plate, a force is applied to the plate and then a reaction force is applied to the object. The built-in force transducer measures the force and can display it in three planes (vertical, anterior-posterior, and medial-lateral). This can be used to calculate the resultant ground reaction force and centre of pressure, which are used in the calculation of joint moments in gait, jumping and other sport activities (Hood et al., 2012). Joint moments are typically calculated using inverse dynamics from force plate data and marker position data collected using a camera motion capture system (Chiari et al., 2005). Joint moments give an indication of the loads on the tissues that move that joint, and have been identified as a potential risk factor for injury (Vannatta et al., 2020), and should therefore be included when considering running related injuries.

2.4.3 Methods of Measurement of Kinematics and Kinetics

When considering the methods of collection of kinematic and kinetic data the sampling frequencies are an important consideration. The selection of sampling frequency depends on several factors; Nyquist's theorem and the type of activity measured.

Nyquist's theorem (Shannon and Weaver, 1949) stated that the sampling frequency must be at least twice the measured highest frequency component in order to accurately reconstruct the signal. Therefore, it is important to consider the type of activity being recorded to determine the highest frequency component and the resulting minimum frequency.

Shen et al. (2021) used an eight camera Vicon motion capture system sampling at 100 Hz to collect the running biomechanics data between runners who develop ITBS and healthy runners. In addition, Yang et al. (2020) used a 10 camera Vicon motion capture system with a sampling frequency of 100 Hz to collect running kinematics data including hip, knee, and ankle joints before and after a 12 week gait retraining intervention. Whereas Foch et al. (2015) used a nine camera Vicon motion capture system sampling at 120 Hz to collect the lower extremity and trunk biomechanics data during running in runners with current ITBS, previous ITBS, and a control group. Ferber et al. (2010b) used a six camera Vicon motion analysis system for collecting kinematic data using a sampling frequency of 120 Hz to examine the differences in running mechanics between runners who had previously sustained ITBS and runners with no knee-related running injuries. Similarly, Noehren et al. (2007) used a sampling frequency of 120 Hz to record kinematics with a six camera motion analysis system to investigate the running biomechanics of lower extremity injuries in female runners. In addition, Miller et al. (2007) used an eight camera Peak Motus motion capture system with a sampling rate of 120 Hz to measure changes in lower limb mechanics during fatigue exercise in runners with and without a history of ITBS.

Higher sampling frequencies have also been used to record kinematic data. Recently Oliveira and Pirscoveanu (2021) used an eight camera Qualisys motion capture system and collected kinematic data at 200 Hz in order to explore running biomechanics on a 20m running track. Similarly, Clansey et al. (2012) used a 12 camera motion capture system with a sampling frequency of 200 Hz to collect running kinematic data in the study of acute effects of progressive fatigue on running mechanics associated with tibial stress fracture risk. Furthermore, Noehren et al. (2014) used a 15 camera motion analysis system with a sampling frequency of 200 Hz to collect running biomechanics data between male runners with ITBS and healthy controls. In addition, Mackay et al.

(2020) used an 18 camera 3D Vicon motion analysis system with a sampling frequency of 250 Hz to collect kinematic data to compare the efficacy of MT in adult female patients with PFP during three tasks: an individualized pain provocative task, an SLS task, and a running task. Similarly, Grau et al. (2011) used a six camera 3D Vicon motion capture system with a sampling frequency of 250 Hz to assess differences in the kinematic characteristics between a healthy control group and runners with ITBS. Although a variety of sampling frequencies have been used there is no one single agreed value for recording running kinematics, and Vanrenterghem et al. (2001) showed that frequencies above 100 Hz were adequate.

After recording, filtering of the signals is an important process which is required to remove noise and errors within the time series data. Kinematics data is typically filtered using a low pass filter, often using a second or fourth order Butterworth filter with a typical cut-off frequency of 6 or 7Hz for walking gait data (Rácz and Kiss, 2021). Faster activities, such as running, typically require a higher cut-off frequency of between 10 and 16Hz (Mackay et al., 2020, Miller et al., 2007, Hickey et al., 2016, Clansey et al., 2012). Mackay et al. (2020) used a 16 Hz fourth-order, zero–phase shift Butterworth digital low-pass filter for kinematics data during SLS and running tasks. Clansey et al. (2012) used a 12 Hz fourth-order, zero–phase shift Butterworth digital low-pass filter for kinematics data in the running task. Whereas Miller et al. (2007) used a fourth-order low pass symmetric Butterworth filter with a cut-off frequency of 10 Hz when considering a fatigue run in individuals with and without a history of ITBS. In addition, Hickey et al. (2016) filtered their kinematic data using a zero-phase-shift, fourth-order, low-pass Butterworth digital filter at 10 Hz when considering lower limb biomechanics during SLS task, and some studies have used a cut-off frequency as low as 8 Hz for running (Noehren et al., 2014, Noehren et al., 2007, Ferber et al., 2010b, Foch et al., 2015).

For kinetic measurements higher sampling frequencies have been suggested. Hori et al. (2009) stated that 200 Hz was suitable for the measurement of various force-time variables. However, other authors recommend that a sampling frequency of 500 Hz or higher ensures greater accuracy, especially when impact is involved (Bartlett, 2007). A common choice of sampling frequency for force plate analysis for human motion is 1000 Hz (Payton and Bartlett, 2007). Ferber et al. (2010b) used force plate data at a sampling

frequency of 960 Hz for collecting lower limb joint moments data in runners who had previously had ITBS and healthy runners. Similarly, Shen et al. (2021) used a force plate sampling frequency of 1000 Hz for collecting data for hip abductor and knee external rotation moments in runners who develop ITBS and healthy runners, whereas Foch et al. (2015) used a sampling frequency of 1200 Hz for collecting the hip abductor moment data during running in runners with current and previous ITBS and a healthy group. A similar sampling frequency of 1080 Hz was used by Noehren et al. (2007) for exploring peak rearfoot, inversion, knee external rotation and hip abduction moments in runners with and without ITBS. However, some studies reported using a higher sampling frequency of 2000 Hz, with Mackay et al. (2020) assessing the 3D ankle, knee, and hip joint angles and moments during SLS and running tasks, while Logan et al. (2010) collected ground reaction force data to compare between running shoes, racing flats, and distance spikes in runners. As with kinematics there is no one single agreed value for recording running kinetics, however a minimum sampling frequency of 500 Hz seems to be a pragmatic balance between the volume of data and temporal measurement precision.

Filtering is also required for kinetic data, and as with kinematic data low-pass filters are essential to remove random noise (Kristianslund et al., 2012). There are various cut-off frequencies reported in the literature for kinetic data. Some studies used the same cut-off frequencies and the same filter techniques for both kinematic and kinetic data. Mackay et al. (2020) used a fourth-order zero lag low-pass Butterworth filter with a cut-off frequency of 16 Hz which was the same as the kinematic low-pass filter, whereas Foch et al. (2015) used an 8 Hz cut-off frequency. However, higher cut-off frequencies have been suggested. Noehren et al. (2007) used a fourth-order zero lag low-pass Butterworth filter with a cut-off frequency of 50 Hz in the collection of running data during stance phase in runner with and without ITBS. Similarly, Ferber et al. (2010b) and Shen et al. (2021) who studied runners with ITBS also used a fourth-order zero-lag Butterworth low-pass filter with a cut-off frequency of 50 Hz.

2.4.4 Measurement of Muscle Activity

Electromyography (EMG) signals are electrical signals associated with muscle contractions and can be detected using EMG sensors either over or indwelling in the

muscle. There are two types of EMG, surface EMG and intramuscular EMG (Chowdhury et al., 2013). Surface EMG assesses muscle function by recording muscle activity by attaching sensors to the skin over the muscles, whereas intramuscular EMG involves either a needle or fine wire being positioned within the muscle. Surface EMG can be recorded by a pair of electrodes or by a more complex arrangement of multiple electrodes. EMG recordings show the potential difference (voltage difference) between separate electrodes usually in a bipolar arrangement. The limitation of this approach is that the surface electrodes are limited to superficial muscles, and the signals can vary significantly depending on the patient's weight. However, specific electrode placements and functional tests have been developed to minimize this risk, thus providing reliable data (Wang et al., 2013).

There are many previous studies that have used EMG to determine muscle activity during running (Willson et al., 2012, Willson et al., 2011, Souza and Powers, 2009). Willson et al. (2012) evaluated differences in the onset time, activation duration, peak muscle activity, and average muscle activity of the gluteal muscles, as well as hip and knee joint frontal and transverse plane kinematics between male and female healthy runners. They found that females were greater peak and average of Gmax muscle activity than males, but there was no difference in the onset time, activation duration between sexes. In addition, there was not differences in the onset time, activation duration, peak and average of Gmed muscle between sexes. Willson et al. (2011) compared the onset time, activation duration, peak muscle activity, and average muscle activity of Gmax and Gmed muscle during running in female runners with and without PFP. The result found that no differences in peak or average Gmed and Gmax muscle activities between female runners with and without PFP. There were no differences in Gmax muscle activity in the onset time or activation duration between females with and without PFP, but females with PFP demonstrated delayed and shorter Gmed activation than females without PFP during running. Similarly, Souza and Powers (2009) determined average Gmax and Gmed muscle activity in female runners with and without PFP. They found a greater in average Gmax muscle activity for females with PFP during the step-down and running tasks, compared to the females without PFP, with no significant was seen in the average Gmed muscle activity during the step-down and running task.

The Frequency content of sEMG signals can be up to 400 Hz (Basmajian, 1985). Based on Nyquist sampling Theorem, the sampling frequency should not be less than twice the maximum signal frequency. Therefore, sEMG signals should be sampled at a minimum of 900 Hz to avoid aliasing of the signals. The majority of research using EMG has sampled at 1000 Hz or higher and a sampling rate of 2000 Hz is often recommended (Wang et al., 2013). Willson et al. (2012) used a sampling frequency of 1560 Hz for collecting the onset time, activation duration, peak muscle activity, and average muscle activity of gluteal muscle data in male and female healthy runners. Willson et al. (2011) used a sampling frequency of 1080 Hz whereas Baker et al. (2018) used a sampling frequency of 2000 Hz to compare average Gmax, Gmed, and TFL muscle activity in runners with and without ITBS. Similarly, Brown et al. (2019) used a sampling frequency of 2000 Hz for collecting the onset activation timing of the Gmed and TFL muscles during overground running in runners with and without ITBS.

EMG data usually requires some signal processing before data extraction for analysis. One source of noise is movement or motion artefacts which are caused by the movement of the sensor on the skin, which are especially present during fast movement such as jumping, running and fast movement sports. A high pass filter can be used to remove motion artefacts. De Luca et al. (2010) provided evidence for the selection of a 20 Hz high-pass filter for sEMG in order to remove low frequency noise sources during isometric contractions or muscle activity during normal movements. Additionally, they stated that selecting a high pass filter frequency below 20 Hz is not recommended because the energy in the sEMG is not stable and does not show a consistent contribution to the sEMG signal. This is similar to the study of Hébert-Losier et al. (2019) and Baker et al. (2018) who used a high-pass filter with a cut-off frequency of 20 Hz. After high pass filtering the EMG signals are usually full wave rectified and then low-pass filtered to provide an “enveloped” EMG signal. Low-pass filtering is often used to provide a better representation of the time-varying EMG amplitude, and previous studies have used a 15 Hz low-pass filter to envelope the EMG signal (Hébert-Losier et al., 2019) and 6 Hz (Chuang and Acker, 2019, Willson et al., 2012).

2.5 Reliability of biomechanical measurements

Repeated gait measurements can be used to evaluate the response to therapeutic interventions such as surgery, physiotherapy, medication, and orthotics. Therefore, the reliability of measures within the same day or day-to-day are important factors to be considered in movement analysis (Alenezi et al., 2016) to ensures that the repeatability and reproducibility of any measures is known when considering the effects of any intervention. There are two main factors that may affect the reliability of measurements in movement analysis, the variability that can occur in participants during repetitive movements and measurement variability due to experimental and equipment limitations (Leibbrandt and Louw, 2018). Measurement variability can occur from many sources, including: bony landmark location, marker placement, marker movement due to skin movement, inconsistent anthropometric measurements, and accuracy of the motion analysis system itself (McGinley et al., 2009). Knowledge of the amount of such variability can enable the researcher to minimise the risk of over-interpreting small differences as meaningful, and can provide greater confidence in any treatment effects that exceed the measurement error (Schwartz et al., 2004).

Between-trial variability during repetitive movement reflects the inherent variation when comparing healthy participants to those with pathology. These variations cannot be reduced; however, they provide a baseline measure of variability independent of other sources of error (Schwartz et al., 2004). Within-day variability has been attributed to measurement error, skin marker movement, and inherent physiological variability during human locomotion (Ferber et al., 2002), whereas the main error for between-day measurements is the reapplication of reflective markers (Della Croce et al., 2005). One of the recognized problems is placement of markers on the skin, both in terms of the day-to-day variability or comparisons between sessions within day. The placement of anatomical markers is particularly important for reliability, as this forms the anatomical coordinate system about which the angles are calculated. Small changes in marker positioning can cause crosstalk between planes of motion, or create offset shifts in the joint angle calculations (Ferber et al., 2002). Past research has reported that within-session measurement variability of kinematics was generally less than between-day variability (Steinwender et al., 2000, Carson et al., 2001, Ferber et al., 2002, Queen et al., 2006, Doma et al., 2012, Mason et al., 2016). The day-to-day reproducibility of the

kinematic and kinetic variables in the sagittal plane were more reproducible than those in the coronal or transverse planes, which may be due to a greater susceptibility to slight changes in marker placement (Queen et al., 2006).

Della Croce et al. (2005) found that when joint anatomy dictates movement primarily in one plane such as the knee joint, variability in the rotations out of this plane are increased by imprecise marker reapplication. This suggests that increased measurement variability in the frontal and transverse plane in running might be highlighted by incorrect reapplication of markers between days. Kadaba et al. (1989) used coefficients of multiple correlations to compare the reproducibility of kinematic and kinetic waveforms to explore within- and between-day repeatability during human walking. Participants were assessed three times on each test day and on three different test days while walking at their self-selected speed. The results showed intra-subject reproducibility was excellent in the sagittal plane kinematics for both within-day tests as well as between-day tests. For frontal and transverse plane kinematics, the repeatability was good for the within-day tests and poor for the between-day tests. They stated that poor between-day reproducibility of frontal and transverse kinematic data was due in part to variability in marker placement.

The reliability or consistency of gait or running biomechanics can be assessed in various ways. Typically, multiple walking trials are collected within a single session or at different times. For example, Ferber et al. (2002) measured the reliability of kinematic data with uninjured recreational runners when running at a speed of 3.65 m/s who then returned one week later and were tested using the same procedure. The same tester attached the markers on all participants and intraclass correlation coefficients were used for the variables of interest to compare within- and between-day reliability. Ferber et al. (2002) showed that the peak knee flexion, adduction and internal rotation angle showed a standard error of measurement (SEM) of 1, 0.04, and 0.03 degrees, respectively, and the ICC of within-day tests were 0.92, 0.98, and 0.98, respectively. In addition, the ICC of the between-day tests for peak knee flexion, adduction and internal rotation angle were 0.93, 0.71, and 0.83, respectively. For hip kinematics, the SEM of within-day tests for peak hip extension, adduction and internal rotation angle were 0.98, 0.32, and 0.35 degrees, respectively, and the ICC were 0.92, 0.98, and 0.98, respectively. Furthermore,

the ICC of between-day tests for peak hip extension, adduction and internal rotation angle were 0.88, 0.69, and 0.54, respectively. These results showed a high degree of reliability for the within-day tests, which were more reliable than the between-day tests in both hip and knee kinematic data. In addition, the kinematic sagittal plane values from the between-day tests were more reliable than frontal and transverse plane values in both hip and knee kinematic data.

Alenezi et al. (2016) assessed the within- and between-day reliability of lower limb biomechanical data collected during running and 90 degrees sidestep cutting tasks. Participants were tested twice during the first visit with a one-hour gap between sessions to investigate within-day reliability. Then, participants were tested one week later to assess the between-day reliability. The result showed the SEM of within-day tests for peak hip flexion, adduction and internal rotation angle were 5.14, 1.99, and 2.46 degrees, respectively, and the ICC were 0.74, 0.75, and 0.76, respectively. Furthermore, the ICC of between-day tests for peak hip flexion, adduction and internal rotation angle were 0.65, 0.51, and 0.72, respectively. For knee kinematics, the peak knee flexion, adduction, and internal rotation angle showed that the SEM of within-day tests were 3.68, 0.98, and 2.84 degrees, respectively, and the ICC of within-day tests were 0.63, 0.94, and 0.74, respectively. In addition, the ICC of between-day tests for peak knee flexion, adduction and internal rotation angle were 0.67, 0.61, and 0.58, respectively. These results showed a high degree of reliability in joint angle measures for the within-day running tests, which were higher than the between-day tests in both hip and knee kinematic data. Furthermore, there was a good reliability of within-day tests for hip kinematics (ICC = 0.74-0.76) and knee kinematics (ICC = 0.63-0.94).

Leibbrandt and Louw (2018) investigated the test-retest reliability of hip, knee and ankle kinematics in the sagittal, coronal and transverse planes in people with anterior knee pain during gait. Participants performed six barefoot walking trials at a self-selected speed and participants returned seven days later to repeat the testing procedure. This interval was chosen because it is long enough to avoid memory bias from the first occasion and short enough to avoid a change in gait due to variations in symptoms. The results demonstrated that all variables had acceptable to excellent test-retest reliability,

with the coronal plane hip and sagittal plane ankle parameters being the most reliable, with the hip transverse plane parameters being the least reliable.

It is important to understand the magnitude of change that is attributed to repositioning of markers especially when assessing a treatment effect or response over time (Ferber et al., 2002). McGinley et al. (2009) suggested that in most common clinical situations an error of 2° or less are highly likely to be considered acceptable, and an error of 2°-5° is also likely to be considered as reasonable. It has been suggested that angular deviations greater than 5° may be sufficient to mislead clinical analyses. To reduce the marker position variability, a single, well trained investigator should apply all markers on successive sessions whilst trying to not remove markers between sessions on the same day (Ferber et al., 2002).

2.6 Summary

Ultimately, the guidelines for the management of ITBS are yet to be confirmed. Runners with ITBS suffer from pain, and rehabilitation can take considerable time before a safe return to running is possible. In many cases the chronic severe pain from ITBS prevents athletes from running completely, which can affect the running careers of professional athletes. Therefore, treatments that offer relief from symptoms so that runners can continue training should be considered.

Kinesio tape is used in the treatment of ITBS and other presentations of knee pain, which have been shown to offer some relief from symptoms, although the mechanisms for this are still unclear. To date no study exists which has evaluated the effects of KT in runners with ITBS. Therefore, the purpose of this study was to initially investigate the effects of two methods of KT on biomechanical parameters in asymptomatic runners, and then to explore the biomechanical and clinical effects on runners with ITBS.

2.7 Aims and objectives

2.7.1 Healthy Participants

The aim of this study was to investigate the immediate effects of KT on lower limb kinematics, joint moments, and muscle activity, as well as perceived changes in comfort, stability and running performance in UK and Thai healthy participants.

2.7.1.1 Objectives

- To determine if the application of Kinesio tape with tension (KTT) and Kinesio tape with no tension (KTNT) significantly alters three-dimensional joint kinematics and moments of the lower limb in healthy participants compared to no tape (NT).
- To determine if muscle activity of the Gmax, Gmed, TFL, VM, and VL muscle are altered with the application of KTT and KTNT in healthy participants compared with NT.
- To determine any perceived changes in the comfort, stability of the knee joint, and benefits to running performance when using KT.

2.7.1.2 Hypotheses for the Healthy Participants

- There will be a significant immediate increase in the hip external rotation angle and decrease in the hip internal rotation and adduction angles and knee internal rotation angle, decrease in the moments, and decrease in the TFL muscle activity in the KTT condition compared to NT condition.
- There will be no significant immediate change in the lower limb kinematics, moments, and muscle activity in the KTNT condition compared to the NT condition.
- There will be perceived improvements in comfort, stability, and running performance in the KTT condition compared to NT condition.

2.7.2 ITBS Participants

The aim of this study is to investigate the efficacy and effectiveness of the application of KT in the short-term management of ITBS in a Thai population in an exploratory randomised controlled trial using two groups, a KTT group and a KTNT group.

2.7.2.1 Objectives

- To determine the immediate effects of KT on the three-dimensional joint kinematics and moments of the lower limb during running in ITBS patients, and to determine any differences between the KTT and KTNT groups.
- To determine the immediate effects of KT on muscle activity of the Gmax, Gmed, TFL, VM, and VL in ITBS patients, and to determine any differences between the KTT and KTNT groups.
- To determine if the short-term perceptions of pain, symptoms, ADL function, sport and recreation function, quality of life, and fear of movement are changed with taping, and to determine any differences between the KTT and KTNT groups.
- To determine any perceived changes in the comfort, stability of the knee joint, and benefits to running performance with taping, and to determine any differences between the KTT and KTNT groups.
- To determine if muscle strength and muscle length are changed with taping, and to determine any differences between the KTT and KTNT groups.
- To determine if the response to the application of KTT and KTNT is different between the sexes.

2.7.2.2 Hypotheses for the ITBS Participants

- There will be a significant immediate increase in the hip external rotation angle and decrease in the hip internal rotation and adduction angles and knee internal rotation angle, decrease in the moments, and decrease TFL muscle activity in the KTT group compared to the KTNT group after the application of KT.
- Both females and males will show similar changes in hip and knee angles, moments and muscle activity after the application of KT.
- There will be significantly greater improvements in the clinical outcomes in the KTT group compared to KTNT group including; pain, fear of movement (TSK score), Knee Injury and Osteoarthritis Outcome Score (KOOS) sub-scores (Symptom, Pain, ADL, Sport and recreation, and Quality of life), Global Rating of Change (GROC) after the KT application across the 7 days of taping.

- There will be significantly greater immediate improvements in the muscle strength, and muscle length after the application of KT.
- Both females and males will show a similar improvement in clinical outcomes after the application of KT across the 7 days of taping.
- There will be perceived improvements in comfort, stability, and running performance after the application of KT across the 7 days of taping in the KTT group but not in the KTNT group.
- Both females and males will show a similar improvement in perceived changes in the comfort, stability of the knee joint, and benefits to running performance after the application of KT across the 7 days of taping.

CHAPTER 3 GENERAL MATERIALS AND METHODS

3.1 Introduction

This chapter describes the details of the instrumentation used within the three experimental chapters including motion capture systems, force platforms and sEMG equipment across two laboratories at UCLan, UK and Mahidol University, Thailand. In addition, this chapter also describes the taping interventions, running biomechanics tests, sEMG sensor placement, marker placement, perceived comfort, stability of the knee joint, and running performance outcomes, and data processing.

3.2 Instrumentation used in the UK healthy participant study

3.2.1 The Qualisys™ passive Motion Capture System

The Qualisys™ passive motion capture system (Qualisys Medical AB, Goteburg, Sweden) (Figure 3-1) uses high speed two-dimensional (2D) digital cameras. The UK healthy study used ten Oqus 7 cameras which emit infrared flashes to capture retro-reflective markers positioned on the body of the participants.

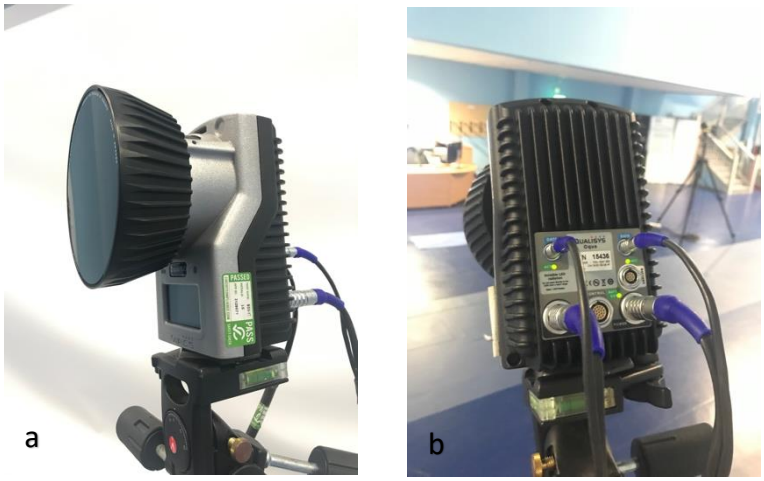


Figure 3-1 Qualisys™ Oqus camera;

a) front view of camera, b) back view of camera.

3.2.1.1 Camera Settings

The cameras were set at a sampling rate of 100 Hz, and were positioned around the data collection area to give a capture volume of 2 x 5 x 2 m (Figure 3-2). Prior to data collection, the position, focus, aperture, and marker threshold of each camera was adjusted so that they could all see three groups of reflective markers within the data

collection area, thus setting the data capture volume (Figure 3-2). Once the camera positions were checked, the calibration of the system was performed. The length of the UK laboratory was 30 metres and the distance that participants were required to run was 10 metres. The research setting in the laboratory at UCLan, UK, and the running distance can be seen in Figure 3-3.

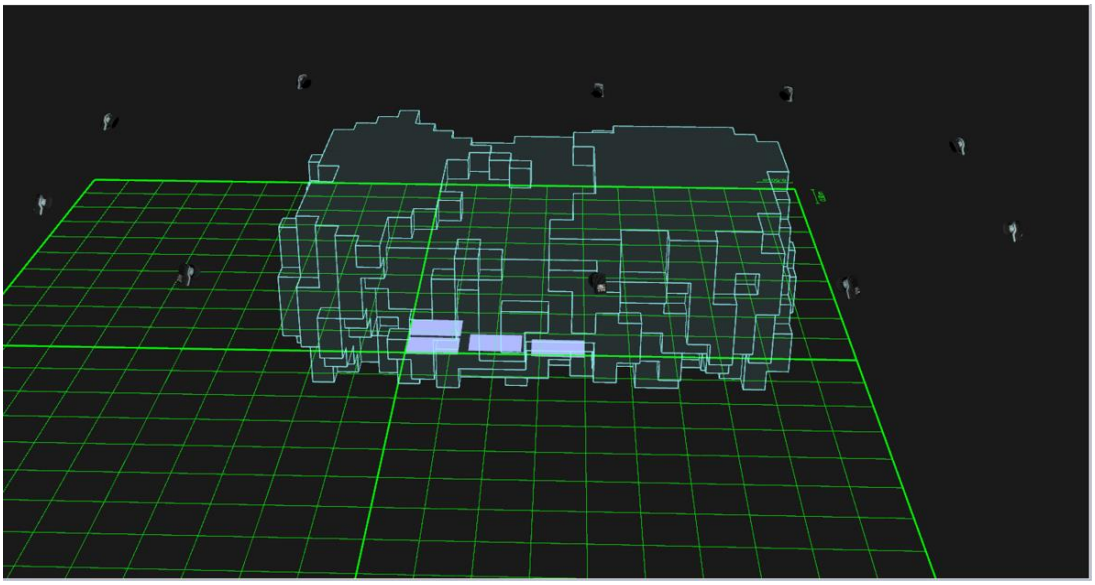


Figure 3-2 Screen shot of the covered volume view from QTM programme.

Figure 3-3 The laboratory setting at UCLan, UK, and the running distance.

3.2.1.2 Kinematic calibration

Before starting data collection, a static and dynamic kinematic calibration was performed to determine the position and orientation of each camera which allows the calculation of three-dimensional marker data.

3.2.1.3 Static calibration

A L-shaped reference frame with four reflective markers (Wand 300 Calibration Kit, Qualisys Medical AB, Gothenburg, Sweden) was used in the static calibration, which was positioned on the corner of one of the force platforms (Figure 3-4a). The position of the L-frame sets the lab global coordinate system reference as XYZ; where the X axis defined the forward/backward direction, the Y axis defined the medial/lateral direction, and the Z axis defined the vertical direction.

3.2.1.4 Dynamic calibration

A “T” shaped calibration wand with two reflective markers (Figure 3-4b) was moved through the capture volume, for 35 seconds. To obtain the calibration values, the calibration algorithm within QTM uses the position and orientation information of the cameras and three-dimensional coordinates of the wand. A resulting average residual factor of less than 1 mm was considered as acceptable following the manufacturers guidelines (Figure 3-5). If the average residual factor exceeded 1.0 mm for any camera, the calibration procedure was repeated until all residual factors were below 1.0 mm.

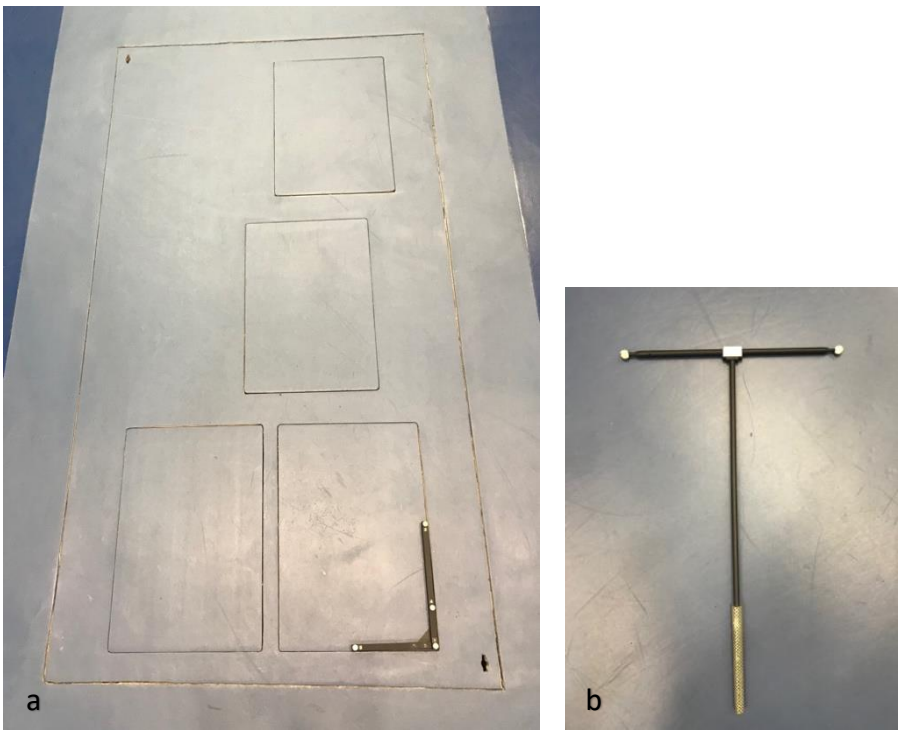


Figure 3-4 a) L-shaped reference frame on force platform 1,

b) T-shape calibration wand for dynamic calibration.

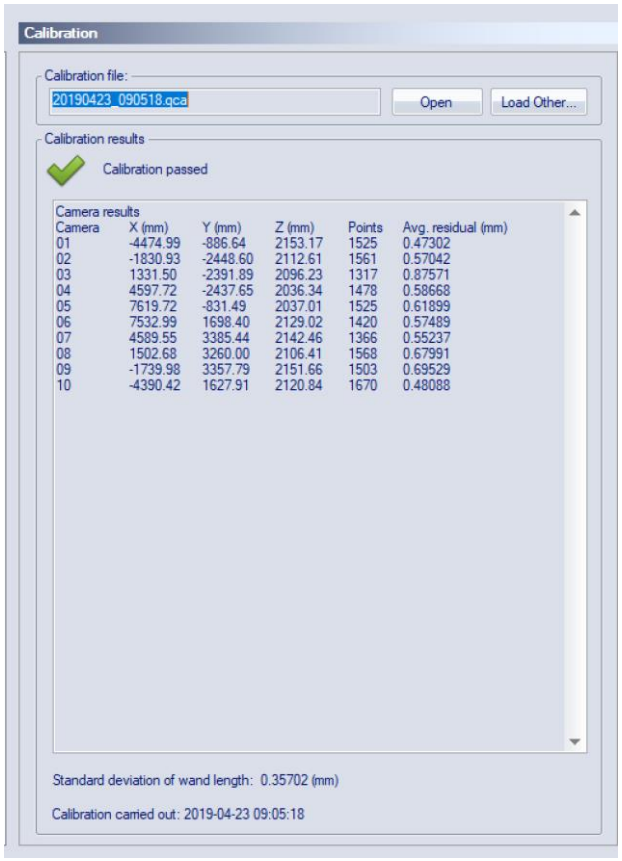


Figure 3-5 Example of the average residual errors of a successful calibration.

3.2.2 Force platform and defining the force platform position

Four force platforms (AMTI BP400600, Advanced Mechanical Technology Inc., USA) were used to collect ground reaction forces for the UK healthy study (Figure 3-6a). The four force platforms were used in order to increase the chance for the participants' foot of the study limb to land within the perimeter of a force platform, thus potentially minimising the number of trials participants were required to run. Each force platform produces a total of six outputs by measuring the three orthogonal force and moment components along the X, Y, and Z axes.

Kinetic data was recorded at a sampling rate of 500 Hz. The force platforms were synchronised with the Qualisys motion capture system using the 'Synchronisation In' connector on the master camera. Additionally, sEMG was synchronised using an external trigger unit which sent a TTL signal to the master camera and the EMG system (Delsys Trigno EMG). Therefore, the time was synchronised between the motion capture system, the force platforms and the EMG system. Upon completion of the kinematic calibration, retroreflective markers were placed on each corner of the four force platforms (Figure 3-6), which was used to define the position of the force platforms within the QTM programme.

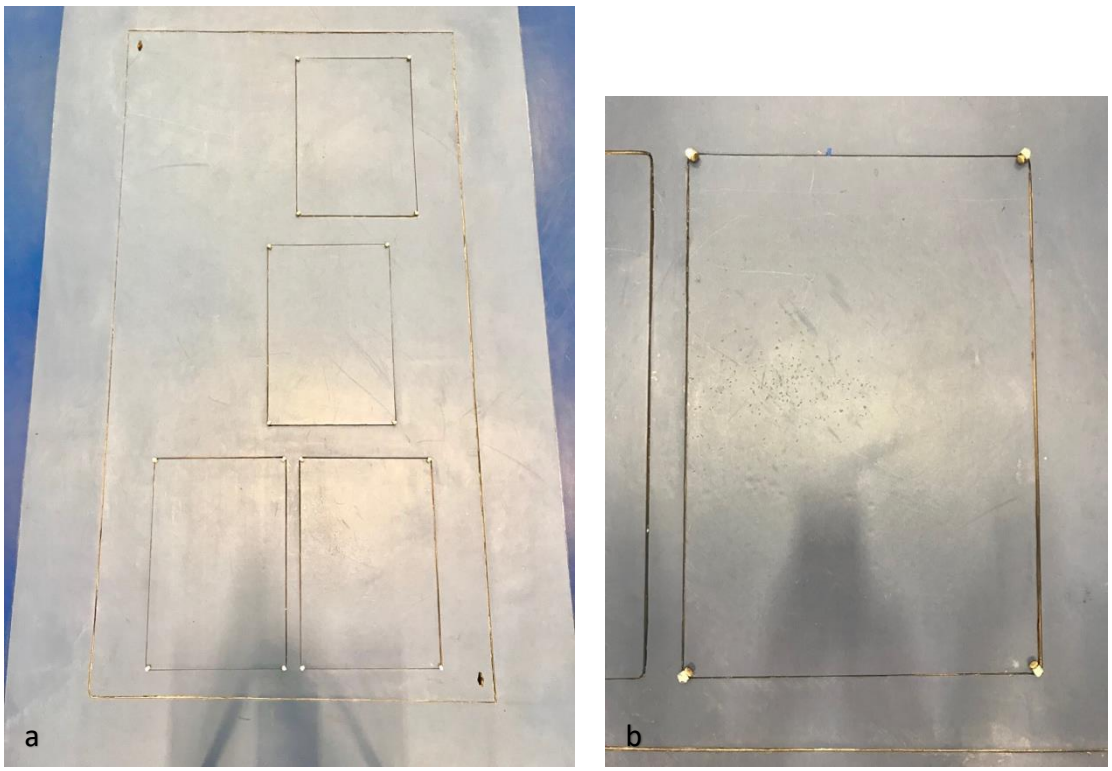


Figure 3-6 a) Marker positions on the four force platforms for positional calibration within the laboratory, b) marker location on one force platform.

3.3 Instrumentation used in the Thai healthy participant and Thai ITBS studies

3.3.1 The Vicon™ passive Motion Capture System

The Vicon™ Vantage passive motion capture system (Oxford Metrics, Oxford, UK) (Figure 3-7) uses multiple high-speed processors to perform real-time proprietary image-processing. This study used ten Vicon Vantage video cameras which emit infrared flashes to capture retroreflective markers positioned on the body of the participants.

Figure 3-7 Vicon™ Vantage camera.

The cameras were set at a sampling rate of 200 Hz, and were placed around the data collection area to cover a capture volume of 2 x 5 x 2 m which was the same capture volume as the UK healthy study (Figure 3-8). As in the UK healthy study, the position, focus, aperture, and marker threshold of each camera was adjusted so that they could all see three groups of reflective markers within the data collection area, thus setting the data capture volume, Figure 3-8. Once the camera positions were checked, the calibration of the system was performed. The length of the Thai laboratory was 16 metres and the distance that participants were required to run was 10 metres. The laboratory setting at Mahidol, Thailand, and the running distance can be seen in Figure 3-9.

Although there was a difference in the length of the two laboratories with the UK laboratory being 30 metres and the Thailand laboratory being 16 metres, both used a run test length of 10 metres, however the shorter distance to decelerate in the Thailand laboratory may account for a lower running speed. In addition, there was a difference in the motion capture systems used between the studies in the UK (the Qualisys motion capture system) and Thailand (the Vicon motion capture system). However, the same marker placements and biomechanical models were used in all studies.

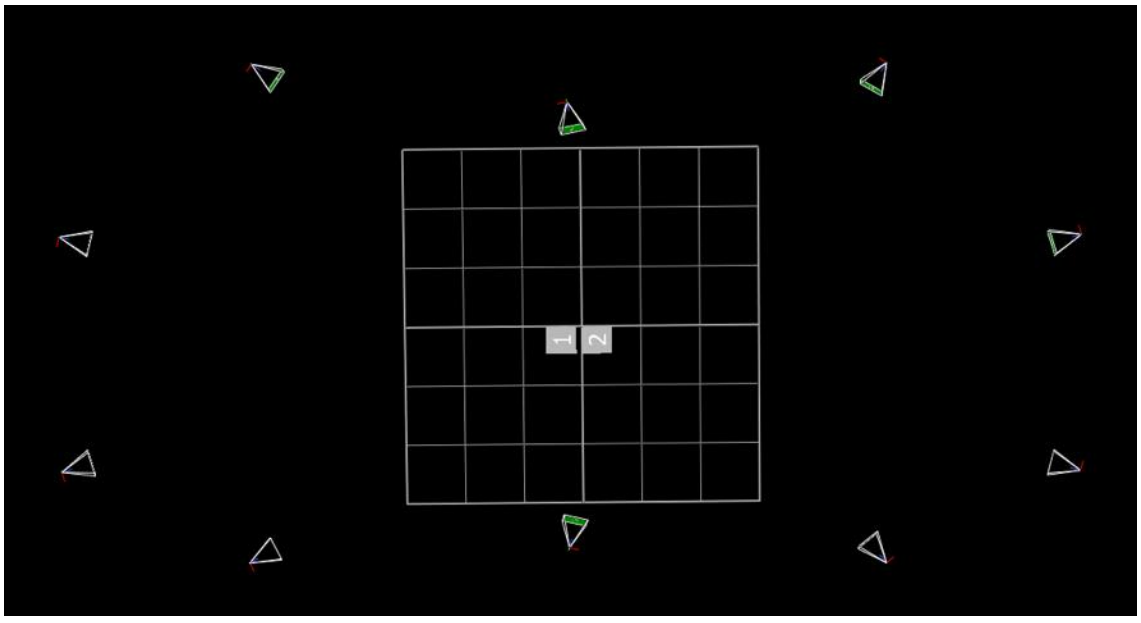


Figure 3-8 The camera positions from the Nexus™ programme.

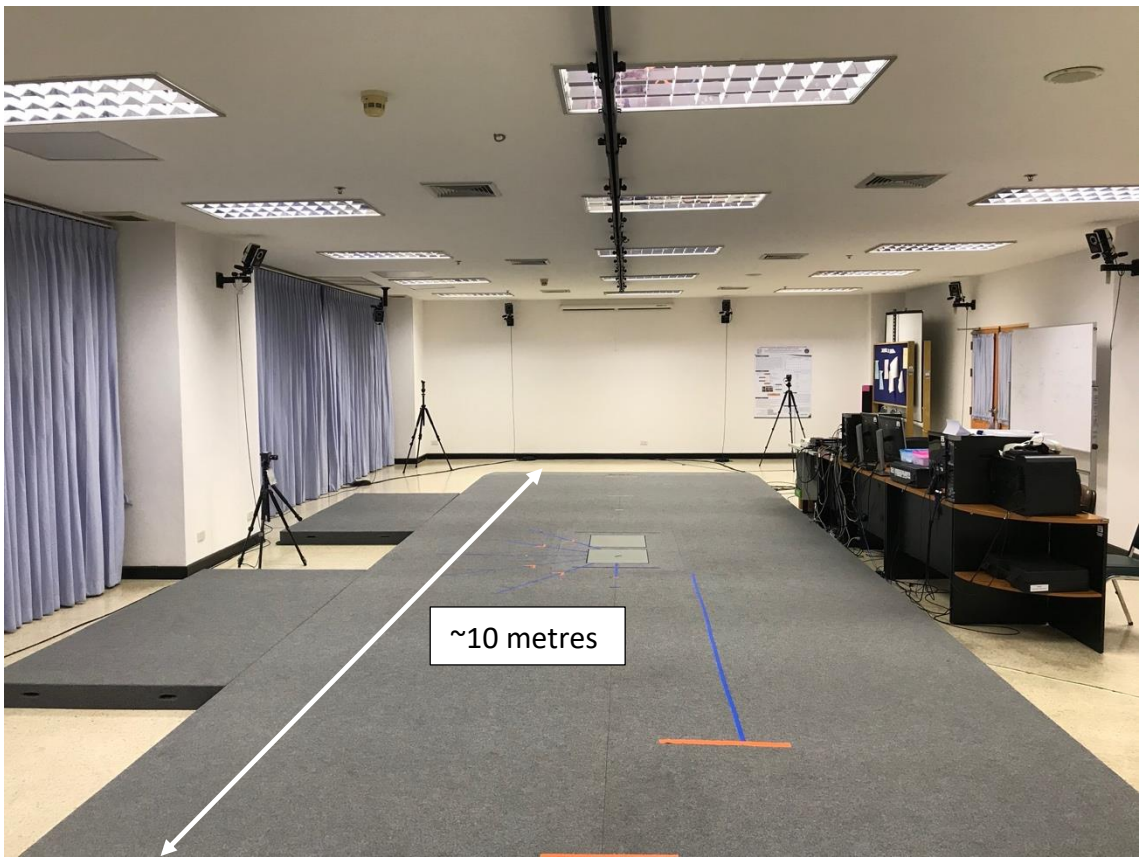


Figure 3-9 The laboratory setting at Mahidol University, Thailand, and the running distance.

The Active Calibration Wand is an electronic motion capture calibration device that contains five pairs of LEDs (Figure 3-10a) and is moved through the capture volume. To obtain the calibration values, the calibration algorithm within Vicon Nexsus programme uses the position and orientation information of the cameras and three-dimensional coordinates of the wand. Following the dynamic calibration, a static calibration was required in which the Active Calibration Wand was positioned on the corner of the force platform (Figure 3-10b) which sets the lab global coordinate system reference as XYZ; where the X axis defined the medial/lateral direction, the Y axis defined the forward/backward direction, and the Z axis defined the vertical direction. Following manufacturers guidelines, a resulting image error factor of less than 0.2 pixels was considered acceptable (Figure 3-11). If the image error factor exceeded 0.2 pixels for any camera, the calibration procedure was repeated.

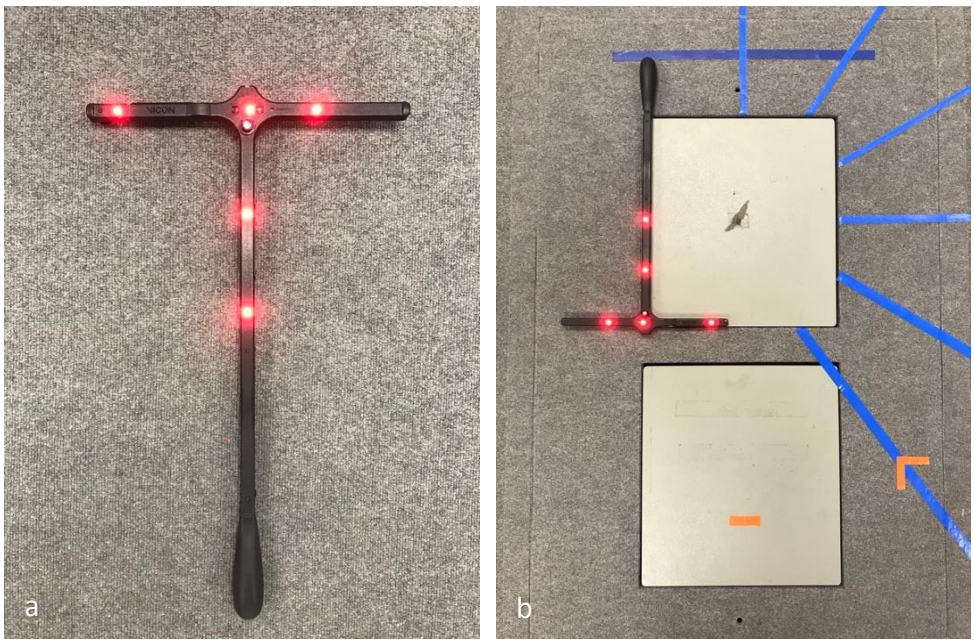


Figure 3-10 a) Active Calibration Wand,

b) Active Calibration Wand positioned on the force platform.

Camera	Wand Count	World Error	Image Error
#1 (Vantage 5)	1885	0.20995	0.0997602
#2 (Vantage 5)	1501	0.0823475	0.0722977
#3 (Vantage 5)	2202	0.246935	0.115989
#4 (Vantage 5)	2309	0.235941	0.0844238
#5 (Vantage 5)	2221	0.254584	0.092624
#6 (Vantage 5)	1770	0.168236	0.0768692
#7 (Vantage 5)	1593	0.0692716	0.0568146
#8 (Vantage 5)	1600	0.166291	0.0757282
#9 (Vantage 5)	2265	0.218474	0.0791177
#10 (Vantage 5)	2419	0.205602	0.0731585

Figure 3-11 Example of the Image errors of a successful calibration.

3.3.2 Force platform and defining the force platform position

Two force platforms (AMTI-OR67, Advanced Mechanical Technology Inc., USA) were used to collect ground reaction forces for the Thai healthy and Thai ITBS studies. Two force platforms were used in order to increase the chances of the participants' foot of the study limb landing within the perimeter of either force platform whilst running, thus potentially minimising the number of trials participants were required to run. Kinetic data was recorded at a sampling rate of 2000 Hz. A Vicon Lock unit was used to

synchronise the time between the Vicon motion capture system, the Delsys Trigno EMG system, and the AMTI force platforms (Figure 3-12).

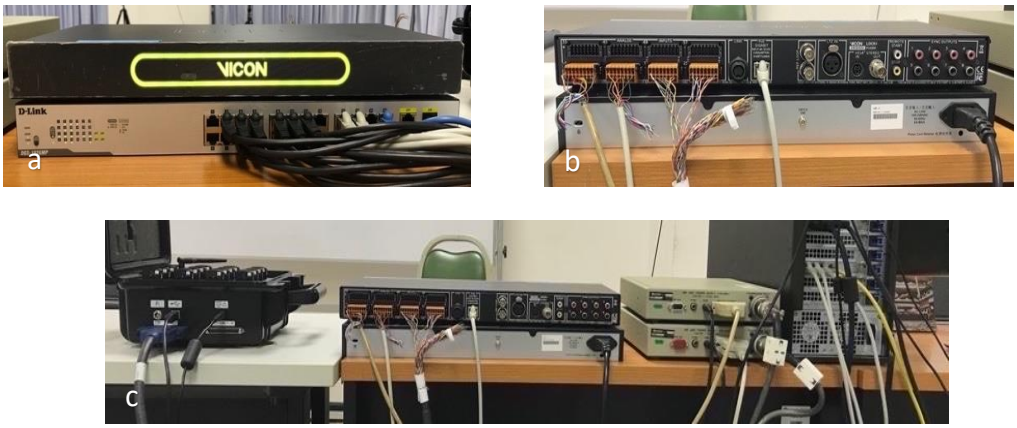


Figure 3-12 Synchronisation of the Vicon Vantage, AMTI force platforms and Delsys systems a) Vicon lock box (front), b) Vicon lock box (back), c) Complete integration and synchronisation of equipment.

3.4 Instrumentation and Methods used in all studies

3.4.1 Surface Electromyography System

Both UK and Thai laboratory used the same EMG system. Five sEMG electrodes (Delsys Trigno Lab system, Delsys Inc., Boston, MA) (Figure 3-13) were used to collect muscle activity data. The Delsys Trigno system uses wireless EMG sensors each with four silver bar contacts which detect EMG signals of the underlying muscles. sEMG signals were collected at a sampling frequency of 1925 Hz from Gluteus Maximus (Gmax), Gluteus Medius (Gmed), Tensor Fascia Latae (TFL), Vastus Medialis (VM), and Vastus Lateralis (VL) muscles.

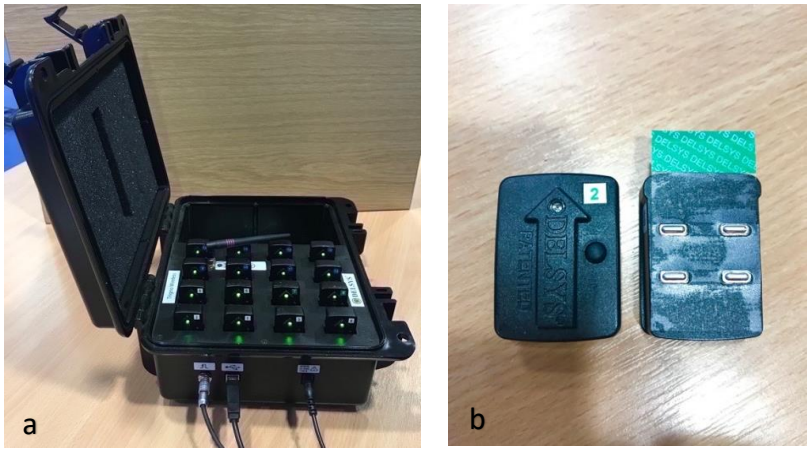


Figure 3-13 The Delsys Trigno System a) The Delsys Trigno System Base, b) The Delsys Trigno EMG sensor.

3.4.2 Running Biomechanics Tests

The procedure for the running biomechanics tests is shown in Figure 3-14.

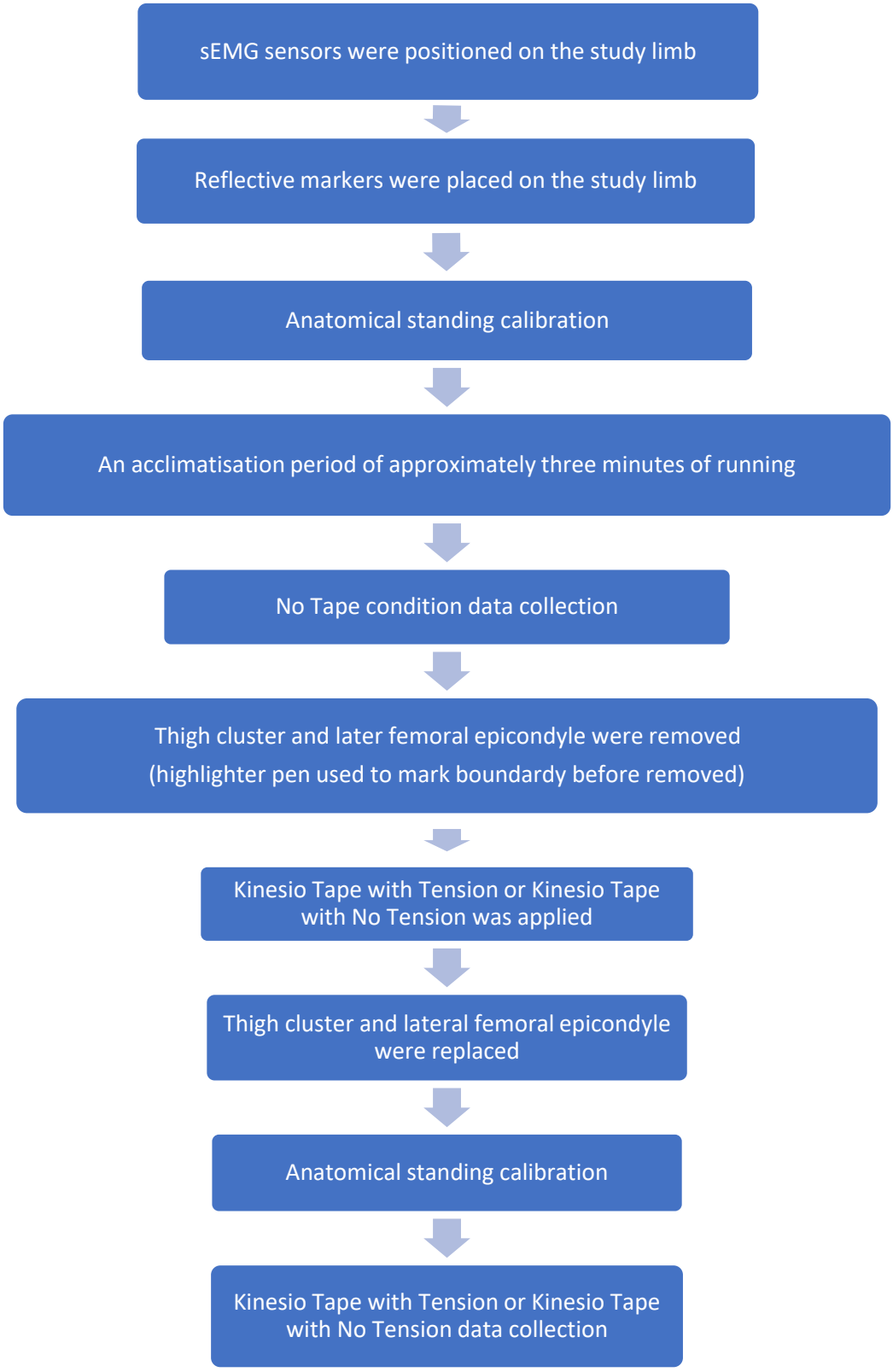


Figure 3-14 Sequence of preparing the participant and running biomechanics test procedures.

3.4.2.1 Participant Preparation

Participants wore their normal sports shirt, sports shorts, and running shoes during the data collection sessions. The sEMG sensors and the reflective markers were placed on the study limb. The study limb in the UK and Thai healthy study was the dominant limb which was defined as the leg they would kick a ball with, and draw a figure of eight on the floor (van Melick et al., 2017). For the ITBS study, the study limb was symptomatic limb which was defined as the leg they had current symptoms of ITBS, positive the Noble compression and Ober's test, reported numeric pain rating scale (NPRS) of at least 3 out of 10 at lateral femoral condyle during running (Noehren et al., 2014).

3.4.2.1.1 sEMG Sensor Placement

sEMG sensors were attached on the skin over the Gmax, Gmed, TFL, VM and VL according to the European Recommendations for Surface Electromyography (Freriks et al., 1999), Table 3-1 and Figure 3-15. The placement of sensors near muscle tendon insertion and innervation zones impairs signal fidelity (Roy et al., 1986). Therefore, the sEMG sensors were placed in the centre of the muscle belly, away from tendons and the boundary of the muscle, with the orientation of the sEMG sensor positioned perpendicular to the muscle fibre direction following the manufacturers guidelines, Figure 3-16.

Table 3-1 Recommendations for sensor locations and orientation in lower extremity muscles (Freriks et al., 1999).

Muscle	Sensor location	Sensor orientation
Gmax	Halfway on the line between the sacral vertebrae and the greater trochanter.	From the posterior superior iliac spine (PSIS) to the middle of the posterior aspect of the thigh.
Gmed	Halfway on the line between the iliac crest and the greater trochanter.	From the iliac crest to the greater trochanter.
TFL	The proximal 1/6 on the line from the anterior superior iliac spine (ASIS) to the lateral femoral condyle.	From the ASIS to the lateral femoral condyle.
VM	At 4/5 on the line between the ASIS and the joint space of anterior border of the medial collateral ligament (MCL).	Almost perpendicular to the line between the ASIS and the joint space of anterior border of the MCL, in vastus medialis oblique fibre direction.
VL	At 2/3 on the line between the ASIS and the lateral side of the patella.	In the VL fibre direction, slightly angle from lateral thigh to patella.

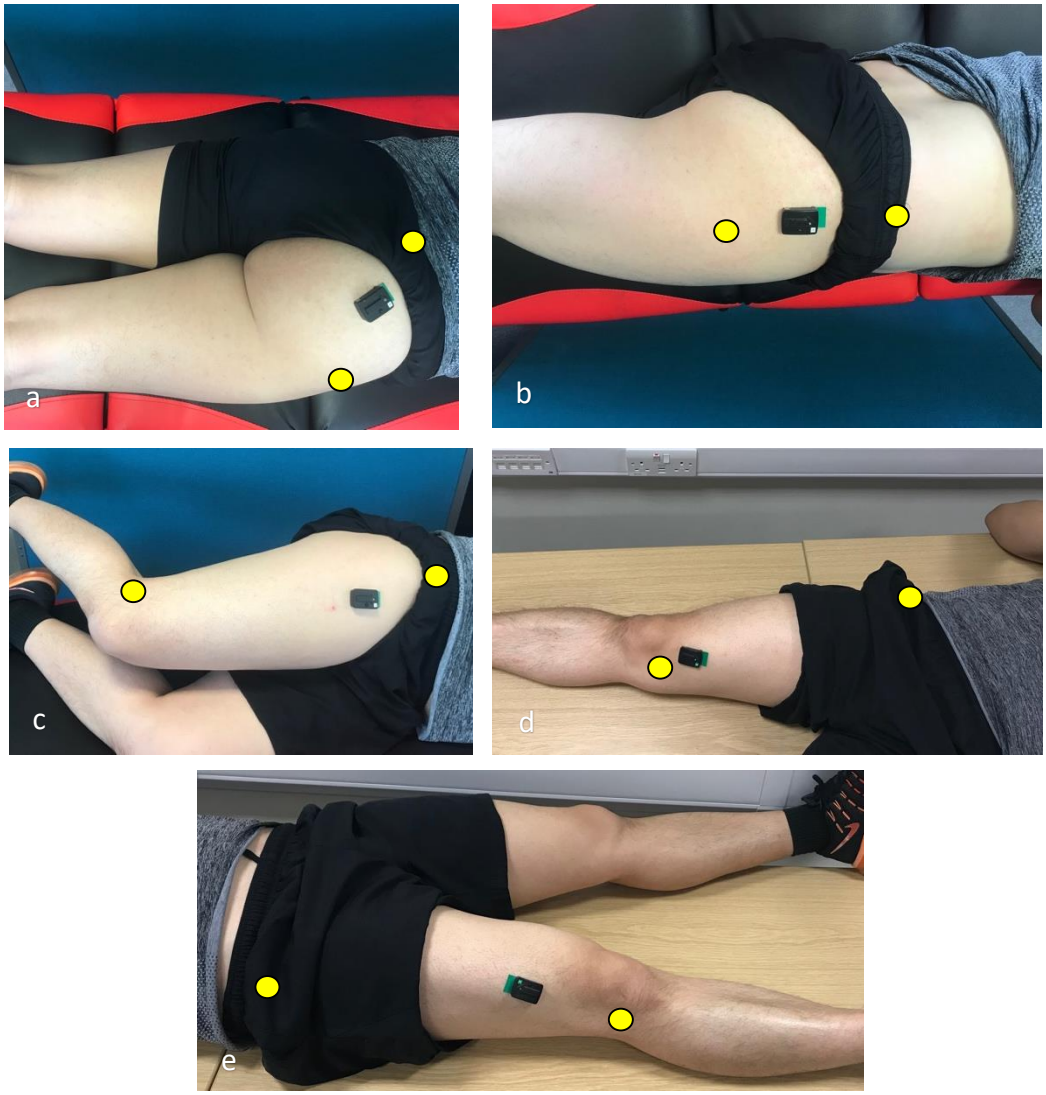


Figure 3-15 EMG position and orientation on the study limb

a) Gmax, b) Gmed, c) TFL, d) VM, and e) VL. Yellow circles represent the anatomical landmarks used to determine the sensor location.

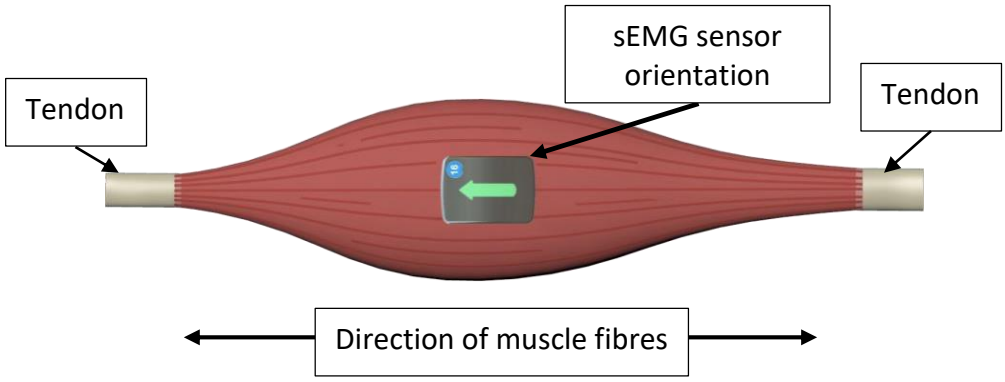


Figure 3-16 Position and orientation of the sEMG sensor

(Image modified from Delsys Inc.).

Prior to placement of the sEMG sensors, the skin at the sensor sites was cleaned with isopropyl alcohol wipes in order to remove dry dermis and any skin oils, oils on the sEMG sensor site and surface residues. After the skin was completely dried, sEMG sensors were attached to the skin surface using Delsys Adhesive Sensor Interfaces. Additionally, participants with excessive hair where the sensor would be positioned, had that site shaved with a razor. If the skin was exceedingly dry, hypoallergenic tape was applied to the skin to remove any dry skin. After preparing the skin and attaching the sEMG sensor on the skin, signal fidelity was checked. Baseline noise was assessed, and values <20 μV RMS (root mean square) were considered acceptable. If the sEMG signal was contaminated with large baseline noise, the procedure of skin preparation and cleaning the sEMG sensor was repeated.

3.4.2.1.2 Marker placement

The same marker placements and biomechanical model was used in all studies. Retroreflective spherical markers (Figure 3-17) were attached to the participant with double-sided tape to define the anatomical reference frames of the pelvis, thigh, shank and foot. The anatomical markers were placed on the right and left ASIS and PSIS, the greater trochanter, the medial and lateral femoral epicondyles, and the medial and lateral malleoli. Four retroreflective markers were position on the calcaneus, first and fifth metatarsal heads, and midfoot which were positioned on the participants' shoes which modelled the foot as a single segment. On the contralateral limb, markers were attached to the foot and the medial and lateral malleoli to identify gait events. Carbon-fibre tracking clusters comprising of four non-orthogonal retroreflective markers were placed onto the lateral surface of the thigh and shank segments on the study limb using the Calibrated Anatomical System Technique (CAST) (Cappozzo et al., 1995). The complete marker set can be seen in Figure 3-18. Prior to running under each taping condition, participants were asked to stand on the force platform in the anatomical position, and a static trial was collected in order to determine the relative position and orientation of the segment clusters with respect to the anatomical markers.

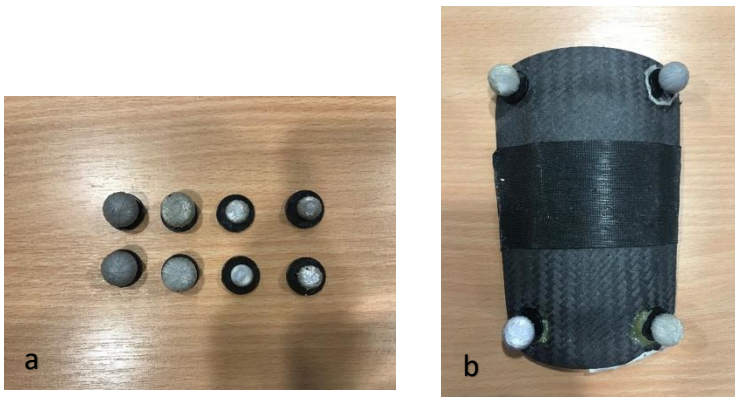


Figure 3-17 a) Reflective spherical markers

b) the carbon-fibre tracking clusters.

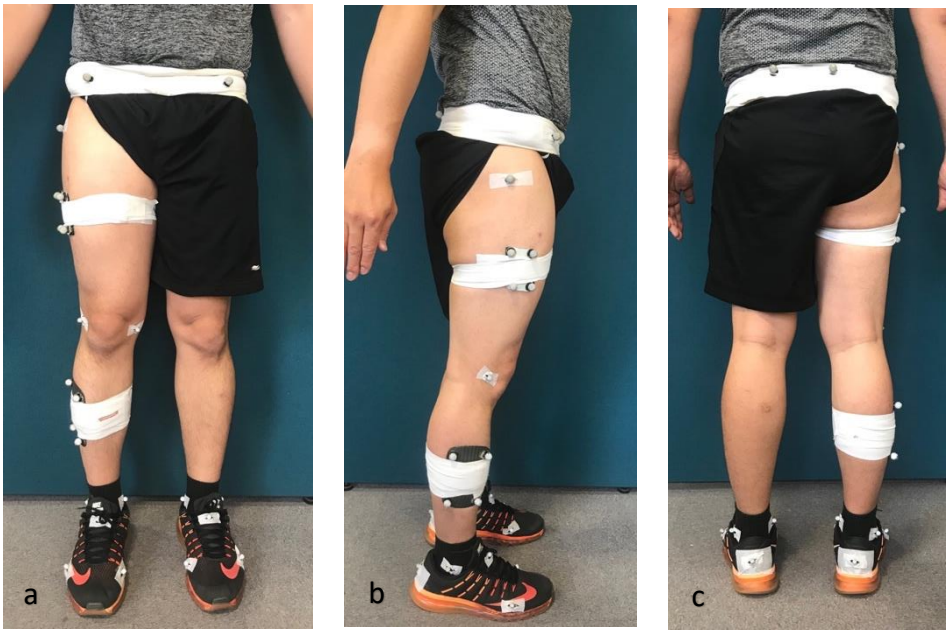


Figure 3-18 Marker set a) anterior view, b) lateral view and c) posterior view.

3.4.2.2 Taping Interventions; Kinesio Tape with Tension (KTT)

Kinesio Tex™ Tape (KT; Kinesio Holding Corporation, Albuquerque, NM) (Figure 3-19) which is an elastic therapeutic adhesive tape that is latex-free, hypoallergenic, waterproof, and porous. The KT techniques and user guide were developed by Kase (2003) who used Kinesio Tex™ in the developing of KT techniques and claimed KT may improve the symptoms of runners with ITBS, for which the author has anecdotal evidence that KT helps runners with ITBS from clinical experience. However, there is no research that has investigated the effect of KT on runners with ITBS. Therefore, the author decided to use the KT brand and technique describe by Kase in this thesis to explore if KT provided any efficacious biomechanical effects or self-reported benefits in runners with ITBS to provide an evidence base for future clinical practice.

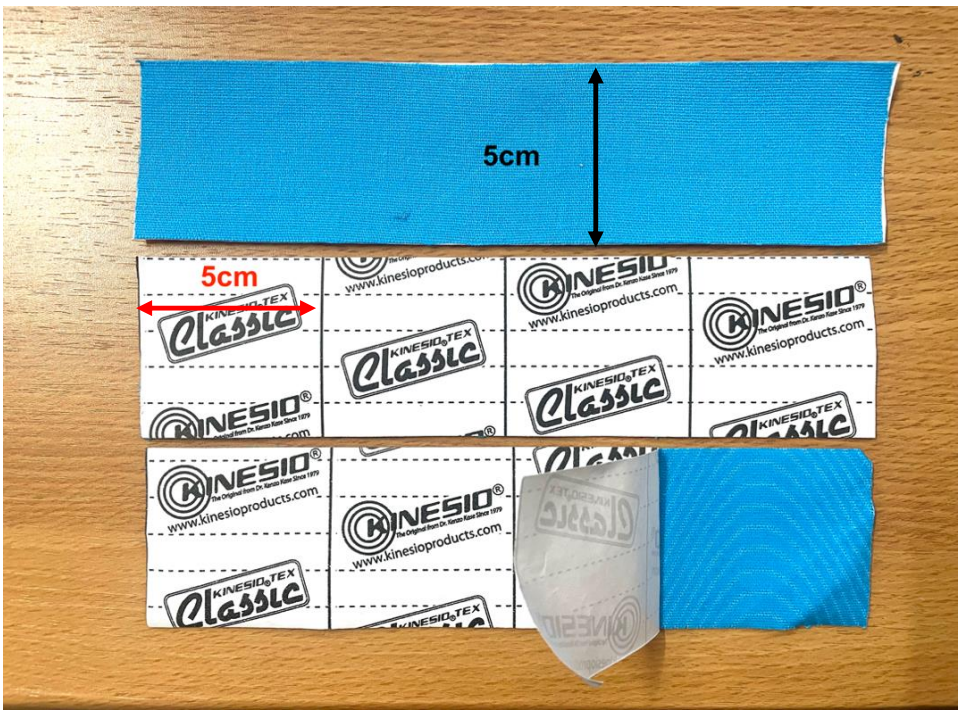


Figure 3-19 The Kinesio tape.

The KT used in this study had a width of 5 cm, a 5 cm length for each block, and a thickness of 0.5 mm (Figure 3-19). The KT application used in this thesis was performed by the author who is a certified KT practitioner (Appendix 1) and has over 3 years' experience using KT within his clinical practice. All KT techniques were applied to the participants' study limb as they lay in a side-lying position on their non-study limb side. The Kinesio tape with tension (KTT) condition consisted of three KT application techniques which are referred to as; Inhibition, Space Correction, and Functional Correction (Figure 3-20), which will now be described in more detail. The example of the percentage stretches of KT application from the length of 20 cm, with the origin of tape for 5 cm and end of tape for 5 cm can be seen in Figure 3-21.

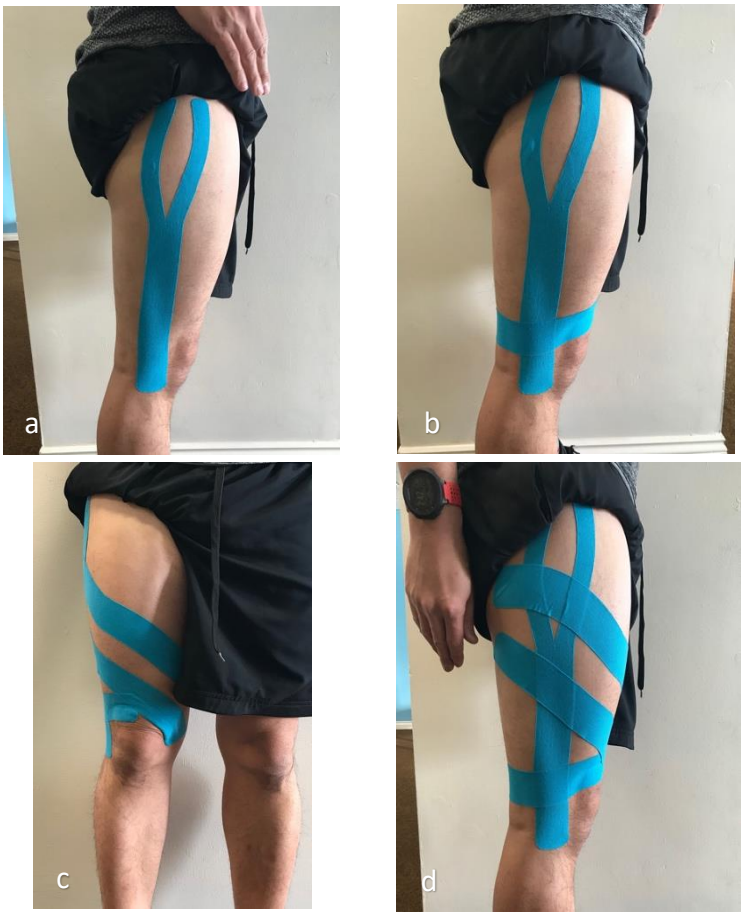


Figure 3-20 Kinesio Tape Application. a) Inhibition technique, b) Space correction technique, c) and d) Functional correction technique.

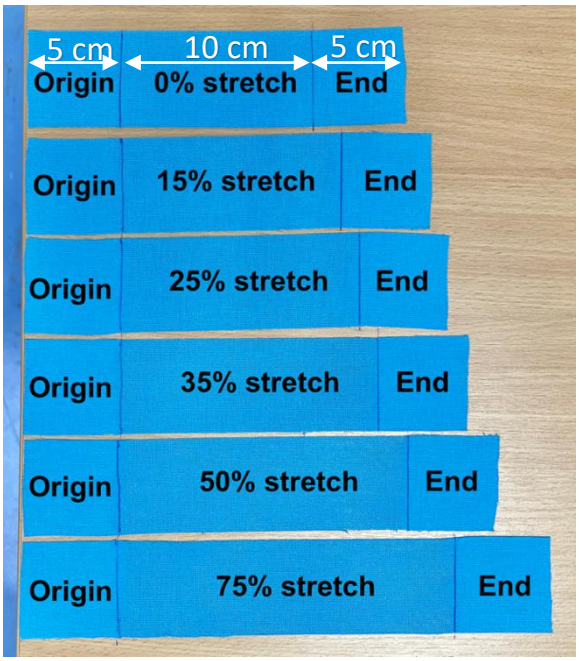


Figure 3-21 The example of the percentage stretches of Kinesio tape application with zero stretch at the origin and end of the tape.

3.4.2.2.1 Inhibition Technique

The first layer of KTT application was applied using an "inhibition technique" (Figure 3-20a), the unstretched length of the KT was measured from the lateral femoral epicondyle (LFE) to the greater trochanter of each participant. A 15-25% stretch over the ITB and TFL with zero stretch at the origin and the end of the tape was used. The KT was cut into a Y shape, with the base of the Y strip (5 cm) positioned inferior to the insertion of the ITB as the origin of tape with zero stretch in neutral position of lower limb (no stretched of muscle around hip joint in side lying position) (Figure 3-22a). The study limb was then moved into hip extension and adduction position in order to stretch the ITB, and the KT was stretched by 15%-25% in both the I and Y strip over the ITB and TFL (Figure 3-22b). The amount of stretch was visually assessed by the author. This consisted of the KT being stretched to 100% stretch and then reducing the amount of stretch to the target amount of stretch. Finally, zero stretch was applied to the end of the tape (5 cm) in the ITB stretched position. The inhibition technique used the KT's recoil effect from the insertion to the origin which has been suggested to induce motor neuron inhibition by stretching the Golgi tendon organs located at the distal end of muscles. This effect has been purported to decrease the tension within the TFL and ITB which has been associated with pain in people with ITBS during running (Yeung and Yeung, 2016).

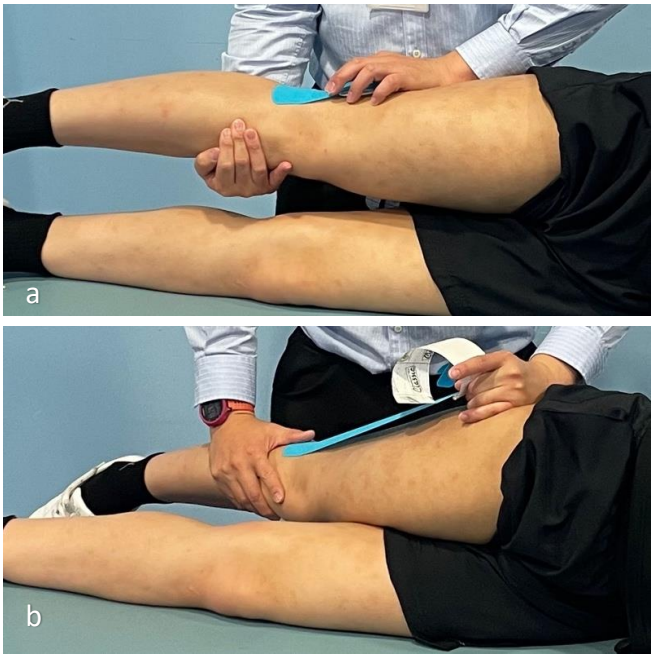


Figure 3-22 Kinesio tape inhibition Technique; a) Starting in a neutral position with applied origin tape with zero stretch, b) Applying tape with 15-25% stretch of KT in ITB stretched position.

3.4.2.2.2 Space Correction Technique

The second layer of KTT was applied using a “space correction technique” (Figure 3-20b), the unstretched length of the KT was based on the measurements from the lateral femoral condyle to the medial femoral condyle of each participant. A 25-35% stretch over the lateral femoral epicondyle with zero stretch at the origin and the end of the tape was used. The participant’s study limb was moved into hip extension and adduction position in order to stretch the ITB, at which point an “I” strip of tape was applied with a 25-35% stretch over the LFE (Figure 3-23). Finally, both origin (5 cm) and end (5 cm) of the KT were applied with zero stretch in the ITB stretched position. The KT user guide by Kase (2003) claimed that the space correction technique has a lifting effect to reduce pressure between the ITB and lateral femoral epicondyle, resulting in a decrease in pain at the ITB insertion at the LFE in people with ITBS.

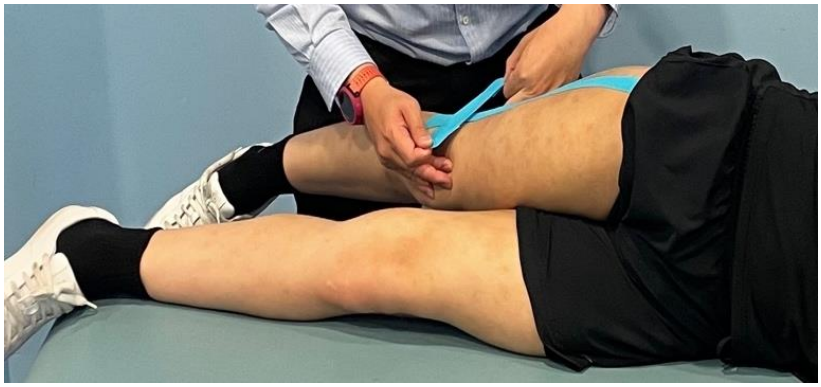


Figure 3-23 Kinesio tape with space correction technique with a 25-35% stretch of KT in ITB stretched position.

3.4.2.2.3 Functional Correction Technique

The third layer of KTT was applied using a “the functional correction technique” (Figure 3-20c-d), the unstretched length of the two “I” strips were measured from the medial femoral condyle to the middle point of the lateral thigh of each participant. A 50-75% stretch over the thigh with zero stretch at the origin and the end of the tape was used. The KT “I” strip (5 cm) was placed at the infero-medial at the thigh 2cm above the knee joint with zero stretch as the origin of the tape with the lower limb in a neutral position (Figure 3-24a). Then, the participant’s leg was moved into hip external rotation and abduction, and a 50-75% stretch in the tape was applied over the thigh in a spiral shape, with the end of the tape (5 cm) attached with zero stretch (Figure 3-24b). Finally, the participant’s leg was moved into a hip internally rotated and adducted position and the KT was attached over the thigh (Figure 3-24c). The functional correction technique has been suggested to assist with hip external rotation and abduction movement through the stimulation of cutaneous mechanoreceptors. Therefore, the KT may increase hip external rotation and abduction or decrease hip internal rotation or adduction during running (Mackay et al., 2020, Song et al., 2015).

Figure 3-24 Functional correction technique; a) Starting in a neutral position with applied origin tape with zero stretch, b) Movement into hip external rotation and abduction whilst applying KT with a 50-75% stretch, c) Hip internal rotation and adduction whilst attached KT.

3.4.2.3 Kinesio Tape with No Tension (KTNT)

For all three studies, a comparator tape condition of Kinesio Tape with no tension (KTNT) was used. This consisted of the same three layers of KT as in the KTT condition, with the unstretched length of the KT in each layer were measured the same as the KTT condition, but the tape was applied without tension (0% stretch of KT) with the participant positioned in a lower limb neutral position.

During running, the three layers of KT in KTT condition applied can pull the skin and stimulate skin mechanoreceptors. The KT was more stretched to increase the stimulation of the mechanoreceptors in the stance phase that there was an increase in the hip internal rotation and adduction angle during this phase. For KTNT condition, which consisted of the same three layers of KT as in the KTT condition but was applied without tension (0% stretch of KT) with the participant positioned in a lower limb neutral position. This would theoretically produce less somatosensory stimulation due to less pulling on the skin, however some stretch effect would be expected as the individual moves, in particular movements in internal and external rotation due to the direction of the application of the tape.

3.4.2.4 The procedure of Running Biomechanics Test

Before testing under the different taping conditions, participants were given an acclimatisation period of approximately three minutes to habituate to the testing environment and interventions, and a static trial was collected prior to running under each taping condition. All participants were tested in the No Tape (NT) condition first to gain a baseline measure for perceived comfort, stability of the knee joint, and running performance. After which, the author used a highlighter pen to mark the boundary of the thigh cluster and LFE anatomical marker on the study limb which were then removed in order to apply the KT. The relevant taping condition/technique (KTT or KTNT) was then applied, the thigh cluster and LFE anatomical marker were then re-attached at the same position. The correct positioning of the LFE marker, which was used to define the shank and thigh coordinate systems, was then checked and the running test was repeated. Figure 3-25 depicts an example of a participant with the full marker set, EMG sensors and taping applied.

The participants were then asked to run at a self-selected speed along a 10m runway 10 times under each condition, with a 1-minute rest between trials. Each participant was instructed to run at the same self-selected speed under the different tape conditions. Participants were instructed to lead with the same limb for each trial, to facilitate the reliability of making a good foot contact within the perimeter of the same force platform. Markers were placed on the floor to indicate the start position and first step length. Participants were asked to stand at the start point and were given the same verbal instructions, “are you ready?, OK, go” at the beginning of each run.

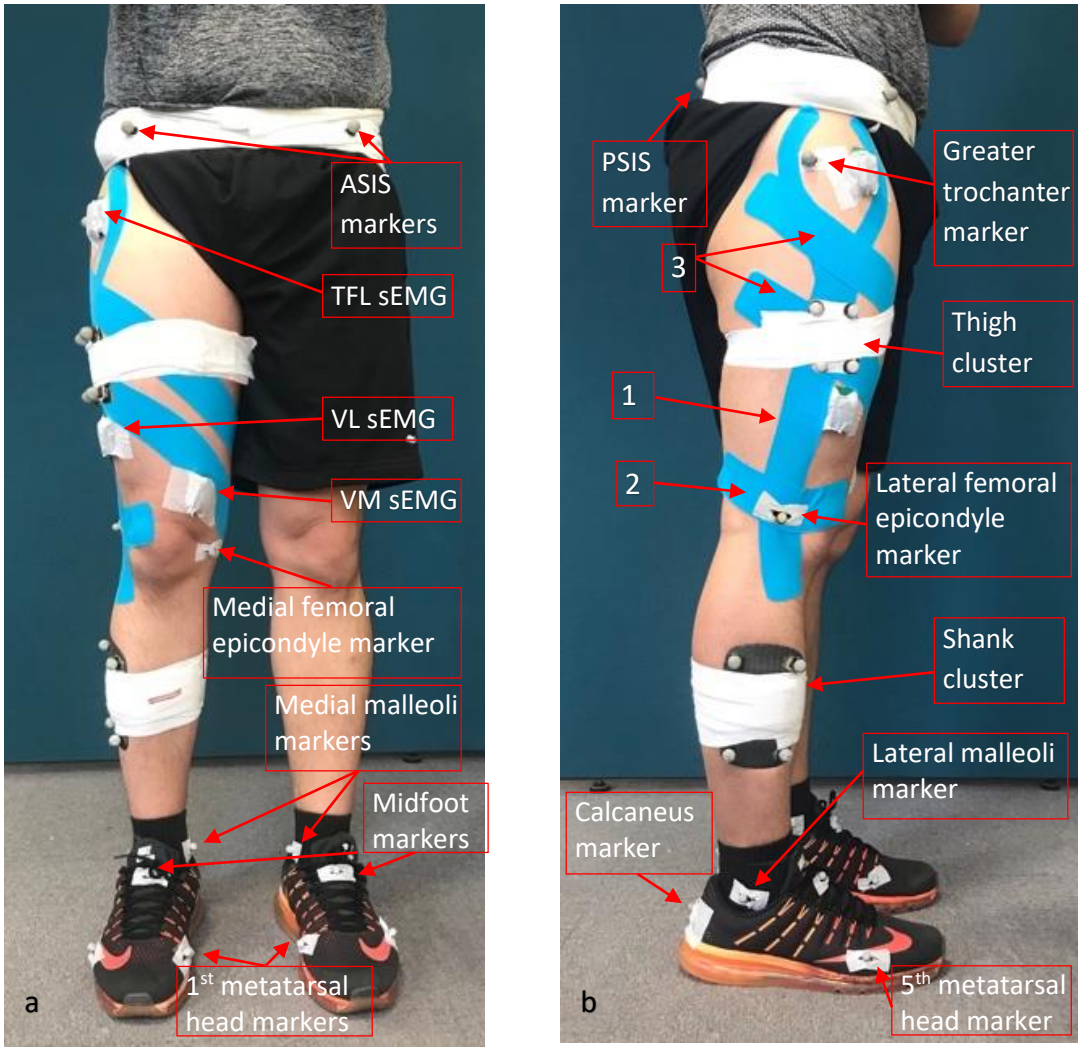


Figure 3-25 a) anterior and b) lateral view of the taping, marker and EMG placement. Kinesio Tape Application of 1) Inhibition technique, 2) Space correction technique, 3) Functional correction technique.

3.4.2.4.1 Perceived comfort, stability of the knee joint, and running performance outcomes

For all studies the perceived comfort, stability of the knee joint, and running performance was assessed after each set of trials under the KTT and KTNT conditions, participants were asked to assess their perceived comfort, stability of the knee joint, and running performance using a seven-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = neutral, 5 = slightly agree, 6 = agree, 7 = strongly agree), Appendix 2. A 2 point change compared to NT condition in perceived scores was chosen to determine the Minimal Clinical Important Change (MCIC) and Minimal Clinical Important Difference (MCID) for this thesis (Kamper et al., 2009).

Participants were asked to answer and were given the same verbal instructions
“Do you think this kinesio tape is comfortable compared to pre-tape?”
“Do you think this kinesio tape helps the stability of your knee compared to pre-tape?
““Do you think this kinesio tape offers benefits to your running performance compared to pre-tape?”

3.4.3 Checking the marker replacement position

The removal and reattachment of the thigh cluster and LFE marker was required in order to apply the KT. This thesis used the CAST technique to model each body segment in six degrees of freedom (Cappozzo et al., 1995). The CAST technique involves the quantification of an anatomical coordinate system for each segment using anatomical landmarks (static markers) which provide a position and orientation in space for the corresponding technical tracking markers positioned on rigid clusters (dynamic tracking markers).

The replacement of the LFE marker in a slightly different position could produce a test-retest error. This was mitigated for by using a highlighter pen to mark around the boundary of both the thigh cluster and LFE marker, with the LFE marker being critical for the position and orientation of the shank and thigh coordinate systems. Therefore, an additional check was performed to determine if the LFE marker was replaced in the same position prior to the taping being applied.

When collecting data for the static trials for the different conditions, the participant may be standing in a slightly different position and posture, therefore, the standing angle may show different joint angles across the different static trials. Based on the CAST model, joint angles are dependent on the coordinate system and the coordinate system depends on the proximal and distal, and medial and lateral anatomical markers. Therefore, the author used a method to create a virtual LFE marker in Visual 3D (C-Motion, Germantown, MD, USA) using a reference position from the medial femoral epicondyle marker based on the shank coordinate system (Figure 3-26), as these markers were not removed between conditions. This was used to check that there was no error in the relocation of the LFE marker after the tape was applied, and therefore no change of the position and orientation of the shank and thigh coordinate systems and any associated knock-on effect on the joint kinematics (Figure 3-27).

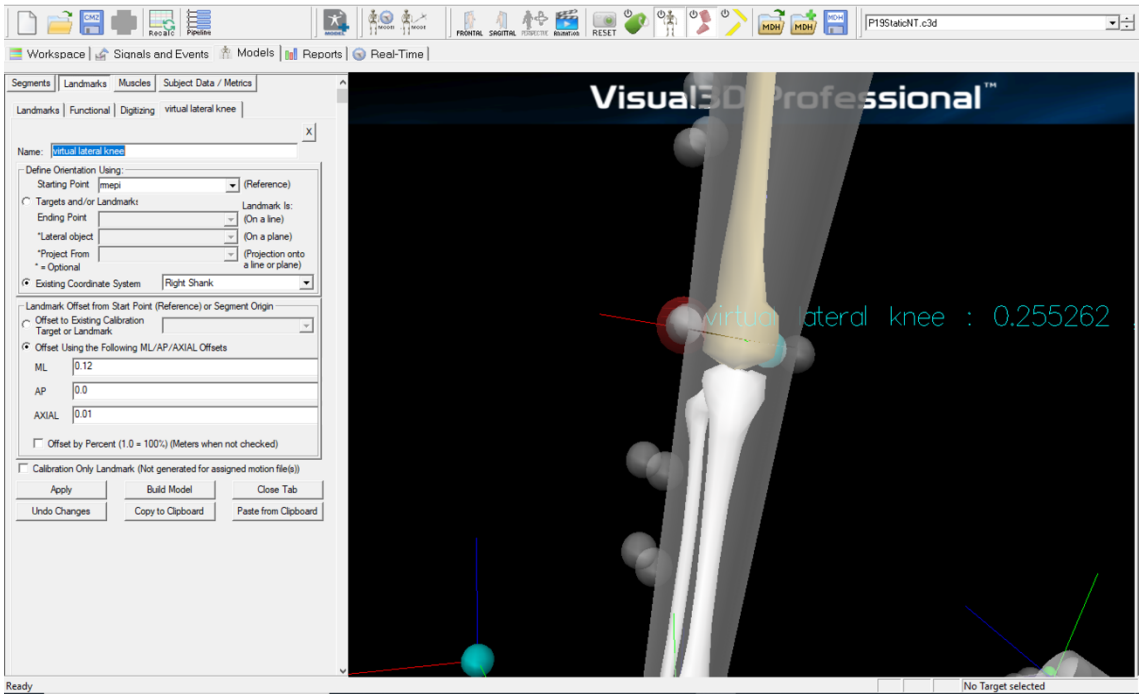


Figure 3-26 Screen shot of the virtual femoral epicondyle marker (red circle) created from the position of the first static anatomical calibration in Visual 3D.

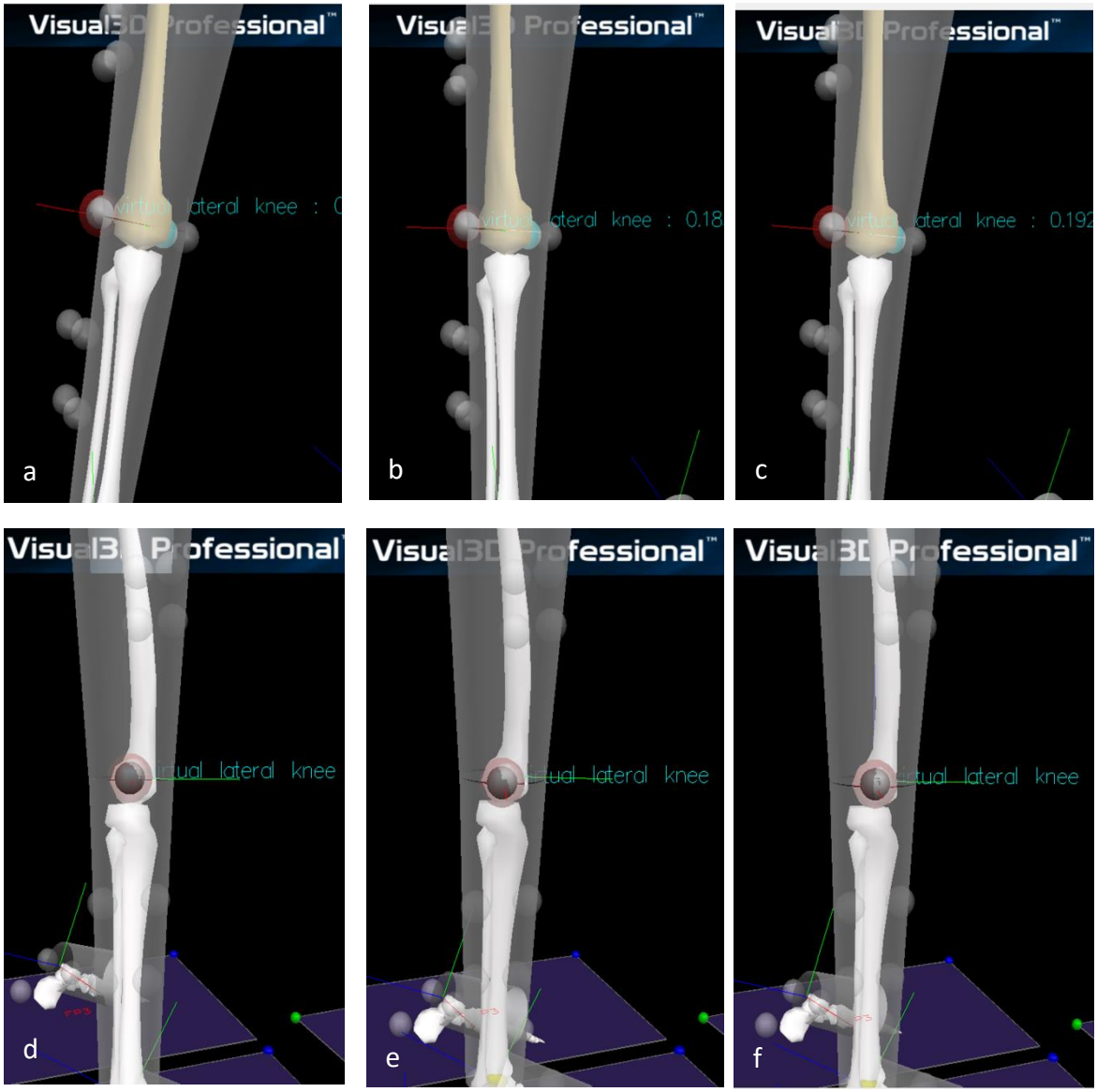


Figure 3-27 An example of one participant illustrating the virtual femoral epicondyle marker created from the first static anatomical calibration (red circle) compared to the femoral epicondyle marker (grey marker) in the anterior and lateral views; a-c) anterior view in NT, KTT, and KTNT conditions, respectively, d-f) lateral view in NT, KTT, and KTNT conditions, respectively.

3.5 Data Processing

Of the 10 trials collected, the last five trials were used for analysis as this considered trials with clear foot contacts with the force platforms. In addition, when looking at the data there were some marker tracking errors in a few trials so these were also not included. Therefore, the last five trials that showed complete data and a clear foot contact with a force platform were used as all participants reached this threshold. This is in line with previous studies which used five trials under each test condition (Noehren et al., 2007, Foch et al., 2015).

Running speed was calculated in Visual 3D by using the RPSIS or LPSIS marker depending on the study limb. The distance this marker travelled from heel-strike on the force platform to the subsequent heel strike was calculated and divided by the time taken.

3.5.1 Modelling of the Segments

3.5.1.1 Modelling of the Pelvis Segment

The pelvis segment was defined by using the markers placed on the left and right ASIS and PSIS. The pelvis origin segment coordinate system was defined as the mid-point between the ASIS markers. The tracking of the pelvis segment used the ASIS and PSIS markers. These markers were also used as the technical frame markers (Figure 3-28). The hip joint centre was calculated using the method described by Bell (Bell et al., 1990), Table 3-2.

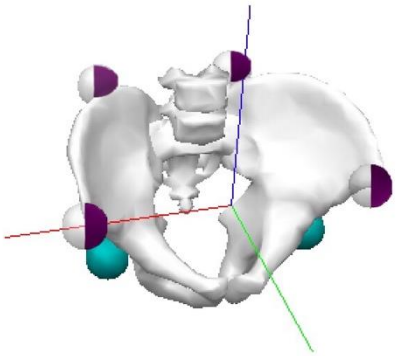


Figure 3-28 Model marker set for the pelvis segment (White = Anatomical Markers, Purple = Technical Frame Markers, White / Purple = Anatomical and Technical Markers, green = Calculated Hip Joint Centre).

Table 3-2 Hip Joint Centre calculation formula with relative planes of motion.

Right Hip Joint Centre	0.36*ASIS Distance (X Axis – Sagittal)	-0.19* ASIS Distance (Y Axis – Coronal)	-0.3 * ASIS Distance (Z Axis – Transverse)
Left Hip Joint Centre	-0.36 * ASIS Distance (X Axis – Sagittal)	-0.19 * ASIS Distance (Y Axis – Coronal)	-0.3 * ASIS Distance (Z Axis – Transverse)

3.5.1.2 Modelling of the Thigh Segment

The thigh segment coordinate system was defined by the proximal markers positioned on the greater trochanter and the distal markers positioned on the medial and lateral femoral epicondyles. The tracking of the thigh segment used the carbon-fibre tracking clusters which were placed on the lateral aspect of the thigh as the technical frame markers (Figure 3-29).

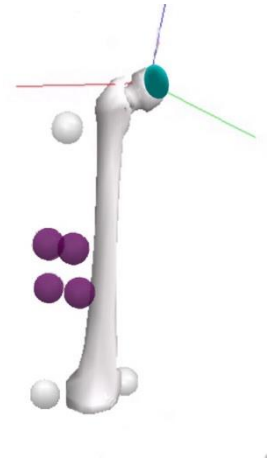


Figure 3-29 Model marker set for the thigh segment (White = Anatomical Markers, Purple = Technical Frame Markers, White / Purple = Anatomical and Technical Markers, green = Calculated Hip Joint Centre).

3.5.1.3 Modelling of the Shank Segment

The shank segment coordinate system was defined by the proximal markers placed on the medial and lateral femoral epicondyles and the distal markers on the medial and lateral malleoli. The tracking of the shank segment used the carbon-fibre tracking clusters positioned on the lateral surface of the shank as the technical frame markers (Figure 3-30).

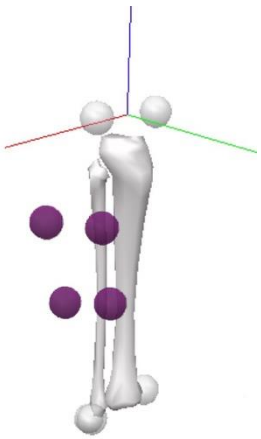


Figure 3-30 Model marker set for the shank segment
(White = Anatomical Markers, Purple = Technical Frame Markers).

3.5.1.4 Modelling of the Foot Segment

The foot segment coordinate system was defined by proximal markers placed over the heads of the 1st and 5th metatarsals on the running shoes and the distal markers were placed on the medial and lateral malleoli (Figure 3-31). The tracking of the foot segment used the markers attached over the heads of the 1st and 5th metatarsals, mid-foot marker and the posterior surface of the calcaneus as the technical frame markers.

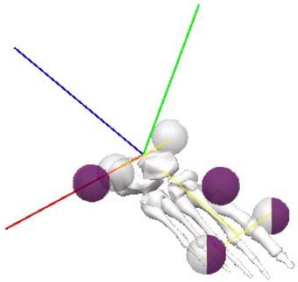


Figure 3-31 Model marker set for the foot segment
(White = Anatomical Markers, Purple = Technical Frame Markers,
White / Purple = Anatomical and Technical Markers).

3.5.2 Kinematic and Kinetics

Qualisys Track Manager for UK healthy studied and Vicon Nexus programme for Thai healthy and Thai ITBS studies were used to track the marker trajectories for the static and dynamic trials, which was then exported to C3D format and imported into Visual 3D. The kinematic and kinetic data were then filtered using a cut-off frequency of 8 Hz and 50 Hz, respectively, using a low-pass Butterworth 4th order zero lag filter (Noehren et al., 2007). Three-dimensional joint angles and moments at the hip and knee were

calculated using an XYZ cardan sequence of rotations (where X = sagittal plane; Y = coronal plane and Z = transverse plane), equivalent to the joint coordinate system (Grood and Suntay, 1983), and lower limb kinematics were calculated using a six degrees of freedom model (Cappozzo et al., 1995). The local coordinate systems were defined as below (Table 3-3). All data were normalised to 100% of the stance phase of the study limb.

Table 3-3 Local coordinate system and axes, planes of motion and respective movements.

Axes	Planes of Motion	Movement
X Axis	Sagittal Plane	Flexion/Extension
Y Axis	Coronal Plane	Adduction/Abduction
Z Axis	Transverse Plane	Internal/External Rotation

3.5.2.1 Joint Angle Calculations

All the kinematic outcome measurements were normalised to 100% of the stance phase using the events of initial contact to toe-off. Heel strike and toe-off were determined using vertical force thresholds of 20 N. Joint angles were defined as the angle between the distal segment with respect to the proximal segment, with the hip angle defined as the thigh segment relative to the pelvis, the knee angle defined as the shank segment relative to the thigh segment.

The right-hand rule was used to define the joints, with the hip and knee joints reported as positive angles representing flexion, adduction, and internal rotation; with negative angles representing extension, abduction, and external rotation. Three-dimensional kinematic measures from the hip and knee joints in the stance phase were extracted for statistical analysis. These included; peak angle, minimum angle and joint range of motion (ROM) in the three planes under each condition (NT, KTT, and KTNT). The example time series graph of three-dimensional hip and knee joint angles across three taping conditions can be seen in the Figure 3-32 and Figure 3-33.

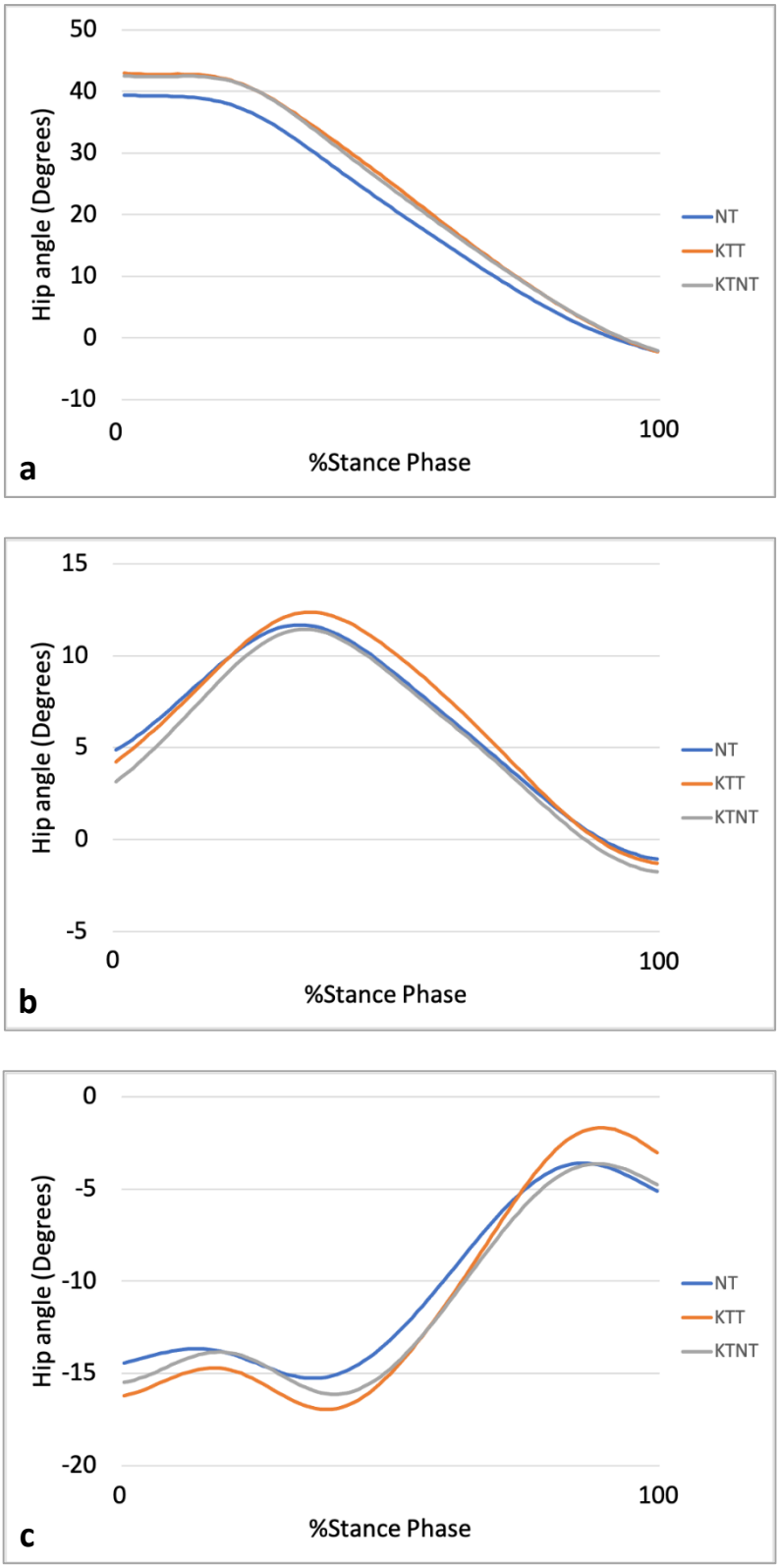
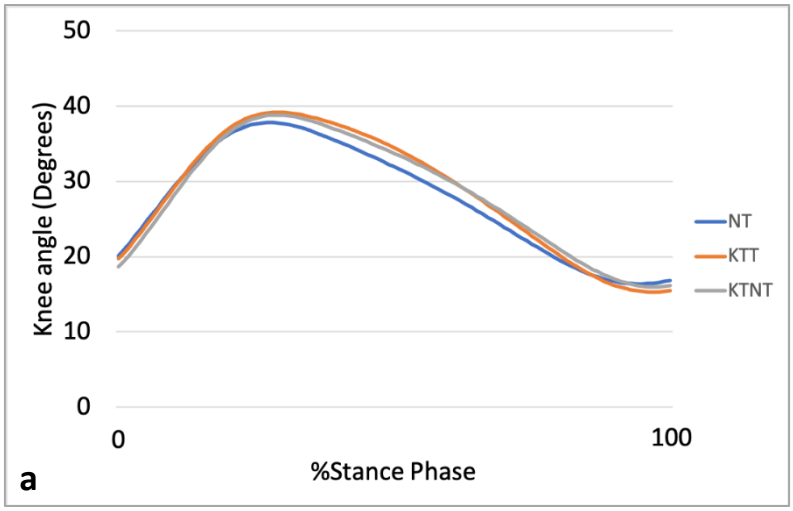
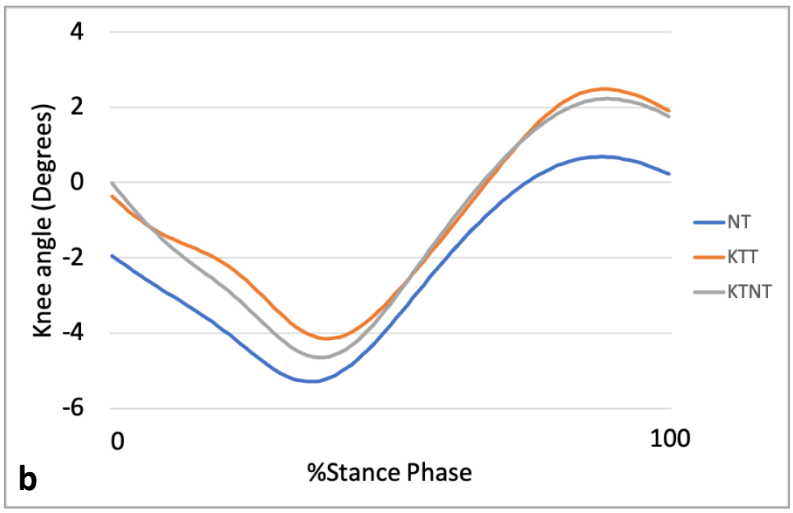


Figure 3-32 Example time series graph of three-dimensional hip joint angles from the UK healthy study (n=1) across three taping conditions; a) Hip extension/flexion, b) Hip abduction/adduction, and c) Hip external and internal rotation. Positive values indicate hip flexion/adduction/internal rotation and negative values indicate hip extension/abduction/external rotation.





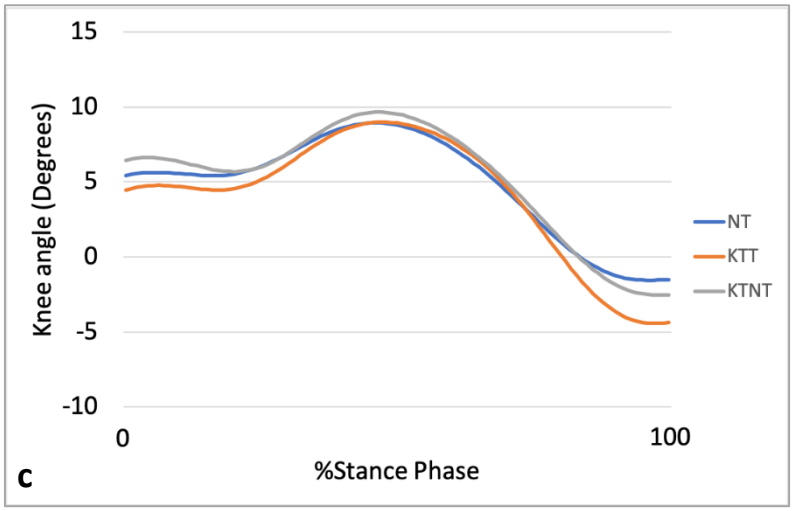
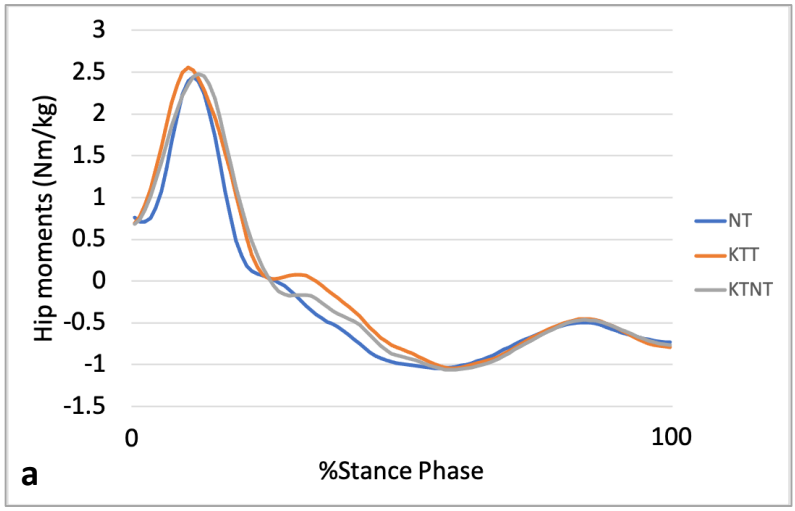
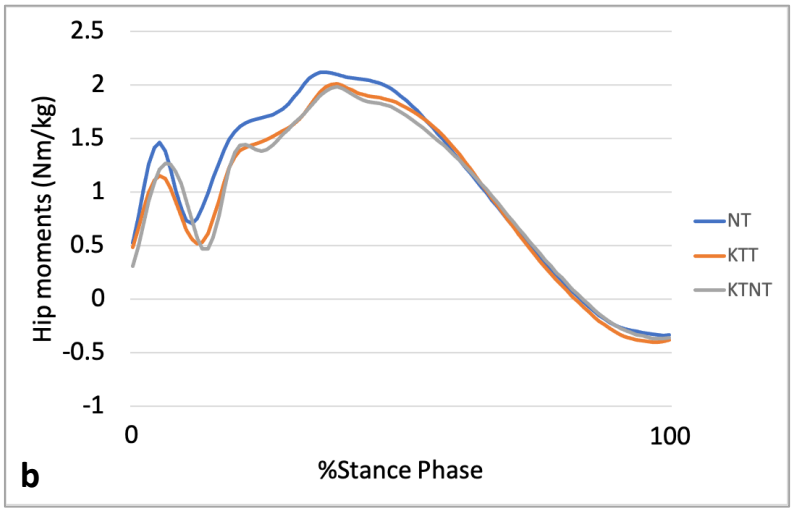


Figure 3-33 Example time series graph of three-dimensional knee joint angles from the UK healthy study (n=1) across three taping conditions; a) Knee extension/flexion, b) Knee abduction/adduction, and c) Knee external and internal rotation. Positive values indicate knee flexion/adduction/internal rotation and negative values indicate knee extension/abduction/external rotation

3.5.2.2 Joint Moment Calculations

Hip and knee joint moments were computed using inverse-dynamics relative to the proximal coordinate system, and data were normalised to 100% of stance phase. At the hip and knee joints, positive moments represented extension, abduction, and external rotation, and negative moments represented flexion, adduction, and internal rotation. To reduce anthropometric influences all moments were normalised to the participants' body mass (kg). Kinetic measures from the hip and knee joints in the stance phase were extracted for statistical analysis included; maximum moments and minimum moments in all three planes under each condition (NT, KTT, and KTNT). The example time series graph of three-dimensional hip and knee joint moments across three taping conditions can be seen in the Figure 3-34 and Figure 3-35.





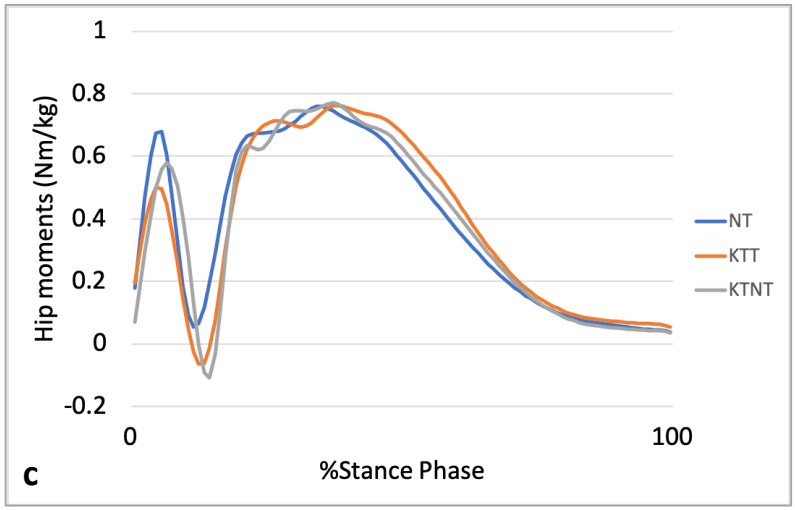


Figure 3-34 Example time series graph of three-dimensional hip moments from the UK healthy study (n=1) across three taping conditions; a) Hip extension/flexion, b) Hip abduction/adduction, and c) Hip external and internal rotation. Positive values indicate hip extension/abduction/external rotation and negative values indicate hip flexion/adduction/internal rotation.

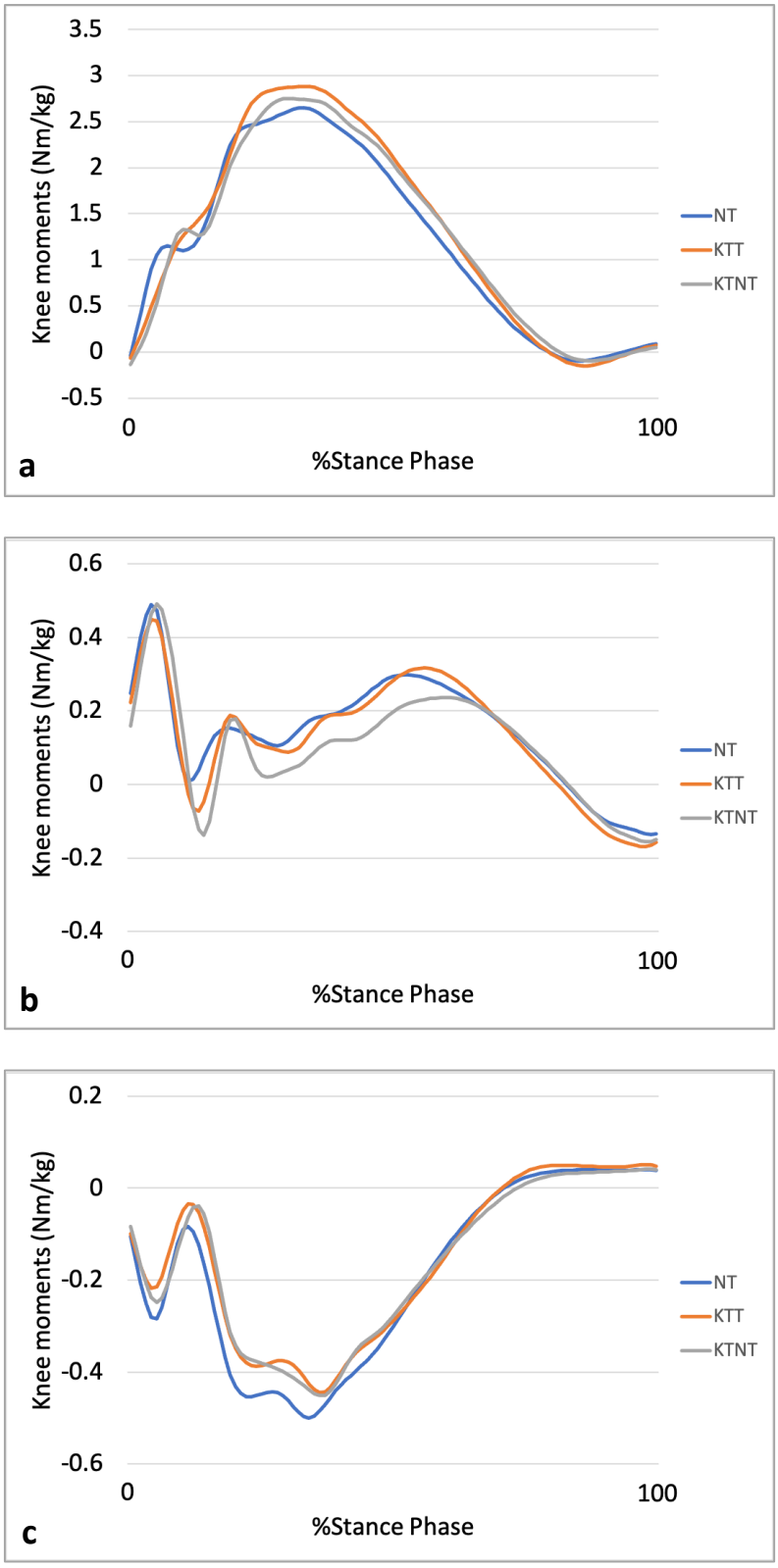


Figure 3-35 Example time series graph of three-dimensional knee moments from the UK healthy study (n=1) across three taping conditions; a) Knee extension/flexion, b) knee abduction/adduction, and c) Knee external and internal rotation. Positive values indicate knee extension/abduction/external rotation and negative values indicate knee flexion/adduction/internal rotation.

3.5.3 sEMG analysis

The sEMG data were exported into Visual 3D. The sEMG data from each muscle was bandpass filtered between 450 Hz and 20 Hz. The EMG signals were processed by removing the direct current offset, then raw sEMG signals (Figure 3-36a) were high-pass filtered at 20 Hz to reduce movement artefacts (Figure 3-36b) (Baker et al., 2018, Hébert-Losier et al., 2019). The signal was then full wave rectified (Figure 3-36c) and then low-pass filtered at 15 Hz to provide an enveloped EMG signal (Figure 3-36d) (Hébert-Losier et al., 2019).

In order to compare across all participants and taping conditions, the sEMG data were normalised. The sEMG data were exported from Visual 3D to excel and the average and peak EMG data were calculated across the five trials for each participant. The maximum observed EMG signal from the filtered data across all trials and conditions for each muscle was then used to normalise the average and peak EMG signals for each participant to a maximum value of 1 indicating the maximum observed signal (Hébert-Losier et al., 2019). Figure 3-37 illustrates an example of the normalised EMG time series graphs of Gmax, Gmed, TFL, VM, and VL muscles across three taping conditions (NT, KTT, KTNT).

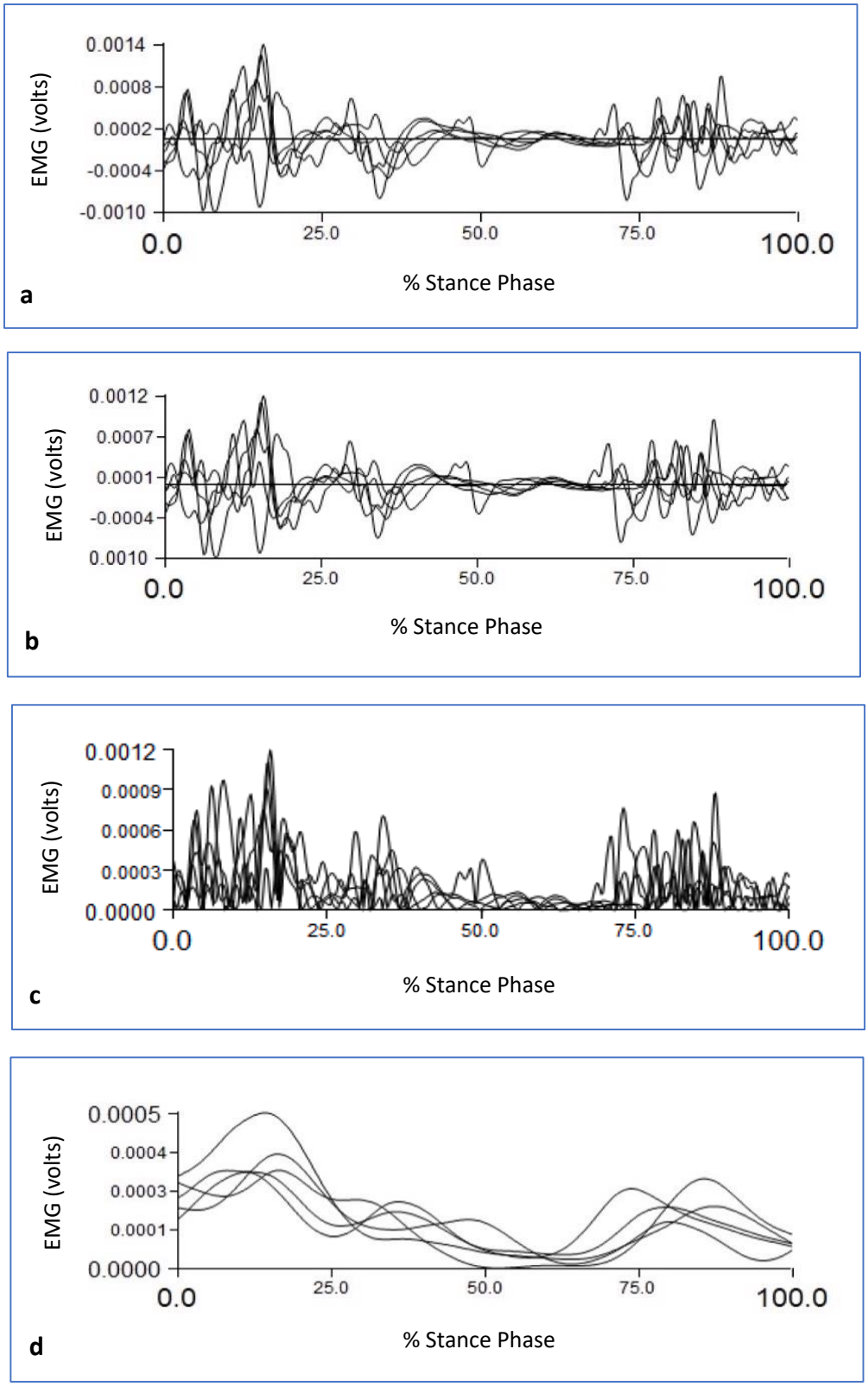


Figure 3-36 An example of the EMG signal processing steps; a) Raw sEMG signal, b) High-pass filtered sEMG signal at 20 Hz, c) Full wave rectified sEMG signal, d) Full wave rectified and enveloped using a 15Hz low pass filter.

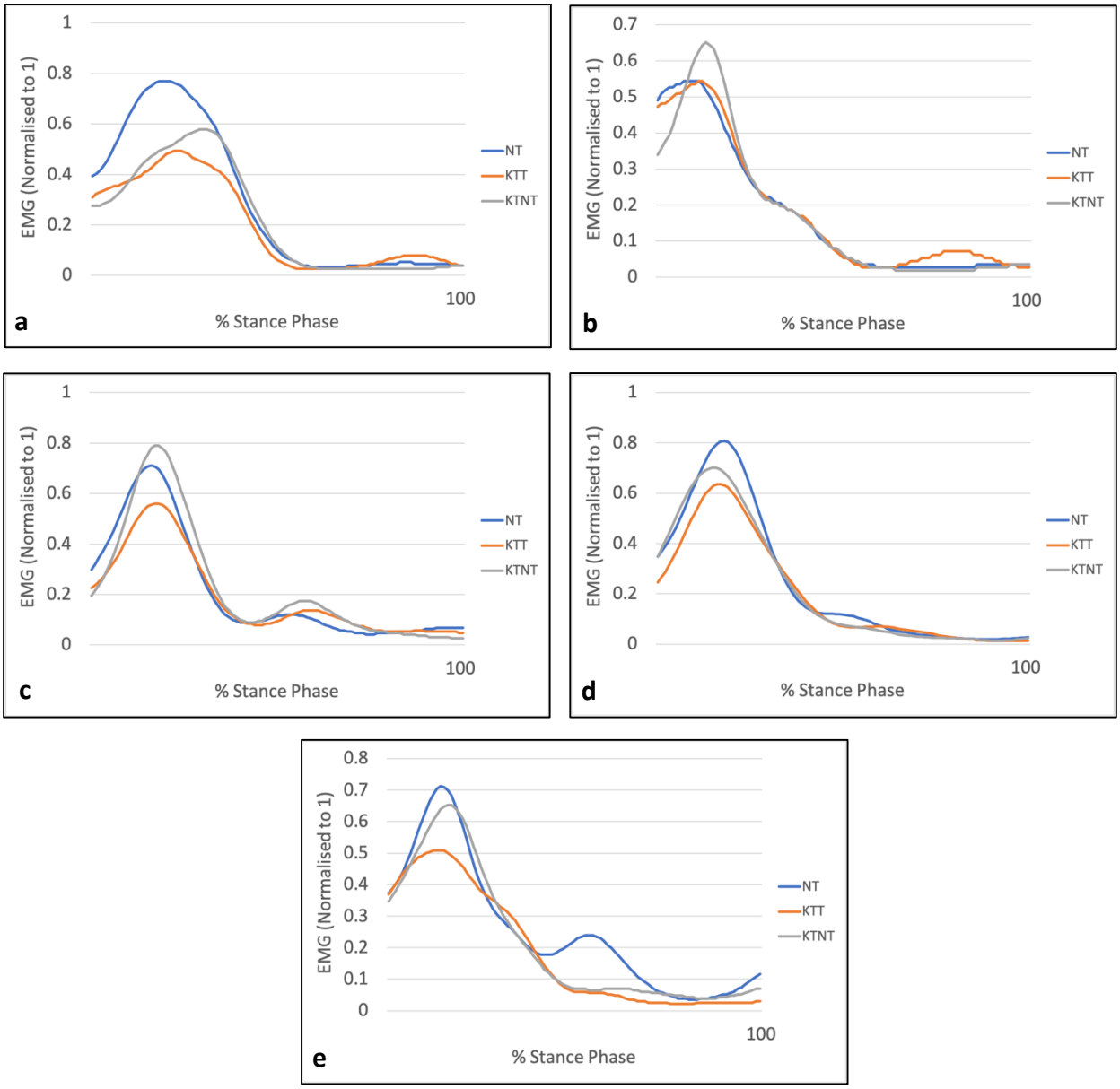


Figure 3-37 Example time series graph of normalised EMG signals from the UK healthy study (n=1) used to find the average and peak EMG for Gmax (a), Gmed (b), TFL (c), VM (d), VL (e) across three taping conditions. Normalised to 1 which represents the maximum observed signal.

CHAPTER 4 THE IMMEDIATE EFFECTS OF KINESIO TAPING ON RUNNING BIOMECHANICS, MUSCLE ACTIVITY, AND PERCEIVED CHANGES IN COMFORT, STABILITY AND RUNNING PERFORMANCE IN UK HEALTHY RUNNERS

The results of this study have been published in Gait and Posture. 2022, Jan;91(2):179-185. Please see Appendix 3 for the published version.

4.1 Introduction

This chapter presents the results of kinesio tape with and without tension on lower limb running biomechanical measures associated with ITBS and perceived outcome measures in a UK cohort of healthy participants.

Kinesio Taping (KT) is a common treatment technique in physical therapy and rehabilitation in the treatment of musculoskeletal problems (Anandkumar et al., 2014, Kase et al., 2003, Liu et al., 2019, Osterhues, 2004, Zhang et al., 2019). Despite the proposed benefits that KT may alter the running biomechanics of individuals with ITBS (Kase et al., 2003), to the authors' knowledge, there is no scientific evidence to support the immediate effect of KT as a treatment for runners with ITBS. Therefore, more work is required to explore if running biomechanics can be modified using KT, specifically in those parameters that have been associated with ITBS which include hip adduction, hip internal rotation, and knee internal rotation (Noehren et al., 2007, Noehren et al., 2014). Prior to such a study, it is important to understand how KT effects the running performance in healthy runners to inform the design and methodology of later studies on Thai healthy participants and Thai participants with ITBS. Consequently, this study aimed to investigate the immediate effect of KT on lower limb kinematics, joint moments, muscle activity and changes in perceived comfort, knee joint stability, and benefits to running performance in healthy UK participants. It was hypothesised that the KT would increase peak hip external rotation, decrease peak hip adduction and internal rotation, decrease peak knee internal rotation, and show perceived improvements.

4.2 Methods

4.2.1 Participants

Male and female participants were recruited from running clubs in Preston and a staff and student population at the University of Central Lancashire (UCLan). The following inclusion criteria were; aged between 18 to 45 years old, regularly run a minimum of 10 km a week, no physical limitations which may interfere with the testing protocol such as fatigue, illness, or dizziness. Exclusion criteria were; history of musculoskeletal injuries to the lower limbs in the past six months, previous surgery to the lower limbs, or a skin allergy to kinesio tape.

Before starting testing, an information sheet was given to the participants, which provided study information and what was expected of them (see Appendix 4). Each participant completed a Physical Activity of Readiness Questionnaire (PAR-Q+) to determine the safety or possible risks associated with inclusion (Appendix 5). Participants who met the inclusion and exclusion criteria were recruited to participate in this study. The dominant limb (hereafter referred to as the study limb) was defined as the leg they would kick a ball with, and draw a figure of eight on the floor (van Melick et al., 2017).

This study was approved by the ethics committee of the University of Central Lancashire (STEMH 966) (see Appendix 6), and all participants provided written informed consent prior to testing (Appendix 7). All testing procedures were conducted in the Movement Analysis Laboratory, Brook Building at the University of Central Lancashire.

4.2.2 Study design

This study was a single testing session repeated measures design with each participant running under three different taping conditions; No Tape (NT), Kinesio Taping with tension (KTT) and Kinesio Taping with no tension (KTNT).

4.2.3 Procedures

Participants visited the Movement Analysis Laboratory (Brook Building, UCLan, Preston Campus, Preston UK) for a single testing session, and following obtaining informed consent, participants were assigned a study ID number to allow anonymisation of the data. Surface EMG, motion capture and force platforms were all used for data collection, see chapter 3 for details relating to the technical and setup features, and section 3.4.2 for full details on running biomechanics test procedures. Participants' skin was prepared for the placement of sEMG sensors, and then sEMG sensors were attached on the skin (see section 3.4.2.1.1 for details), followed by attachment of retroreflective spherical markers on the study limb (see section 3.4.2.1.2). Following camera and force platform calibration (see section 3.2.1.2-3.2.1.4 and 3.2.2, respectively), a static trial was collected prior to running under each taping condition. Participants first ran 10 times along a 10m runway under the NT condition in order to gain a baseline measure for perceived comfort, stability of the knee joint, and running performance. Following this, 10 trials under both KTT and KTNT conditions were performed in a block randomised order using http://www.randomization.com. Perceived comfort, and changes in stability of the knee joint and running performance were assessed after each set of trials under the KTT and KTNT conditions compared to the NT condition (see section 3.4.2.4.1). For details of data processing see section 3.5.

4.2.4 Data Analysis

Statistical analysis was performed using SPSS version 26, with the alpha value set to 0.05. Shapiro-Wilk tests were performed to determine the distribution of the data. For normally distributed data, the means and standard deviations for joint kinematics, joint moments, electromyography, and running speed data from the healthy participants were reported. Repeated Measures Analysis of Variance (RM ANOVA) with between group analyses were used to explore the effects of the taping conditions and sex, significant main effects were further explored with post hoc Least Significant Difference (LSD) test and effect sizes for all significant findings were calculated using partial Eta^2 (η_p^2) to show how much the independent variable was affected by the dependent variable. Effect sizes were contextualized using the following guidelines; small. 0.01, medium. 0.06 and large. 0.14 (Cohen, 1988). In addition, mean differences and 95%

confidence intervals were reported. For non-normally distributed data, descriptive statistics included the median and 25th and 75th percentiles were reported. Friedman tests were used to explore the effects of the taping conditions within the two sexes separately, and significant effects were further explored with Wilcoxon tests, and Mann-Whitney U test were used to explore the between sex analysis. Effect sizes using Kendall's W (W) that were contextualized using the following guidelines; small. 0.1, medium. 0.3 and large. 0.5 (Cohen, 1988). Likert scale data were analysed using descriptive statistics to describe any perceived changes due to the taping conditions.

4.3 Results

4.3.1 Participants Characteristics

Twenty healthy participants individuals consisting of ten males and ten females participated in this study. Table 4.1 presents the descriptive statistics from the participants.

Table 4-1 Participant demographics values are reported as Mean (SD) and ranges.

	Mean (SD)	**Range**
Age (year)	30.60 (7.80)	19 - 43
Weight (kg)	70.84 (13.42)	51 - 98
Height (cm)	172.99 (11.35)	152 - 192
BMI (kg/m^2)	23.58 (3.14)	18.62 – 32.87
Average running distance per week (km)	30.71 (14.70)	12 - 64

4.3.2 Running Speed

No significant difference was observed in running speed between taping conditions (p=0.319). The mean (SD) running speed was 3.88 (0.59) m/s, 3.82 (0.57) m/s and 3.81 (0.63) m/s in the NT, KTT and KTNT conditions, respectively.

4.3.3 Hip Kinematic Data

The Shapiro-Wilk test demonstrated a normal data distribution in almost all parameters except peak hip abduction angle, peak hip external rotation angle, and hip range of motion (ROM) in the transverse plane. The descriptive statistics for hip kinematics, Table 4-2 and Table 4-3. The RM ANOVA results showed no significant interactions between sex and taping conditions for any hip kinematic parameters ($p>0.05$).

4.3.3.1 Sagittal Plane Hip Kinematics

The RM ANOVA showed a significant difference between taping conditions for the peak hip flexion angle ($p=0.016$, $\eta_p^2=0.204$), Table 4-2, Row 1. The LSD post hoc test showed a significant greater hip flexion angle under both KTT and KTNT conditions compared to the NT condition ($p=0.029$, $p=0.007$), respectively. No significant difference was seen between the KTT and KTNT conditions ($p=0.936$), Table 4-4. Figure 4-1 presents the comparison of mean and standard deviation for peak hip flexion angle under the different taping conditions. Figure 4-2 presents the hip flexion/extension angle time series graph under the three taping conditions.

Moreover, the RM ANOVA showed no significant difference between taping conditions for peak hip extension angle ($p=0.060$) or sagittal plane hip ROM ($p=0.537$). In addition, there was no significant difference for sex differences on peak hip flexion angle ($p=0.364$), peak hip extension angle ($p=0.172$), and sagittal plane hip ROM ($p=0.765$), as shown in Table 4-2.

4.3.3.2 Coronal Plane Hip Kinematics

The RM ANOVA demonstrated no significant effect of taping on peak hip adduction angle ($p=0.156$), and hip ROM in the coronal plane ($p=0.931$), Table 4-2. However, there was a significant difference for sex differences on peak hip adduction angle ($p=0.037$, $\eta_p^2=0.220$) and coronal plane hip ROM ($p=0.026$, $\eta_p^2=0.247$). The pairwise comparison for sex showed that females had a significantly greater peak hip adduction angle and coronal plane hip ROM compared to males, Table 4-5.

The Friedman test showed a significant difference between taping conditions for peak hip abduction angle in males (p=0.025, W=0.370), but no significant difference for peak hip abduction angle was seen in females (p=0.273), Table 4-3, Row 1. The Wilcoxon Signed Rank test for peak hip abduction angle in males showed a small but significant decrease (≤ 2 degrees) in peak hip abduction angle in the KTT condition compared to the NT condition (p=0.022). There was no significant difference between the KTT and KTNT conditions (p=0.878), and between the KTNT and NT (p=0.139), Table 4-6. Figure 4-3 presents the comparisons in peak hip abduction angle for males under the three taping conditions. Figure 4-4 presents the hip abduction/adduction angle time series graph for males under the three taping conditions. In addition, the Mann-Whitney U-tests showed no significant difference between sexes for peak hip abduction angle (p=0.880).

4.3.3.3 Transverse Plane Hip Kinematics

The RM ANOVA demonstrated no significant effect of taping for peak hip internal rotation angle (p=0.098), and there was no significant difference between sexes for peak hip internal rotation angle (p=0.362), Table 4-2, and Friedman tests showed no significant difference for the transverse plane hip ROM for males and females (p=0.670, p=0.497), respectively, Table 4-3. However, the Friedman test showed a significant effect of taping on peak hip external rotation angle in males (p=0.025, W=0.370), but no significant difference was seen in females (p=0.273), Table 4-3, Row 2. Post hoc Wilcoxon Signed Rank test showed a small but significant increase (≤ 2 degrees) in peak hip external rotation angle in the KTT condition compared to NT condition (p=0.047), and a small but significant increase (≤ 2 degrees) in peak hip external angle between the KTT condition when compared to the KTNT condition (p=0.037). No significant difference was seen between the KTNT and NT conditions (p=0.508), Table 4-7. The comparison for peak hip external rotation angle for males among the three conditions can be seen in Figure 4-5. Figure 4-6 presents the hip internal rotation/external rotation angle time series graph for males under the three taping conditions. The Mann-Whitney U-tests demonstrated no significant difference for sex differences on peak hip external rotation angle (p=0.545) and transverse plane hip ROM (p=1.000).

Table 4-2 Mean (SD) and repeated measures ANOVA for peak hip angle and hip ROM in the sagittal, coronal and transverse plane.

Hip Kinematics (degrees)[a]	Males (n=10)			Females (n=10)			P-value (η_p^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Peak flexion †,‡	35.98 (9.20)	38.84 (8.70)	38.63 (9.61)	33.58 (5.28)	35.18 (7.19)	35.25 (6.10)	0.016*(0.204)	0.364 (0.046)
Peak extension	-6.07 (6.25)	-3.23 (6.73)	-3.22 (6.09)	-8.53 (5.63)	-7.92 (7.62)	-8.14 (7.08)	0.060 (0.159)	0.172 (0.101)
Sagittal plane ROM	42.04 (8.10)	42.07 (7.87)	41.86 (9.09)	42.11 (3.63)	43.10 (4.67)	43.40 (4.09)	0.537 (0.034)	0.765 (0.005)
Peak adduction	11.90 (3.35)	10.85 (4.22)	10.76 (3.95)	15.29 (4.29)	14.38 (2.99)	15.28 (4.89)	0.156 (0.098)	0.037* (0.220)
Coronal plane ROM	12.02 (2.06)	12.04 (2.61)	12.13 (2.51)	14.85 (2.63)	14.84 (2.95)	14.91 (3.13)	0.931 (0.004)	0.026* (0.247)
Peak internal rotation	1.03 (4.99)	-1.51 (5.81)	0.94 (5.36)	2.10 (3.78)	1.17(4.23)	2.57 (5.20)	0.098 (0.121)	0.362 (0.046)

* Significant main effect at the 0.05 level.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

[a] Positive values indicate hip flexion/adduction/internal rotation and negative values indicate hip extension/abduction/external rotation.

Table 4-3 Median (Q1, Q3) and Freidman test for peak hip angle and hip ROM in the sagittal, coronal and transverse plane.

Hip Kinematics (degrees)[a]	Males (n=10)			Females (n=10)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Males	Tape effect for Females
Peak abduction †	1.23 (-1.82, 2.03)	-0.44 (-1.89, 0.96)	-1.37 (-2.35, 1.19)	1.18 (-2.26, 2.40)	-0.88 (-2.33, 1.63)	0.46 (-2.28, 2.52)	0.025* (0.370)	0.273 (0.130)
Peak external rotation †,¥	-7.44 (-9.49, -4.33)	-8.70 (-17.60, -5.76)	-6.87 (-12.43, -2.30)	-5.04 (-9.60, -2.43)	-5.44 (-13.97, -3.63)	-7.72 (-12.31, -1.75)	0.025* (0.370)	0.273 (0.130)
Transverse plane ROM	8.40 (6.33, 10.24)	9.09 (7.03, 10.73)	7.24 (-6.49, 10.07)	7.71 (5.96, 12.15)	7.97 (7.35, 10.93)	8.39 (6.21, 11.89)	0.670 (0.040)	0.497 (0.070)

* Significant difference at the 0.05 level.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

[a] Positive values indicate hip flexion/adduction/internal rotation and negative values indicate hip extension/abduction/external rotation.

Table 4-4 Pairwise comparisons for peak hip flexion angle.

Peak hip flexion (degrees)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT vs NT	2.24	0.029*	0.25	4.22
KTNT vs NT	2.17	0.007*	0.68	3.65
KTT vs KTNT	0.07	0.936	-1.70	1.83

* Significant difference at the 0.05 level.

Positive values indicate a greater hip flexion in the first condition when compared with the second condition.

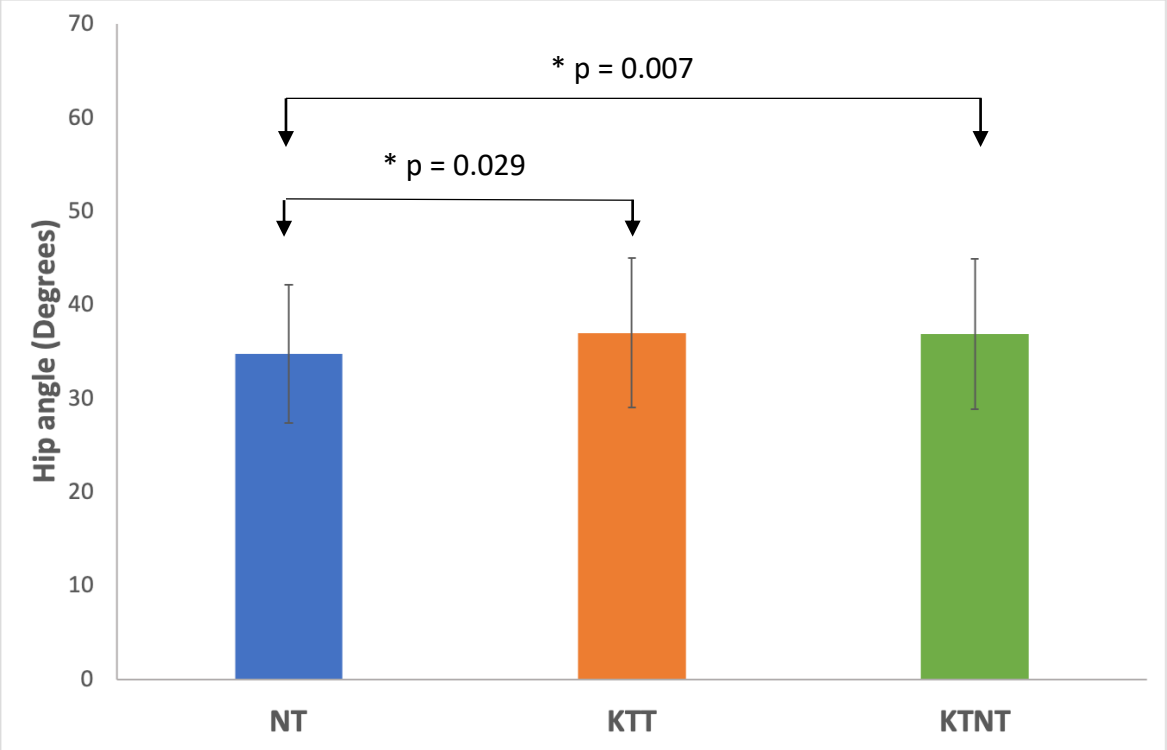


Figure 4-1 Comparison of mean (SD) for peak hip flexion angle under the three taping conditions (* represents a significant difference at the 0.05 level).

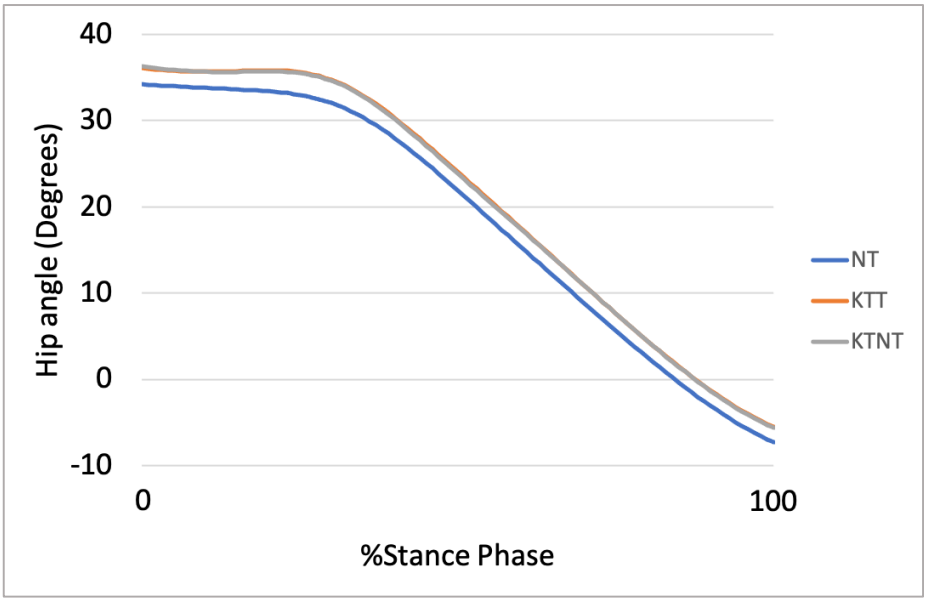


Figure 4-2 Time series graph for hip flexion/extension angle under the three taping conditions. (Positive values indicate hip flexion and negative values indicate hip extension).

Table 4-5 Pairwise comparison for sex differences of hip kinematics.

Hip kinematics (degrees)	Mean Difference (Females vs Males)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Peak adduction	3.81	0.037*	0.25	7.37
Coronal plane ROM	2.80	0.026*	0.38	5.23

* Significant difference at the 0.05 level.

Positive values indicate a greater hip adduction angle and coronal plane ROM in the females when compared with the males.

Table 4-6 Wilcoxon Signed Rank test for peak hip abduction angle for males.

Peak hip abduction for males (degrees)	Median Difference	P-value
KTT vs NT	-1.67ϒ	0.022*
KTNT vs NT	-2.61	0.139
KTT vs KTNT	-0.23	0.878

* Significant difference at the 0.05 level.

ϒ indicates a significant difference with a small change in magnitude (≤ 2 degrees), as an error of 2 degrees or less as these are likely to be susceptible to clinical misinterpretation. Negative values indicate a greater hip abduction angle in the first condition when compared with the second condition.

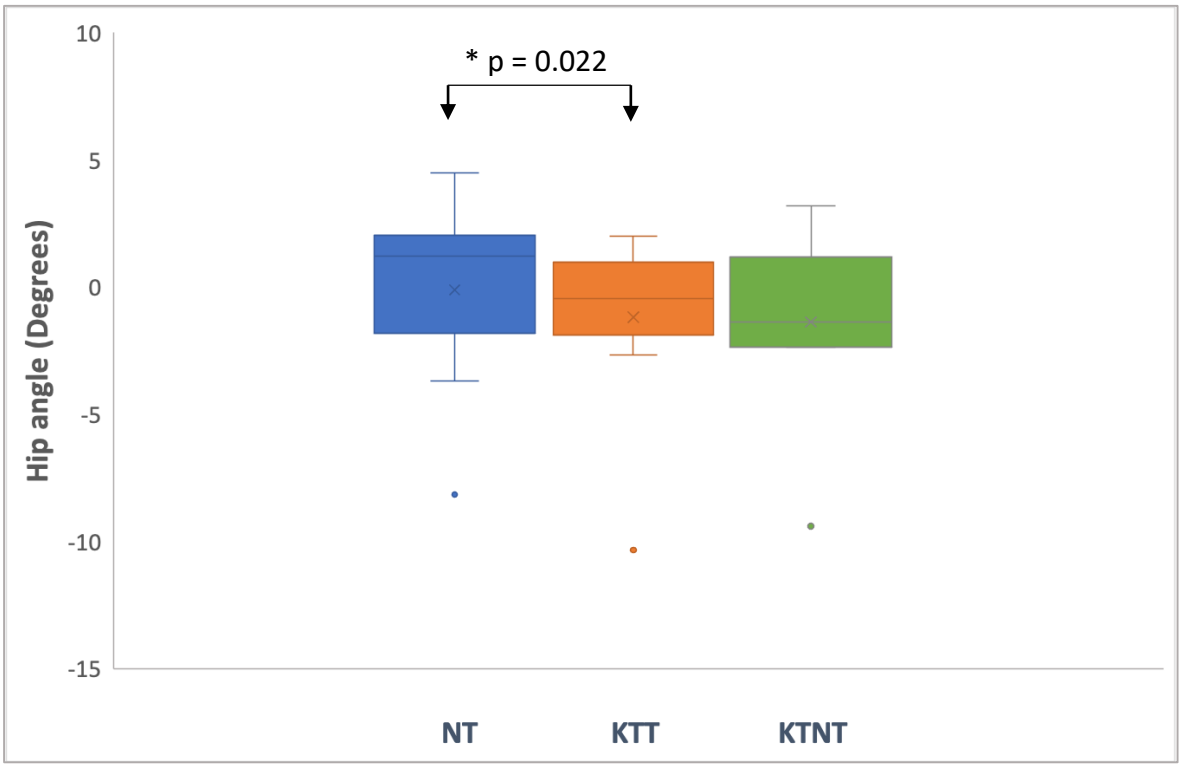


Figure 4-3 Comparisons in peak hip abduction angle for males under the three taping conditions (* represents a significant difference at the 0.05 level).

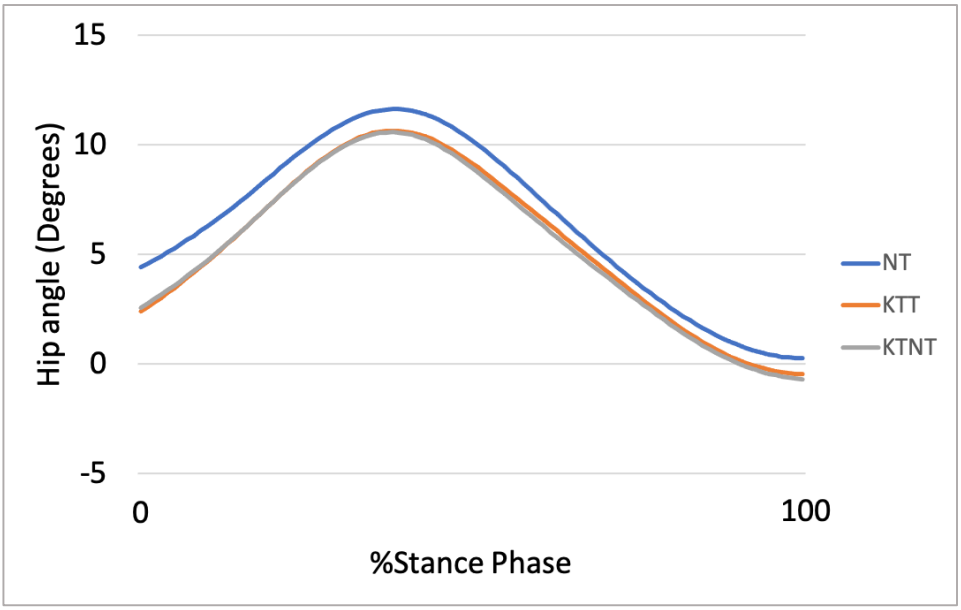


Figure 4-4 Time series graph for hip abduction/adduction angle for males under the three taping conditions. (Positive values indicate hip adduction and negative values indicate hip abduction).

Table 4-7 Wilcoxon Signed Rank test for peak hip external rotation angle for males.

Peak hip external rotation for males (degrees)	Median Difference	P-value
KTT vs NT	-1.26$^{\Upsilon}$	0.047*
KTNT vs NT	0.57	0.508
KTT vs KTNT	-1.83$^{\Upsilon}$	0.037*

* Significant difference at the 0.05 level.

$^{\Upsilon}$ indicates a significant difference with a small change in magnitude (≤ 2 degrees), as an error of 2 degrees or less as these are likely to be susceptible to clinical misinterpretation. Negative values indicate a greater hip external rotation angle in the first condition when compared with the second condition.

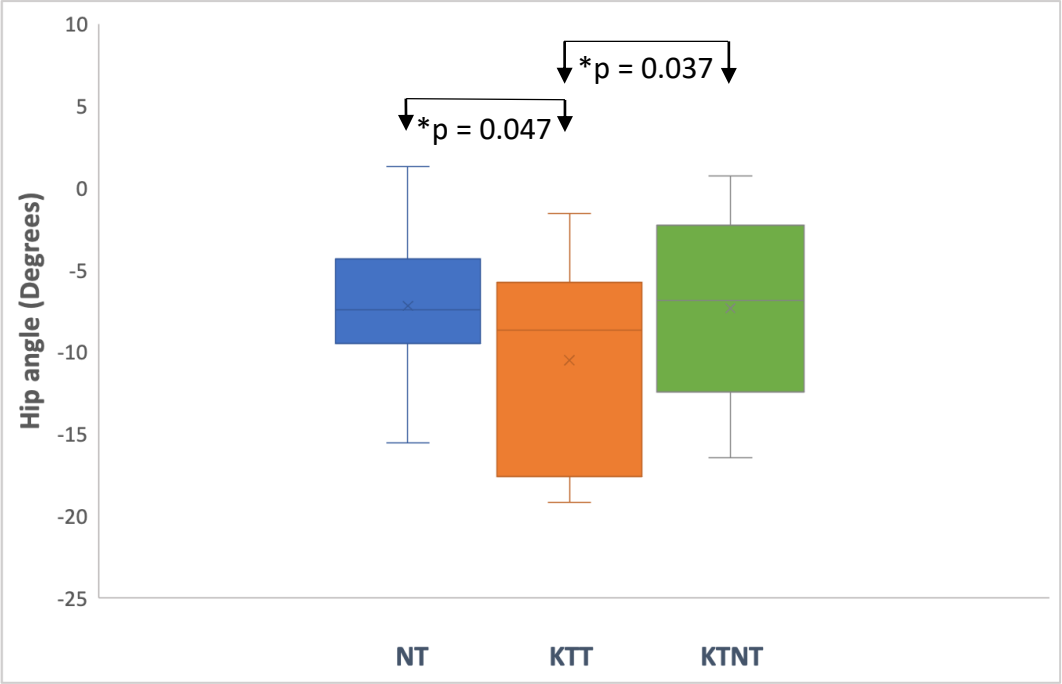


Figure 4-5 Comparisons in peak hip external rotation angle for males among the three conditions (* represents a significant difference at the 0.05 level).

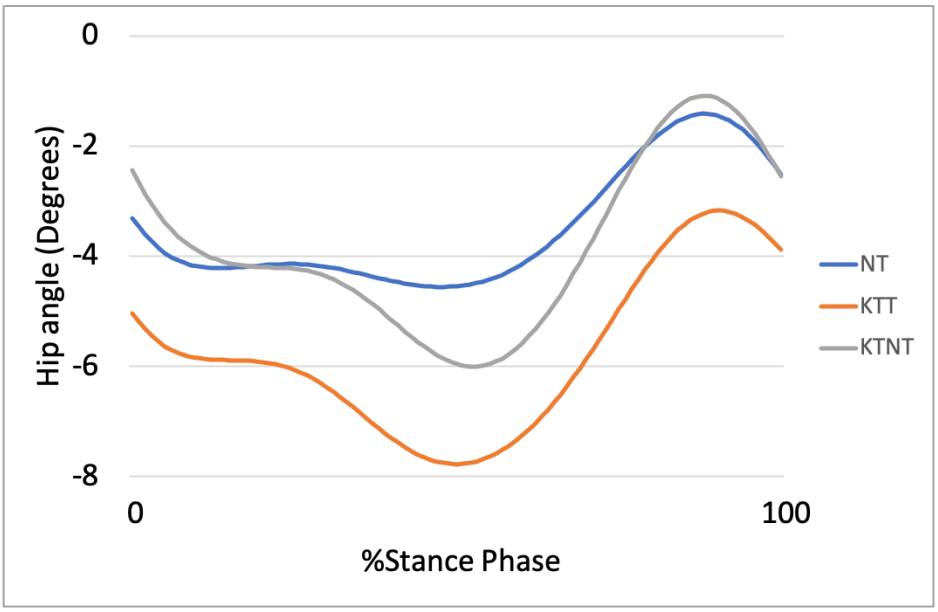


Figure 4-6 Time series graph for hip internal rotation/external rotation angle for males under the three taping conditions. (Positive values indicate hip internal rotation and negative values indicate hip external rotation).

4.3.4 Knee Kinematic Data

The Shapiro-Wilk test demonstrated a normal data distribution in almost all parameters except minimum knee flexion angle, peak knee adduction angle, peak knee abduction angle, and transverse plane knee ROM. The descriptive statistics for peak knee angle and knee ROM in sagittal, coronal, and transverse planes can be seen in Table 4-8 and Table 4-9. The RM ANOVA results showed no significant interactions between sex and taping conditions for any knee kinematic parameters ($p>0.05$).

4.3.4.1 Sagittal Plane Knee Kinematics

The RM ANOVA showed a significant effect of taping for peak knee flexion angle ($p=0.042$, $\eta_p^2=0.181$), Table 4-8, Row 1. LSD post hoc tests showed a significantly greater the peak knee flexion angle in the KTNT condition compared to the NT condition ($p<0.001$). There was no significant difference between the KTT and NT conditions ($p=0.109$), or the KTT and KTNT conditions ($p=0.440$), Table 4-10. Figure 4-7 presents the comparison of mean and standard deviation for peak knee flexion angle under the different taping conditions. Figure 4-8 presents the knee flexion/extension angle time series graph under the three taping conditions. In addition, the RM ANOVA tests showed no significant effect of taping for sagittal plane knee ROM ($p=0.388$), and no significant differences between sexes for peak knee flexion angle ($p=0.103$) and sagittal plane knee ROM ($p=0.260$), Table 4-8. The Friedman test showed no significant effect of taping for minimum knee flexion angle for both males and females ($p=0.273$, $p=0.497$), respectively, Table 4-9. In addition, the Mann-Whitney U-tests showed no significant differences between males and females for the minimum knee flexion angle ($p=0.364$).

4.3.4.2 Coronal Plane Knee Kinematics

The RM ANOVA showed no significant effect of taping for the coronal plane knee ROM ($p=0.165$), and no significant difference was seen between the sexes ($p=0.107$), Table 4-8. The Friedman test showed no significant effect of taping for peak knee adduction angle for males and females ($p=0.202$, $p=0.122$), respectively, or peak knee abduction angle for males and females ($p=1.000$, $p=0.273$), respectively, Table 4-9. However, the Mann-Whitney U-tests showed a significant difference between sexes for the peak knee abduction angle ($p=0.049$) with females showing greater values than males, but no

significant differences was seen between males and females for peak knee adduction angle (p=0.450), Table 4-11.

4.3.4.3 Transverse Plane Knee Kinematics

The RM ANOVA showed no significant effect of taping for peak knee internal rotation angle (p=0.369) and peak knee external rotation angle (p=0.514), and no significant differences were seen between the sexes for peak knee internal rotation angle (p=0.743) and peak knee external rotation angle (p=0.461), Table 4-8. The Friedman test showed no significant effect of taping for transverse plane knee ROM for males and females (p=0.407, p=0.905), respectively, Table 4-9. The Mann-Whitney U-tests showed no significant difference between the sexes for transverse plane knee ROM (p=0.059).

Table 4-8 Mean (SD) and repeated measures ANOVA for peak knee angle and knee ROM in the sagittal, coronal, and transverse plane.

Knee Kinematics (degrees)[a]	Males (n=10)			Females (n=10)			P-value (η_p^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Peak flexion‡	36.62 (7.01)	38.43 (6.51)	38.37 (7.30)	40.64 (3.37)	41.59 (3.49)	43.05 (3.64)	0.042* (0.181)	0.103 (0.181)
Sagittal plane ROM	28.87 (6.50)	28.53 (5.03)	28.64 (5.98)	30.56 (3.52)	30.90 (2.95)	31.84 (3.67)	0.388 (0.051)	0.260 (0.070)
Coronal plane ROM	4.96 (1.17)	5.61 (1.62)	5.94 (1.48)	6.60 (2.10)	6.65 (2.37)	7.00 (2.26)	0.165 (0.095)	0.107 (0.138)
Peak internal rotation	9.42 (4.91)	11.75 (6.30)	10.35 (5.26)	11.86 (5.20)	11.08 (5.45)	10.83 (4.78)	0.369 (0.051)	0.743 (0.006)
Peak external rotation	-4.71 (4.13)	-3.80 (6.46)	-4.86 (5.65)	-5.72 (5.54)	-6.24 (5.73)	-6.75 (5.67)	0.514 (0.036)	0.461 (0.031)

* Significant main effect at the 0.05 level.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

[a] Positive values indicate knee flexion/adduction/internal rotation and negative values indicate knee extension/abduction/external rotation.

Table 4-9 Median (Q1, Q3) and Freidman test for peak knee angle and knee ROM in the sagittal, coronal and transverse plane.

Knee Kinematics (degrees)[a]	Males (n=10)			Females (n=10)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Males	Tape effect for Females
Minimum flexion	9.04 (3.83, 11.21)	10.91 (5.42, 13.76)	8.33 (6.90,13.81)	10.04 (8.07, 11.02)	10.65 (6.79, 13.63)	12.04 (8.45, 13.06)	0.273 (0.130)	0.497 (0.070)
Peak adduction	1.28 (-1.41, 2.85)	2.03 (0.49, 2.84)	1.89 (-0.07, 4.24)	-0.05 (-2.46, 2.76)	0.92 (-1.55, 3.73)	1.27 (-2.84, 4.10)	0.202 (0.160)	0.122 (0.210)
Peak abduction	-4.81 (-5.74, -2.19)	-3.51 (-5.27, -1.90)	-4.42 (-5.77, -1.85)	-6.55 (-8.07, -4.82)	-4.71 (-7.54, -3.18)	-6.43 (-7.83, -3.95)	1.000 (<0.001)	0.273 (0.130)
Transverse plane ROM	14.16 (11.15, 17.56)	15.47 (13.24, 18.10)	15.24 (12.88, 17.30)	16.70 (14.03, 19.99)	16.69 (13.42, 19.30)	17.91 (12.47, 21.13)	0.407 (0.090)	0.905 (0.010)

[a] Positive values indicate knee flexion/adduction/internal rotation and negative values indicate knee extension/abduction/external rotation.

Table 4-10 Pairwise comparisons for peak knee flexion angle.

Peak knee flexion (degrees)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT vs NT	1.38	0.109	-0.34	3.10
KTNT vs NT	2.08	<0.001*	1.07	3.09
KTT vs KTNT	-0.70	0.440	-2.56	1.16

* Significant difference at the 0.05 level.

Positive values indicate a greater knee flexion angle in the first condition when compared with the second condition.

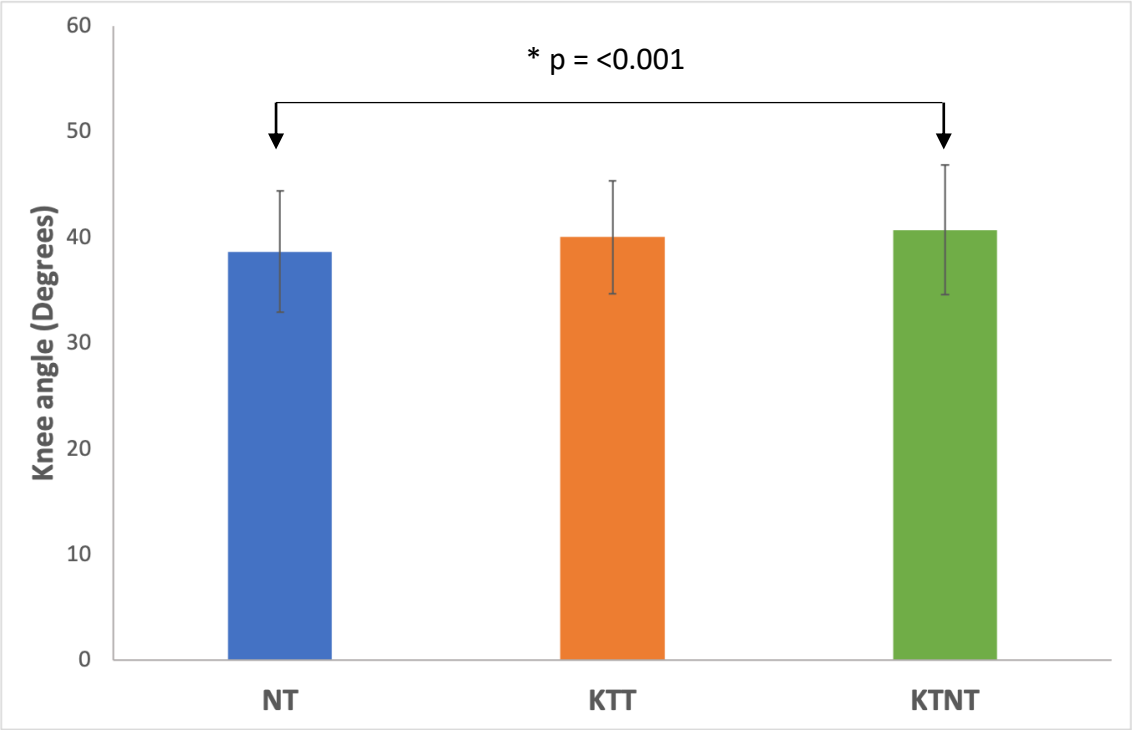


Figure 4-7 Comparison of mean (SD) for peak knee flexion angle under the three taping conditions (* represents a significant difference at the 0.05 level).

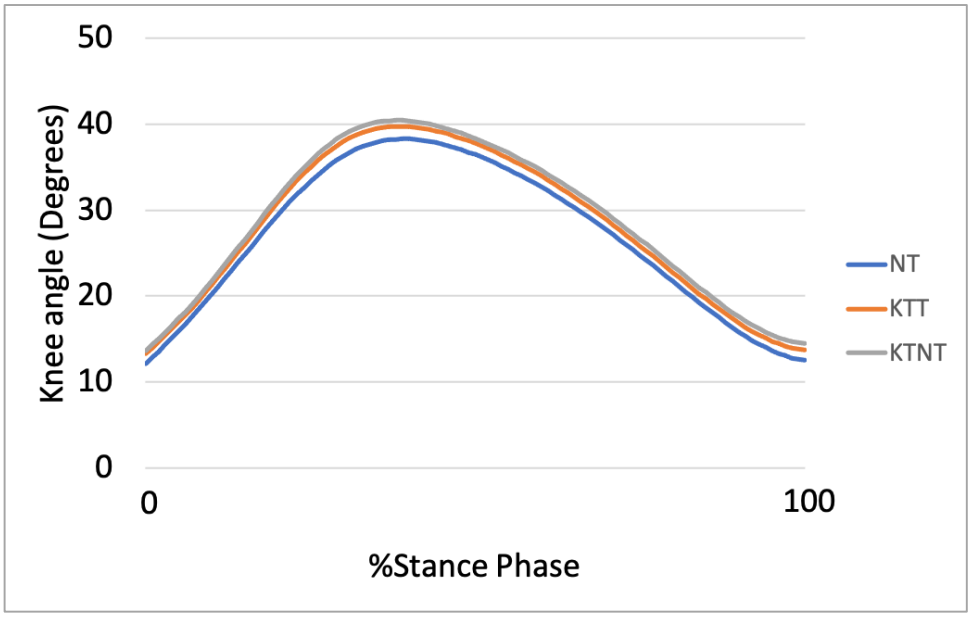


Figure 4-8 Time series graph for knee flexion/extension angle under the three taping conditions. (Positive values indicate knee flexion and negative values indicate knee extension).

Table 4-11 The Mann-Whitney U-tests results for sex differences of knee kinematics.

Knee kinematics (degrees)	Median Difference (Females vs Males)	P-value
Peak abduction	-1.74	0.049*

* Significant difference at the 0.05 level.

Negative values indicate a greater knee abduction angle in the females when compared with the males.

4.3.5 Hip Moments Data

The Shapiro-Wilk test demonstrated a normal data distribution for peak hip extension, peak hip flexion, and peak hip external rotation moments. However, peak hip abduction moments, peak hip adduction moments, and peak hip internal rotation moments were found to be not normally distributed. The descriptive statistics for peak hip moments in sagittal, coronal, and transverse planes can be seen in Table 4-12 and Table 4-13. The RM ANOVA results showed no significant interactions between sex and taping conditions for any hip moment parameters ($p>0.05$).

4.3.5.1 Sagittal Plane Hip Moments

The RM ANOVA showed no significant effect of taping for peak hip extension moments (p=0.450) and peak hip flexion moments (p=0.102), Table 4-12. For sex differences, there was not a significant difference for sex differences of peak hip flexion moments (p=0.760) but peak hip extension moments showed a significant difference (p=0.022, η_p^2=0.258), Table 4-12. The pairwise comparison for sex showed that males had a significantly greater a peak hip extension moment compared to females, Table 4-14.

4.3.5.2 Coronal Plane Hip Moments

The Friedman test showed no significant effect of taping for peak hip abduction moments for both males and females (p=0.741, p=0.905), respectively, and peak hip adduction moments for males and females (p=0.905, p=0.741), respectively, Table 4-13. The Mann-Whitney U-tests showed no significant difference between sexes for peak hip abduction and adduction moments (p=0.290, p=0.326), respectively.

4.3.5.3 Transverse Plane Hip Moments

The RM ANOVA showed no significant effect of taping for peak hip external rotation moments (p=0.532), and no significant difference was seen between sexes (p=0.983), Table 4-12. The Friedman test showed no significant effect of taping for peak internal rotation moments for males and females (p=0.670, p=0.905), respectively, Table 4-13. In addition, the Mann-Whitney U-tests showed no significant difference between sexes for peak internal rotation moments (p=0.174).

Table 4-12 Mean (SD) and repeated measures ANOVA for peak hip moments in the sagittal, coronal, and transverse plane.

Hip Moments (Nm/kg)[a]	Males (n=10)			Females (n=10)			P-value (ηp^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Peak extension	2.58 (0.70)	2.58 (0.57)	2.55 (0.57)	1.86 (0.51)	1.96 (0.50)	2.07 (0.57)	0.450 (0.043)	0.022* (0.258)
Peak flexion	-1.02 (0.55)	-0.93 (0.45)	-0.92 (0.37)	-1.06 (0.38)	-0.97 (0.26)	-1.00 (0.32)	0.102 (0.131)	0.760 (0.005)
Peak external rotation	0.60 (0.28)	0.62 (0.31)	0.59 (0.33)	0.59 (0.15)	0.61 (0.16)	0.61 (0.21)	0.532 (0.034)	0.983 (<0.001)

* Significant main effect at the 0.05 level.

[a] Positive value indicate hip extension/abduction/external rotation and negative values indicate hip flexion/adduction/internal rotation.

Table 4-13 Median (Q1, Q3) and Freidman test results of peak hip moments in the sagittal, coronal, and transverse plane.

Hip Moments (Nm/kg)[a]	Males (n=10)			Females (n=10)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Males	Tape effect for Females
Peak abduction	2.10 (1.58, 2.29)	2.03 (1.44, 2.28)	2.04 (1.21, 2.31)	1.85 (1.39, 2.12)	1.73 (1.50, 2.04)	1.90 (1.40, 2.13)	0.741 (0.030)	0.905 (0.010)
Peak adduction	-0.32 (-0.79, -0.26)	-0.32 (-0.77, -0.20)	-0.29 (-0.74, -0.21)	-0.33 (-0.42, -0.15)	-0.32 (-0.42, -0.13)	-0.32 (-0.42, -0.16)	0.905 (0.010)	0.741 (0.030)
Peak internal rotation	-0.12 (-0.36/-0.04)	-0.07 (-0.28/-0.04)	-0.08 (-0.32/-0.05)	-0.06 (-0.11/-0.02)	-0.08 (-0.13/-0.01)	-0.10 (-0.18/-0.01)	0.670 (0.040)	0.905 (0.010)

[a] Positive value indicate hip extension/abduction/external rotation and negative values indicate hip flexion/adduction/internal rotation.

Table 4-14 Pairwise comparison for sex differences of hip moments.

Hip Moments (Nm/kg)	Mean Difference (Females vs Males)	P-Value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Peak extension	-0.61	0.022*	-1.11	-0.10

* Significant difference at the 0.05 level.

Positive values indicate a greater hip extension moment in the females when compared with the males.

4.3.6 Knee Moments Data

The Shapiro-Wilk test demonstrated a normal data distribution in almost all parameters except peak knee adduction moments, and peak knee external rotation moments. The descriptive statistics for peak knee moments in sagittal, coronal, and transverse planes can be seen in Table 4-15 and Table 4-16. The RM ANOVA results showed no significant interactions between sex and taping conditions for any knee moment parameters ($p>0.05$).

4.3.6.1 Sagittal Plane Knee Moments

The RM ANOVA result indicated that there was a significant effect of taping on peak knee flexion moments ($p=0.012$, $\eta_p^2=0.219$), Table 4-15, Row 2. The LSD post hoc tests showed significant lesser the peak knee flexion moments in the KTNT condition compared to the NT condition ($p=0.010$), and lesser moments in the KTNT condition compared to the KTT condition ($p=0.027$). No significant difference was observed between the NT and KTT conditions ($p=0.323$), Table 4-17. Figure 4-9 presents the comparison of mean and standard deviation peak knee flexion moments under the different taping conditions. Figure 4-10 presents the knee flexion/extension moments time series graph under the three taping conditions. In addition, the RM ANOVA showed no significant effect of taping for the peak knee extension moments ($p=0.736$), and no significant differences between sexes for peak knee extension moments ($p=0.612$) and peak knee flexion moments ($p=0.267$), Table 4-15.

4.3.6.2 Coronal Plane Knee Moments

The RM ANOVA showed no significant effect of taping for the peak knee abduction moments (p=0.741). However, there was a significant difference for sex differences of the peak knee abduction moment (p=0.048, η_p^2=0.201), the Table 4-15. The pairwise comparison for sex showed that males had a significantly greater a peak knee abduction moment compared to females, Table 4-18.

The Friedman test showed no a significant effect of taping for peak knee adduction moments for both males and females (p=0.741, p=0.905), respectively, Table 4-16. The Mann-Whitney U-tests showed that there was not a significant difference between sexes for knee adduction moments (p=0.406).

4.3.6.3 Transverse Plane Knee Moments

The RM ANOVA demonstrated that no a significant effect of taping for peak knee internal rotation moments (p=0.975), and no significant differences were seen between the sexes for peak knee internal rotation moments (p=0.965), Table 4-15.

The Friedman test showed no significant effect of taping for the peak knee external rotation moments for both males and females (p=0.670, p=0.122), respectively, Table 4-16. The Mann-Whitney U-tests showed that no significant difference between the sexes for the peak knee external rotation moments (p=0.762).

Table 4-15 Mean (SD) and repeated measures ANOVA for peak knee moments in the sagittal, coronal, and transverse plane.

Knee Moments (Nm/kg)[a]	Males (n=10)			Females (n=10)			P-value (η_p^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Peak extension	2.87 (0.78)	2.92 (0.76)	2.83 (0.68)	2.73 (0.25)	2.74 (0.37)	2.76 (0.33)	0.736 (0.017)	0.612 (0.015)
Peak flexion‡,¥	-0.33 (0.16)	-0.29 (0.17)	-0.24 (0.17)	-0.20 (0.18)	-0.21 (0.21)	-0.18 (0.19)	0.012* (0.219)	0.267 (0.068)
Peak abduction	0.53 (0.27)	0.52 (0.27)	0.52 (0.28)	0.29 (0.18)	0.33 (0.17)	0.31 (0.17)	0.741 (0.011)	0.048* (0.201)
Peak internal rotation	-0.41 (0.24)	-0.42 (0.28)	-0.42 (0.29)	-0.42 (0.14)	-0.41 (0.11)	-0.41 (0.16)	0.975 (0.001)	0.965 (<0.001)

* Significant main effect at the 0.05 level.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

[a] Positive values indicate knee extension/abduction/external rotation and negative values indicate knee flexion/adduction/internal rotation.

Table 4-16 Median (Q1, Q3) and Freidman test for peak knee moments in the sagittal, coronal, and transverse plane.

Knee Moments (Nm/kg)[a]	Males (n=10)			Females (n=10)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Males	Tape effect for Females
Peak adduction	-0.15 (-0.30, -0.11)	-0.15 (-0.42, -0.09)	-0.18 (-0.33, -0.10)	-0.21 (-0.32, -0.13)	-0.20 (-0.27, -0.13)	-0.17 (-0.23, -0.14)	0.741 (0.030)	0.905 (0.010)
Peak external rotation	0.04 (0.02, 0.13)	0.04 (0.01, 0.12)	0.03 (0.01, 0.13)	0.04 (0.01, 0.05)	0.03 (0.01, 0.10)	0.04 (0.02, 0.06)	0.670 (0.040)	0.122 (0.210)

[a] Positive values indicate knee extension/abduction/external rotation and negative values indicate knee flexion/adduction/internal rotation.

Table 4-17 Pairwise comparisons for peak knee flexion moments.

Peak knee flexion moments (Nm/kg)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT vs NT	0.02	0.323	-0.02	0.06
KTNT vs NT	0.05	0.010*	0.02	0.09
KTT vs KTNT	-0.04	0.027*	-0.07	-0.01

* Significant difference at the 0.05 level.

Negative values indicate a greater knee flexion moment in the first condition when compared with the second condition.

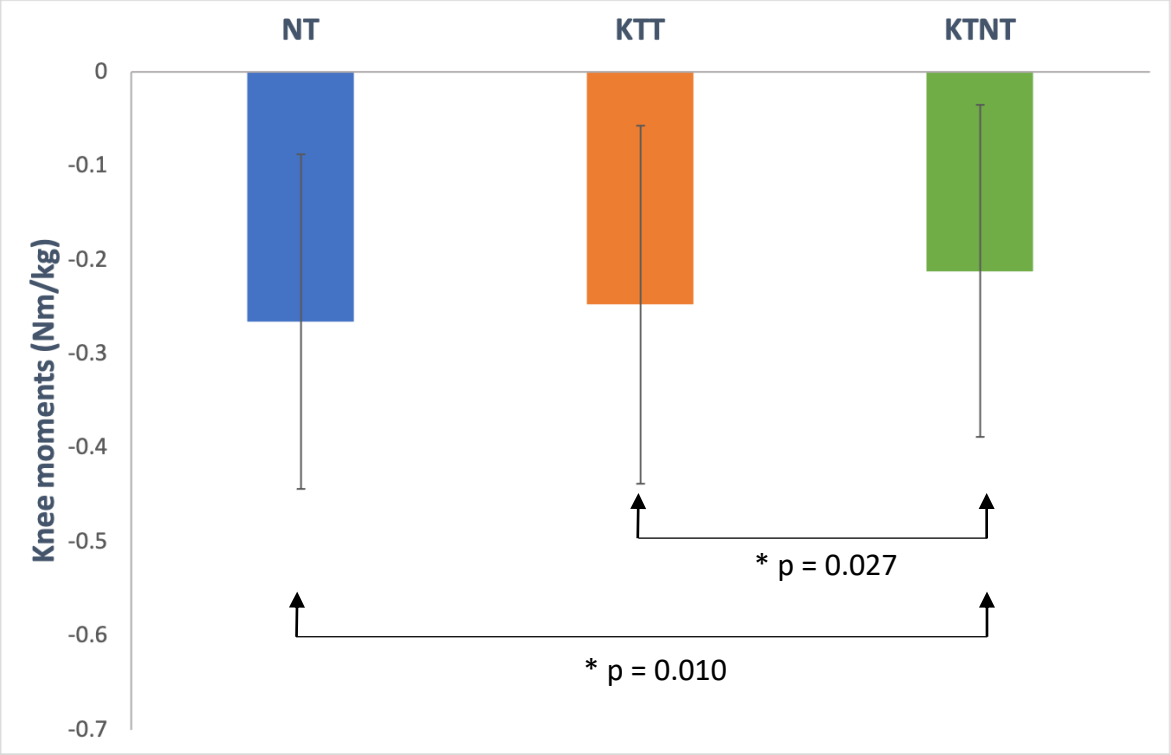


Figure 4-9 Comparisons of mean (SD) for peak knee flexion moments under the three taping conditions (* represents a significant difference at the 0.05 level).

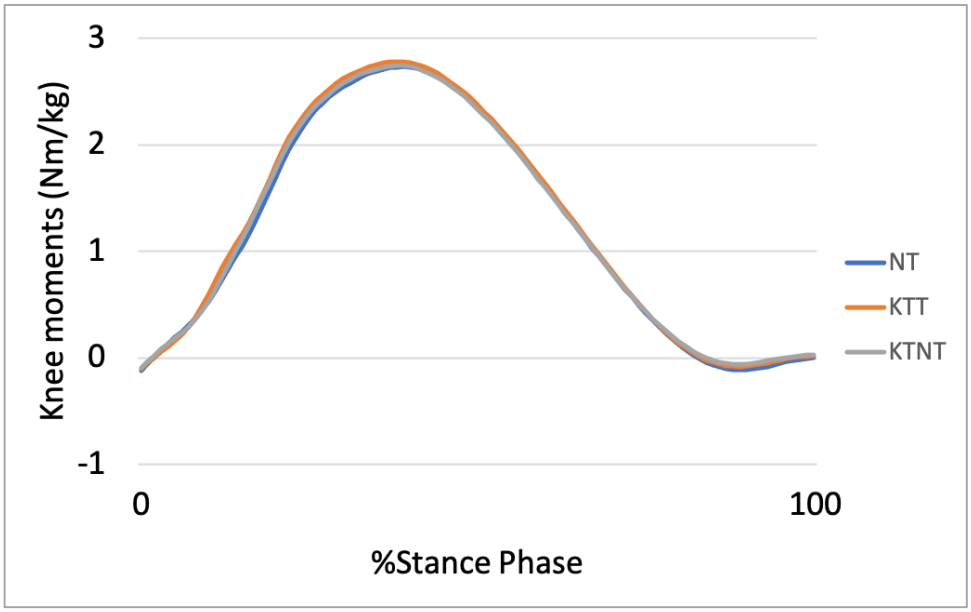


Figure 4-10 Time series graph for knee flexion/extension moments under the three taping conditions. (Positive values indicate knee extension and negative values indicate knee flexion).

Table 4-18 Pairwise comparison for sex differences of knee moments.

Knee Moments (Nm/kg)	Mean Difference (Females vs Males)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Peak abduction	-0.212	0.048*	-0.42	-0.002

* Significant difference at the 0.05 level.

Positive values indicate a greater knee abduction moment in the females when compared with the males.

4.3.7 Average Electromyography Data

The Shapiro-Wilk test demonstrated a normal data distribution in almost all parameters except average EMG for Gmed and VM. The descriptive statistics for average EMG can be seen in Table 4-19 and Table 4-20. The RM ANOVA results showed no significant interactions between sex and taping conditions for any average EMG parameters ($p>0.05$).

The RM ANOVA showed a significant effect of taping for average EMG for Gmax ($p=0.003$, $\eta_p^2=0.275$) and TFL ($p=0.042$, $\eta_p^2=0.178$). The LSD post hoc tests showed average Gmax EMG exhibited a significantly decrease in the KTNT condition compared to the NT condition ($p=0.004$). There was no significant difference between the KTT and NT conditions ($p=0.075$), or the KTT and KTNT conditions ($p=0.054$) (Table 4-21). Figure 4-11 presents the comparison of mean and standard deviation for the average normalised EMG for Gmax under the three taping conditions. Figure 4-12 presents the normalised Gmax EMG signals time series graph under the three taping conditions. The average TFL EMG demonstrated a significantly decrease in the KTT condition compared to the NT condition ($p=0.005$). There was no significant difference between the KTNT and NT conditions ($p=0.399$), or the KTT and KTNT conditions ($p=0.057$), Table 4-22. Figure 4-13 presents the comparison of mean and standard deviation for the average normalised EMG for TFL under the three taping conditions. Figure 4-14 presents the normalised TFL EMG signals time series graph under the three taping conditions However, the RM ANOVA showed that there was not a significant difference in the average VL EMG ($p=0.173$). In addition, no significant differences between sexes for average EMG for Gmax ($p=0.799$), TFL ($p=0.937$), and VL ($p=0.751$), Table 4-19.

The Friedman test demonstrated that no a significant effect of taping for average Gmed EMG for both males and females ($p=0.905$, $p=0.741$) and the average VM EMG for both males and females ($p=0.273$, $p=0.150$), Table 4-20. The Mann-Whitney U-tests showed that there was not a significant difference for sex differences for average Gmed EMG ($p=0.821$) and the average VM EMG ($p=0.940$).

Table 4-19 Mean (SD) and repeated measures ANOVA for normalised values from average EMG signal analysis in each group during stance phase.

Average Normalised EMG	Males (n=10)			Females (n=10)			P-value (η_p^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Gmax‡	0.119 (0.032)	0.100 (0.025)	0.099 (0.033)	0.122 (0.033)	0.116 (0.055)	0.091 (0.040)	0.003* (0.275)	0.799 (0.004)
TFL †	0.115 (0.041)	0.098 (0.033)	0.108 (0.033)	0.119 (0.047)	0.097 (0.042)	0.110 (0.054)	0.042* (0.178)	0.937 (<0.001)
VL	0.083 (0.022)	0.091 (0.031)	0.084 (0.027)	0.076 (0.041)	0.089 (0.038)	0.081 (0.039)	0.173 (0.093)	0.751 (0.006)

* Significant main effect at the 0.05 level. Normalised to 1 which represents the maximum observed signal.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

Table 4-20 Median (Q1, Q3) and Friedman test for normalised values from average EMG signal analysis in each group during stance phase.

Average Normalised EMG	Males (n=10)			Females (n=10)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Males	Tape effect for Females
Gmed	0.112 (0.087, 0.143)	0.102 (0.079, 0.112)	0.105 (0.068, 0.126)	0.128 (0.078, 0.148)	0.115 (0.089, 0.132)	0.110 (0.089, 0.134)	0.905 (0.010)	0.741 (0.030)
VM	0.103 (0.087, 0.128)	0.098 (0.078, 0.126)	0.094 (0.079, 0.129)	0.113 (0.079, 0.143)	0.094 (0.076, 0.114)	0.099 (0.081, 0.112)	0.273 (0.130)	0.150 (0.190)

Normalised to 1 which represents the maximum observed signal.

Table 4-21 Pairwise comparisons of average EMG for Gmax.

Average Normalised EMG for Gmax	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT vs NT	-0.013	0.075	-0.027	0.001
KTNT vs NT	-0.026	0.004*	-0.042	-0.009
KTT vs KTNT	0.013	0.054	0	0.026

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

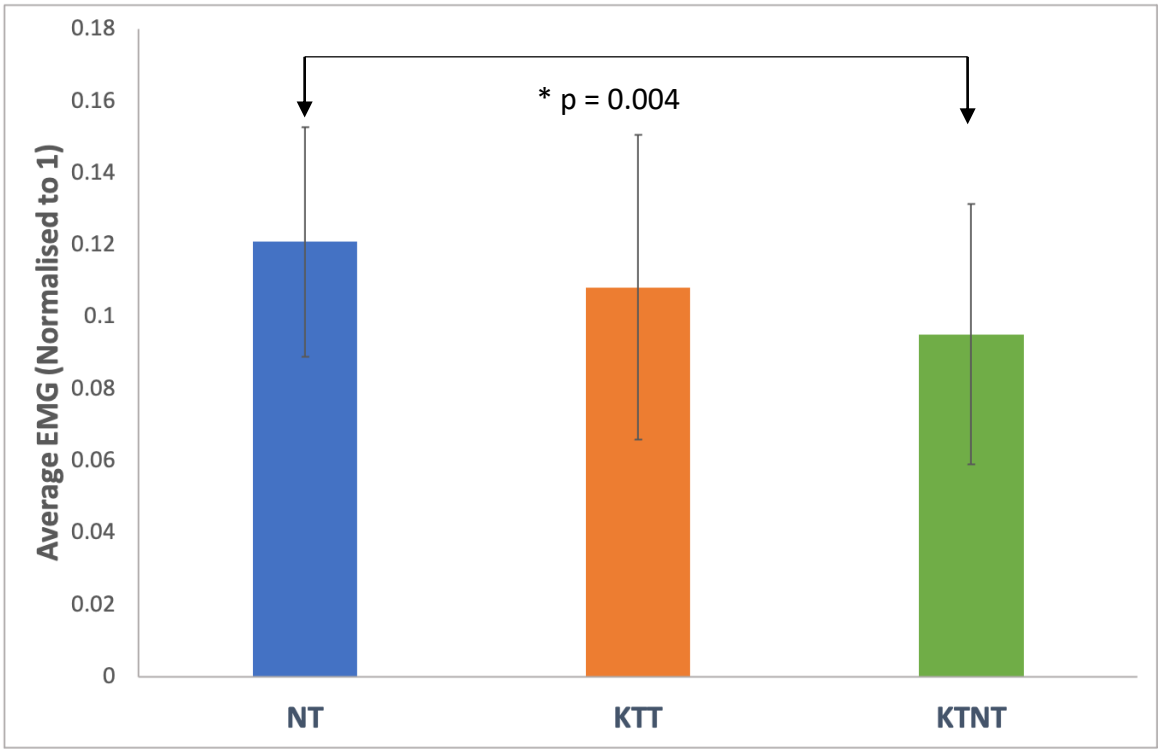


Figure 4-11 Comparisons of mean (SD) for average normalised EMG for Gmax under the three taping conditions (* represents a significant difference at the 0.05 level, Normalised to 1 which represents the maximum observed signal).

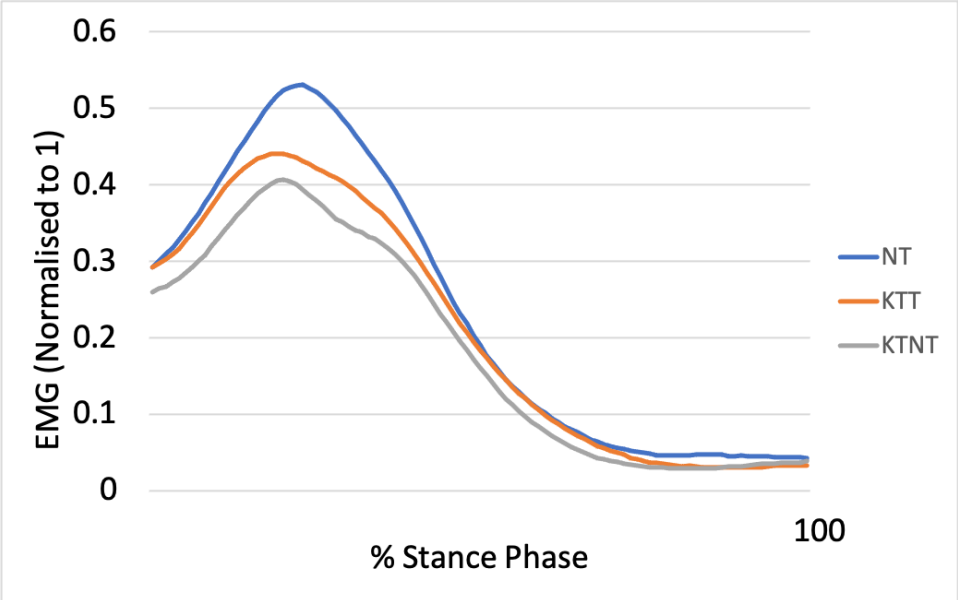


Figure 4-12 Time series graph for normalised EMG signals for Gmax under the three taping conditions. Normalised to 1 which represents the maximum observed signal.

Table 4-22 Pairwise comparisons of average EMG for TFL.

Average Normalised EMG for TFL	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT vs NT	-0.019	0.005*	-0.032	-0.006
KTNT vs NT	-0.007	0.399	-0.025	0.011
KTT vs KTNT	-0.012	0.057	-0.024	0

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

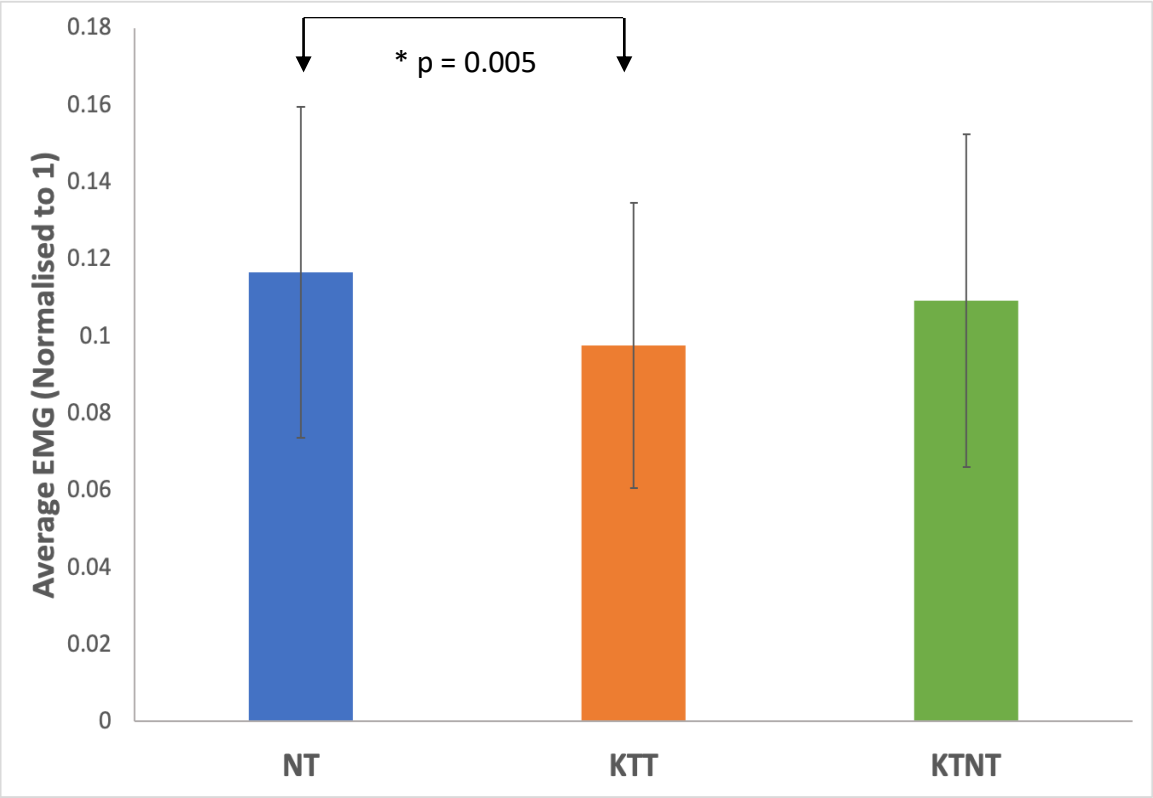


Figure 4-13 Comparison of mean (SD) for average normalised EMG for TFL under the three taping conditions (* represents a significant difference at the 0.05 level, Normalised to 1 which represents the maximum observed signal).

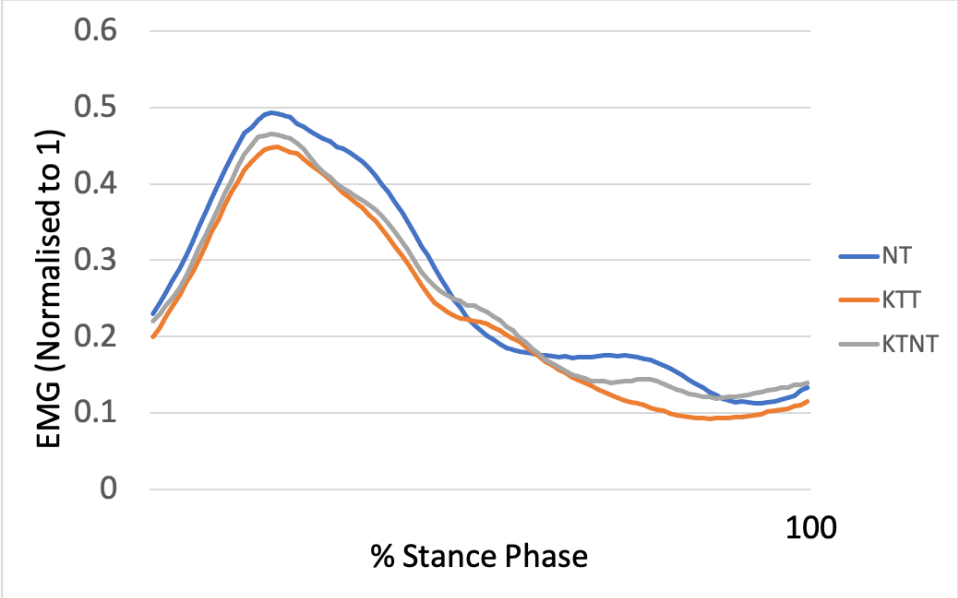


Figure 4-14 Time series graph for normalised EMG signals for TFL under the three taping conditions. Normalised to 1 which represents the maximum observed signal.

4.3.8 Peak Electromyography Data

The Shapiro-Wilk test demonstrated all peak EMG parameters were normal data distribution. The descriptive statistics for peak EMG can be seen in Table 4-23. The RM ANOVA results showed no significant interactions between sex and taping conditions for any peak EMG parameters ($p>0.05$).

The RM ANOVA showed a significant effect of taping for peak EMG for Gmax ($p=0.007$, $\eta_p^2=0.240$). The LSD post hoc tests showed a significantly lesser for peak Gmax EMG in the KTNT condition compared to the NT condition ($p=0.007$), and lesser in the KTNT condition compared to the KTT condition ($p=0.033$). No significant difference was observed between the NT and KTT conditions ($p=0.137$), Table 4-24. Figure 4-15 presents mean and standard deviation for the peak EMG for Gmax under the three taping conditions. In addition, the RM ANOVA demonstrated no a significant difference the effect of taping for the peak EMG for Gmed, TFL, VM and VL ($p=0.321$, $p=0.446$, $p=0.494$, $p=0.120$), respectively, Table 4-23. There was no significant difference between sexes for peak EMG for Gmax ($p=0.686$), Gmed ($p=0.820$), TFL ($p=0.996$), VM ($p=0.810$) and VL ($p=0.348$), as shown in Table 4-23.

Table 4-23 Mean (SD) and repeated measures ANOVA for normalised values from peak EMG signal analysis in each group during stance phase.

Peak Normalised EMG	Males (n=10)			Females (n=10)			P-value (ηp^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Gmax‡,¥	0.615 (0.097)	0.528 (0.126)	0.521 (0.138)	0.608 (0.086)	0.562 (0.170)	0.449 (0.128)	0.007* (0.240)	0.686 (0.009)
Gmed	0.631 (0.080)	0.587 (0.160)	0.613 (0.151)	0.641 (0.115)	0.578 (0.177)	0.642 (0.127)	0.321 (0.059)	0.820 (0.003)
TFL	0.560 (0.196)	0.531 (0.164)	0.545 (0.152)	0.590 (0.113)	0.512 (0.224)	0.536 (0.184)	0.446 (0.044)	0.996 (<0.001)
VM	0.653 (0.113)	0.620 (0.098)	0.633 (0.091)	0.652 (0.117)	0.596 (0.169)	0.628 (0.181)	0.494 (0.038)	0.810 (0.003)
VL	0.535 (0.098)	0.624 (0.179)	0.608 (0.160)	0.475 (0.246)	0.584 (0.164)	0.549 (0.166)	0.120 (0.111)	0.348 (0.049)

* Significant main effect at the 0.05 level. Normalised to 1 which represents the maximum observed signal.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

Table 4-24 Pairwise comparisons of peak EMG for Gmax.

Peak Normalised EMG for Gmax	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT vs NT	-0.067	0.137	-0.158	0.024
KTNT vs NT	-0.126	0.007*	-0.213	-0.04
KTT vs KTNT	0.059	0.033*	0.005	0.113

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

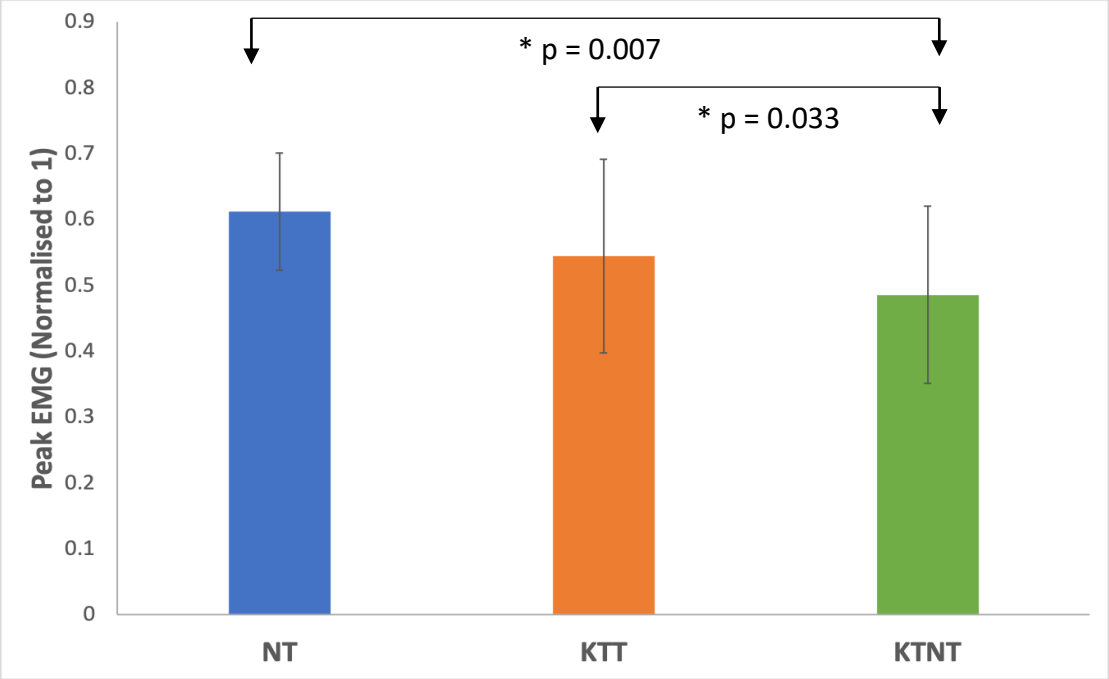


Figure 4-15 Comparison of mean (SD) for peak EMG for Gmax under the three taping conditions (* represents a significant difference at the 0.05 level, Normalised to 1 which represents the maximum observed signal).

4.3.9 Perceived comfort, stability of the knee joint, and running performance outcomes

There was a 1 to 7 score in each Likert scale questionnaire to show the rating after taping in the KTT and KTNT conditions compared to the NT condition, including feeling of comfort, feeling of knee joint stability, and feeling of benefits to running performance (1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = neutral, 5 = slightly agree, 6 = agree, 7 = strongly agree).

4.3.9.1 Comfort Scores

The number of participants for each comfort score category for the KTT and KTNT conditions is shown in Figure 4-16. Ten participants indicated a clinically important change (+2 or greater) when using KTT, and thirteen when using the KTNT, with the remainder indicating no clinically important change (between -1 and +1).

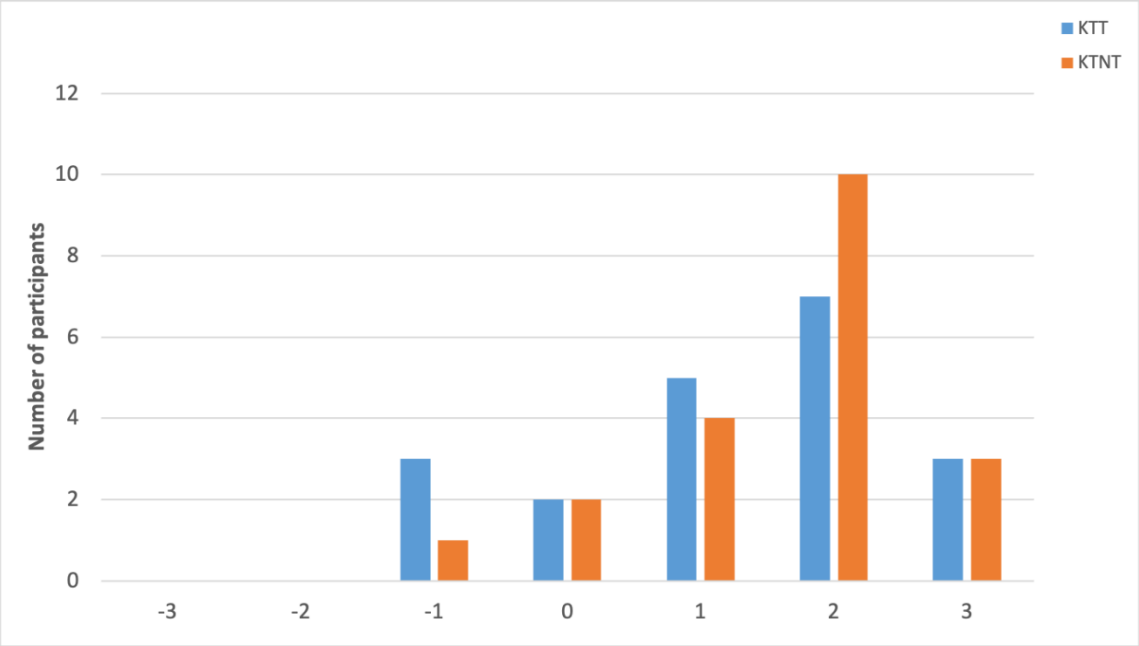


Figure 4-16 Number of participants in each comfort score category in KTT and KTNT taping conditions compared to NT condition. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree. The question asked was "Do you think this kinesio tape is comfortable compared to pre-tape?".

4.3.9.2 Stability Scores

The number of participants for each stability score category for the KTT and KTNT conditions is shown in Figure 4-17. Six participants indicated a clinically important change (+2 or greater) when using both KTT and KTNT, with the remainder indicating no clinically important change (between -1 and +1).

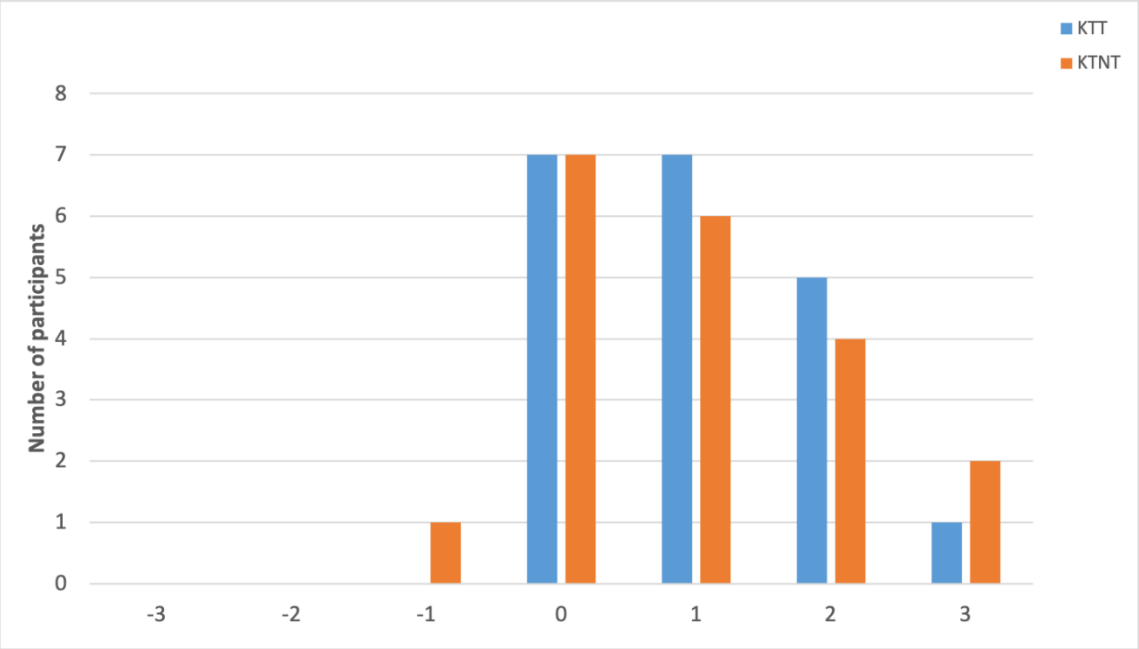


Figure 4-17 Number of participants in each stability score category in KTT and KTNT taping conditions compared to NT condition. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree. The question asked was "Do you think this kinesio tape helps the stability of your knee compared to pre-tape?"

4.3.9.3 Running Performance Scores

The number of participants for each running performance score category for the KTT and KTNT conditions is shown in Figure 4-18. Seven participants indicated a clinically important change (+2 or greater) when using KTT and KTNT, with the remainder in the KTNT indicating no clinically important change (between -1 and +1), with 2 in the KTT reporting a clinically important negative effect on performance.

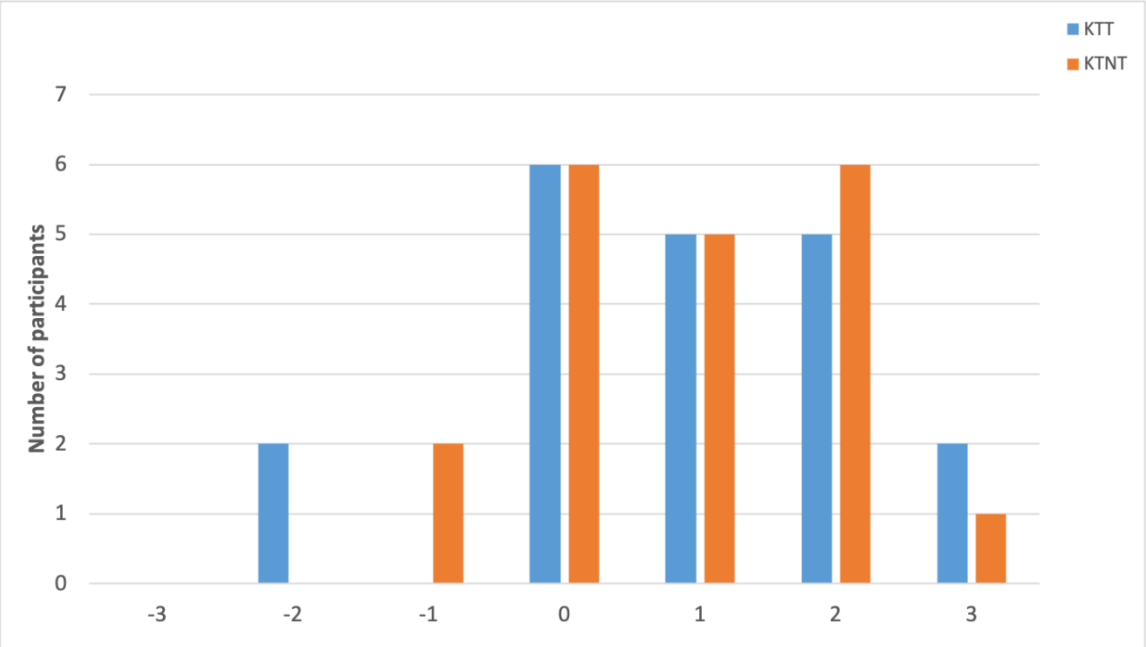


Figure 4-18 Number of participants in each running performance score category in KTT and KTNT taping conditions compared to NT condition. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree. The question asked was "Do you think this kinesio tape offers benefits to your running performance compared to pre-tape?".

4.4 Discussion

The main aim of this thesis was the exploration of the efficacy and short-term effectiveness of KT with and without tension on runners with ITBS. However, it was first important to understand how KT effects the running biomechanics in healthy runners to inform the further exploration in individuals with ITBS. The aim of the study in healthy participants was to investigate the immediate effects of KT on biomechanics, muscle activity, and perceived benefits.

The summary findings indicated that the KT significantly increased the peak hip external rotation angle, peak hip flexion angle, peak hip abduction angle, and peak knee flexion angle during the stance phase of running. There was a significant decrease in peak knee flexion moments. Additionally, peak hip internal rotation and adduction angle in the KTT condition showed a trend towards a decrease compared to the NT condition. In addition, there was a significant decrease in average TFL muscle activity, and average and peak Gmax muscle activity. No participants reported any negative important changes in comfort perception and knee joint stability; however, two participants reported an important negative effect on running performance after using KTT.

4.4.1 The effect of KT on Transverse Plane Hip Kinematics and Moments

The changes seen in the hip in the transverse plane under the KTT condition in this study are particularly interesting. The transverse plane hip kinematics may be considered an important parameter as previous studies have reported that individuals with ITBS have an increased hip internal rotation angle during stance phase which can shorten the ITB (Noehren et al., 2014). Therefore, an increase in peak hip external rotation angle under the KTT condition could help to increase the hip external rotation and reduce the hip internal rotation during the stance phase of running in individuals with ITBS. A greater peak hip external rotation angle was seen in the KTT compared to the NT and the KTNT conditions, however no significant differences were seen between the KTNT and NT conditions. In addition, there was no significant difference in peak hip external and internal rotation moments immediately post taping compared to pre-taping. These results supported the thesis hypothesis and can imply that the increase in peak hip external rotation angle is due to the tension applied to the KT. From the literature review

and to the author's knowledge, there is no research exploring the effect of KT on the biomechanics associated with the ITB in runners. However, there is previous research that investigated both rigid and KT taping in healthy participants which showed agreement with this current study with an increase in hip external rotation or decrease in the hip internal rotation (Masters et al., 2018, Song et al., 2015, Song et al., 2017), and no significant difference was detected on peak hip moments in hip transverse plane between KT and NT during running trials (Howe et al., 2015).

When considering the KT method in this study that increase hip external rotation angle, peak hip internal rotation angle should have a significant decrease after taping with tension. However, there was not a significant difference after taping with tension or without tension. Although this was not seen a significant decreased peak hip internal rotation angle in the KTT compared to the NT condition~~,~~ in the UK healthy participants, the KTT condition showed a trend towards a decrease with 21% less internal rotation compared to the NT condition. These findings are in contrast with Masters et al. (2018) who used a rigid hip taping technique that consisted of abduction and external rotation components on a cohort of healthy runners. They found that hip taping exhibited a significant decrease in the hip internal rotation angles in the stance phase compared to both sham and no tape conditions. Similarly, Song et al. (2015) and Song et al. (2017) found no significant decrease in peak hip internal rotation angle after taping compared to the NT condition in healthy control participants. When considering the KT technique used by Song et al (2015, 2017), they used one line of KT to increase hip external rotation with a 20% stretch in the KT, whereas the present study used two lines with 50-75% stretch in the KT. It has been suggested that the somatosensory stimulations vary depending on the amount of tension applied to the tape which may help to explain these differences between the present findings and Song et al (2015, 2017).

4.4.2 The effect of KT on TFL Muscle Activity

The TFL muscle activation should be considered as a key finding as previous studies have shown that the TFL muscle activation in runners with ITBS was greater compared to healthy controls during running (Baker et al., 2018), and they advised using this finding to support treatments which could modify TFL muscle activity. Based on the anatomy

that ITB is a lateral fascia which is formed by the tensor fascia latae and gluteus maximus muscles, unusual tension of the ITB may be related to increased activation of the TFL muscle (Stecco et al., 2013), and rapid rate of loading of the ITB (Hamill et al., 2008, Meardon et al., 2012). The TFL muscle has various functions comprising of hip abduction, flexion and internal rotation (Richard et al., 2009). Therefore, the tightness in the TFL can cause an increase in the hip internal rotation angle in running (Noehren et al., 2014). The results demonstrated that the average TFL muscle activity was significantly lower in the KTT condition compared to the NT condition, but no significant differences between the KTNT and NT conditions or the KTT and KTNT conditions were seen.

The reduction in TFL muscle activity may be associated with the increase in the hip external rotation angle as the TFL function has been associated with hip internal rotation (Besomi et al., 2020). One explanation for the effect of KT with tension to facilitate hip external rotation is somatosensory stimulation. A larger surface area for the proprioceptive effect of the tape as the hip externally rotates during running may provide cutaneous stimulation leading to a change in movement strategy (Nakajima and Baldridge, 2013). This is supported by Yeung and Yeung (2016) who proposed that KT may stimulate skin mechanoreceptors, increase motor unit excitability and elicit a muscle spindle reflex through a recoil effect. Additionally, they proposed that the KT pulling force may also stretch the Golgi tendon organs if the directions of the pull and the muscle contraction are in opposite directions. In this case, KT may inhibit TFL muscle activity leading to an increase in hip external rotation movement (Akbaş et al., 2011). However, the underlying mechanism of KT in this study warrants further investigation in runners with ITBS.

4.4.3 The effect of KT on Coronal Plane Hip Kinematics and Moments

For the coronal plane hip kinematics, the effect of the KT was hypothesised to reduce the peak hip adduction angle and also increase the peak hip abduction angle. There was a significant increase in peak hip abduction angle in the KTT compared to the NT condition. Similarly, Tsai et al. (2020) showed significantly increased hip abduction angle at the instant of the maximal vertical ground reaction force when using KT for correction hip compared to NT during lay-up jump.

A greater peak hip adduction angle has been reported in people with ITBS when compared to healthy controls (Grau et al., 2011, Ferber et al., 2010b, Noehren et al., 2007). However, no significant differences in the peak hip adduction angle were observed, although KTT condition showed a trend towards a decrease of approximately 7.2%. This trend supports the findings of Masters et al. (2018) who investigated hip taping in asymptomatic runners and showed a significant decrease in the hip adduction angles throughout the stance phase of running when compared to sham and no taping. However, no significant difference was observed in the peak hip abduction and adduction moments immediately post-taping compared to pre-taping. This was supported by Howe et al. (2015) who showed no significant difference on peak hip moments in hip coronal plane between KT and NT during running trials.

4.4.4 The effect of KT on Gmed Muscle Activity

Associated with an increase in hip adduction angle in runners with ITBS, there would potentially be a greater eccentric demand on the hip abductors muscle and associated increase in Gmed muscle activity (Baker et al., 2018, Foch et al., 2020). The KT technique used in this study may help to reduce the hip adduction angle, and may help to decrease Gmed muscle activity after taping. However, there was no significant effect of taping in the peak hip adduction angle or any associated changes in Gmed muscle activity. This is consistent with Silva et al. (2021) who showed that KT did not change Gmed muscle activation in single-leg squat, drop landing, and jump landing movements compared to the NT condition. Similarly, Song et al. (2015) showed healthy participants who used femoral rotational KT showed no significant differences in Gmed muscle activity compared to the NT condition during a single-leg squat task.

4.4.5 The effect of KT on Hip Sagittal Plane Kinematics and Moments

For the peak hip flexion angle, the result showed a significantly greater peak hip flexion angle in KTT and KTNT compared to the NT condition, the greater peak hip flexion angle in the KTT and KTNT conditions. This finding is in contrast to a previous study by Howe et al. (2015) which showed no significant differences in peak hip flexion between KT and NT conditions. The differences in outcomes between the present study and Howe et al. (2015) could potentially be explained by the taping techniques used. Howe et al. (2015)

used a vastus medialis facilitation and medial patellar glide KT technique around the knee joint and did not continue proximally. Nevertheless, no significant difference was observed in the peak hip extension and flexion moments immediately post-taping compared to pre-taping. Similarly, Howe et al. (2015) who indicated no significant difference on peak hip moments in hip sagittal plane between KT and NT during running trials.

4.4.6 The effect of KT on Gmax Muscle Activity

The Gmax muscle activity showed a significant decrease in the average and peak Gmax muscle activity in the KTNT compared to both the NT and KTT conditions, but no significant differences were seen between KTT and NT conditions. The results was in contrast to Song et al. (2015) who found no significant differences in Gmax muscle activity in healthy participants when using femoral rotational KT. In addition, Briem et al. (2011) examined the effect of rigid adhesive tape and KT compared to a NT condition on muscle activity of the peroneus longus during a sudden inversion perturbation in male athletes. They found that rigid tape showed a significantly greater average Gmax muscle activity, while KT had no significant effect on peak or average Gmax muscle activity when compared with no tape for both stable and unstable conditions. However, the present studies on healthy participants indicated that the KT application appears to change the muscle activity which may help to improve hip flexion or extension movement and decrease the load in the muscle. This is consistent with Watanabe (2019) who showed that the application of KT can decrease neuromuscular activation of the knee extensor muscles, however, there was a difference between the present study and Watanabe (2019) as they applied KT on the skin directly over the knee extensor muscles, whereas the present study applied KT on the thigh.

4.4.7 The effect of KT on Knee Kinematics and Moments

When considering the effect of taping on peak knee flexion angle, there was a significantly greater knee flexion in the KTNT condition compared to the NT condition. This finding is in contrast to previous studies that demonstrated no significant difference in the peak knee flexion angle after KT with and without tension, this may potentially be due to the differences in the taping techniques used (Song et al., 2015, Song et al., 2017).

For the peak knee flexion moments, the result showed a significant decrease in the peak knee flexion moments in the KTNT condition compared to the NT condition and lower moments in the KTNT condition compared to the KTT condition. The result of peak knee flexion angle above showed that there was significantly greater knee flexion in the KTNT condition compared to the NT condition. The lower moments might be linked to a decrease in the patellofemoral joint loads and a decrease risk of developing PFP (Teng et al., 2015), which is in contrast to a systematic review that concluded that KT does not offer any enhanced functional benefit over taping without tension (Parreira Pdo et al., 2014). However, the principal mechanism of the perceived taping effects in this study are likely multifactorial and need further investigation within different patient populations.

Peak knee internal rotation angle is an important parameter that previous studies showed, with ITBFS patients demonstrating an increase in knee internal rotation compared to healthy controls group (Noehren et al., 2007, Baker and Fredericson, 2016, Shen et al., 2019). However, no significant difference was seen in the effect of KT on this parameter in present study and previous studies did not demonstrate the effect of KT on peak knee internal rotation angle (Song et al., 2015, Song et al., 2017). This may be due to investigate in healthy participants or taping technique.

4.4.8 Sex differences in Running Biomechanics

Previous research examining sex differences in running biomechanics have reported a difference between healthy male and female runners (Ferber et al., 2003, Nigg et al., 2012). Several studies have reported greater peak hip adduction, hip internal rotation and knee abduction angles in healthy female runners when compared with male runners (Phinyomark et al., 2014, Phinyomark et al., 2015, Chumanov et al., 2008). In the current studies, females demonstrated a significantly greater peak hip adduction angle, coronal plane hip ROM, peak knee abduction angle, and a trend towards greater peak hip internal rotation, whilst males demonstrated a significantly greater peak hip extension moment and a greater peak knee abduction moment.

This result is in support of Ferber et al. (2003) who reported that healthy women exhibit greater hip internal rotation and peak hip adduction angle during running compared to men. Noehren et al. (2014) indicated that runners with ITBS have an increased hip internal rotation angle compared to control healthy runners. Therefore, the results of the present study imply that females may have a greater risk of ITBS to males (Taunton et al., 2002b), which may result in a greater load in the ITB and subsequently lead to ITBS (Charles and Rodgers, 2020).

4.4.9 Perception of Comfort, Joint Stability, and Running Performance

The comfort, joint stability, and running performance are factors to consider when applying taping techniques as these should be comfortable, and not interfere with joint stability or running performance. If taping is uncomfortable, causes the perception of joint instability, or impairs athletic performance it may cause more drawbacks than benefits and will adversely affect adherence. Therefore, we need to assess comfort, knee stability and running performance when using such techniques.

The result of the Likert scale questionnaire showed that 50% of the total participants (10 out of 20 participants) indicated a clinically important change (+2 or greater) when using KTT, and 13 participants when using the KTNT, with no participant reporting any negative changes in comfort perception in the KTT condition. For perception of stability of the knee joint, 30% of the total participants (6 out of 20 participants) indicated a clinically important change when using both KTT and KTNT. There was no participant reported any negative changes in perception of stability of the knee joint in the KTT and KTNT conditions. For perception of benefit to running performance, 35% of the total participants (7 out of 20 participants) indicated a clinically important change when using both KTT and KTNT, with 2 participants reporting negative changes in perception of benefit to running performance in the KTT condition.

To the author's knowledge, no research reported perceived comfort, knee stability and running performance in ITBS when using taping or KT. In addition, there are a limited number of studies that have reported perceived comfort, knee stability and running performance when using KT. However, previous studies demonstrated the perceived

comfort, joint stability and running performance when using taping or bracing. The present study is consistent with Hébert-Losier et al. (2019) who demonstrated that most elite cyclists perceive KTT to be comfortable, increase knee stability, and improve performance. Similarly, Abián-Vicén et al. (2009) studied the perception of comfort using a scale from zero (minimum) to ten (maximum) in elastic versus inelastic prophylactic ankle taping techniques in twenty-seven young women. The results of their study found that elastic taping was shown to be comfortable with comfort scores of 7.8, while inelastic taping had a comfort score of 5.1. This supports a greater perception of comfort when using elastic taping when compared to inelastic taping. Additionally, the present studies are consistent with Long et al. (2017) who investigated the effects of KT and rigid taping on ankle proprioception through perceived comfort, perceived support and perceived proprioceptive performance whilst wearing the two forms of taping. The result showed that participants were very comfortable, perceived support, and were confident about their proprioceptive performance when either KT or rigid taping was applied. These results support the findings of the present study which reported that the majority of participants perceived KTT to be comfortable, with some perceiving improved stability and running performance.

A limitation within this study was the sampling frequency of the kinematics which was set to 100 Hz. Although this is in line with previous studies (Shen et al., 2019, Pelletier et al., 2019) a higher sampling frequency may provide greater detail in both the kinematic and moment data. Furthermore, the length of habituation to the different conditions of taping may have influenced the perception of participants to kinesio tape, with longer term perceived effects still needing to be explored in the future. This current work considered running at a comfortable speed, and although no differences were seen between speeds, the use of a controlled running speed between conditions may reveal other subtle changes in biomechanics not observed in this current study. Additionally, this study only investigated the effect of tape on the dominant limb so the effects on the non-dominant limb also require further investigation.

CHAPTER 5 THE IMMEDIATE EFFECTS OF KINESIO TAPING ON RUNNING BIOMECHANICS, MUSCLE ACTIVITY, AND PERCEIVED CHANGES IN COMFORT, STABILITY AND RUNNING PERFORMANCE IN THAI HEALTHY RUNNERS

5.1 Introduction

This chapter, the second study of this thesis, was conducted on healthy participants in Thailand to explore the effect of KT on running biomechanics compared to the UK cohort. There were notable differences between the UK and Thai studies including the motion analysis system, the sampling frequency used to collect the kinematic and kinetic data, and the laboratory sizes. This data was collected from a Thai healthy cohort using the same facilities as the participants with ITBS, which was the final study within this thesis, see chapter 6.

5.2 Methods

5.2.1 Participants

Male and female healthy runners were recruited from running clubs and the staff and student population at Mahidol University in Thailand. Thai healthy participants were screened using the same inclusion and exclusion criteria as in the UK healthy study (Chapter 4, section 4.2.1). This study used a Thai participant information sheet (Appendix 8) and screening questionnaire to determine the safety or possible risks associated with inclusion (PAR-Q+) (Appendix 9), a Thai healthy informed consent form (Appendix 10), and a Thai Likert scale questionnaire (Appendix 11).

This study was approved by the ethics committee of the University of Central Lancashire (STEMH 966) (see Appendix 6) and the Mahidol University Central Institutional Review Board (MU-CIRB) (COA No.MU-CIRB 2019/224.1912) (see Appendix 12).

5.2.2 Procedures

This study was conducted in the Movement Analysis Laboratory (Faculty of Physical Therapy, Mahidol University, Nakhon Pathom, Thailand). The study design and procedures of Thai healthy study used the same as the UK healthy study in Chapter 4, section 4.2.2.-4.2.3.

Many of the methods relating to the technical and setup features were common between the UK and Thai healthy studies which are covered in Chapter 3. These included; the sEMG equipment (Chapter 3, section 3.4.1), skin preparation for sEMG sensor placement (Chapter 3, section 3.4.2.1.1), marker placement (Chapter 3, section 3.4.2.1.2), taping Interventions (Chapter 3, section 3.4.2.2-3.4.2.3), Running biomechanics test procedures, see section 3.4.2 for full details, perceived comfort, stability of the knee joint, and running performance outcome questionnaires (Chapter 3, section 3.4.2.4.1), data processing (Chapter 3, section 3.5), and data analysis (Chapter 4, section 4.2.4).

There were some differences in the equipment used between this study and the UK healthy studied (see Chapter 3 for full description). In this study, a Vicon motion capture system, sampling at 2000Hz were used to capture kinematics data, with two force platforms sampling at 500Hz to acquire kinetic data. The size of the Thai laboratory was 16 m long compared to the 30 m laboratory used in the UK study.

5.3 Results

5.3.1 Participants Characteristics

Twenty Thai healthy participants individuals consisting of ten males and ten females participated in this study. Table 5-1 presents the descriptive statistics from the participants.

Table 5-1 Participant demographics values are reported as Mean (SD) and ranges.

	Mean (SD)	Range
Age (year)	36 (6.77)	22 - 45
Weight (kg)	63.5 (16.25)	38.75 - 88
Height (cm)	166.38 (11.49)	146.5 - 183
BMI (kg/m^2)	22.51 (2.95)	18.05 – 26.76
Average running distance per week (km)	28.8 (19.25)	10 - 80

5.3.2 Running Speed

The running speed was not normal distributed; therefore, the Friedman test was used to analyse the running speed data among three taping conditions in each sex separately. The Friedman test showed a significant difference of taping condition on running speed for males ($p=0.027$, $W=0.360$) but there was no significant difference between taping conditions on running speed for female ($p=0.741$).

The post-hoc Wilcoxon Signed Rank test demonstrated that males ran significantly faster in KTNT condition compared to the NT condition ($p=0.007$). There was no significant difference between the KTT and KTNT conditions ($p=0.203$), and between the KTT and NT conditions ($p=0.093$). In addition, the Mann-Whitney U test showed no significant difference between sexes for running speed ($p=0.705$).

5.3.3 Hip Kinematic Data

The Shapiro-Wilk test showed a normal data distribution in the majority of hip kinematic parameters except sagittal and transverse plane hip ROM. The descriptive statistics for

hip kinematics can be seen in the Table 5-2 and Table 5-3. The RM ANOVA results showed no significant interactions between sex and taping conditions for any hip kinematic parameters ($p>0.05$).

5.3.3.1 Sagittal Plane Hip Kinematics

The RM ANOVA showed a significant main effect for the taping condition for the peak hip extension angle ($p<0.001$, $\eta_p^2=0.365$), Table 5-2, Row 2. The Least Significant Difference (LSD) post hoc test showed a significantly greater peak hip extension angle in both KTT and KTNT conditions compared to the NT condition ($p<0.001$, $p=0.027$), respectively and a significantly greater angle in the KTT condition compared to the KTNT condition ($p=0.050$), Table 5-4. Figure 5-1 presents the comparison of mean and standard deviation for peak hip extension angle under the different taping conditions. Figure 5-2 shows presents the hip flexion/extension angle time series graph under the three taping conditions.

In addition, the RM ANOVA showed no significant main effect of sex for peak hip extension angle ($p=0.054$). For peak hip flexion angle, there was no significant main effect of taping ($p=0.526$), Table 5-2. However, there was a significant difference between sexes for the peak hip flexion angle ($p=0.019$, $\eta_p^2=0.271$), with the pairwise comparison showing females had a significantly greater peak hip flexion compared to males, Table 5-5.

The Friedman test showed a significant difference between taping conditions for sagittal plane hip ROM in females ($p=0.002$, $W=0.610$), but no significant difference for sagittal plane hip ROM was seen in males ($p=0.670$), Table 5-3, Row 1. The Wilcoxon Signed Rank test for sagittal plane hip ROM in females showed a significantly greater sagittal plane hip ROM in both KTT and KTNT conditions compared to the NT condition ($p=0.005$, $p=0.022$), respectively, but there was not a significant difference between the KTT compared to the KTNT conditions ($p=0.646$), Table 5-6. Figure 5-3 presents comparison of sagittal plane hip ROM for females under the three taping conditions. In addition, the Mann-Whitney U-tests showed no significant difference between sexes for sagittal plane hip ROM ($p=0.406$).

5.3.3.2 Coronal Plane Hip Kinematics

The RM ANOVA demonstrated a significant main effect of taping condition for the coronal plane hip ROM (p=0.004, η_p^2=0.263), Table 5-2, Row 5. The LSD post hoc test demonstrated the KTT condition significantly increased coronal plane hip ROM compared to the NT condition (p=0.002), and no significant difference was seen between the KTNT and NT conditions (p=0.075), and between the KTT and KTNT (p=0.110), Table 5-7. Figure 5-4 showed the comparison of mean and standard deviation for coronal plane hip ROM under the different taping conditions.

In addition, the RM ANOVA showed no significant effect of taping on peak hip adduction and abduction angle (p=0.955, p=0.054), respectively, Table 5-2. There was a significant difference for sex differences on peak hip abduction angle (p=0.016, η_p^2=0.280). The pairwise comparison for main sex effect showed that males had a significantly greater peak hip abduction angle compared to females, Table 5-5. However, there was no significant difference between sexes for the peak hip adduction angle (p=0.305) and the coronal plane hip ROM (p=0.128), Table 5-2.

5.3.3.3 Transverse Plane Hip Kinematics

The RM ANOVA showed a significant main effect of taping for peak hip internal rotation angle (p=0.021, η_p^2=0.193) and peak hip external rotation angle (p=0.003, η_p^2=0.277), Table 5-2, Row 6-7. The LSD post hoc tests showed the KTT condition significant decrease in the peak hip internal rotation compared to NT condition (p=0.022). There was no significant difference between the KTNT and NT conditions (p=0.119), or the KTT and KTNT conditions (p=0.123) Table 5-8. Figure 5-5 showed the comparison of mean and standard deviation for peak hip internal rotation angle under the different taping conditions. The LSD post hoc tests demonstrated a significantly greater peak hip external rotation angle in the KTT condition compared to NT and KTNT conditions (p=0.005 and p=0.012), respectively. No significant difference was seen between the KTNT and NT conditions (p=0.259), Table 5-9. Figure 5-6 showed the comparison of mean and standard deviation for peak hip external rotation angle under the different taping conditions, and Figure 5-7 demonstrates the hip internal rotation/external rotation angle time series graph under the three taping conditions.

In addition, there were significant differences between sexes for peak hip internal rotation angle (p=0.001, η_p^2=0.480) and peak hip external rotation angle (p=0.001, η_p^2=0.445), Table 5-2. The pairwise comparison showed that females had a significantly greater peak hip internal rotation angle compared to males, while males had a significantly greater peak hip external rotation angle compared to females, Table 5-5.

The Friedman tests showed no significant difference for the transverse plane hip ROM for males and females (p=0.273, p=0.407), respectively, Table 5-3. The Mann-Whitney U-tests demonstrated no significant difference between sexes for the transverse plane hip ROM (p=1.000).

Table 5-2 Mean (SD) and repeated measures ANOVA for peak hip angle and hip ROM in the sagittal, coronal and transverse plane.

Hip Kinematics (degrees)[a]	Males (n=10)			Females (n=10)			P-value (η_p^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Peak flexion	31.11 (6.64)	30.86 (7.91)	31.15 (7.26)	38.41 (5.77)	38.28 (6.02)	39.03 (5.87)	0.526 (0.035)	0.019* (0.271)
Peak extension†,‡,¥	-5.71 (4.53)	-6.59 (4.48)	-6.38 (4.46)	-1.07 (4.94)	-3.03 (4.67)	-1.94 (4.73)	<0.001*(0.365)	0.054 (0.191)
Peak adduction	8.84 (2.66)	8.70 (2.26)	8.67 (2.48)	9.79 (3.09)	10.03 (2.86)	10.16 (3.23)	0.955 (0.003)	0.305 (0.058)
Peak abduction	-2.42 (2.45)	-3.32 (2.20)	-3.45 (2.75)	0.31 (3.40)	-0.19 (2.97)	0.65 (3.40)	0.054 (0.150)	0.016* (0.280)
Coronal plane ROM†	11.26 (3.39)	12.03 (3.41)	12.12 (3.91)	9.48 (2.08)	10.21 (2.20)	9.51 (2.10)	0.004* (0.263)	0.128 (0.124)
Peak internal rotation†	-2.86 (5.95)	-4.50 (5.07)	-4.18 (5.22)	5.39 (4.25)	3.99 (3.67)	5.31 (5.36)	0.021* (0.193)	0.001* (0.480)
Peak external rotation†,¥	-11.11 (6.14)	-12.87 (4.86)	-11.98 (4.65)	-2.29 (5.36)	-4.16 (4.97)	-2.56 (6.43)	0.003* (0.277)	0.001* (0.445)

* Significant main effect at the 0.05 level.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

[a] Positive values indicate hip flexion/adduction/internal rotation and negative values indicate hip extension/abduction/external rotation.

Table 5-3 Median (Q1, Q3) and Freidman test for peak hip angle and hip ROM in the sagittal, coronal and transverse plane.

Hip Kinematics (degrees)[a]	Males (n=10)			Females (n=10)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Male	Tape effect for Female
Sagittal plane ROM†,‡	37.05 (31.26, 42.67)	39.00 (33.86, 42.73)	38.60 (32.45, 43.43)	39.95 (38.41, 42.92)	42.89 (40.07, 43.70)	41.83 (38.42, 43.40)	0.670 (0.040)	0.002*(0.610)
Transverse plane ROM	7.05 (5.64, 10.37)	6.87 (5.52, 10.62)	6.56 (4.99, 10.46)	7.82 (5.20, 9.54)	9.02 (6.49, 9.61)	8.15 (5.96, 9.83)	0.273 (0.130)	0.407 (0.090)

* Significant difference at the 0.05 level.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

[a] Positive values indicate hip flexion/adduction/internal rotation and negative values indicate hip extension/abduction/external rotation.

Table 5-4 Pairwise comparisons for peak hip extension angle.

Peak hip extension (degrees)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	-1.42ϒ	<0.001*	-2.07	-0.78
KTNT and NT	-0.77ϒ	0.027*	-1.45	-0.10
KTT and KTNT	-0.65ϒ	0.050*	-1.30	-0.001

* Significant difference at the 0.05 level.

ϒ indicates a significant difference with a small change in magnitude (≤ 2 degrees), as an error of 2 degrees or less as these are likely to be susceptible to clinical misinterpretation. Negative values indicate a greater hip extension angle in the first condition when compared with the second condition.

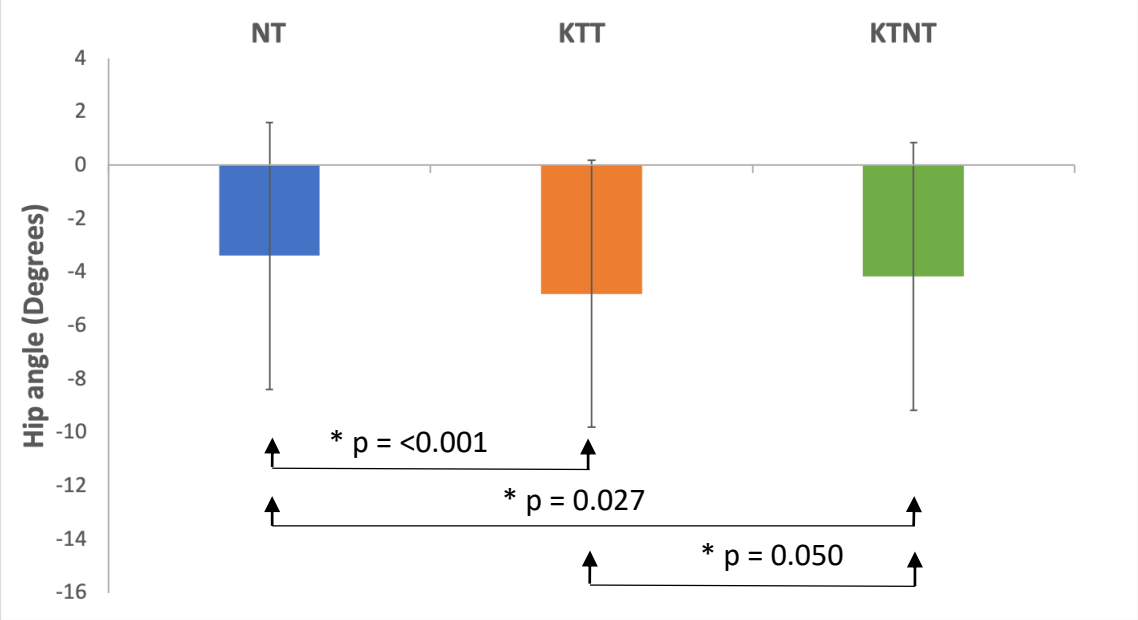


Figure 5-1 Comparison of mean (SD) for peak hip extension angle under the three taping conditions (* represents a significant difference at the 0.05 level).

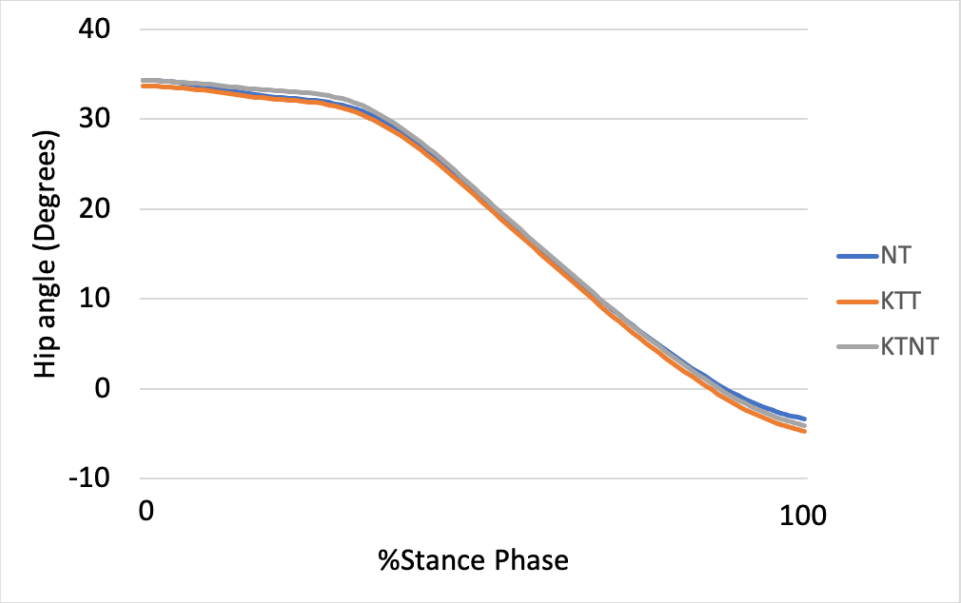


Figure 5-2 Time series graph for hip flexion/extension angle under the three taping conditions (Positive values indicate hip flexion and negative values indicate hip extension).

Table 5-5 Pairwise comparison for sex differences of hip kinematics.

Hip kinematics (degrees)	Mean Difference (Female vs Male)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Peak flexion	7.53	0.019*	1.41	13.66
Peak abduction	3.32	0.016*	0.68	5.96
Peak internal rotation	8.75	0.001*	4.24	13.25
Peak external rotation	8.98	0.001*	4.02	13.95

* Significant difference at the 0.05 level.

Positive values indicate a greater hip flexion and internal rotation angle in the females when compared with the males.

Negative values indicate a greater hip abduction and external rotation angle in the females when compared with the males.

Table 5-6 Wilcoxon Signed Rank test for sagittal plane hip ROM for females.

Sagittal plane hip ROM for females (degrees)	Median Difference	P-value
KTT and NT	2.95	0.005*
KTNT and NT	1.89ϒ	0.022*
KTT and KTNT	1.06	0.646

* Significant difference at the 0.05 level.

ϒ indicates a significant difference with a small change in magnitude (≤ 2 degrees), as an error of 2 degrees or less as these are likely to be susceptible to clinical misinterpretation. Positive values indicate a greater sagittal plane hip ROM in the first condition when compared with the second condition.

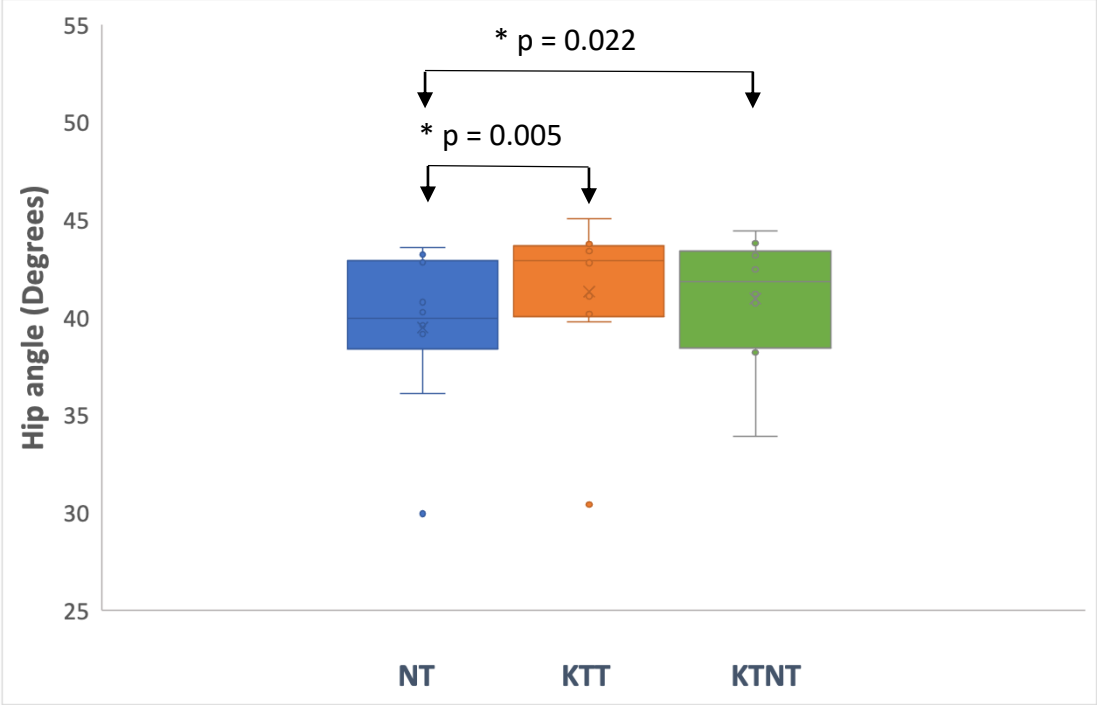


Figure 5-3 Comparisons in sagittal plane hip ROM for females under the three taping conditions (* represents a significant difference at the 0.05 level).

Table 5-7 Pairwise comparisons for coronal plane hip ROM.

Coronal plane hip ROM (degrees)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	0.75ϒ	0.002*	0.31	1.20
KTNT and NT	0.45	0.075	-0.05	0.95
KTT and KTNT	0.31	0.110	-0.08	0.69

* Significant difference at the 0.05 level.

ϒ indicates a significant difference with a small change in magnitude (≤ 2 degrees), as an error of 2 degrees or less as these are likely to be susceptible to clinical misinterpretation. Positive values indicate a greater coronal plane hip ROM in the first condition when compared with the second condition.

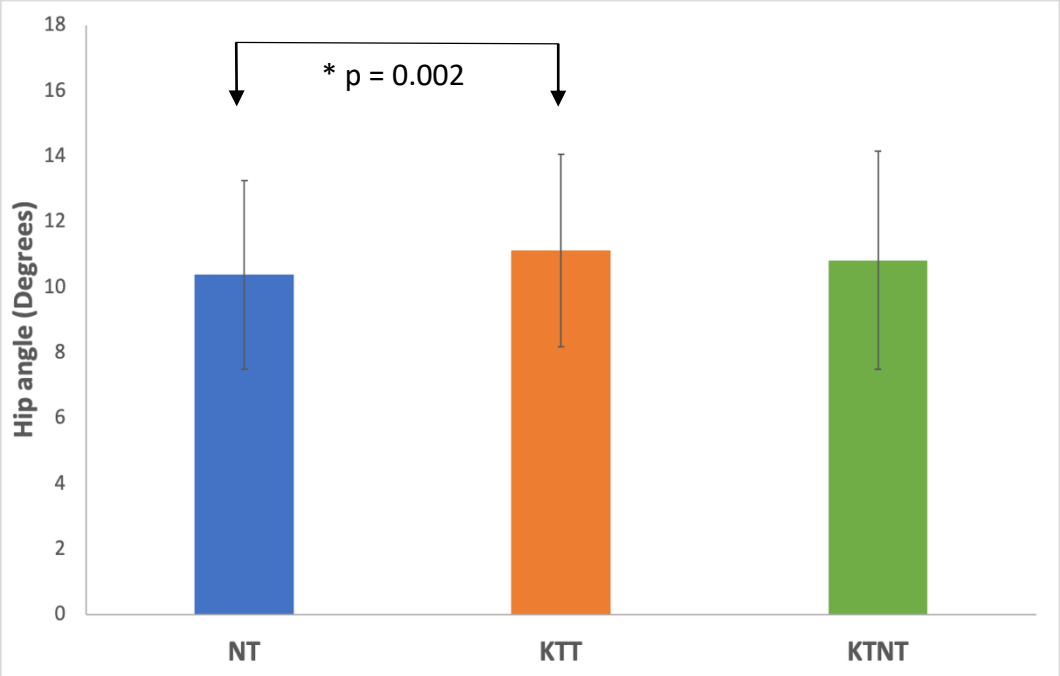


Figure 5-4 Comparison of mean (SD) for coronal plane hip ROM under the three conditions (* represents a significant difference at the 0.05 level).

Table 5-8 Pairwise comparisons for peak hip internal rotation angle.

Peak hip internal rotation (degrees)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	-1.52ϒ	0.022*	-2.79	-0.24
KTNT and NT	-0.70	0.119	-1.59	0.20
KTT and KTNT	-0.82	0.123	-1.89	0.24

* Significant difference at the 0.05 level.

ϒ indicates a significant difference with a small change in magnitude (≤ 2 degrees), as an error of 2 degrees or less as these are likely to be susceptible to clinical misinterpretation. Positive values indicate a greater hip internal rotation angle in the first condition when compared with the second condition.

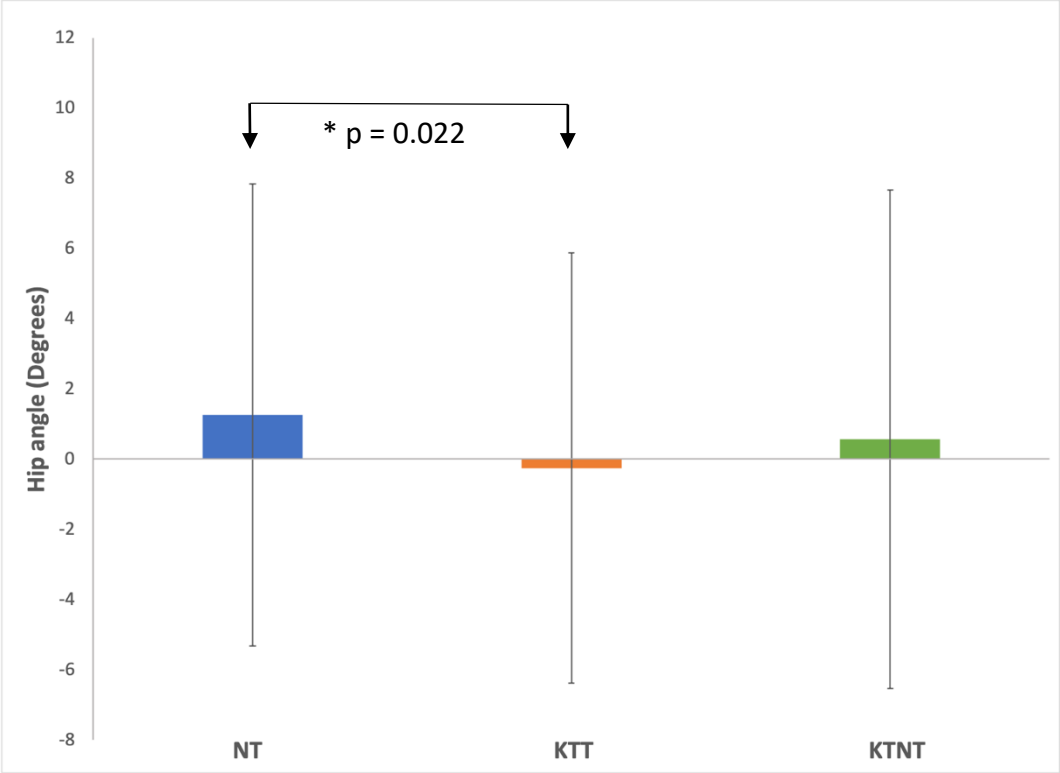


Figure 5-5 Comparison of mean (SD) for peak hip internal rotation angle under the three conditions (* represents a significant difference at the 0.05 level).

Table 5-9 Pairwise comparisons for peak hip external rotation angle.

Peak hip external rotation (degrees)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	-1.81ϒ	0.005*	-2.99	-0.64
KTNT and NT	-0.57	0.259	-1.60	0.46
KTT and KTNT	-1.25ϒ	0.012*	-2.18	-0.31

* Significant difference at the 0.05 level.

ϒ indicates a significant difference with a small change in magnitude (≤ 2 degrees), as an error of 2 degrees or less as these are likely to be susceptible to clinical misinterpretation. Negative values indicate a greater hip external rotation angle in the first condition when compared with the second condition.

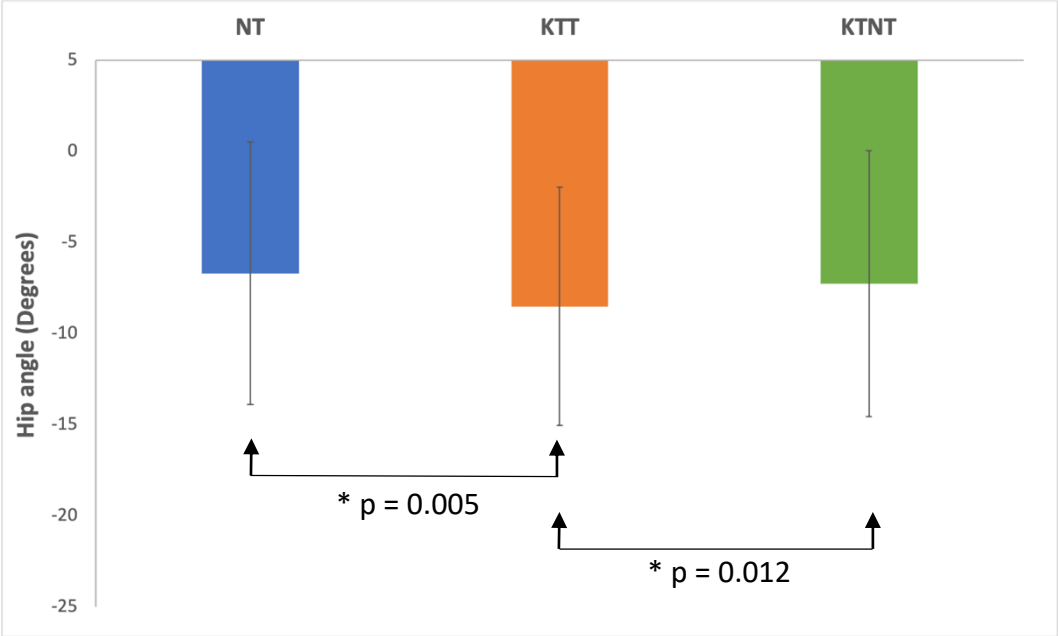


Figure 5-6 Comparison of mean (SD) for peak hip external rotation angle under the three conditions (* represents a significant difference at the 0.05 level).

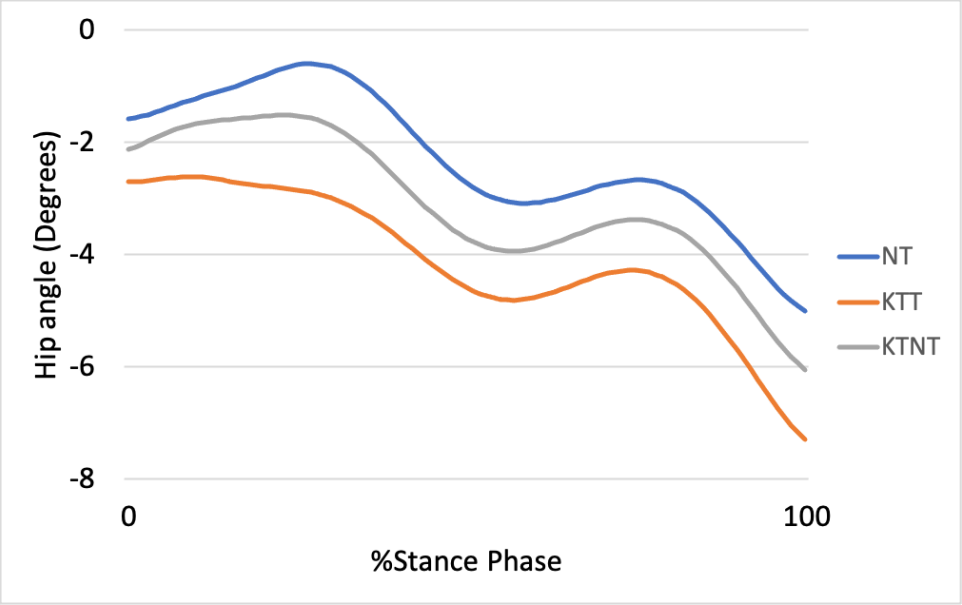


Figure 5-7 Time series graph for hip internal rotation/external rotation angle under the three taping conditions (Positive values indicate hip internal rotation and negative values indicate hip external rotation).

5.3.4 Knee Kinematic Data

The Shapiro-Wilk test demonstrated a normal data distribution for the majority of parameters except peak knee flexion angle. The descriptive statistics for peak knee angle and knee ROM in sagittal, coronal, and transverse planes can be seen in the Table 5-10 and Table 5-11. The RM ANOVA results showed no significant interactions between sex and taping conditions for any knee kinematic parameters ($p>0.05$).

5.3.4.1 Sagittal Plane Knee Kinematics

The RM ANOVA showed no significant effect of taping for minimum knee flexion angle ($p=0.228$) and sagittal plane knee ROM ($p=0.583$), and no significant differences between sexes for sagittal plane knee ROM ($p=0.239$), Table 5-10. However, there was a significant difference between sexes for minimum knee flexion angle ($p=0.028$, $\eta_p^2=0.242$). The pairwise comparison for main sex effect showed that females demonstrated significantly greater minimum knee flexion angle compared to males, Table 5-12.

The Friedman test showed no significant effect of taping for peak knee flexion angle for both males and females (p=0.670, p=0.407), respectively, Table 5-11. However, the Mann-Whitney U tests showed a significant difference between sexes for the peak knee flexion angle (p=0.008) with females showing greater peak knee flexion than males, Table 5-13.

5.3.4.2 Coronal Plane Knee Kinematics

The RM ANOVA showed no significant effect of taping for the peak knee adduction angle (p=0.389), the peak knee abduction angle (p=0.091), and the coronal plane knee ROM (p=0.699), Table 5-10. Additionally, no significant difference was seen between the sexes for the coronal plane knee ROM (p=0.541); however, there was a significant difference for sex differences on the peak knee adduction angle (p=0.044, η_p^2=0.206) and the peak knee abduction angle (p=0.032, η_p^2=0.232), Table 5-10. The pairwise comparison for sex showed that females had a significantly greater peak knee adduction angle compared to males, but females demonstrated significantly less peak knee abduction angle compared to males, Table 5-12.

5.3.4.3 Transverse Plane Knee Kinematics

The RM ANOVA showed a significant main effect of taping conditions for the peak knee internal rotation angle (p=0.009, η_p^2=0.229), Table 5-10, Row 6. The LSD post hoc tests showed a significantly greater peak knee internal rotation angle in the KTT condition compared to the NT condition (p=0.008). There was no significant difference between the KTNT and NT conditions (p=0.055), or the KTT and KTNT conditions (p=0.313), Table 5-14. Figure 5-8 showed the comparison of mean and standard deviation for peak knee internal rotation angle under the different taping conditions, and Figure 5-9 presents the knee internal rotation/external rotation angle time series graph under the three taping conditions.

Moreover, the RM ANOVA showed no significant effect of taping for the peak knee external rotation angle (p=0.096) and transverse plane knee ROM (p=0.432). In addition, there was not a significant difference between sexes for the peak knee internal rotation angle (p=0.258), the peak knee external rotation angle (p=0.061) and transverse plane knee ROM (p=0.307), Table 5-10.

Table 5-10 Mean (SD) and repeated measures ANOVA for peak knee angle and knee ROM in the sagittal, coronal, and transverse plane.

Knee Kinematics (degrees)[a]	Males (n=10)			Females (n=10)			P-value (η_p^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Minimum flexion	12.15 (3.21)	12.54 (2.48)	13.03 (3.17)	16.58 (3.14)	15.01 (4.84)	16.35 (3.45)	0.228 (0.079)	0.028* (0.242)
Sagittal plane ROM	26.53 (4.06)	26.10 (5.14)	26.18 (4.30)	28.02 (4.03)	28.97 (5.25)	29.07 (4.31)	0.583 (0.025)	0.239 (0.076)
Peak adduction	1.64 (3.13)	1.01 (2.53)	1.18 (2.80)	4.21 (3.51)	3.79 (2.54)	3.92 (3.14)	0.389 (0.051)	0.044* (0.206)
Peak abduction	-3.29 (2.70)	-4.45 (2.75)	-3.98 (2.98)	-1.33 (1.98)	-1.74 (1.93)	-1.52 (2.19)	0.091 (0.125)	0.032* (0.232)
Coronal plane ROM	4.93 (1.45)	5.47 (1.47)	5.16 (1.03)	5.54 (2.11)	5.53 (1.22)	5.54 (1.52)	0.699 (0.02)	0.541 (0.021)
Peak internal rotation†	4.58 (5.24)	6.36 (5.29)	5.94 (4.73)	1.94 (5.36)	3.53 (5.56)	3.13 (6.38)	0.009* (0.229)	0.258 (0.071)
Peak external rotation	-8.35 (5.74)	-6.78 (4.49)	-6.53 (2.85)	-11.90 (5.37)	-11.00 (5.57)	-11.46 (5.39)	0.096 (0.122)	0.061 (0.181)
Transverse plane ROM	12.93 (3.22)	13.13 (3.97)	12.46 (3.94)	13.84 (2.90)	14.54 (2.70)	14.59 (2.65)	0.432 (0.046)	0.307 (0.058)

* Significant main effect at the 0.05 level.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

[a] Positive values indicate knee flexion/adduction/internal rotation and negative values indicate knee extension/abduction/external rotation

Table 5-11 Median (Q1, Q3) and Freidman test for peak knee angle and knee ROM in the sagittal, coronal and transverse plane.

Knee Kinematics (degrees)[a]	Males (n=10)			Females (n=10)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Male	Tape effect for Female
Peak flexion	40.40 (35.25, 43.21)	39.76 (33.46, 44.42)	39.98 (35.14, 44.35)	44.46 (42.05, 47.18)	43.91 (39.70, 47.57)	45.01 (42.54, 47.85)	0.670 (0.040)	0.407 (0.090)

[a] Positive values indicate knee flexion/adduction/internal rotation and negative values indicate knee extension/abduction/external rotation.

Table 5-12 Pairwise comparison for sex differences of knee kinematics.

Knee kinematics (degrees)	Mean Difference (Female vs Male)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Minimum flexion	3.40	0.028*	0.42	6.39
Peak adduction	2.70	0.044*	0.08	5.32
Peak abduction	2.38	0.032*	0.24	4.52

* Significant difference at the 0.05 level.

Positive values indicate a greater knee adduction angle in the females when compared with the males.

Negative values indicate a greater minimum flexion knee flexion and knee abduction angle in the females when compared with the males.

Table 5-13 The Mann-Whitney U-tests results for sex differences of knee kinematics.

Knee kinematics (degrees)	Median Difference (Females vs Males)	P-value
Peak flexion	4.06	0.008*

* Significant difference at the 0.05 level.

Positive values indicate a greater knee flexion angle in the females when compared with the males.

Table 5-14 Pairwise comparisons for peak knee internal rotation angle.

Peak Knee internal rotation (degrees)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	1.69ϒ	0.008*	0.49	2.88
KTNT and NT	1.28	0.055	-0.03	2.58
KTT and KTNT	0.41	0.313	-0.42	1.24

* Significant difference at the 0.05 level.

ϒ indicates a significant difference with a small change in magnitude (≤ 2 degrees), as an error of 2 degrees or less as these are likely to be susceptible to clinical misinterpretation. Positive values indicate a greater knee internal rotation angle in the first condition when compared with the second condition.

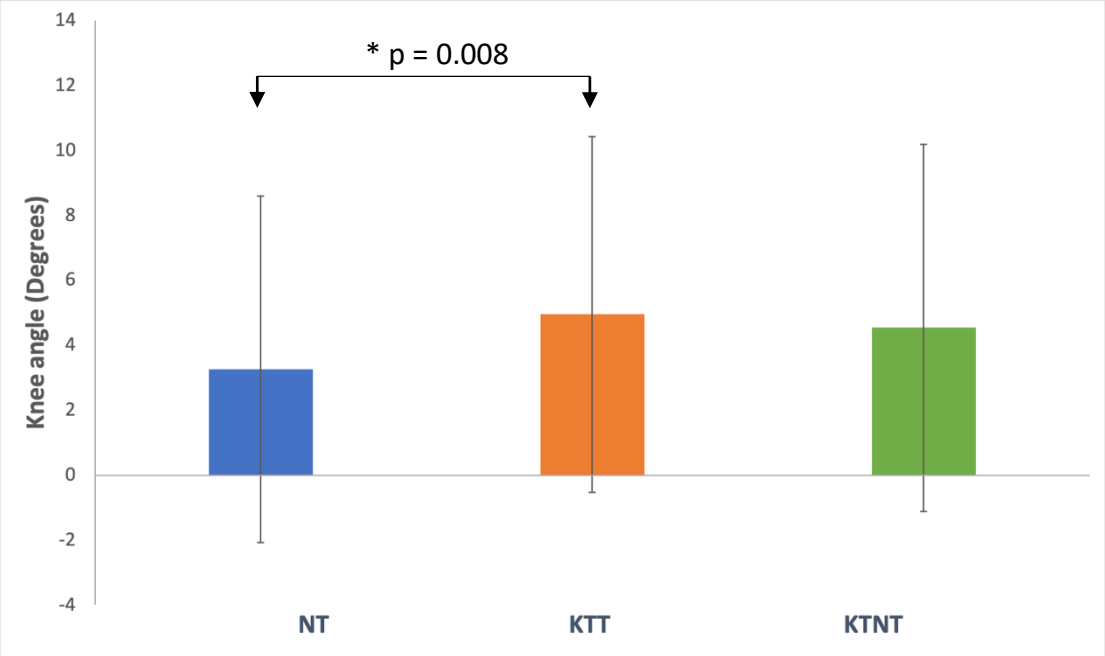


Figure 5-8 Comparison of mean (SD) for peak knee internal rotation under the three taping conditions (* represents a significant difference at the 0.05 level).

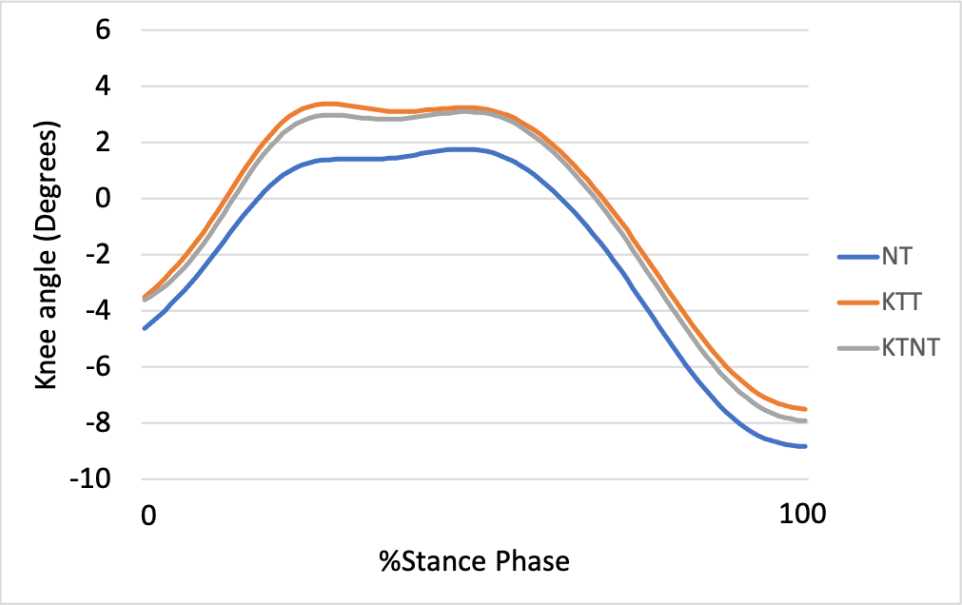


Figure 5-9 Time series graph for knee internal rotation/external rotation angle under the three taping conditions (Positive values indicate knee internal rotation and negative values indicate knee external rotation).

5.3.5 Hip Moments Data

The Shapiro-Wilk test demonstrated a normal data distribution for the majority of hip moment data except peak hip flexion and peak hip abduction moments. The descriptive statistics for peak hip moments in sagittal, coronal, and transverse planes can be seen in Table 5-15 and Table 5-16. The RM ANOVA results showed no significant interactions between sex and taping conditions for any hip moment parameters ($p>0.05$).

5.3.5.1 Sagittal Plane Hip Moments

The RM ANOVA showed no significant main effect of taping for peak hip extension moments ($p=0.321$), and there was no significant difference between sexes for peak hip extension moments ($p=0.076$), Table 5-15. The Friedman test showed no significant effect of taping for peak hip flexion moments for both males and females ($p=0.882$, $p=0.882$), respectively, Table 5-16. The Mann-Whitney U test revealed that there was no significant difference between sexes for peak hip flexion moments ($p=0.674$).

5.3.5.2 Coronal Plane Hip Moments

The RM ANOVA showed no significant main effect of taping for hip adduction moments ($p=0.228$), and there was no significant difference between sexes for hip adduction moments ($p=0.203$), Table 5-15. The Friedman test showed no significant effect of taping for peak hip abduction moments for both males and females ($p=0.325$, $p=0.197$), respectively, Table 5-16. The Mann-Whitney U test revealed no significant difference between sexes for peak hip abduction moments ($p=0.248$).

5.3.5.3 Transverse Plane Hip Moments

The RM ANOVA showed no significant main effect of taping for peak hip external rotation and internal rotation moments ($p=0.973$, $p=0.370$), respectively. In addition, no significant difference was seen between sexes for peak hip external and internal rotation moments ($p=0.746$, $p=0.246$), respectively, Table 5-15.

Table 5-15 Mean (SD) and repeated measures ANOVA for peak hip moments in the sagittal, coronal, and transverse plane.

Hip Moments (Nm/kg)[a]	Males (n=8)			Females (n=8)			P-value (η_p^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Peak extension	1.76 (0.32)	1.68 (0.32)	1.76 (0.30)	1.33 (0.54)	1.33 (0.46)	1.43 (0.45)	0.321 (0.078)	0.076 (0.208)
Peak adduction	-0.19 (0.06)	-0.17 (0.08)	-0.18 (0.07)	-0.14 (0.07)	-0.15 (0.07)	-0.12 (0.08)	0.228 (0.100)	0.203 (0.113)
Peak external rotation	0.59 (0.15)	0.60 (0.18)	0.59 (0.19)	0.56 (0.21)	0.56 (0.19)	0.56 (0.21)	0.973 (0.002)	0.746 (0.008)
Peak internal rotation	-0.11 (0.07)	-0.09 (0.05)	-0.10 (0.06)	-0.07 (0.05)	-0.06 (0.03)	-0.07 (0.07)	0.370 (0.069)	0.246 (0.095)

[a] Positive value indicate hip extension/abduction/external rotation and negative values indicate hip flexion/adduction/internal rotation.

Table 5-16 Median (Q1, Q3) and Freidman test results of peak hip moments in the sagittal, coronal, and transverse plane.

Hip Moments (Nm/kg)[a]	Males (n=8)			Females (n=8)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Male	Tape effect for Female
Peak flexion	-0.72 (-1.25, -0.63)	-0.78 (-1.25, -0.66)	-0.87 (-1.13, -0.67)	-0.72 (-0.76, -0.64)	-0.73 (-0.79, -0.63)	-0.73 (-0.78, -0.60)	0.882 (0.016)	0.882 (0.016)
Peak abduction	1.67 (1.51, 2.02)	1.55 (1.39, 2.07)	1.48 (1.34, 2.10)	1.53 (1.48, 1.66)	1.45 (1.24, 1.57)	1.50 (1.14, 1.61)	0.325 (0.141)	0.197 (0.203)

[a] Positive values indicate hip extension/abduction/external rotation and negative values indicate hip flexion/adduction/internal rotation.

5.3.6 Knee Moments Data

The Shapiro-Wilk test demonstrated a normal data distribution in almost all parameters except peak knee external rotation moments. The descriptive statistics for peak knee moments in sagittal, coronal, and transverse planes can be seen Table 5-17 and Table 5-18. The RM ANOVA results showed no significant interactions between sex and taping conditions for any knee moment parameters ($p>0.05$).

5.3.6.1 Sagittal Plane Knee Moments

The RM ANOVA showed no significant main effect of taping for peak knee extension moments ($p=0.079$) and peak knee flexion moments ($p=0.772$), Table 5-17. In addition, no significant difference was seen between sexes for peak knee extension moments ($p=0.220$) but there was a significant difference between sexes for peak knee flexion moments ($p=0.002$, $\eta_p^2=0.105$), Table 5-17. The pairwise comparison for sex showed that males had a significantly greater peak knee flexion moments compared to females, Table 5-19.

5.3.6.2 Coronal Plane Knee Moments

The RM ANOVA showed a significant difference between taping conditions for the peak knee abduction moments ($p=0.016$, $\eta_p^2=0.255$), Table 5-17, Row 3. The LSD post hoc tests showed peak knee abduction moments was significantly decreased in both KTT and KTNT conditions compared to the NT conditions ($p=0.039$, $p=0.011$), respectively. No significant difference was seen between the KTT and KTNT conditions ($p=0.657$), Table 5-20. Figure 5-10 presents the comparison of mean and standard deviation for peak knee abduction moments under the different taping conditions, and Figure 5-11 presents the knee abduction/adduction moments time series graph under the three taping conditions. Moreover, the RM ANOVA showed no significant effect of taping for the peak knee adduction moments ($p=0.518$), and there was not a significant difference between the sexes both peak knee abduction moments ($p=0.827$) and the peak knee adduction moments ($p=0.132$), Table 5-17.

5.3.6.3 Transverse Plane Knee Moments

The RM ANOVA demonstrated that no a significant main effect of taping for peak knee internal rotation moments (p=0.121), and no significant differences were seen between the sexes for peak knee internal rotation moments (p=0.620), Table 5-17.

The Friedman test showed no significant effect of taping for the peak knee external rotation moments for both males and females (p=0.607 and p=0.093), respectively, Table 5-18. The Mann-Whitney U test showed that no significant difference between the sexes for the peak knee external rotation moments (p=0.141).

Table 5-17 Mean (SD) and repeated measures ANOVA for peak knee moments in the sagittal, coronal, and transverse plane.

Knee Moments (Nm/kg)[a]	Males (n=8)			Females (n=8)			P-value (η_p^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Peak extension	2.75 (0.62)	2.87 (0.48)	2.91 (0.53)	2.56 (0.26)	2.60 (0.28)	2.57 (0.27)	0.079 (0.166)	0.220 (0.105)
Peak flexion	-0.33 (0.10)	-0.32 (0.07)	-0.32 (0.09)	-0.17 (0.09)	-0.18 (0.09)	-0.16 (0.11)	0.772 (0.018)	0.002* (0.502)
Peak abduction†,‡	0.67 (0.40)	0.58 (0.38)	0.58 (0.36)	0.61 (0.25)	0.54 (0.23)	0.57 (0.24)	0.016* (0.255)	0.827 (0.004)
Peak adduction	-0.12 (0.06)	-0.12 (0.04)	-0.12 (0.05)	-0.09 (0.04)	-0.09 (0.03)	-0.08 (0.04)	0.518 (0.037)	0.132 (0.155)
Peak internal rotation	-0.33 (0.14)	-0.31 (0.16)	-0.30 (0.14)	-0.37 (0.10)	-0.34 (0.10)	-0.33 (0.12)	0.121 (0.154)	0.620 (0.018)

* Significant main effect at the 0.05 level.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

[a] Positive values indicate knee extension/abduction/external rotation and negative values indicate knee flexion/adduction/internal rotation.

Table 5-18 Median (Q1, Q3) and Freidman test for peak knee moments in the sagittal, coronal, and transverse plane.

Knee Moments (Nm/kg)[a]	Males (n=8)			Females (n=8)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Male	Tape effect for Female
Peak external rotation	0.04 (0.02, 0.09)	0.04 (0.02, 0.09)	0.03 (0.02, 0.07)	0.02 (0.02, 0.04)	0.02 (0.02, 0.04)	0.02 (0.02, 0.03)	0.607 (0.063)	0.093 (0.297)

[a] Positive values indicate knee extension/abduction/external rotation and negative values indicate knee flexion/adduction/internal rotation.

Table 5-19 Pairwise comparison for sex differences of knee moments.

Knee Moments (Nm/kg)	Mean Difference (Females vs Males)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Peak flexion	0.16	0.002*	0.07	0.24

* Significant difference at the 0.05 level.

Negative values indicate a greater knee flexion moment in the females when compared with the males.

Table 5-20 Pairwise comparisons for peak knee abduction moments.

Peak knee abduction moments (Nm/kg)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	-0.08	0.039*	-0.15	-0.01
KTNT and NT	-0.07	0.011*	-0.12	-0.02
KTT and KTNT	-0.01	0.657	-0.06	0.04

* Significant difference at the 0.05 level.

Negative values indicate a greater knee abduction moment in the first condition when compared with the second condition.

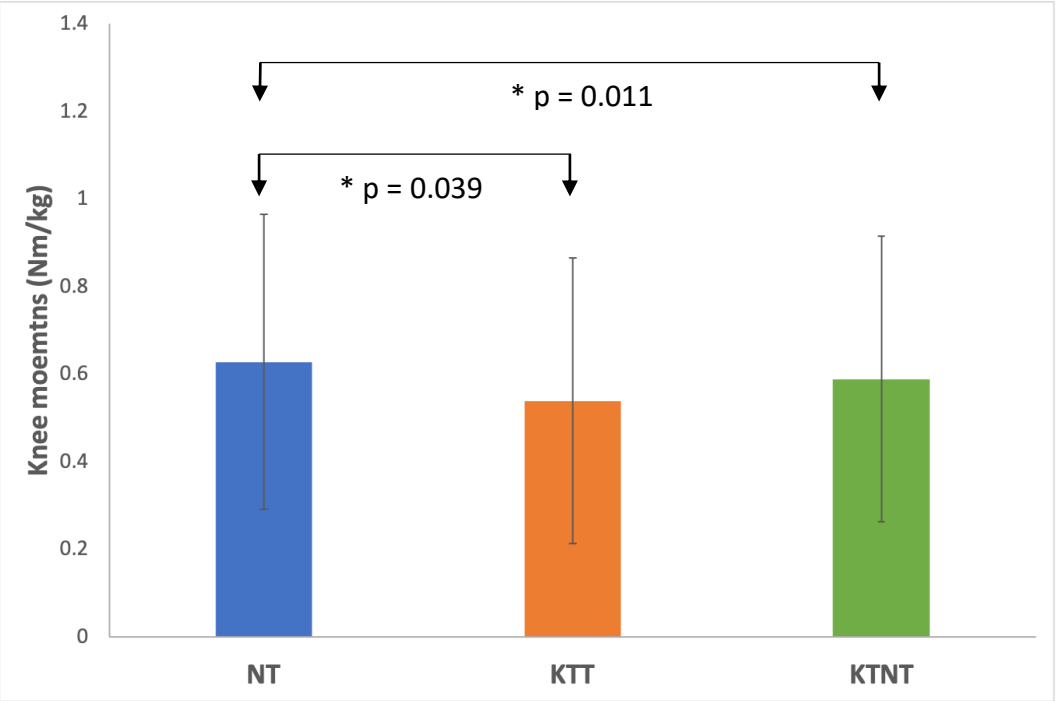


Figure 5-10 Comparison of mean (SD) for peak knee abduction moments under the three taping conditions (* represents a significant difference at the 0.05 level).

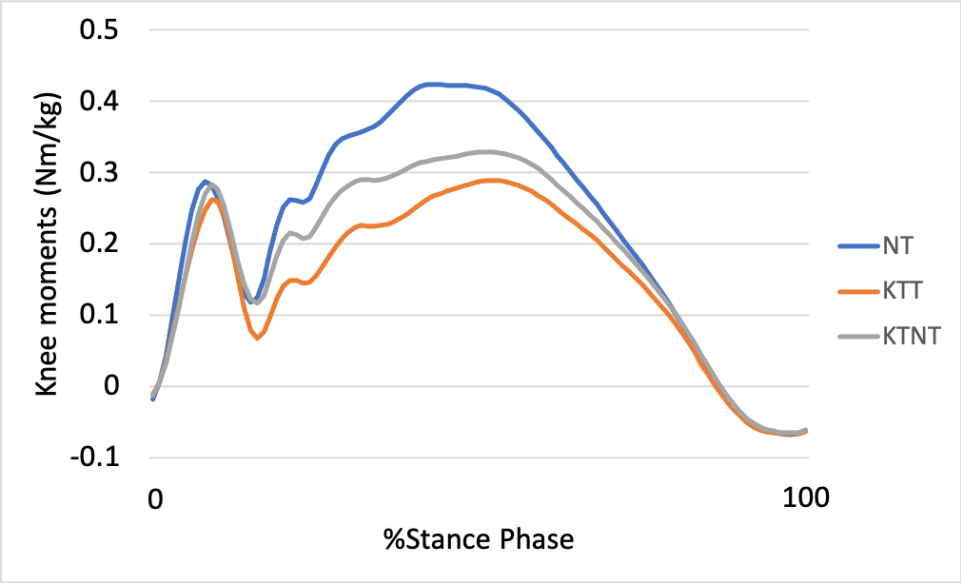


Figure 5-11 Time series graph for knee abduction/adduction moments under the three taping conditions (Positive values indicate knee abduction and negative values indicate hip adduction).

5.3.7 Average Electromyography Data

The Shapiro-Wilk test demonstrated a normal data distribution in almost all parameters except average TFL and VM EMG. The descriptive statistics for average EMG can be seen in Table 5-21 and Table 5-22. The RM ANOVA results showed no significant interactions between sex and taping conditions for the majority of parameters. There was a significant interaction between sex and taping conditions on average Gmax EMG ($p=0.001$, $\eta_p^2=0.313$). Therefore, the one-way repeated measure ANOVA with LSD post hoc test was used to further analysis the effect of taping for average EMG for Gmax in each sex separately. The RM ANOVA showed a significant effect of taping for the average Gmax EMG for females ($p=0.016$, $\eta_p^2=0.439$) but no significant effect of taping was seen for the average Gmax EMG for males ($p=0.201$), Table 5-23. The LSD post hoc tests showed average Gmax EMG for females exhibited a significantly decrease in the KTNT condition compared to the NT and KTT conditions ($p=0.010$, $p=0.001$), respectively, Table 5-24. The RM ANOVA showed no significant main effect of taping ($p=0.147$) and between sexes ($p=0.425$) for the average Gmax EMG. Figure 5-12 presents the comparison of mean and standard deviation for the average Gmax EMG for females under the different taping conditions. average Gmax EMG for females. Figure 5-13 presents the normalised Gmax EMG signals for female's time series graph under the three taping conditions.

In addition, the RM ANOVA showed a significant effect of taping for the average Gmed EMG ($p=0.010$, $\eta_p^2=0.226$), Table 5-21. The LSD post hoc tests showed average Gmed muscle activity was significantly decreased in both KTT and KTNT conditions compared to the NT conditions ($p=0.035$ and $p=0.005$), respectively. No significant difference was seen between the KTT and KTNT conditions ($p=0.603$), Table 5-25. Figure 5-14 presents the comparison of mean and standard deviation for the average Gmed EMG under the different taping conditions. Figure 5-15 presents the normalised Gmed EMG signals time series graph under the three taping conditions. However, the RM ANOVA showed that there was not a significant difference effect of taping for the average VL EMG ($p=0.326$), and no significant differences between sexes for the average Gmed EMG ($p=0.394$), and average VL EMG ($p=0.319$), Table 5-21.

The Friedman test demonstrated that there was a significant effect of taping for the average TFL EMG in males (p=0.045, W=0.310), but no significant difference for the average TFL EMG in females (p=0.273), Table 5-22. The Wilcoxon Signed Rank test for the average TFL EMG in males showed no significant difference between KTT and NT (p=0.059), KTNT and NT (p=0.059), and KTT and KTNT conditions (p=0.333), Table 5-26. Moreover, the Friedman test showed that there were not significantly difference for average VM EMG in both males and females (p=0.150, p=0.905), respectively, Table 5-22. The Mann-Whitney U test showed that there was not a significant difference between sexes for average TFL EMG (p=0.406) and the average VM EMG (p=0.290).

Table 5-21 Mean (SD) and repeated measures ANOVA for normalised values from average EMG signal analysis in each group during stance phase.

Average Normalised EMG	Males (n=10)			Females (n=10)			P-value (ηp^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Gmax [λ]	0.106 (0.031)	0.102 (0.032)	0.110 (0.030)	0.121 (0.025)	0.122 (0.023)	0.104 (0.021)	0.147 (0.101)	0.425 (0.036)
Gmed [†,‡]	0.128 (0.038)	0.116 (0.031)	0.113 (0.030)	0.115 (0.040)	0.100 (0.047)	0.099 (0.045)	0.010* (0.226)	0.394 (0.041)
VL	0.100 (0.023)	0.098 (0.024)	0.094 (0.042)	0.112 (0.032)	0.116 (0.038)	0.100 (0.027)	0.326 (0.06)	0.319 (0.055)

* Significant main effect at the 0.05 level. Normalised to 1 which represents the maximum observed signal.

† indicates a significant difference between NT and KTT.

‡ indicates a significant difference between NT and KTNT.

¥ indicates a significant difference between KTT and KTNT.

λ = significant interaction between sex and taping conditions.

Table 5-22 Median (Q1, Q3) and Friedman test for normalised values from average EMG signal analysis in each group during stance phase.

Average Normalised EMG	Males (n=10)			Females (n=10)			P-value (W)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect for Male	Tape effect for Female
TFL	0.131 (0.124, 0.138)	0.112 (0.104, 0.126)	0.113 (0.109, 0.133)	0.116 (0.096, 0.142)	0.118 (0.102, 0.147)	0.113 (0.100, 0.122)	0.045* (0.310)	0.273 (0.130)
VM	0.109 (0.082, 0.116)	0.101 (0.085, 0.114)	0.105 (0.088, 0.141)	0.116 (0.084, 0.131)	0.117 (0.101, 0.179)	0.116 (0.103, 0.186)	0.150 (0.190)	0.905 (0.010)

* Significant difference at the 0.05 level. Normalised to 1 which represents the maximum observed signal.

Table 5-23 The repeated measures ANOVA for average Gmax EMG in each sex separately.

Average Normalised EMG for Gmax	Tape effect P-value (η_p^2)
Males	0.201 (0.163)
Females	0.016* (0.439)

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

Table 5-24 Pairwise comparisons of average Gmax EMG for females.

Average Normalised Gmax EMG for females	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	0.001	0.863	-0.015	0.018
KTNT and NT	-0.018	0.010*	-0.03	-0.005
KTT and KTNT	0.019	0.001*	0.011	0.027

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

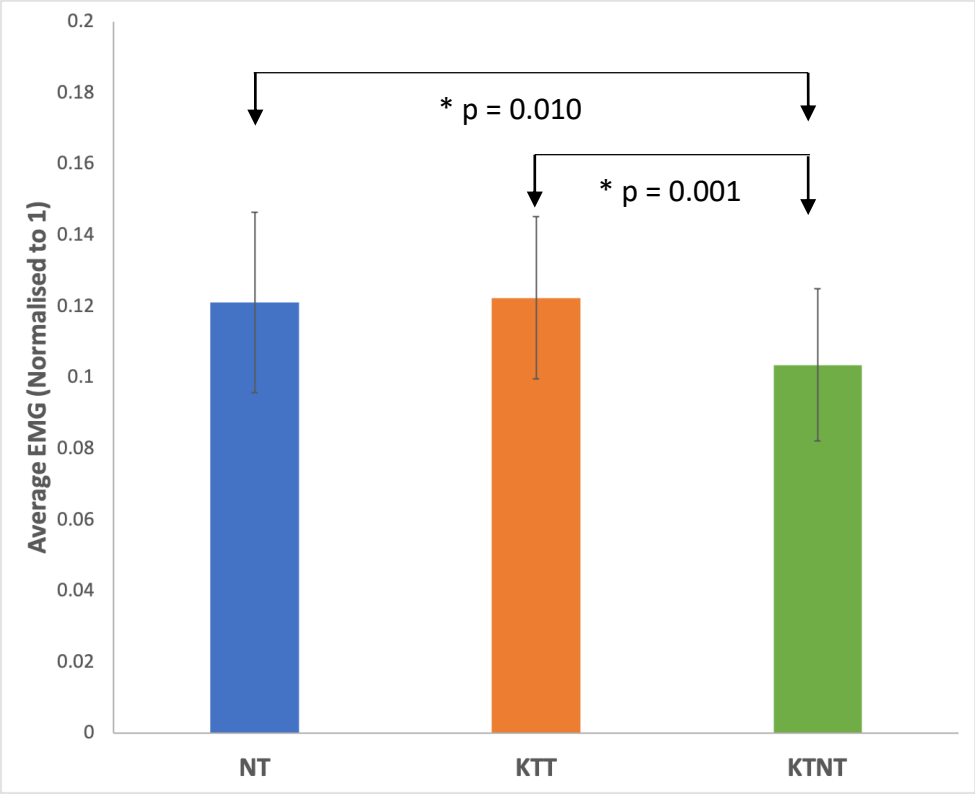


Figure 5-12 Comparison of mean (SD) for average Gmax EMG for females under the three taping conditions (* represents a significant difference at the 0.05 level, Normalised to 1 which represents the maximum observed signal).

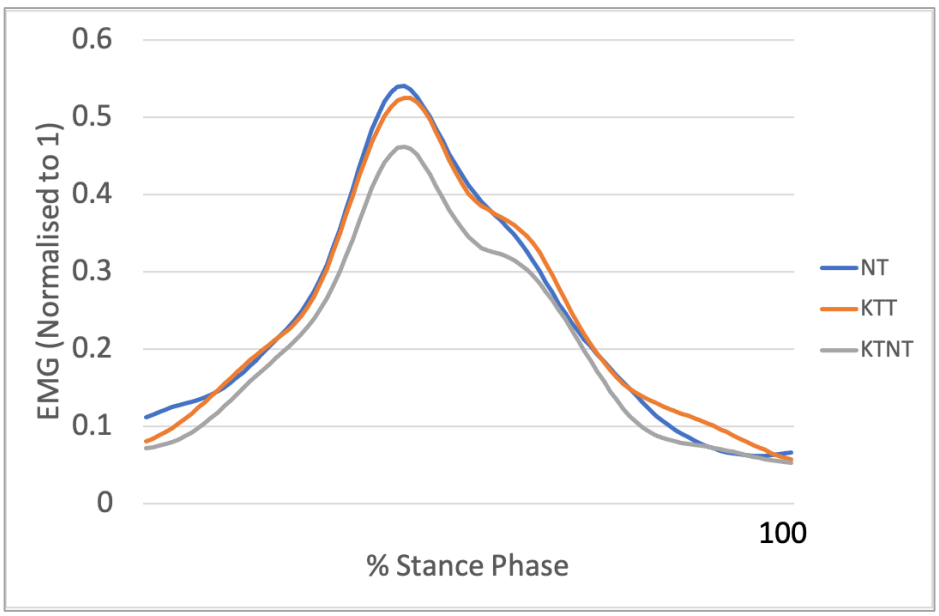


Figure 5-13 Time series graph for normalised Gmax EMG signals for females under the three taping conditions. Normalised to 1 which represents the maximum observed signal.

Table 5-25 Pairwise comparisons of average EMG for Gmed.

Average Normalised EMG for Gmed	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	-0.013	0.035*	-0.025	-0.001
KTNT and NT	-0.016	0.005*	-0.026	-0.005
KTT and KTNT	0.003	0.603	-0.008	0.013

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

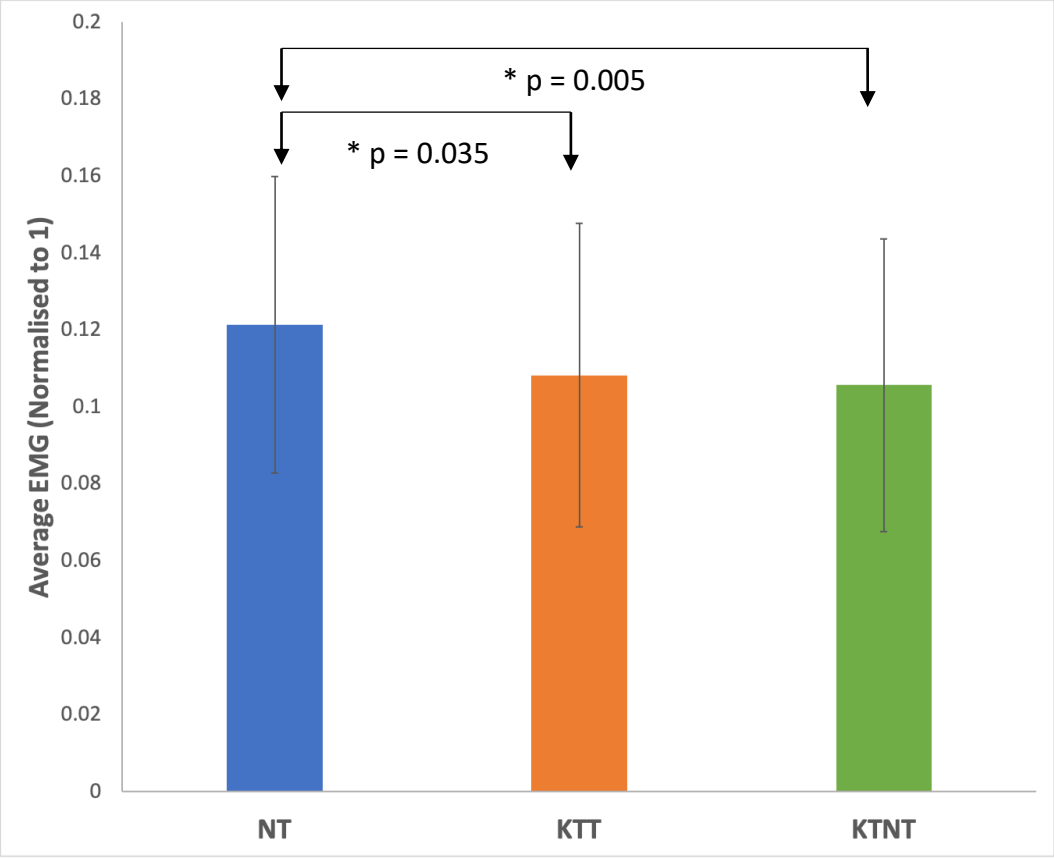


Figure 5-14 Comparison of mean (SD) for average normalised Gmed EMG under the three taping conditions (* represents a significant difference at the 0.05 level, Normalised to 1 which represents the maximum observed signal).

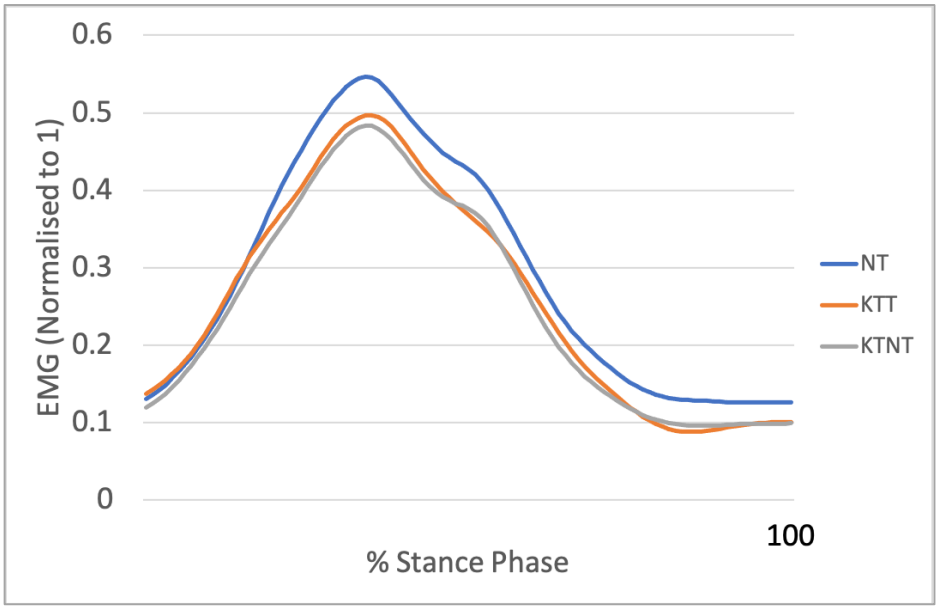


Figure 5-15 Time series graph for normalised Gmed EMG signals under the three taping conditions. Normalised to 1 which represents the maximum observed signal.

Table 5-26 Wilcoxon test for average TFL EMG for males.

Average Normalised TFL EMG for males	Median Difference	P-value
KTT and NT	-0.019	0.059
KTNT and NT	-0.018	0.059
KTT and KTNT	0	0.333

Normalised to 1 which represents the maximum observed signal.

5.3.8 Peak Electromyography Data

The Shapiro-Wilk test demonstrated all peak EMG parameters were normal data distribution. The descriptive statistics for peak EMG parameters can be seen in Table 5-27. The RM ANOVA results showed no significant interactions between sex and taping conditions for the majority of parameters. There was a significant interaction between sex and taping conditions on peak Gmax EMG ($p=0.002$, $\eta_p^2=0.299$), but showed no significant main effect of taping for peak Gmax EMG ($p=0.584$). Therefore, the one-way repeated measure ANOVA with LSD post hoc test was used to further analyse the effect of taping for peak Gmax EMG in each sex separately. The RM ANOVA showed a

significant effect of taping for the peak Gmax EMG for females (p=0.014, η_p^2=0.456) but no significant effect of taping was seen for peak Gmax EMG for males (p=0.132), Table 5-28. The LSD post hoc tests showed a significantly decreased peak Gmax EMG for females in the KTNT condition compared to the NT and KTT conditions (p=0.009, p<0.001), respectively, Table 5-29. Figure 5-16 presents the comparison of mean and standard deviation for the peak Gmax EMG for females under the different taping conditions.

The RM ANOVA showed a significant effect of taping on peak Gmed EMG (p=0.027, η_p^2=0.181), Table 5-27. The LSD post hoc tests showed a significantly decreased peak Gmed EMG in both KTT and KTNT conditions compared to the NT conditions (p=0.041 and p=0.028), respectively. No significant difference was seen between the KTT and KTNT conditions (p=0.964), Table 5-30. Figure 5-17 presents the comparison of mean and standard deviation for the peak Gmed EMG under the different taping conditions. However, the RM ANOVA showed that there was not a significant difference effect of taping for peak TFL EMG (p=0.496), VM (p=0.417), and VL (p=0.165). In addition, no significant differences between sexes for all peak EMG parameters including Gmax (p=0.909), Gmed (p=0.272), TFL (p=0.956), VM (p=0.107), and VL (p=0.796), Table 5-27.

Table 5-27 Mean (SD) and repeated measures ANOVA for normalised values from peak EMG signal analysis in each group during stance phase.

Peak Normalised EMG	Males (n=10)			Females (n=10)			P-value (η_p^2)	
	NT	KTT	KTNT	NT	KTT	KTNT	Tape effect	Sex effect
Gmax [λ]	0.554 (0.174)	0.521 (0.106)	0.618 (0.097)	0.613 (0.117)	0.601 (0.104)	0.494 (0.098)	0.584 (0.029)	0.909 (0.001)
Gmed[†,‡]	0.696 (0.102)	0.629 (0.130)	0.607 (0.132)	0.644 (0.129)	0.553 (0.151)	0.573 (0.161)	0.027* (0.181)	0.272 (0.067)
TFL	0.639 (0.130)	0.526 (0.065)	0.567 (0.149)	0.563 (0.221)	0.643 (0.149)	0.534 (0.140)	0.496 (0.034)	0.956 (<0.001)
VM	0.521 (0.086)	0.557 (0.176)	0.625 (0.108)	0.609 (0.256)	0.639 (0.108)	0.639 (0.148)	0.417 (0.044)	0.107 (0.138)
VL	0.662 (0.131)	0.603 (0.165)	0.545 (0.220)	0.640 (0.162)	0.635 (0.159)	0.576 (0.162)	0.165 (0.095)	0.796 (0.004)

* Significant main effect at the 0.05 level. Normalised to 1 which represents the maximum observed signal.

[†] indicates a significant difference between NT and KTT.

[‡] indicates a significant difference between NT and KTNT.

[¥] indicates a significant difference between KTT and KTNT.

[λ] = significant interaction between sex and taping conditions.

Table 5-28 The repeated measures ANOVA for peak Gmax EMG in each sex separately.

Peak Normalised EMG for Gmax	Tape effect p-value (η_p^2)
Males	0.132 (0.201)
Females	0.014* (0.456)

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

Table 5-29 Pairwise comparisons of peak Gmax EMG for females.

Peak Normalised Gmax EMG for females	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	-0.012	0.780	-0.108	0.084
KTNT and NT	-0.119	0.009*	-0.201	-0.038
KTT and KTNT	0.107	<0.001*	0.066	0.148

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

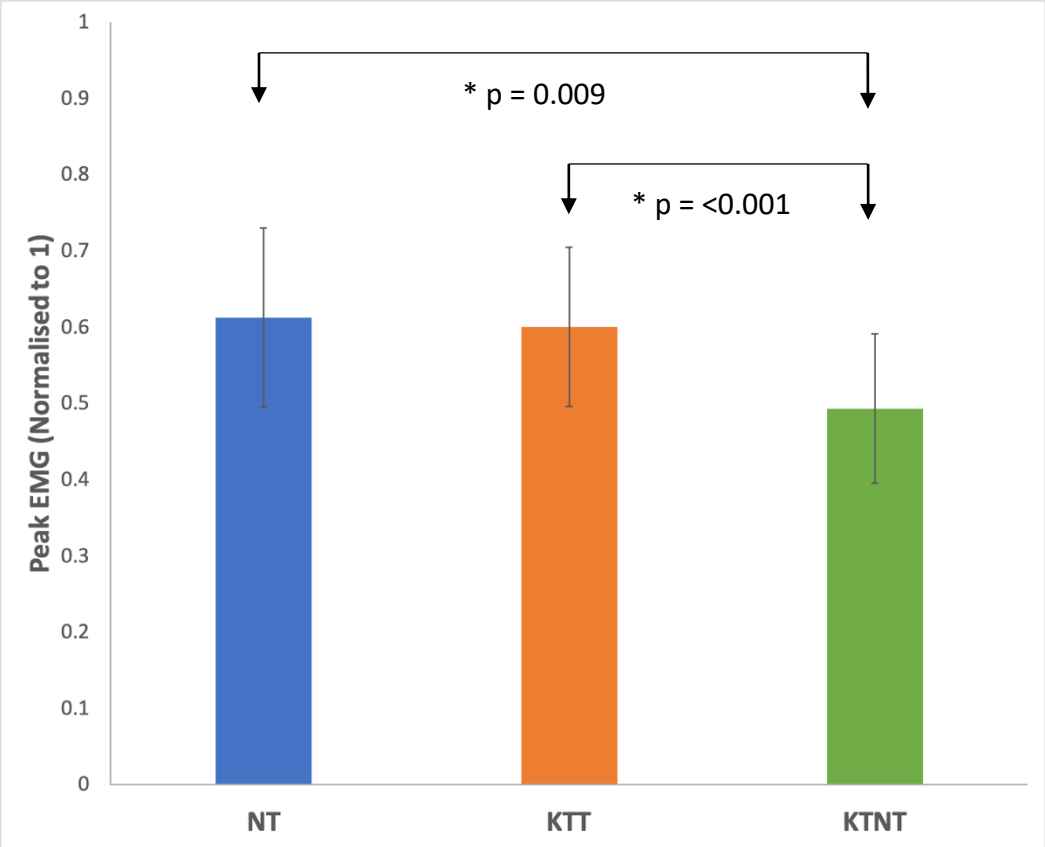


Figure 5-16 Comparison of mean (SD) for peak Gmax EMG for females under the three taping conditions (* represents a significant difference at the 0.05 level, Normalised to 1 which represents the maximum observed signal).

Table 5-30 Pairwise comparisons of peak EMG for Gmed.

Peak Normalised EMG for Gmed	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT and NT	-0.079	0.041*	-0.153	-0.004
KTNT and NT	-0.080	0.028*	-0.150	-0.010
KTT and KTNT	0.001	0.964	-0.057	0.059

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

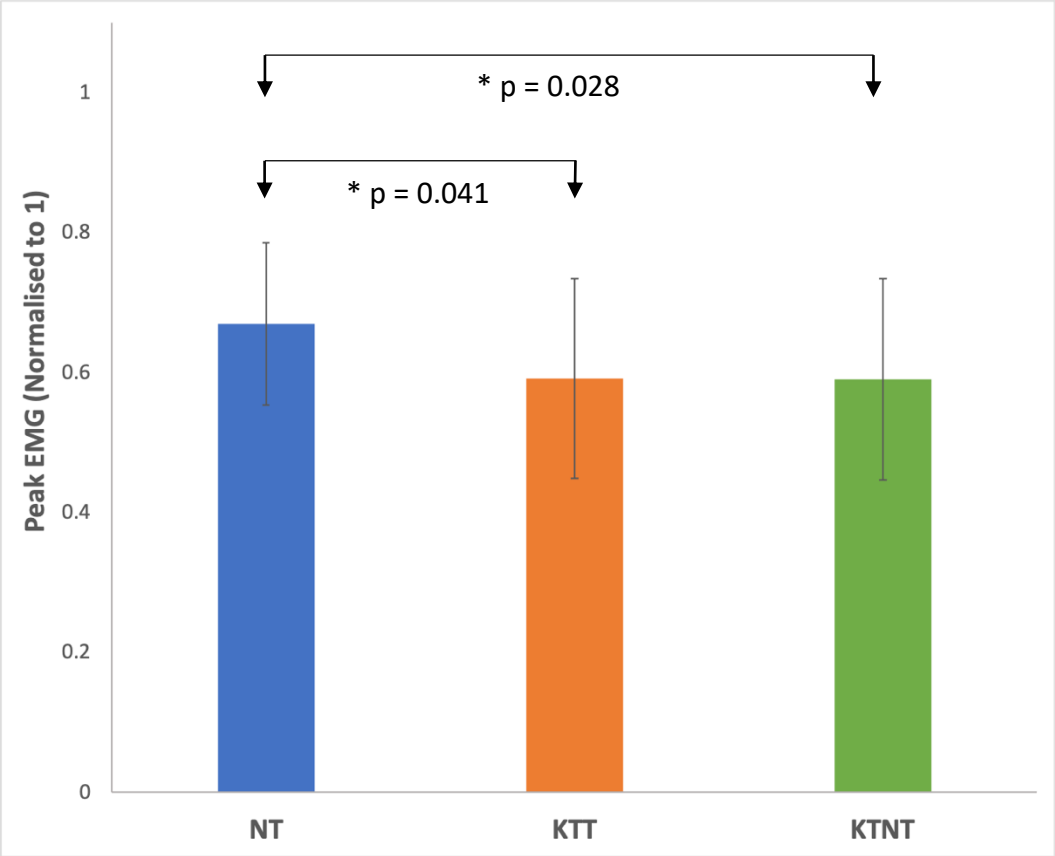


Figure 5-17 Comparison of mean (SD) for peak EMG for Gmed under the three taping conditions (* represents a significant difference at the 0.05 level, Normalised to 1 which represents the maximum observed signal).

5.3.9 Perceived comfort, stability of the knee joint, and running performance outcomes

5.3.9.1 Comfort Scores

The number of participants for each comfort score category for the KTT and KTNT conditions is shown in Figure 5-18. Seven participants indicated a clinically important change (+2 or greater) when using KTT, and six when using the KTNT, with the remainder indicating no clinically important change (between -1 and +1), with one in the KTT reporting a clinically important negative effect on comfort.

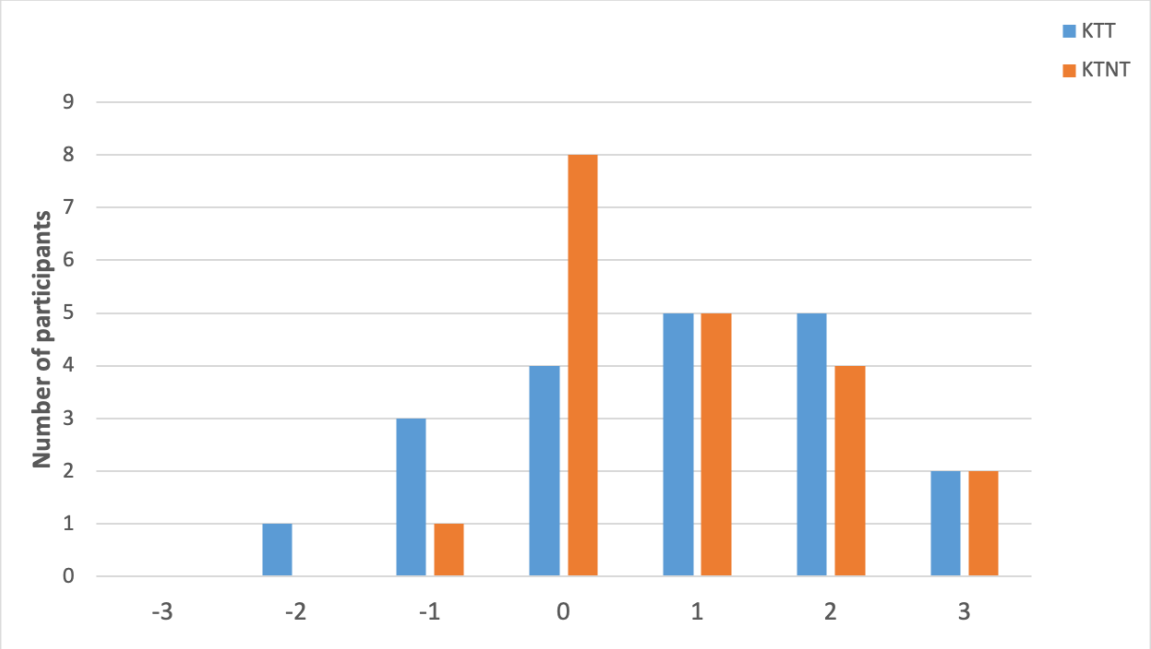


Figure 5-18 Number of participants in each comfort score category in KTT and KTNT taping conditions compared to NT condition. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree. The question asked was "Do you think this kinesio tape is comfortable compared to pre-tape?".

5.3.9.2 Stability Scores

The number of participants for each stability score category for the KTT and KTNT conditions is shown in Figure 5-19. Twelve participants indicated a clinically important change (+2 or greater) when using KTT, and nine when using the KTNT, with the remainder indicating no clinically important change (between -1 and +1).

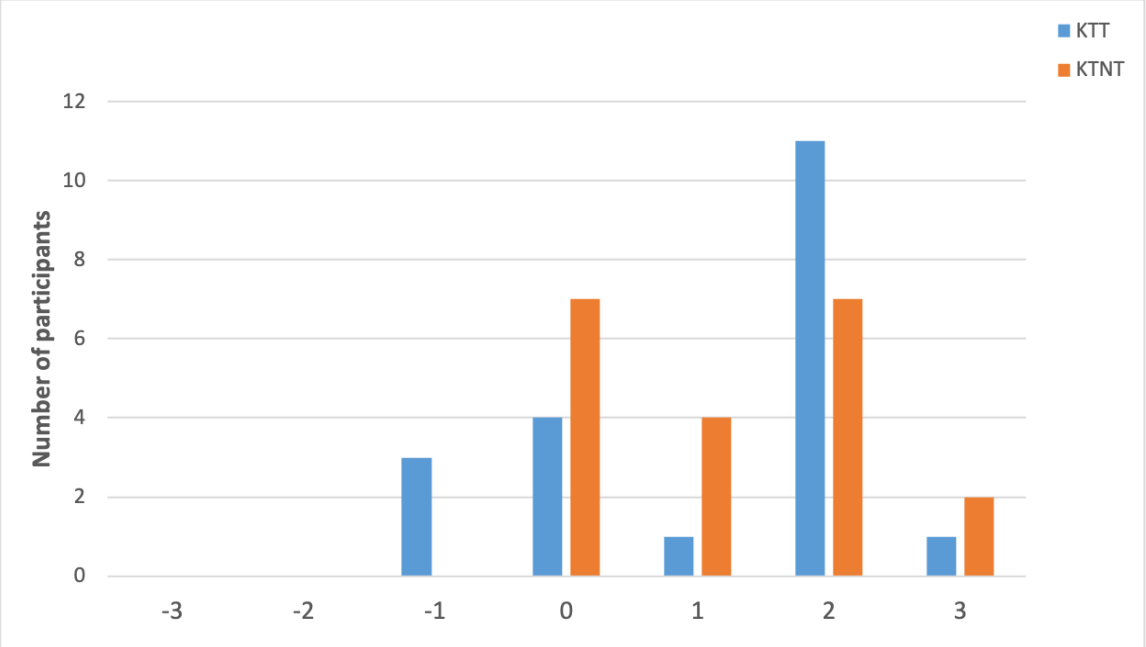


Figure 5-19 Number of participants in each stability score category in KTT and KTNT taping conditions compared to NT condition. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree. The question asked was "Do you think this kinesio tape helps the stability of your knee compared to pre-tape?"

5.3.9.3 Running Performance Scores

The number of participants for each running performance score category for the KTT and KTNT conditions is shown in Figure 5-20. Ten participants indicated a clinically important change (+2 or greater) when using KTT, and eight when using the KTNT, with the remainder in the KTNT indicating no clinically important change (between -1 and +1), with one in the KTT reporting a clinically important negative effect on running performance.

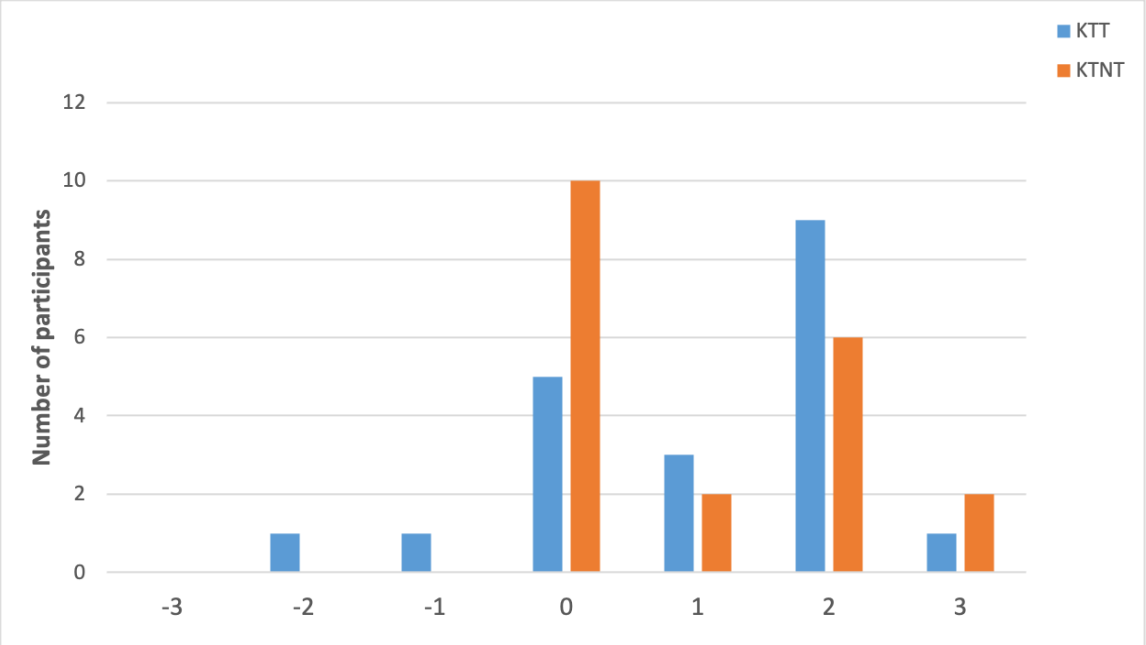


Figure 5-20 Number of participants in each running performance score category in KTT and KTNT taping conditions compared to NT condition. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree. The question asked was "Do you think this kinesio tape offers benefits to your running performance compared to pre-tape?".

5.4 Discussion

The aim of the study was to investigate the immediate effects of KT on biomechanics, muscle activity, and perceived benefits on Thai healthy participants to determine if responses were similar to the UK healthy participants. In summary, the Thai healthy study showed that KT significantly increased peak hip external rotation angle, peak hip extension angle, sagittal plane hip ROM, coronal plane hip ROM, and peak knee internal rotation angle during the stance phase of running. In addition, there was a decrease in peak hip internal rotation angle and peak knee abduction moments, and the peak hip abduction angle in the KTT condition showed a trend towards an increase compared to the NT condition. Furthermore, there was a decrease in the average and peak Gmax muscle activity, the average and peak Gmed muscle activity, and the trend toward a decrease in the average TFL muscle activity. Seven out of 20 participants indicated a positive clinically important change in comfort perception with one participant reporting negative important changes in comfort perception. No participant reported any negative important changes for knee joint stability, with one participant reporting an important negative effect on running performance after using KTT.

When comparing the response to KT within both the UK and Thai healthy studies, there was a similar response in the main outcome with an increase in peak hip external rotation angle and decrease in the average TFL muscle activity. In addition, there was a similar response with a decrease in the peak hip internal rotation angle and Gmax muscle activity, and an increase in peak hip abduction angle, Table 5-31. However, some parameters showed a different response between the UK and Thai healthy participants including peak hip flexion angle, peak hip extension angle, sagittal plane hip ROM, coronal plane hip ROM, peak knee flexion angle, peak knee internal rotation angle, peak knee flexion moments, peak knee abduction moments, and Gmed muscle activity, Table 5-31. Differences between the UK and Thai healthy participants were further explored between the UK and Thai healthy participants under the NT condition using unpaired t-tests (Appendix 13). This was to explore if these responses could in part be explained by baseline differences between the UK and Thai healthy participants. This additional analysis showed that there were four parameters (out of 16) demonstrated a difference in the NT condition between the two studies which were; peak hip extension angle,

sagittal plane hip ROM, peak knee flexion angle, peak knee internal rotation angle, Table 5-31. This may help to explain the different responses to the tape within these measures, however the remainder of the parameters were not due to baseline differences between the two studies.

Table 5-31 Comparison of the biomechanical response to all taping conditions for UK and Thai healthy participants. Significant changes are represented as solid green, red and amber represent a significant response decrease, increases or no change, trends towards significance to decrease (green hashed), and trend to increase (red hashed).

	UK Healthy			Thai Healthy		
	KTT vs NT	KTNT vs NT	KTT vs KTNT	KTT vs NT	KTNT vs NT	KTT vs KTNT
Hip Kinematics						
Peak flexion						
Peak extension						
Sagittal plane Hip ROM						
Peak abduction						
Coronal plane Hip ROM						
Peak internal rotation						
Peak external rotation						
Knee Kinematics						
Peak flexion						
Peak internal rotation						
Knee Moments						
Peak flexion						
Peak abduction						
Average muscle activities						
Gmax						
Gmed						
TFL						
Peak muscle activities						
Gmax						
Gmed						

It was interesting to note that the running speed between the two studies showed significant differences, with a median running speed in the UK healthy study of 3.87 m/s compared to 2.79 m/s for the Thai healthy study (Appendix 13). One explanation for the differences in running speed between the two studies was the length of the two laboratories. The length of the UK laboratory was 30 metres, whereas in Thailand it was 16 metres, therefore, the shorter laboratory showed slower running speeds.

Despite differences in running speed between the two healthy cohorts, both the UK and Thai healthy studies showed a similar response in the main outcomes with an increase in peak hip external rotation angle and decrease in the average TFL muscle activity. These results suggest that, regardless of the difference observed in running speed, the application of KT can still change lower limb biomechanical measures associated with ITBS. A further exploration of the effect of taping at different controlled running speeds in runners with ITBS would be interesting and could explore if there is a different response to taping at the different speeds, but this was outside of the scope of this thesis.

An interesting finding is that males demonstrated a significant increase in running speed under the KTNT when compared to the NT condition whereas there was no significant difference in the males' running speed between the KTT and KTNT, and KTT and NT conditions. The lack of an effect on running speed under the KTT condition, but an increase in the KTNT condition, may be due to a psychological effect, with a possible feeling of restriction under the KTT not producing the same effect, however there was not a corresponding feeling of discomfort. As the participants were allowed to run at their comfortable speed and this was not controlled it is possible that this is an effect of a small sample size and happened by chance. Future studies may consider controlling running speed to fully understand the effect of the interventions being investigated. However, no previous studies have reported the psychological effects of KT regarding running speed and it would be interesting to study this further, however this was outside the scope of this thesis.

5.4.1 The effect of KT on Transverse Plane Hip Kinematics and Moments

Peak hip external rotation angle in the Thai healthy participants was similar to the UK healthy participants. A greater peak hip external rotation angle was seen in Thai healthy participants in the KTT compared to the NT and the KTNT conditions, however no significant differences were seen between the KTNT and NT conditions. These results imply that the increase in peak hip external rotation angle is due to the tension applied to the KT. Furthermore, there was no significant difference in peak hip external and internal rotation moments immediately post-taping compared to pre-taping.

The present findings also demonstrated that in the Thai healthy participants, a significant decreased peak hip internal rotation angle in the KTT compared to the NT condition, although no significant difference was seen between the KTNT and NT conditions or between the KTNT and KTT conditions. In addition, this was not seen a significant decreased peak hip internal rotation angle in the KTT compared to the NT condition in the UK healthy participants, although the KTT condition showed a trend towards a decrease hip internal rotation compared to the NT condition, Table 5-31. In contrast, Song et al. (2015) and Song et al. (2017) showed no significant reduction in peak hip internal rotation angle after taping compared to the NT condition in healthy control participants. This result of peak hip internal rotation angle may be due to examining taping in healthy participants and/or due to taping techniques used, both of which warrants further investigation in runners with ITBS.

5.4.2 The effect of KT on TFL Muscle Activity

The increase in peak hip external rotation angle under KTT conditions compared to NT condition could be explained by the decrease in TFL muscle activity in the KTT condition compared to NT condition, as TFL is associated with hip internal rotation (Besomi et al., 2020). The result of average TFL muscle activity was similar between healthy cohorts, with UK healthy participants showing a decrease in TFL muscle activity between the tape conditions. However, Wilcoxon Signed Rank tests demonstrated no significant differences were seen between taping conditions. There was a trend towards a decrease in the average TFL muscle activity under the KTT condition compared to the NT condition, Table 5-31. The KT of this study may inhibit TFL muscle activity leading to an increase in hip external rotation movement (Akbaş et al., 2011), although the result showed a trend toward a decrease in TFL muscle activity that may be due to investigation in healthy participants and need to further investigation in runners with ITBS.

5.4.3 The effect of KT on Coronal Plane Hip Kinematics and Moments

There was a significant increase in peak hip abduction angle in the KTT compared to the NT condition in the UK healthy participant but the Thai healthy participants only showed a trend towards an increase in the peak hip abduction angle in the KTT condition compared to the NT condition, Table 5-31. Additionally, no significant difference was

seen in the peak hip abduction and adduction moments immediately post-taping compared to pre-taping. This finding is in accordance with Song et al. (2015, 2017), who found a non-significant reduction of peak hip adduction angle between kinesio tape and no tape condition in a healthy control participant. In addition, the result of this study was similar to Howe et al. (2015) who showed no significant difference in hip moments in the coronal plane between KT and NT during running trials.

5.4.4 The effect of KT on Gmed Muscle Activity

The Thai healthy participants demonstrated significantly decreased average and peak Gmed muscle activity in both KTT and KTNT conditions compared to the NT conditions. The UK healthy participants showed a different response with no significant effect of taping in Gmed muscle activation, which may be associated with the difference in the running speed between the two studies. This could suggest that KT may only have an effect on Gmed muscle activity at slower running speeds. This result was in contrast to Song et al. (2015) who showed no significant differences in Gmed muscle activity compared to the NT condition during a single-leg squat task. This is interesting to further explore in the runners with ITBS because runners with ITBS associated with an increase in Gmed muscle activity (Baker et al., 2018, Foch et al., 2020). Therefore, the decrease Gmed muscle activity may help to reduce pain in the runners with ITBS.

5.4.5 The effect of KT on Hip Sagittal Plane Kinematics and Moments

When considering the effect of taping on peak hip extension angle, there was a different response in peak hip extension angle between the UK and Thai healthy participants (Table 5-31). The Thai healthy participants showed a significantly greater peak hip extension angle in both KTT and KTNT conditions compared to the NT condition, and a significantly greater angle in the KTT condition compared to the KTNT condition. Further investigation of the comparisons in the NT condition between the UK and Thai healthy participants showed that the peak hip extension angle was significantly greater in the UK participants than the Thai participants by approximately 4 degrees (Appendix 13). This suggests that hip extension is greater when running faster. In addition, this would imply that when participants run slower (Thai healthy participants), the tape may have a proprioceptive effect which is diminished at faster running speeds when more hip

extension is present. This effect of running speed is supported by Fukuchi et al. (2017) who investigated the effects of running speed on lower extremity kinematics and kinetics, and showed that at a running speed of 3.5 m/s there was significantly greater peak hip extension angle when compared with running at 2.5 m/s by approximately 4 degrees. Furthermore, there was not a significant difference in the peak hip flexion angle between the UK and Thai healthy participants in the NT condition, therefore, the effect of the difference in the NT condition in the peak hip extension angle between the UK and Thai healthy studies might also have an effect on the sagittal plane hip ROM. Consequently, it was not surprising that the UK healthy participants had significantly greater sagittal plane hip ROM than the Thai healthy participants in the NT condition by approximately 4 degrees (Appendix 13). Furthermore, there was a different response in the sagittal plane hip ROM between the UK and Thai healthy participants, Table 5-31. There was a significantly greater sagittal plane hip ROM in both KTT and KTNT conditions compared to the NT condition in the Thai healthy participants, however no significant difference was seen between taping conditions for sagittal plane hip ROM in the UK healthy participants. In addition, no significant difference was observed in the peak hip extension and flexion moments or peak hip flexion angle immediately post-taping compared to pre-taping in Thai healthy participants that is similar to a previous study by Howe et al. (2015) which showed no significant differences in peak hip flexion or peak hip moments between KT and NT conditions during running trials. Nevertheless, this needs to further investigation in runners with ITBS.

5.4.6 The effect of KT on Gmax Muscle Activity

The Gmax muscle activity showed the same response of taping in both the UK and Thai healthy participants, Table 5-31. Both showed a significant decrease in the average and peak Gmax muscle activity in the KTNT compared to both the NT and KTT conditions, but no significant differences were seen between KTT and NT conditions. The results were in contrast to Song et al. (2015) who found no significant differences in Gmax muscle activity when using femoral rotational KT. The decreasing Gmax muscle activity may help runners with ITBS because Baker et al., (2018) reported Gmax muscle activity was more active in the runners with ITBS compared to healthy control runners (Baker et

al., 2018). Therefore, future studies examining the effect of KT on runners with ITBS, should consider Gmax muscle activity in association with a change in pain.

5.4.7 The effect of KT on Knee Kinematics and Moments

When considering the effect of taping on peak knee flexion angle, there was a different response in peak knee flexion angle between the UK and Thai healthy participants (Table 5-31), which only showed there was a significantly greater knee flexion in the KTNT condition compared to the NT condition in the UK healthy participants, Table 5-31. This result contrasts with previous studies that showed no significant difference in the peak knee flexion angle after KTT or KTNT, this may due to the different taping techniques used (Song et al., 2015, Song et al., 2017). Further investigation of the comparisons in the NT condition between the UK and Thai healthy participants showed that the peak knee flexion angle was significantly greater in the Thai participants than the UK participants by approximately 3.4 degrees (Appendix 13). This is in contrast to the previous studied that showed a greater peak knee flexion angle at faster running speeds when compared with slower running speeds (Orendurff et al., 2018).

The Thai healthy participants presented a significant increase in peak knee internal rotation angle in the KTT condition compared to the NT condition. This result was similar to Masters et al. (2018) who showed that hip taping increases knee internal rotation compared to no tape. This result is in contrast to the hypothesis that the peak knee internal rotation angle would significantly decrease under KTT condition. However, the UK healthy participants showed no significant effect of taping on peak knee internal rotation angle. Further comparisons in the NT condition between the UK and Thai healthy participants showed that peak knee internal rotation angle was significantly greater in the UK participants than the Thai participants by 7.36 degrees (Appendix 13), which is likely to be associated with running speed. Previous studied supported that there was a greater peak knee internal rotation angle at faster running speeds when compared with slower running speeds (Fukuchi et al., 2017). A slower running speed might have an effect on peak knee internal rotation and the ability of the tape to have a meaningful effect which is not seen at the faster running speeds (UK healthy participants).

For the peak knee abduction moments, there was no significant effect of taping in the UK healthy participants, but Thai healthy participants showed that the KTT condition significantly decreased peak knee abduction moments compared to both the NT and KTNT conditions. This suggests that the decrease in knee abduction moments is due to the tension applied to the KT. The knee abduction moments is primarily resisted by the lateral soft tissue restraints of the knee, namely the lateral collateral ligament and the ITB (Powers, 2010). Therefore, it maybe plausible to suggest that a decrease in the knee abduction moments would also decrease ITB strain, as this structure plays an important role in resisting knee abduction moments (Hutchinson et al., 2022). However, this effect was only present in the Thai healthy participants and there was no significant difference in the NT condition between the UK and Thai healthy participants. This again maybe due to the slower running speeds in the Thai healthy participants, but could also be due to associations between knee abduction moments and foot posture (Powell et al., 2016), footwear or wedged footwear (Lewinson et al., 2013), or step width (Brindle et al., 2014) which can also influence the lower limb kinematics and moments, but these were outside the scope of this current work.

5.4.8 Sex differences in Running Biomechanics

The female Thai healthy participants showed a significantly greater peak hip flexion angle, peak hip internal rotation angle, peak knee adduction angle, and peak knee flexion angle, whilst Thai males demonstrated a significantly greater peak hip abduction angle, peak hip external rotation angle, minimum knee flexion angle, peak knee abduction angle, and peak knee flexion moment. Although there was a difference in running speed between the UK and Thai healthy participants, both the UK and Thai healthy studies showed the same response, a greater peak hip internal rotation angle and a trend towards an increase in peak hip adduction angle in the female runners compared to males. The results of the present study support previous findings and suggest that male and female movement patterns may be classifiable (Ferber et al., 2003, Nigg et al., 2012), and suggests that females may be a higher risk for ITBS than males (Taunton et al., 2002b).

5.4.9 Perception of Comfort, Joint Stability, and Running Performance

The result of the perception questionnaires in Thai healthy participants showed a similar response to the UK healthy participants, 35% of the total participants (seven out of 20 participants) indicated a clinically important change when using KTT, and six participants when using the KTNT, with one in the KTT reporting a clinically important negative effect on comfort. For perception of stability of the knee joint, 60% (12 out of 20 participants) indicated a clinically important change and nine participants when using the KTNT. There was no participant reported any negative changes in perception of stability of the knee joint in the KTT and KTNT conditions. For perception of benefit to running performance, 50% of the total participants (10 out of 20 participants) indicated a clinically important change when using KTT, and eight participants when using the KTNT, with one in the KTT reporting a clinically important negative effect on perception of benefit to running performance. This suggests that this KT technique used in this study can change lower limb biomechanics with a favorable perception on knee stability, comfort and running performancewhich may be useful in the management of individuals with running related injuries.

CHAPTER 6 THE EFFECTS OF KINESIO TAPING ON RUNNING BIOMECHANICS, MUSCLE ACTIVITY, AND CLINICAL OUTCOME MEASURES IN RUNNERS WITH ILIOTIBIAL BAND SYNDROME: A RANDOMISED CONTROLLED TRIAL

6.1 Introduction

The previous two studies in this thesis were conducted on healthy individuals and showed that kinesio tape can alter key biomechanical measures that have been associated with symptomatic of runners with ITBS. In addition, healthy participants reported KT was comfortable, improved knee joint stability and improved running performance. However, to the author's knowledge, no research has examined the effect of KT in participants with ITBS on running biomechanics and clinical outcomes. Therefore, the aim of the present study was to conduct a randomised controlled trial (RCT) to investigate the immediate effects of KTT compared to KTNT in runners with ITBS on lower limb kinematics, joint moments, muscle activity during running and short-term effects on clinical outcome measures. It was hypothesised based on abnormal running biomechanics of runners with ITBS that the KTT would increase peak hip external rotation, decrease peak hip adduction and internal rotation, decrease peak knee internal rotation, decrease TFL muscle activity, and show improvements in clinical outcome measures.

6.2 Methods

6.2.1 Participants

All participants were Thai nationals and were recruited from running clubs and a staff and student population at Mahidol University, Thailand. Potential participants with ITBS were screened using the following criteria; aged between 18 to 45 years old, regularly run a minimum of 10 km a week, current symptoms of ITBS, positive the Noble compression and Ober's test, reported numeric pain rating scale (NPRS) of at least 3 out of 10 at lateral femoral condyle during running, no physical limitations which may interfere with the testing protocol such as fatigue, illness or dizziness. Exclusion criteria were; history of taking any analgesic or anti-inflammatory drugs for 72 hours prior to

testing or previous surgery to the lower limbs, and skin allergy to KT. Signs or symptoms of other knee pathologies including; patellofemoral pain, knee joint osteoarthritis, lateral meniscus injury, common peroneal nerve injury, referred pain from lumbar spine, superior tibiofibular joint sprain, popliteus or bicep femoris tendinitis, and a reported pain of at least 8 out of 10 on NPRS during running.

This study was approved by the ethics committees of the University of Central Lancashire (STEMH 966) (see Appendix 6) and the Mahidol University Central Institutional Review Board (MU-CIRB) (COA No.MU-CIRB 2019/224.1912) (see Appendix 12). Before starting testing, a Thai ITBS participant information sheet was given to each participant, which provided study information and what was expected of the participant (see Appendix 14). Each participant completed a PAR-Q+ screening questionnaire to determine the safety or possible risks associated with inclusion (Appendix 9). Individuals with ITBS were evaluated by a researcher who was a licensed physical therapist to determine eligibility and those participants that that met the inclusion and exclusion criteria were recruited. This study collected data on only the symptomatic limb (hereafter referred to as the study limb). All participants provided written informed consent prior to testing (Appendix 15). All testing procedures were conducted in the movement analysis laboratory, Faculty of Physical Therapy, Mahidol University, Salaya Campus, Nakhon Prathom Thailand.

6.2.2 Study design

This study was a two-arm parallel group RCT registered on clinicaltrials.gov database (NCT04164316). Upon recruitment, Thai ITBS participants were randomised on a 1:1 basis using http://www.randomization.com to receive either the Kinesio Taping with tension (KTT group) or the Kinesio Taping with no tension (KTNT group). Participants were assigned an ID number to allow anonymisation of the data. The KT interventions in this study used the same protocol, as described in Chapter 3, section 3.4.2.2 and 3.4.2.3, to apply the allocated taping intervention to the participants in each randomised group.

6.2.3 Sample Size Calculation

As there is no published data examining the effect of KT on ITBS running biomechanics, the sample size of this study was calculated from a total of 10 participants in the pilot study who were divided with 5 participants in each taping group (KTT and KTNT). The primary outcome used was peak hip external rotation angle values (KTT=-8.43±3.58 degrees, KTNT=-4.60±4.76 degrees) and NPRS was used as a secondary outcome (KTT=1.20±1.64, KTNT=3.00±2.24). 19 participants were required in each group but allowing for 10% drop out an additional two participants were added to each group. Therefore, a total of 21 participants were required in each group.

6.2.4 Procedures

At the initial visit, participants' demographic information was collected, including; age, gender, weight, height, study limb, average running distance per week, medical history, and symptoms. Participants then underwent a pre-tape running biomechanical test, clinical assessments, and completed clinical outcome measures questionnaires. Subsequently, participants received their allocated taping intervention which was applied by a researcher after which participants repeated the running biomechanical test, clinical assessments, and completed clinical outcome measures questionnaires (immediate post-tape). Participants were then instructed to wear their allocated taping intervention whilst being instructed to carry out their normal activities of daily living and run the same mileage prior to participating in the study. On day 4 of taping, the taping intervention was replaced and participants completed the clinical outcome measures questionnaires. On day 7 of taping, participants completed the clinical outcome measures questionnaires over the telephone before they exited the study. The study procedure for the ITBS participants is shown in Figure 6-1.

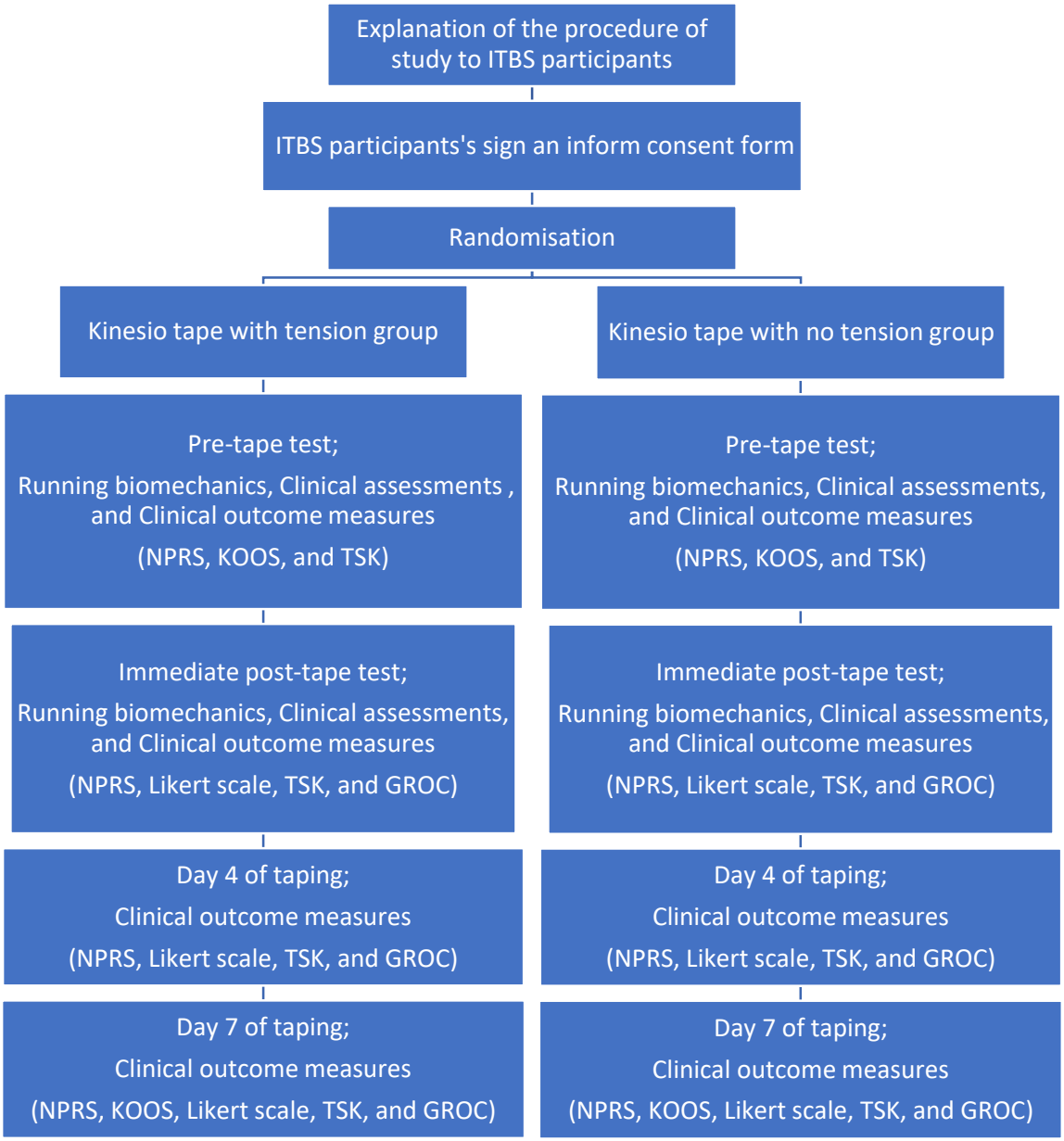


Figure 6-1 Study procedure for ITBS participants.

6.2.5 Biomechanical running assessment

The running assessment in this study used the same protocol as described in section 3.4.2. Participant wore their normal sports t-shirt, sports shorts, and running shoes during the data collection session at initial visit. The sEMG sensors placement and markers set and placement were performed on the study limb before starting running biomechanics test as described in section 3.4.2.1.1 and 3.4.2.1.2.

6.2.6 Clinical Outcome Measures.

6.2.6.1 Numerical Pain Rating scale (NPRS)

The NPRS is one of the most commonly used pain scales in medicine and research (Hjermstad et al., 2011). This study used an 11-point scale from zero to ten, with zero being no pain and ten being the worst pain possible, (Appendix 16). The scale was set up on a horizontal line, and participants were asked to rate their pain intensity during running and a 2-point change on the NPRS represents a Minimal Clinical Important Change (MCIC) for and Minimal Clinical Important Difference (MCID) (Farrar et al., 2001, Michener et al., 2011, Childs et al., 2005). Participants were assessed over a one-week period at the pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping.

6.2.6.2 Knee Injury and Osteoarthritis Outcome Score (KOOS)

The Knee Injury and Osteoarthritis Outcome Score (KOOS) is a popular questionnaire used for research purposes in clinical trials (Roos and Lohmander, 2003). This study used the Thai version of KOOS which has been shown to have high reliability (Chaipinyo and Karoonsupcharoen, 2009) (Appendix 17). Participants were assessed over a one-week period at the pre-tape and day 7 of taping.

The KOOS consists of five subscale scores with 42 items in total, covering the domains of pain (nine items), symptoms (seven items), activities of daily living (ADL) (17 items), function in Sport and Recreation (five items), and knee-related quality of life (four items). Standardized answer options are given (5 Likert boxes) with each question was assigned a score from 0 to 4. A total normalised score of 100 is calculated, with a score of 100 indicating no symptoms and 0 indicating extreme symptoms, with the score for each subscale also being calculated. The MCIC and MCID of KOOS in this study used 10 points for clinically meaningful change (Roos and Lohmander, 2003).

6.2.6.3 Tampa Scale for Kinesiophobia (TSK)

The Tampa Scale for Kinesiophobia (TSK) was used to assess the subjective rating of kinesiophobia or fear of movement. This study used the Thai version of TSK which has been shown to have a good internal consistency ($\alpha = 0.90$) and high test-retest reliability

(ICC = 0.934) (Areeudomwong and Buttagat, 2017). Participants were assessed at the pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping.

The TSK is a 17-item self-rated questionnaire using a 4-point Likert scale regarding specific situations, performance, the fear of reinjury and activity avoidance (Appendix 18). The four points are defined as; 1 (strongly disagree), 2 (somewhat disagree), 3 (somewhat agree), and 4 (strongly agree). The scores on items 4, 8, 12, and 16 are reversed. TSK scores can range from 17 to 68, , where scores of 17 indicate no kinesiophobia and scores of 68 indicate extreme kinesiophobia (Pool et al., 2009). A score of 37 or over is considered a high score, indicating a high degree of kinesiophobia, while scores below 37 are considered as low scores (Vlaeyen et al., 1995a). The MCIC and MCID of TSK have been reported to be 0.8 and 1.3, respectively (Huang et al., 2019) and therefore a score of 1 and 2 was chosen to demonstrate a MCIC and MCID, respectively.

6.2.6.4 Global Rating Of Change Scale (GROC)

Global Rating of Change (GROC) scales provide a measure of self-perceived change in health status over time (Jaeschke et al., 1989). Participants were assessed at immediate post-tape, day 4 of taping, and day 7 of taping. This study used a 15-point GROC score, with the middle '0' score corresponding to 'no change', with negative values representing magnitudes of deterioration, with −7 indicating a very great deal worse, and positive values indicating an improvement with +7 indicating a very great deal better (Appendix 19). This study defined a MCIC and MCID as ±5, which was based on a clinical observation that patients with lower scores continue to seek treatment (Stratford et al., 1994).

6.2.6.5 Perceived comfort, stability of the knee joint, and running performance outcomes

This study used a seven-point Likert scale, as described in section 3.4.4 to assess participants' perceived comfort, stability of the knee joint, and running performance under their allocated taping condition (Appendix 11). These measures were assessed immediate post-tape, day 4 of taping, and day 7 of taping. A 2 point change compared

to pre-tape in perceived scores was chosen to determine a MCIC and MCID for this thesis (Kamper et al., 2009).

6.2.7 Clinical Assessments

6.2.7.1 Muscle strength test

The hip abductor and external rotator strength testing were performed on the initial visit at pre-tape and immediate post-tape by using the Lafayette Hand-Held Dynamometer (HHD) (model 01165, Lafayette Instrument Company) (Figure 6-2). It is an ergonomic hand-held device for objectively quantifying muscle strength, and has been reported to provide accurate, objective and reliable measurements (Mentiplay et al., 2015). This HHD registers 0.0 to 136.1 kg with a precision of 0.1 kg. The HHD was used to measure each participant's study limb, which has previously been reported as a reliable procedure (Cahalan et al., 1989, Ireland et al., 2003, Jaramillo et al., 1994, Noehren et al., 2014).

Figure 6-2 Lafayette Hand-Held Dynamometer.

For hip abduction isometric strength testing, the participants were positioned in side-lying on their non-involved side on a testing bed and the pillow was used to support the study limb. The HHD was placed and secured 5 cm proximal to the tibiofemoral joint line with a stabilization strap around the dynamometer and the testing bed, and a second

stabilization strap were positioned around the pelvis to prevent compensatory movements (Figure 6-3). Participants were asked to avoid any hip internal rotation or hip flexion or any hip hiking through use of the quadratus lumborum during the testing. The hip external rotation isometric strength test was subsequently measured in a seated position, with the hip and knees flexed to 90 degrees, and the dynamometer placed on the inside of the study limb 5 cm superior to the ankle joint and held in place with a stabilization strap. A second stabilization strap was positioned around the mid-thigh to prevent compensatory movements (Figure 6-4). Participants were asked to avoid any hip flexion or hip adduction during the testing.

For both strength tests, two practice trials were performed before testing commenced to ensure each participant understood the instructions, followed by three testing trials with a one-minute rest between each trial. Participants were instructed to gradually increase how much they pushed over three seconds and then to hold their maximum effort for the next two seconds. The tester used the following standard verbal cues while measuring muscle strength, “push against the HHD as hard as possible slowly and smoothly. One, two, three, go”

For each participant, the maximum isometric raw force values were multiplied by the participant’s femur length to calculate a joint moment value, which was then normalised by the participant’s mass to account for body size, and then multiplied by 100. Femur length was measured as the distance from the greater trochanter to the medial tibiofemoral joint line. The peak isometric hip abductor and external rotator moments were then averaged for the three testing trials (Noehren et al., 2014).

Figure 6-3 Hip abduction strength test a) posterior view, b) superior view.

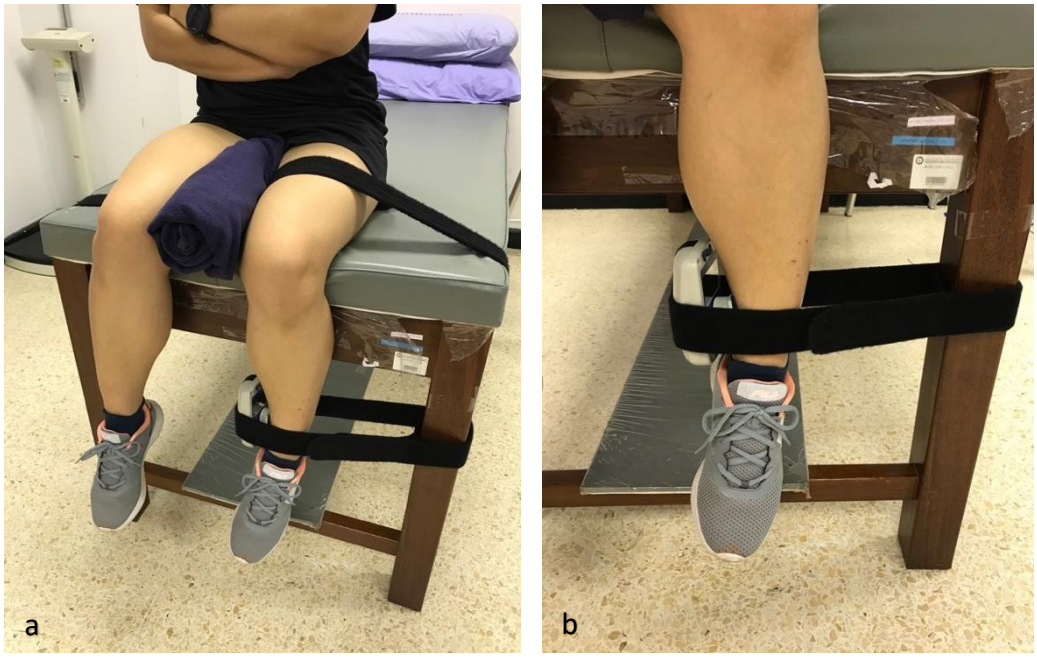


Figure 6-4 Hip external rotation strength test a) oblique view, b) anterior view.

6.2.7.2 Assessment of the length of tensor fascia latae (TFL) and Iliotibial Band (ITB)

Measurements of the length of the TFL and ITB were examined on the initial visit at pre-tape and immediate post-tape by using the modified Ober's test with a digital inclinometer (Baseline® Digital Inclinometer, model 12-1057; Fabrication Enterprises, Inc, White Plains, NY, accuracy of 0.1 degrees) (Figure 6-5), using previously established procedures (Noehren et al., 2014, Piva et al., 2005, Reese and Bandy, 2003). The participants were placed in a side-lying position with their non-involved side on a testing bed and the pelvis perpendicular to the table, and the examiner standing posteriorly. The participant's pelvis was blocked by the examiner's body and the pelvis was stabilized with the examiner's free hand. While maintaining the knee extension position, the participants' study limb was then moved into hip extension and abduction. Next, the examiner asked the participants to relax all muscles of the lower extremity whilst slowly lowering their study limb into hip adduction direction until the motion was restricted. Hip inclination was measured at the point at which lateral tilting of the pelvis was palpated and/or when the hip adduction movement stopped. The examiner had to make sure that the hip did not internally rotate and flex and the pelvis remained stabilized during the test. The examiner press hold button on a digital inclinometer that was placed 5 cm from the distal lateral femoral epicondyle, giving a measure in degrees from the horizontal (Figure 6-6). If the lower limb was horizontal this was reflected by a measurement of 0 degrees on a digital inclinometer, if below the horizontal (adducted), it was reported as a positive number; and if above the horizontal (abducted), it was reported as a negative number. The angles indicated by the digital inclinometer during the modified Ober's test were averaged over three trials and served as a measure of the length of the TFL and ITB.

Figure 6-5 Baseline® Digital Inclinometer.

Figure 6-6 Participant position and digital inclinometer positioning for assessment of the length of the TFL and ITB.

6.2.8 Data Processing

The processing of kinematic, kinetic and EMG data has previously been described in section 3.5.

6.2.9 Data analysis

Shapiro-Wilk tests were used to determine the distribution of the data, and all analyses used an alpha level of 0.05. For normally distributed joint kinematics, joint moments, average EMG, peak EMG, muscle strength, muscle length data, and running speed data, unpaired t-tests were used to test the pre-tape differences as baseline between the two groups. Mixed Methods ANOVA tests were used to explore the immediate post-tape effects, and differences between the two groups and sexes. Any significant interactions between group and pre-immediate post-tape were further explored with paired t-tests to determine any differences between time points within the two groups separately. Any significant interactions between sex and pre-immediate post-tape were also explored with paired t-test to determine any differences between time points within the two sexes separately. For the non-normally distributed data, Mann-Whitney U tests were used to explore the differences between sexes, and Wilcoxon Signed Rank tests

were performed to determine any differences between pre- and immediate post-tape within the two groups and two sexes separately, and Mann-Whitney U tests were used to explore for differences between pre- and immediate post-tape, between the two groups separately.

For normally distributed clinical data the effects of taping were explored across the pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping for the two groups using Mixed Methods ANOVA tests. If significant main effects between time points were seen, post hoc Least Significant Difference (LSD) tests were used within the two groups separately. Any significant interactions between group and time were further explored with Repeated Measures Analysis of Variance (RM ANOVA) to consider the effect of time within each group separately. Any significant interactions between sex and time were explored with a RM ANOVA to determine the effect of time in the two sexes separately, and any significant main effects were further explored using post hoc LSD tests. The KOOS was taken at pre-tape and day 7 of taping, therefore the differences between the two groups, across the two time points, and between the two sexes were analysed using the same methods as the biomechanical data. For non-normally distributed data, Friedman tests were used to test for the differences within the two groups and sexes separately. Significant effects identified by the Friedman test were further explored with Wilcoxon Signed Rank tests to determine any differences between time points within the two groups or two sexes separately.

Between group differences for participant characteristics were explored using unpaired t-tests. Effect sizes of Mixed Methods ANOVA were reported using partial Eta^2 (η_p^2). Effect sizes were contextualized using the following guidelines; small. 0.01, medium. 0.06 and large. 0.14 (Cohen, 1988). In addition, mean differences and 95% confidence intervals were reported. Whereas the effect sizes of Friedman tests using Kendall's W (W) that were contextualized using the following guidelines; small. 0.1, medium. 0.3 and large. 0.5 (Cohen, 1988).

6.3 Results

6.3.1 Recruitment

Initially, 42 Thai participants with ITBS were assessed for eligibility, of which two participants were excluded as they did not meet the inclusion criteria. Therefore, 40 participants were included in the RCT, 20 in each group and all 40 participants completed the study, Figure 6-7.

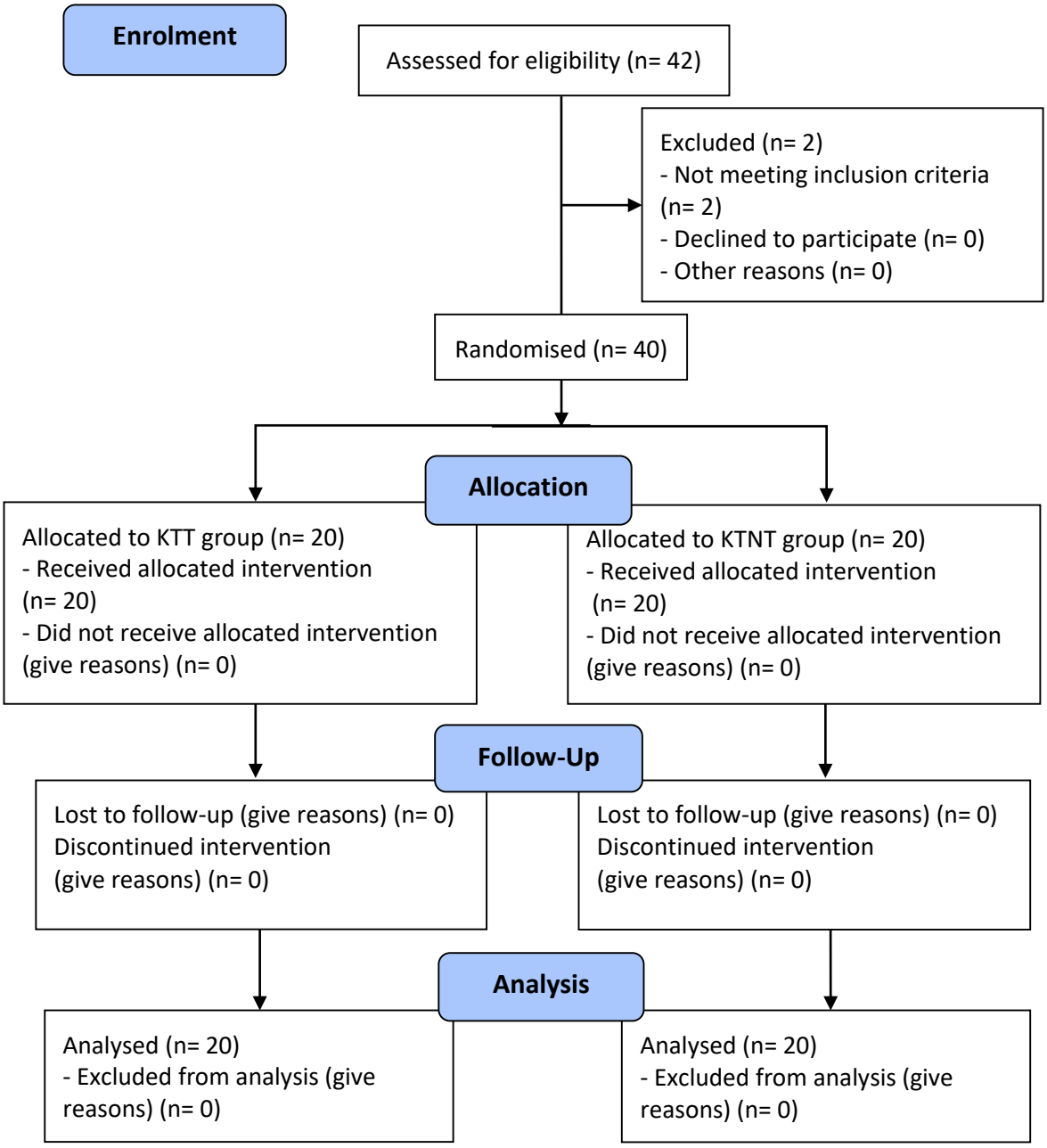


Figure 6-7 Flow diagram of participants recruitment, allocation and analyses.

6.3.2 Participant Characteristics

The KTT group consisted of 9 females and 11 males, and the KTNT group consisted of 10 females and 10 males. Both groups were found to have a similar age, weight, height, and body mass index (BMI); and had no significant differences in their average running distance ($p>0.05$), Table 6-1.

Table 6-1 Participant demographics values are reported as Mean (SD) and ranges.

	KTT group		KTNT group		P-value
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	
Age (year)	35.7 (5.29)	22 - 44	36.65 (6.75)	24 - 45	0.623
Weight (kg)	64.67 (12.52)	49- 91	60.50 (12.35)	42- 90	0.296
Height (cm)	166.90 (7.75)	157- 179	165.85 (10.77)	145- 188	0.725
BMI (kg/m^2)	23.04 (2.99)	19.14– 30.06	21.79 (2.36)	18.47– 27.02	0.151
Average running distance (km/week)	39.13 (19.50)	12.5 - 70	35.10 (12.95)	10 - 60	0.447

6.3.3 Running Speed

The Shapiro-Wilk test demonstrated that the running speed was normally distributed. The Mixed Methods ANOVA showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape ($p>0.05$). No significant main effects were seen for pre-immediate post-tape, group, and sex ($p>0.05$). The mean (SD) running speed in the KTT group was 2.70 (0.30) m/s for pre-tape and 2.69 (0.31) m/s for immediate post-tape, and for the KTNT group was 2.81 (0.42) m/s for pre-tape and 2.80 (0.42) m/s for immediate post-tape.

6.3.4 Hip Kinematics Data

6.3.4.1 Sagittal Plane Hip Kinematics

The peak hip flexion angle, peak hip extension angle, and sagittal plane hip ROM were found to be normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak hip flexion angle, peak hip extension angle, and sagittal plane hip ROM ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in all sagittal plane hip kinematic parameters ($p>0.05$). The Mixed Methods ANOVA tests showed no significant main effects for pre-immediate post-tape for peak hip flexion angle, peak hip extension angle, and sagittal plane hip ROM ($p=0.513$, $p=0.791$, $p=0.196$), respectively. In addition, no significant main effects for group were observed for peak hip extension angle, peak hip extension angle, and sagittal plane hip ROM ($p=0.218$, $p=0.503$, $p=0.350$), respectively. However, significant main effects were seen for sex for peak hip flexion angle ($p=0.025$, $\eta_p^2=0.131$) and sagittal plane hip ROM ($p<0.001$, $\eta_p^2=0.304$), with no significant difference seen for peak hip extension angle ($p=0.514$), Table 6-2. Post hoc pairwise comparisons using LSD tests showed that females had a significantly greater peak hip flexion angle and sagittal plane hip ROM compared to males, Table 6-3.

6.3.4.2 Coronal Plane Hip Kinematics

The peak hip adduction angle, peak hip abduction angle, and coronal plane hip ROM were found to be normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak hip adduction angle, peak hip abduction angle, and coronal plane hip ROM ($p>0.05$).

The Mixed Methods ANOVA showed a significant interaction between group and pre-immediate post-tape for coronal plane hip ROM. Post hoc paired t-tests showed a significant decrease in the coronal plane hip ROM immediate post-tape in the KTT group ($p=0.025$) but not in the KTNT group ($p=0.244$), Table 6-4. There were no significant interactions between group and pre-immediate post-tape for peak hip adduction and

abduction angle nor no significant interactions between sex and pre-immediate post-tape in all coronal plane hip kinematic parameters (p>0.05).

The Mixed Methods ANOVA showed no significant main effects for pre-immediate post-tape in peak hip adduction and abduction angle (p=0.183, p=0.493), respectively. No significant main effects were seen for group in peak hip adduction and abduction angle (p= 0.461, p=0.604), respectively. However, significant main effects were seen for sex for peak hip adduction angle (p=0.011, η_p^2=0.168) but not for peak hip abduction angle (p=0.257), Table 6-2. For coronal plane hip ROM, the Mixed Methods ANOVA showed a significant main effect for sex for coronal plane hip ROM (p=0.034, η_p^2=0.119), Table 6-2. However, no significant main effects were seen for pre-immediate post-tape or group for coronal plane hip ROM (p=0.360, p=0.666), respectively, Table 6-2. The LSD post hoc pairwise comparisons showed that females had a significantly greater peak hip adduction angle and coronal plane hip ROM compared to males, Table 6-3.

6.3.4.3 Transverse Plane Hip Kinematics

Peak hip internal rotation angle, peak hip external rotation angle, and transverse plane hip ROM were found to be non-normally distributed. Differences between pre- and immediate post-tape for the two groups were explored using Wilcoxon Sign Rank tests. For the KTT group, peak hip external rotation angle in females showed a small but significant increase (≤ 2 degrees) in immediate post-tape compared to the pre-tape (p=0.011) whereas the male runners showed a greater significant change (~ 4 degrees) in immediate post-tape compared to pre-tape (p=0.010). Transverse plane hip ROM was significant greater immediate post-tape in males compared to pre-tape (p=0.021). However, there were no significant differences between pre- and immediate-post tape for transverse plane hip ROM in females (p=0.859) and peak hip internal rotation in both females and males (p=0.139, p=0.091), respectively. Figure 6-8 and Figure 6-9 presents the hip internal rotation/external rotation angle time series graph under the two taping conditions in KKT group for females and males, respectively. For the KTNT group, Wilcoxon Sign Rank tests showed no significant effects for pre-immediate post-tape for peak hip internal rotation angle, peak hip external rotation angle, and transverse plane hip ROM in both females and males (p>0.05), Table 6-5.

The differences in transverse plane hip kinematic parameters between the KTT and KTNT groups and sexes were explored using Mann-Whitney U tests. No significant differences between groups for pre-tape and immediate post-tape were observed ($p>0.05$), Table 6-5. However, the Mann-Whitney U-tests demonstrated a significant difference between sexes for the peak hip internal rotation at pre-tape ($p=0.037$) and immediate post-tape ($p=0.011$) in the KTT group. This showed that females had a significantly greater peak hip internal rotation compared to males in both pre-tape and immediate post-tape. Nevertheless, no significant difference was observed between sexes for the peak hip internal rotation in the KTNT group in both pre-tape and immediate post-tape ($p>0.05$). For the peak hip external rotation, the Mann-Whitney U-tests demonstrated a significant difference between sexes at immediate post-tape ($p=0.037$) but no significant difference was observed at pre-tape in the KTT group. Furthermore, there were no significant differences between sexes for the peak hip external rotation in KTNT groups in both pre-tape and immediate post-tape or for the transverse plane hip ROM in both groups in pre-tape and immediate post-tape ($p>0.05$), Table 6-5. Therefore, the transverse plane hip ROM group effects can be further analysed with mixed sexes using Wilcoxon Sign Rank tests. The Wilcoxon Sign Rank tests showed no significant difference between pre- and immediate post-tape for the transverse plane hip ROM in both the KTT and KTNT groups ($p>0.05$).

Table 6-2 Mean (SD) and Mixed Methods ANOVA for peak hip angle and hip ROM in the sagittal, coronal and transverse plane.

Hip kinematics [a] (degrees)	KTT group				KTNT group				P-value (η_p^2)		
	Females (n=9)		Males (n=11)		Females (n=10)		Males (n=10)		Pre-Immediate post effect	Group effect	Sex effect
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape			
Peak flexion	35.55 (4.35)	35.80 (3.97)	31.84 (8.30)	32.22 (9.74)	39.46 (5.16)	39.37 (5.45)	33.26 (6.14)	33.65 (6.38)	0.513 (0.012)	0.218 (0.042)	0.025* (0.131)
Peak extension	-1.74 (4.65)	-1.79 (4.22)	-0.80 (5.31)	-1.30 (7.34)	-1.07 (4.08)	-0.96 (4.26)	0.49 (6.74)	0.59 (6.19)	0.791 (0.002)	0.503 (0.013)	0.514 (0.012)
Sagittal plane ROM	37.29 (3.12)	37.59 (3.18)	32.64 (4.67)	33.52 (4.82)	40.53 (5.70)	40.34 (5.20)	32.77 (5.54)	33.07 (5.01)	0.196 (0.046)	0.350 (0.024)	<0.001* (0.304)
Peak adduction	10.21 (3.61)	10.00 (3.46)	8.02 (2.68)	7.21 (3.43)	11.14 (2.01)	10.96 (2.72)	8.15 (3.73)	8.17 (3.84)	0.183 (0.049)	0.461 (0.015)	0.011* (0.168)
Peak abduction	-0.33 (2.49)	0.10 (2.40)	-0.94 (2.34)	-1.08 (2.08)	0.48 (2.06)	-0.07 (2.45)	-0.46 (2.39)	-0.68 (2.56)	0.493 (0.013)	0.604 (0.008)	0.257 (0.036)
Coronal plane ROM [δ]	10.54 (3.34)	9.90 (3.30)	8.96 (3.08)	8.29 (3.05)	10.67 (2.29)	11.03 (2.78)	8.61 (1.84)	8.85 (1.65)	0.360 (0.023)	0.666 (0.005)	0.034* (0.119)

* Significant main effect at the 0.05 level, [δ] = significant interaction between Group x Pre-Immediate post-tape.

[a] Positive values indicate hip flexion/adduction/internal rotation and negative values indicate hip extension/abduction/external rotation.

Table 6-3 Pairwise comparison for sex differences of hip kinematics.

Hip kinematics (degrees)	Mean Difference (Female vs Male)	P-Value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Peak flexion	4.80	0.025*	0.63	8.98
Sagittal plane ROM	5.94	<0.001*	2.91	8.97
Peak adduction	2.69	0.011*	0.67	4.72
Coronal plane ROM	1.86	0.034*	0.15	3.57

* Significant difference at the 0.05 level.

Positive values indicate a greater hip flexion angle, sagittal plane hip ROM, hip adduction angle and coronal plane hip ROM in the females when compared with the males.

Table 6-4 The Paired t-test for Coronal plane Hip ROM in each group separately.

Coronal plane Hip ROM (degrees)	Mean Difference (Pre-tape vs Immediate post-tape)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT	0.66	0.025*	0.09	1.22
KTNT	-0.30	0.244	-0.83	0.22

* Significant difference at the 0.05 level.

Table 6-5 Median (Q1, Q3), Wilcoxon Sign Rank test for within the two groups and two sexes separately, and Mann-Whitney U-tests for between group and between sexes for peak hip angle and hip ROM in the sagittal, coronal and transverse plane.

Hip kinematics (degrees) [a]	KTT group				KTNT group				P-value	
	Females (n=9)		Males (n=11)		Females (n=10)		Males (n=10)		Between Group Pre- tape	Between Group Immediate post-tape
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape		
Peak internal rotation [b, c]	8.14 (5.04, 10.89)	7.70 (4.20, 9.38)	2.41 (-5.78, 8.09)	2.65 (-8.75, 5.52)	3.13 (-1.34, 11.24)	2.42 (-2.09, 9.30)	4.77 (0.93, 9.58)	5.25 (1.86, 10.03)	0.935	0.589
Pre-immediate post-tape (p-value)	0.139		0.091		0.241		0.508			
Peak external rotation [c]	-1.79 (-4.75, 1.13)	-3.37 (-6.97, 0.52)	-4.47 (-12.27, -0.50)	-8.89 (-14.23, -4.00)	-5.66 (-9.63, -2.03)	-8.40 (-11.05, -2.46)	-1.91 (-7.22, 2.16)	-1.18 (-5.95, 2.24)	0.787	0.417
Pre-immediate post-tape (p-value)	0.011*,ϒ		0.010*		0.285		0.203			
Transverse plane ROM	9.55 (5.43, 12.95)	8.40 (6.85, 12.47)	6.40 (5.24, 10.14)	6.64 (5.87, 11.11)	6.09 (5.04, 16.47)	6.82 (5.14, 15.26)	7.36 (6.12, 9.20)	7.79 (5.10, 8.79)	0.957	0.482
Pre-immediate post-tape (p-value)	0.859		0.021*,ϒ		0.508		0.445			

* Significant difference at the 0.05 level., [b] = significant between sexes at pre-tape in KTT group, [c] = significant between sexes at immediate post-tape in KTT group, ϒ indicates a significant difference with a small change in magnitude (≤ 2 degrees), as an error of 2 degrees or less as these are likely to be susceptible to clinical misinterpretation.

[a] Positive values indicate hip flexion/adduction/internal rotation and negative values indicate hip extension/abduction/external rotation.

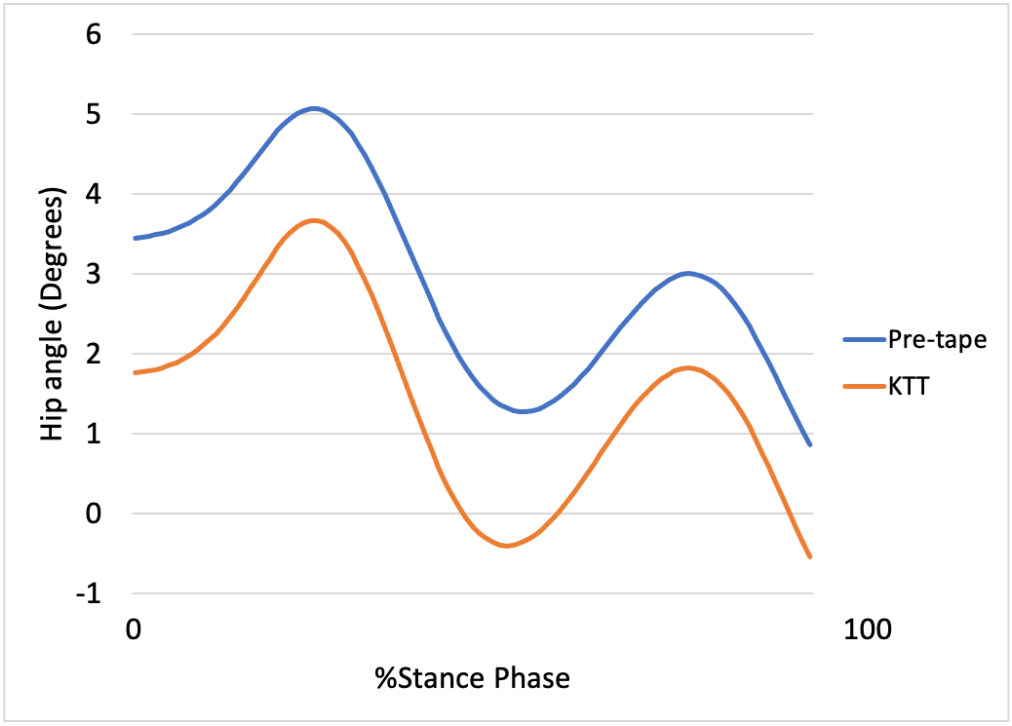


Figure 6-8 Time series graph for hip internal rotation/external rotation angle for females in KTT group under the two taping conditions. (Positive values indicate hip internal rotation and negative values indicate hip external rotation).

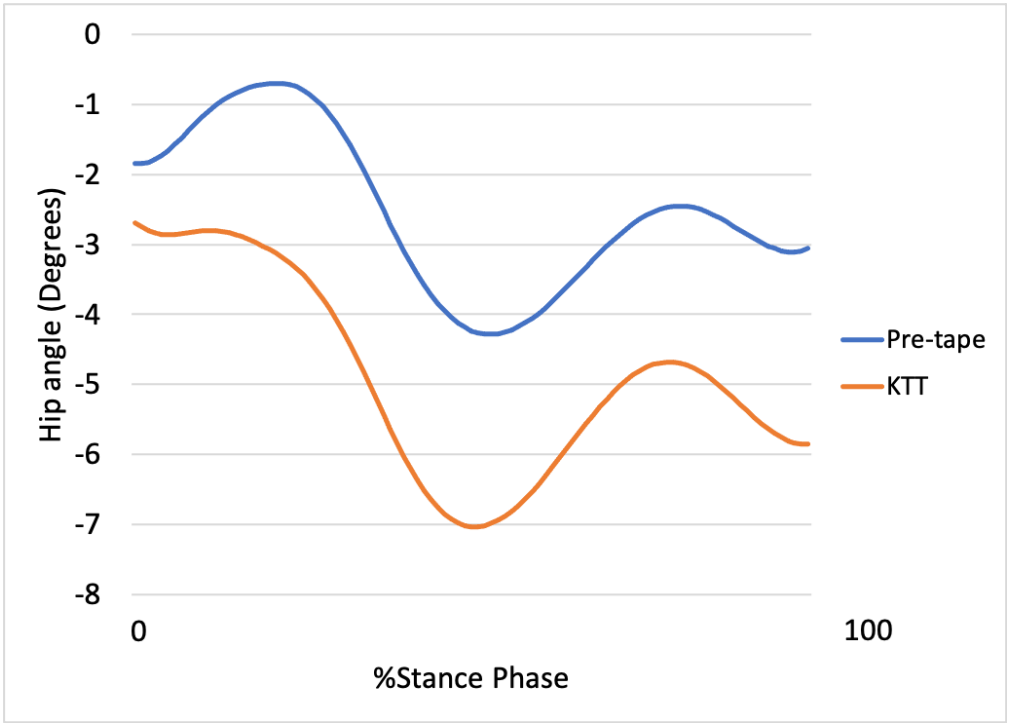


Figure 6-9 Time series graph for hip internal rotation/external rotation angle for males in KTT group under the two taping conditions. (Positive values indicate hip internal rotation and negative values indicate hip external rotation).

6.3.5 Knee Kinematic Data

6.3.5.1 Sagittal Plane Knee Kinematics

The peak knee flexion angle, peak knee extension angle, and sagittal plane knee ROM were found to be normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak knee flexion angle, peak knee extension angle, and sagittal plane knee ROM ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in all sagittal plane knee kinematic parameters ($p>0.05$). The Mixed Methods ANOVA showed no significant main effect for pre-immediate post-tape in peak knee flexion angle, minimum knee flexion, and sagittal plane knee ROM ($p=0.931$, $p=0.829$, $p=0.728$), respectively. In addition, there was no significant difference in the main effect for group for peak knee flexion angle, minimum knee flexion, and sagittal plane knee ROM ($p=0.588$, $p=0.893$, $p=0.658$), respectively. However, there was a significant main effect for sex for peak knee flexion angle ($p=0.008$, $\eta_p^2=0.180$) but no significant difference was seen for minimum knee flexion ($p=0.125$), and sagittal plane knee ROM ($p=0.190$), Table 6-6. Post hoc pairwise comparison using LSD revealed that females had a significantly greater peak knee flexion angle compared to males, Table 6-7.

6.3.5.2 Coronal Plane Knee Kinematics

The peak knee adduction and abduction angle were found to be normally distributed but the coronal plane knee ROM was found to be non-normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak knee adduction angle and peak knee abduction angle ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in the peak knee adduction and abduction angles ($p>0.05$). In addition, the Mixed Methods ANOVA showed no significant main effects for pre-immediate post-tape, group, or sex for peak knee adduction angle ($p=0.976$, $p=0.101$, $p=0.225$), respectively. Additionally, the Mixed

Methods ANOVA showed no significant main effects for pre-immediate post-tape, group, or sex for peak knee abduction angle (p=0.290, p=0.361, p=0.312), respectively, Table 6-6.

Wilcoxon Sign Rank tests were used to explore the differences between pre- and immediate post-tape for the two groups for the coronal plane knee ROM. For the KTT group, there were no significant differences between pre- and immediate post-tape for coronal plane knee ROM in both females and males (p=0.214, p=0.062), respectively. In addition, for the KTNT group, no significant effect of pre-immediate post-tape for coronal plane knee ROM was seen in both females and males (p=0.721, p=0.721), respectively, Table 6-8.

Mann-Whitney U tests were used to explore the differences in coronal plane knee ROM between the KTT and KTNT groups, and sexes. These showed no significant differences between groups for pre-tape and immediate post-tape (p>0.05). Additionally, no significant difference was observed between sexes for the coronal plane knee ROM in both KTT and KTNT groups for pre-tape and immediate post-tape (p>0.05), Table 6-8. Therefore, the coronal plane knee ROM group effects were further analysed with mixed sexes using Wilcoxon Sign Rank tests which showed no significant difference between pre- and immediate post-tape for the coronal plane knee ROM in both the KTT and KTNT groups (p>0.05).

6.3.5.3 Transverse Plane Knee Kinematics

The peak knee external rotation angle and transverse plane knee ROM were found to be normally distributed but the peak knee internal rotation angle was found to be non-normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak knee external rotation angle and transverse plane knee ROM (p>0.05).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in the peak knee external rotation angle and transverse plane knee ROM (p>0.05). The Mixed Methods ANOVA showed no significant main effects for pre-immediate post-tape,

group, or sex for peak knee external rotation angle (p=0.314, p=0.324, p=0.853), respectively. Additionally, the Mixed Methods ANOVA showed no significant main effects for pre-immediate post-tape, group, or sex for transverse plane knee ROM (p=0.745, p=0.405, p=0.191), respectively, Table 6-6.

Wilcoxon Sign Rank tests were used to explore the differences between pre- and immediate post-tape for the two groups for the peak knee internal rotation angle. For the KTT group, there were no significant differences between pre- and immediate post-tape for peak knee internal rotation angle in both females and males (p=0.515, p=0.477), respectively. In addition, for the KTNT group, no significant effect of pre-immediate post-tape for peak knee internal rotation angle was seen in both females and males (p=0.241, p=0.445), respectively, Table 6-8.

Mann-Whitney U tests were used to explore the differences in peak knee internal rotation angle between the KTT and KTNT groups, and sexes. These showed no significant differences between groups for pre-tape and immediate post-tape (p>0.05). Additionally, no significant difference was observed between sexes for the peak knee internal rotation angle in both the KTT and KTNT groups for pre-tape and immediate post-tape (p>0.05), Table 6-8. Therefore, the peak knee internal rotation angle group effects were further analysed with mixed sexes using Wilcoxon Sign Rank tests which showed no significant difference between pre- and immediate post-tape for the peak knee internal rotation angle in both the KTT and KTNT groups (p>0.05).

Table 6-6 Mean (SD) and Mixed Methods ANOVA for peak knee angle and knee ROM in the sagittal, coronal, and transverse plane.

Knee kinematics [a] (degrees)	KTT group				KTNT group				P-value (ηp^2)		
	Females (n=9)		Males (n=11)		Females (n=10)		Males (n=10)		Pre-Immediate post effect	Group effect	Sex effect
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape			
Peak flexion	42.44 (3.55)	41.95 (3.27)	38.41 (4.19)	38.72 (5.14)	42.64 (1.63)	42.64 (2.38)	39.42 (4.69)	39.48 (5.13)	0.931 (<0.001)	0.588 (0.008)	0.008* (0.180)
Minimum flexion	14.05 (1.80)	13.91 (3.06)	11.68 (4.61)	11.94 (6.05)	14.11 (4.24)	13.66 (3.53)	11.91 (3.58)	12.55 (3.10)	0.829 (0.001)	0.893 (0.001)	0.125 (0.064)
Sagittal plane ROM	28.39 (3.55)	28.05 (2.43)	26.74 (2.62)	26.78 (2.69)	28.53 (4.88)	28.98 (4.76)	27.51 (3.21)	26.93 (4.35)	0.728 (0.003)	0.658 (0.005)	0.190 (0.047)
Peak adduction	1.59 (1.79)	1.20 (2.17)	2.67 (3.25)	2.80 (2.20)	3.07 (2.92)	3.25 (3.89)	4.17 (4.25)	4.21 (3.58)	0.976 (<0.001)	0.101 (0.073)	0.225 (0.041)
Peak abduction	-3.46 (1.95)	-3.56 (2.57)	-2.65 (3.16)	-3.50 (3.32)	-3.14 (3.61)	-3.24 (4.38)	-1.42 (4.39)	-1.27 (4.17)	0.290 (0.031)	0.361 (0.023)	0.312 (0.028)
Peak external rotation	-9.89 (4.08)	-9.65 (3.80)	-9.55 (6.79)	-9.62 (8.03)	-12.12 (5.17)	-10.82 (5.46)	-11.29 (2.58)	-10.83 (2.18)	0.314 (0.028)	0.324 (0.027)	0.853 (0.001)
Transverse plane ROM	14.74 (3.99)	14.65 (4.40)	14.62 (4.25)	15.38 (3.92)	12.68 (3.90)	12.11 (3.04)	15.16 (3.54)	15.40 (3.67)	0.745 (0.003)	0.405 (0.019)	0.191 (0.047)

* Significant main effect at the 0.05 level.

[a] Positive values indicate knee flexion/adduction/internal rotation and negative values indicate knee extension/abduction/external rotation.

Table 6-7 Pairwise comparison for sex differences of knee kinematics.

Knee kinematics (degrees)	Mean Difference (Female vs Male)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Peak flexion	3.41	0.008*	0.95	5.88

* Significant difference at the 0.05 level. Positive values indicate a greater knee flexion angle in the females when compared with the males.

Table 6-8 Median (Q1, Q3), Wilcoxon Sign Rank test for within the two groups and two sexes separately, and Mann-Whitney U-tests for between group and between sexes for peak knee angle and knee ROM in the sagittal, coronal and transverse plane.

Knee kinematics (degrees) [a]	KTT group				KTNT group				P-value	
	Females (n=9)		Males (n=11)		Females (n=10)		Males (n=10)		Between Group Pre-tape	Between Group Immediate post-tape
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape		
Coronal plane ROM	5.04 (4.24, 6.00)	5.15 (3.29, 6.03)	5.70 (4.24, 6.37)	6.16 (5.20, 7.43)	6.27 (4.50, 7.71)	6.34 (4.22, 8.23)	5.52 (4.43, 6.51)	6.00 (4.32, 6.41)	0.194	0.417
Pre-immediate post tape (p-value)	0.214		0.062		0.721		0.721			
Peak internal rotation	5.37 (2.46, 7.37)	5.88 (2.68, 8.13)	5.58 (2.84, 7.56)	7.26 (3.21, 9.30)	0.99 (-5.34, 5.01)	3.66 (-6.23, 6.54)	2.35 (-0.04, 8.89)	3.13 (0.49, 9.29)	0.083	0.110
Pre-immediate post tape (p-value)	0.515		0.477		0.241		0.445			

[a] Positive values indicate knee flexion/adduction/internal rotation and negative values indicates knee extension/abduction/external rotation.

6.3.6 Hip Moments Data

6.3.6.1 Sagittal Plane Hip Moments

Peak hip extension and flexion moments were found to be non-normally distributed. Differences between pre- and immediate post-tape for the two groups were explored using Wilcoxon Sign Rank tests. For the KTT group, there were no significant differences between pre- and immediate post-tape for peak hip extension moments in both females and males ($p=0.866$, $p=0.575$), respectively, and no significant effect in pre-immediate post-tape was seen for the peak hip flexion moments in both females and males ($p=0.310$, $p=0.799$), respectively. In addition, for the KTNT group, no significant effect of pre-immediate post-tape for peak hip extension moments was observed in both females and males ($p=0.866$, $p=0.678$), respectively, and no significant effect in pre-immediate post-tape was seen for the peak hip flexion moments in both females and males ($p=0.612$, $p=0.953$), respectively, Table 6-10.

Mann-Whitney U tests were used to explore the differences in peak hip extension moments and peak hip flexion moments between the KTT and KTNT groups, and sexes. These showed no significant differences between groups in the peak hip extension and flexion moments for pre-tape and immediate post-tape ($p>0.05$), Table 6-10. Additionally, no significant difference was observed between sexes for the peak hip extension and flexion moments in both pre-tape and immediate post-tape in the KTT and KTNT groups ($p>0.05$), Table 6-10. Therefore, the peak hip extension moments and peak hip flexion moments group effects can be further analysed with mixed sexes using Wilcoxon Sign Rank tests which showed no significant difference between pre- and immediate post-tape for the peak hip extension and flexion moments in both the KTT and KTNT groups ($p>0.05$).

6.3.6.2 Coronal Plane Hip Moments

The peak hip abduction moments were found to be normally distributed but the peak hip adduction moments were found to be non-normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak hip abduction moments ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in the peak hip abduction moments ($p>0.05$). The Mixed Methods ANOVA showed no significant main effects for pre-immediate post-tape, group, or sex ($p=0.704$, $p=0.910$, $p=0.767$), respectively, Table 6-9.

Wilcoxon Sign Rank tests were used to explore the differences between pre- and immediate post-tape for the two groups for peak hip adduction moments. For the KTT group, there were no significant differences between pre- and immediate post-tape for peak hip adduction moments in both females and males ($p=0.273$, $p=0.878$), respectively. In addition, for the KTNT group, no significant effect in pre-immediate post tape was seen for the peak hip adduction moments in both females and males ($p=0.176$, $p=0.260$), respectively, Table 6-10.

Mann-Whitney U tests were used to explore the differences in peak hip adduction moments between the KTT and KTNT groups, and sexes. This showed no significant differences between groups for pre-tape and immediate post-tape ($p>0.05$). However, the Mann-Whitney U-tests demonstrated a significant difference between sexes for the peak hip adduction moments at immediate post-tape ($p=0.019$) but no significant difference was observed at pre-tape in the KTT group. This showed that males had a significantly greater peak hip adduction moments compared to females at immediate post-tape in the KTT group. Nevertheless, no significant difference was observed between sexes for the peak hip adduction moments in the KTNT group in both pre-tape and immediate post-tape ($p>0.05$), Table 6-10.

6.3.6.3 Transverse Plane Hip Moments

The peak hip external rotation moments were found to be normally distributed but the peak hip internal rotation moments were found to be non-normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak hip external rotation moments ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in the peak

hip external rotation moments ($p>0.05$). The Mixed Methods ANOVA showed no significant main effects for pre-immediate post-tape, group, or sex ($p=0.742$, $p=0.995$, $p=0.202$), respectively, Table 6-9.

Wilcoxon Sign Rank tests were used to explore the differences between pre- and immediate post-tape for the two groups for the peak hip internal rotation moments. For the KTT group, there were no significant differences between pre- and immediate post-tape for peak hip internal rotation moments in both females and males ($p=0.176$, $p=0.114$), respectively. Furthermore, for the KTNT group, no significant effect in pre-immediate post-tape was observed for the peak hip internal rotation moments in both females and males ($p=0.735$, $p=0.441$), respectively, Table 6-10.

Mann-Whitney U tests were used to explore the differences in peak hip internal rotation moments between the KTT and KTNT groups, and sexes. This showed no significant differences between groups for pre-tape and immediate post-tape ($p>0.05$). However, the Mann-Whitney U-tests demonstrated a significant difference between sexes for the peak hip external rotation moments at pre-tape ($p=0.025$) in the KTT group, and at pre-tape ($p=0.050$) and immediate post-tape ($p=0.039$) in the KTNT group. These showed that males had a significantly greater peak hip internal rotation moments compared to females. Nevertheless, no significant difference was observed between sexes for the peak hip internal rotation moments at immediate post-tape in the KTT group ($p>0.05$), Table 6-10.

Table 6-9 Mean (SD) and Mixed Methods ANOVA for peak hip moments in the sagittal, coronal, and transverse plane.

Hip Moments (Nm/kg) [a]	KTT group				KTNT group				P-value (ηp^2)		
	Females (n=7)		Males (n=10)		Females (n=7)		Males (n=9)		Pre-Immediate post effect	Group effect	Sex effect
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape			
Peak abduction	1.75 (0.36)	1.74 (0.36)	1.56 (0.36)	1.58 (0.32)	1.54 (0.37)	1.50 (0.43)	1.76 (0.30)	1.77 (0.27)	0.704 (0.005)	0.910 (<0.001)	0.767 (0.003)
Peak external rotation	0.61 (0.19)	0.62 (0.20)	0.55 (0.26)	0.54 (0.30)	0.65 (0.18)	0.63 (0.20)	0.51 (0.16)	0.52 (0.16)	0.742 (0.004)	0.995 (<0.001)	0.202 (0.056)

[a] Positive values indicate hip extension/abduction/external rotation and negative values indicate hip flexion/adduction/internal rotation.

Table 6-10 Median (Q1, Q3), Wilcoxon Sign Rank test for within group and within sex, and Mann-Whitney U-tests for between group for peak hip moments in the sagittal, coronal, and transverse plane.

Hip Moments (Nm/kg) [a]	KTT group				KTNT group				P-value	
	Females (n=7)		Males (n=10)		Females (n=7)		Males (n=9)		Between Group Pre-tape	Between Group Immediate post-tape
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape		
Peak extension	1.35 (1.18, 1.88)	1.50 (1.21, 1.63)	1.57 (1.26, 2.01)	1.56 (1.21, 2.22)	1.45 (1.07, 2.07)	1.56 (1.09, 1.83)	1.71 (1.22, 2.10)	1.63 (1.27, 2.15)	0.564	0.857
Pre-immediate post tape (p-value)	0.866		0.575		0.866		0.678			
Peak flexion	-0.70 (-0.74, -0.64)	-0.74 (-0.79, -0.68)	-0.77 (-1.36, -0.58)	-0.78 (-1.33, -0.64)	-0.65 (-0.82, -0.51)	-0.73 (-0.78, -0.50)	-0.84 (-1.04, -0.57)	-0.88 (-1.15, -0.54)	0.914	0.564
Pre-immediate post tape (p-value)	0.310		0.799		0.612		0.953			
Peak adduction [c]	-0.09 (-0.13, -0.07)	-0.09 (-0.12, -0.07)	-0.15 (-0.19, -0.08)	-0.13 (-0.18, -0.12)	-0.13 (-0.21, -0.07)	-0.14 (-0.19, -0.11)	-0.16 (-0.20, -0.05)	-0.15 (-0.21, -0.08)	0.692	0.313
Pre-immediate post tape (p-value)	0.237		0.878		0.176		0.260			
Peak internal rotation [b, d, e]	-0.05 (-0.07, -0.04)	-0.08 (-0.09, -0.03)	-0.15 (-0.20, -0.05)	-0.14 (-0.19, -0.05)	-0.04 (-0.07, -0.02)	-0.04 (-0.06, -0.03)	-0.10 (-0.21, -0.05)	-0.11 (-0.19, -0.07)	0.494	0.914
Pre-immediate post tape (p-value)	0.176		0.114		0.735		0.441			

[a] Positive values indicate hip extension/abduction/external rotation and negative values indicate hip flexion/adduction/internal rotation.

[b] = significant between sexes at pre-tape in KTT group, [c] = significant between sexes at immediate post-tape in KTT group,

[d] = significant between sexes at pre-tape in KTNT group, [e] = significant between sexes at immediate post-tape in KTNT group.

6.3.7 Knee Moments Data

6.3.7.1 Sagittal Plane Knee Moments

The peak knee extension and flexion moments were found to be normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak knee extension moments and peak knee flexion moments ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in all sagittal plane knee moments parameters ($p>0.05$). The Mixed Methods ANOVA tests showed no significant main effects for pre-immediate post-tape for peak knee extension and flexion moments ($p=0.257$, $p=0.723$), respectively. In addition, no significant main effects for group were observed for peak knee extension and flexion moments ($p=0.800$, $p=0.669$), respectively. However, significant main effects for sex were seen for peak knee flexion moments ($p=0.003$, $\eta_p^2=0.272$) with no significant difference seen for peak knee extension moments ($p=0.834$), Table 6-11. The LSD post hoc test showed that males had a significantly greater peak knee flexion moment compared to females, Table 6-12.

6.3.7.2 Coronal Plane Knee Moments

The peak knee abduction moments were found to be normally distributed but the peak knee adduction moments were found to be non-normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak knee abduction moments ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in the peak knee abduction moments ($p>0.05$). The Mixed Methods ANOVA showed no significant main effects for pre-immediate post-tape, group, or sex ($p=0.298$, $p=0.988$, $p=0.242$), respectively, Table 6-11.

Wilcoxon Sign Rank tests were used to explore the differences between pre- and immediate post-tape for the two groups for the peak adduction moments. For the KTT group, there were no significant differences between pre- and immediate post-tape for

peak knee adduction moments in both females and males (p=0.398, p=0.508), respectively. Furthermore, for the KTNT group, no significant effect in pre-immediate post-tape was observed for the peak knee adduction moments in both females and males (p=0.237, p=0.859), respectively, Table 6-13.

Mann-Whitney U tests were used to explore the differences in the peak knee adduction moments between the KTT and KTNT groups, and sexes. This showed no significant differences between groups in the peak knee adduction moments for pre-tape and immediate post-tape (p>0.05). However, the Mann-Whitney U tests demonstrated a significant difference between sexes for the peak knee adduction moments at immediate post-tape (p=0.023) but no significant difference was observed at pre-tape in the KTNT group. Nevertheless, no significant difference was observed between sexes for the peak knee adduction moments in the KTT group in both pre-tape and immediate post-tape (p>0.05), Table 6-13.

6.3.7.3 Transverse Plane Knee Moments

The peak knee internal rotation moments were found to be normally distributed but the peak knee external rotation moments were found to be non-normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak knee abduction moments (p>0.05).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in the peak knee internal rotation moments (p>0.05). The Mixed Methods ANOVA showed no significant main effects for pre-immediate post-tape, group, or sex (p=0.561, p=0.390, p=0.520), respectively, Table 6-11.

Wilcoxon Sign Rank tests were used to explore the differences between pre- and immediate post-tape for the two groups for the peak knee external rotation moments. For the KTT group, no significant differences between pre- and immediate post-tape was seen for peak knee external rotation moments in both females and males (p=0.176, p=0.508), respectively. Additionally, for the KTNT group, there was no significant effect

in pre-immediate post-tape for the peak knee external rotation moments in both females and males (p=0.612, p=0.314), respectively, Table 6-13.

Mann-Whitney U tests were used to explore the differences in peak knee external rotation moments between the KTT and KTNT groups, and sexes. These showed no significant differences between groups for pre-tape (p=0.183), but a significant difference was seen for immediate post-tape (p=0.044). This showed peak knee external rotation moment in the KTT group were significantly decreased compared to KTNT at immediate post-tape, Table 6-13. Additionally, no significant difference was observed between sexes for the peak knee external rotation moments in both pre-tape and immediate post-tape in KTT and KTNT groups (p>0.05), Table 6-13. Therefore, the peak knee external rotation moments can be further analysed with mixed sexes using Wilcoxon Sign Rank tests which showed no significant difference between pre- and immediate post-tape for the peak knee external rotation moments in both the KTT and KTNT groups (p>0.05).

Table 6-11 Mean (SD) and Mixed Methods ANOVA for peak knee moments in the sagittal, coronal and transverse plane.

Knee Moments (Nm/kg)[a]	KTT group				KTNT group				P-value (η_p^2)		
	Females (n=7)		Males (n=10)		Females (n=7)		Males (n=9)		Pre-Immediate post effect	Group effect	Sex effect
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape			
Peak extension	2.29 (0.45)	2.26 (0.53)	2.30 (0.34)	2.27 (0.42)	2.31 (0.28)	2.27 (0.30)	2.34 (0.41)	2.34 (0.45)	0.257 (0.044)	0.800 (0.002)	0.834 (0.002)
Peak flexion	-0.22 (0.06)	-0.22 (0.06)	-0.32 (0.07)	-0.32 (0.10)	-0.20 (0.14)	-0.20 (0.09)	-0.32 (0.12)	-0.31 (0.10)	0.723 (0.004)	0.669 (0.006)	0.003* (0.272)
Peak abduction	0.64 (0.21)	0.60 (0.22)	0.67 (0.32)	0.67 (0.30)	0.57 (0.31)	0.54 (0.37)	0.74 (0.24)	0.73 (0.20)	0.298 (0.037)	0.988 (<0.001)	0.242 (0.047)
Peak internal rotation	-0.47 (0.19)	-0.45 (0.16)	-0.36 (0.14)	-0.37 (0.14)	-0.36 (0.14)	-0.34 (0.19)	-0.39 (0.08)	-0.39 (0.07)	0.561 (0.012)	0.390 (0.026)	0.520 (0.014)

* Significant main effect at the 0.05 level.

[a] Positive values indicate knee extension/abduction/external rotation and negative values indicate knee flexion/adduction/internal rotation.

Table 6-12 Pairwise comparison for sex differences of knee moments.

Knee Moments (Nm/kg)	Mean Difference (Female vs Male)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Peak flexion	0.11	0.003*	0.04	0.17

* Significant difference at the 0.05 level.

Negative values indicate a greater knee flexion moment in the females when compared with the males.

Table 6-13 Median (Q1, Q3), Wilcoxon Sign Rank test for within group and within sex, and Mann-Whitney U-tests for between group for peak knee moments in the sagittal, coronal, and transverse plane.

Knee Moments (Nm/kg) [a]	KTT group				KTNT group				P-value	
	Females (n=7)		Males (n=10)		Females (n=7)		Males (n=9)		Between Group Pre-tape	Between Group Immediate post-tape
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape		
Peak adduction [b]	-0.04 (-0.05, -0.04)	-0.02 (-0.06, -0.01)	-0.05 (-0.10, -0.03)	-0.05 (-0.08, -0.03)	-0.08 (-0.15, -0.05)	-0.11 (-0.15, -0.08)	-0.04 (-0.08, -0.04)	-0.04 (-0.08, -0.03)	0.692	0.098
Pre-immediate post tape (p-value)	0.398		0.508		0.237		0.859			
Peak external rotation	0.02 (0.01, 0.02)	0.01 (<0.01, 0.02)	0.02 (0.02, 0.03)	0.02 (0.02, 0.02)	0.03 (0.01, 0.04)	0.03 (0.01, 0.04)	0.02 (0.01, 0.04)	0.02 (0.01, 0.04)	0.183	0.044*
Pre-immediate post tape (p-value)	0.176		0.508		0.612		0.314			

* Significant difference at the 0.05 level, [b] = significant between sexes at immediate post-tape in KTNT group.

[a] Positive values indicate knee extension/abduction/external rotation and negative values indicate knee flexion/adduction/internal rotation.

6.3.8 Average Electromyography Data

All parameters of average EMG were found to be normally distributed. Unpaired t-tests showed no pre-tape differences between groups in all parameters of average EMG ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape conditions for any average EMG parameters ($p>0.05$). In addition, there were no significant interactions between sex and pre-immediate post-tape conditions in almost all parameters except average TFL EMG. The Mixed Methods ANOVA showed a significant main effect for pre-immediate post-tape for average Gmax EMG ($p=0.003$, $\eta_p^2=0.217$), average Gmed EMG ($p<0.001$, $\eta_p^2=0.344$), average TFL EMG ($p<0.001$, $\eta_p^2=0.343$), and average VM EMG ($p=0.037$, $\eta_p^2=0.115$) but no significant difference was seen for average VL EMG ($p=0.086$). However, no significant main effect was observed for group or sex for any average EMG parameters ($p>0.05$), Table 6-14. The LSD post hoc tests showed a significantly lower average EMG for Gmax, Gmed, TFL, and VM immediate post-tape compared to pre-tape, Table 6-15. The significant interaction between sex and pre-immediate post-tape conditions for the average TFL EMG was further explored using post hoc paired t-tests. This showed a significant decrease for the average TFL EMG in females immediate post-tape ($p<0.001$) but no significant change was seen in the males ($p=0.164$), Table 6-16. Figure 6-10 presents the normalised EMG signals for Gmax, Gmed, TFL, and VM time series graph under pre-tape and immediate post-tape conditions in KTT and KTNT groups.

Table 6-14 Mean (SD) and Mixed Methods ANOVA for normalised values from average EMG signal analysis in each group during stance phase.

Average Normalised EMG	KTT group				KTNT group				P-value (η_p^2)		
	Females (n=9)		Males (n=11)		Females (n=10)		Males (n=10)		Pre-Immediate post effect	Group effect	Sex effect
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape			
Gmax	0.141 (0.044)	0.125 (0.025)	0.125 (0.033)	0.120 (0.036)	0.130 (0.025)	0.114 (0.016)	0.123 (0.024)	0.115 (0.023)	0.003* (0.217)	0.408 (0.019)	0.449 (0.016)
Gmed	0.123 (0.032)	0.096 (0.035)	0.120 (0.040)	0.112 (0.042)	0.118 (0.028)	0.091 (0.032)	0.115 (0.033)	0.102 (0.029)	<0.001 * (0.344)	0.519 (0.012)	0.600 (0.008)
TFL $^{\phi}$	0.129 (0.032)	0.098 (0.027)	0.136 (0.035)	0.123 (0.028)	0.140 (0.025)	0.101 (0.031)	0.129 (0.030)	0.121 (0.041)	<0.001 * (0.343)	0.875 (0.001)	0.256 (0.036)
VM	0.112 (0.034)	0.100 (0.027)	0.109 (0.022)	0.100 (0.032)	0.131 (0.020)	0.117 (0.024)	0.113 (0.029)	0.114 (0.025)	0.037* (0.115)	0.073 (0.086)	0.431 (0.017)
VL	0.114 (0.037)	0.090 (0.025)	0.106 (0.030)	0.103 (0.021)	0.106 (0.037)	0.111 (0.030)	0.116 (0.029)	0.113 (0.026)	0.086 (0.080)	0.355 (0.024)	0.648 (0.006)

* Significant main effect at the 0.05 level. Normalised to 1 which represents the maximum observed signal.

$^{\phi}$ = significant interaction between Sex x Pre-Immediate post-tape.

Table 6-15 Pairwise comparisons of main pre-immediate post-tape effect for average EMG

Average Normalised EMG	Mean Difference (Pre-tape vs Immediate post-tape)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Gmax	0.011	0.003*	0.004	0.019
Gmed	0.019	<0.001*	0.010	0.027
TFL	0.023	<0.001*	0.012	0.033
VM	0.009	0.037*	0.001	0.017

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

Table 6-16 The Paired t-test on pre-immediate post-tape for average TFL EMG in each sex separately.

Average Normalised TFL EMG	Mean Difference (Pre-tape vs Immediate post-tape)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Females	0.035	<0.001*	0.020	0.050
Males	0.011	0.164	-0.005	0.026

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

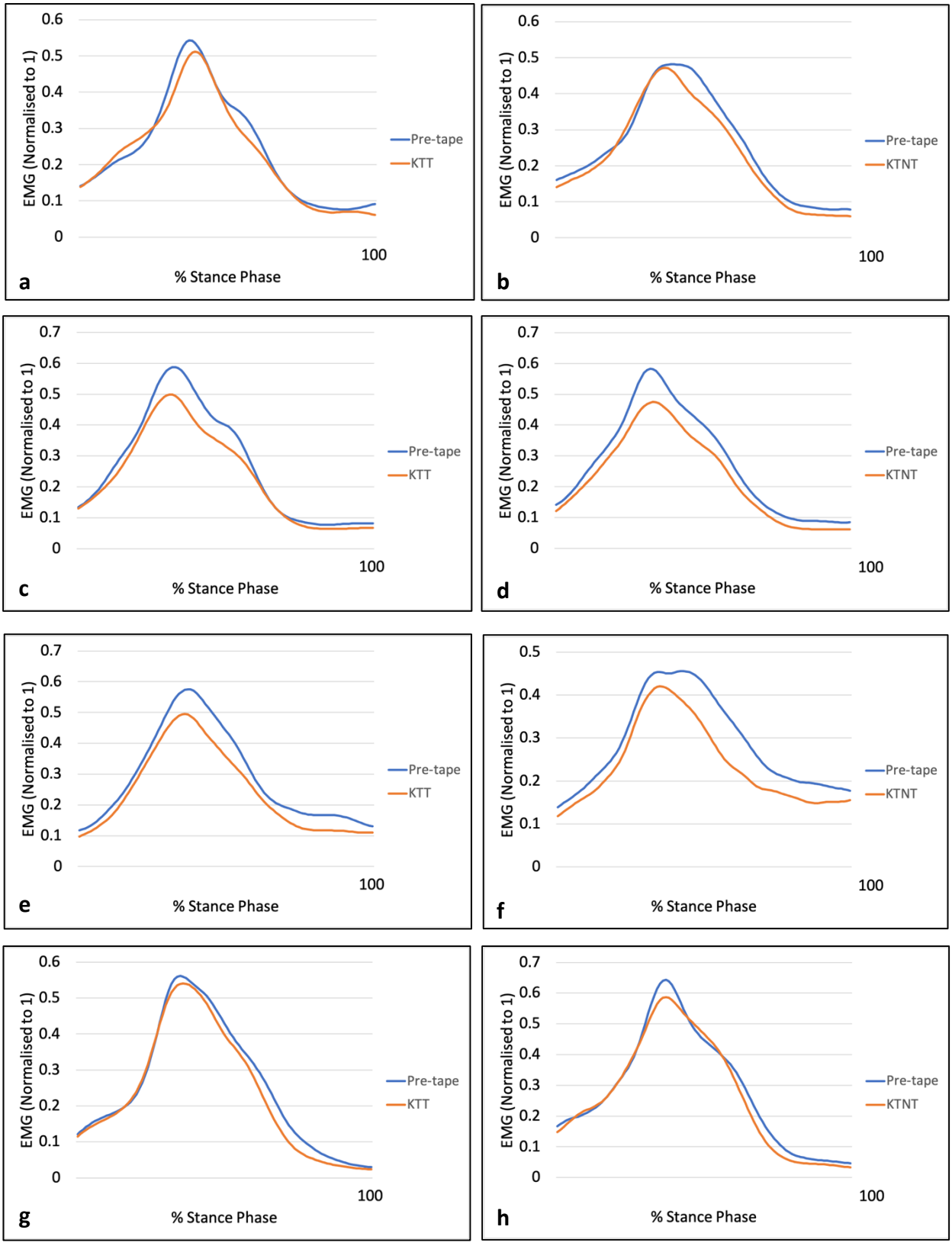


Figure 6-10 Time series graph for normalised EMG signals for Gmax (a, b), Gmed (c, d), TFL (e, f), VM (g, h) under pre-tape and immediate post-tape conditions in KTT and KTNT groups. Normalised to 1 which represents the maximum observed signal.

6.3.9 Peak Electromyography Data

Only peak Gmax EMG was found to be normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the peak Gmax EMG ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in the peak Gmax EMG ($p>0.05$). The Mixed Methods ANOVA showed no significant main effect for pre-immediate post-tape for peak Gmax EMG ($p=0.114$). No significant main effect was seen for group for peak Gmax EMG ($p=0.538$). However, there was a significant main effect for sex for the peak Gmax EMG ($p=0.008$, $\eta_p^2=0.182$), Table 6-17. The LSD post hoc tests showed that females had a significantly decreased peak Gmax EMG compared to males, Table 6-18.

Wilcoxon Sign Rank tests were used to explore the differences between pre- and immediate post-tape for the two groups for the peak EMG of Gmed, TFL, VM, and VL. For the KTT group, there was a significant difference between pre- and immediate post-tape for peak Gmed EMG in females ($p=0.038$). However, there were no significant differences between pre- and immediate post-tape for peak Gmed EMG in males ($p=0.929$) and peak EMG of TFL, VM, and VL in both females and males ($p>0.05$), Table 6-19. For the KTNT group, there was a significant main effect of pre-immediate post-tape for peak EMG of Gmed, TFL, and VM in females ($p=0.047$, $p=0.028$, $p=0.022$), respectively. No significant differences between pre- and immediate post-tape were seen for peak EMG of Gmed, TFL, VM in males ($p=0.203$, $p=0.445$, $p=0.575$), respectively, and peak EMG of VL in both females and males ($p=0.169$, $p=0.386$), respectively, Table 6-19.

Mann-Whitney U tests were used to explore the differences in the peak EMG of Gmed, TFL, VM, and VL between the KTT and KTNT groups, and sexes. These showed a significant difference between groups at pre-tape for the peak VM EMG ($p=0.030$) but no significant difference was seen at immediate post-tape ($p=0.372$). However, there was no a significant difference between KTT and KTNT group at pre-tape and immediate post-tape for peak EMG of Gmed, TFL, and VL ($p>0.05$), Table 6-19.

In addition, the Mann-Whitney U tests demonstrated significant differences between sexes for peak EMG of Gmed and VL at immediate post-tape in the KTT group (p=0.044, p=0.044), respectively. This showed that males had a significantly greater peak Gmed EMG and VL compared to females at immediate post-tape. However, no significant differences were seen between sexes for peak EMG of TFL and VM in both pre-tape and immediate post-tape in both the KTT and KTNT groups (p>0.05), Table 6-19. Therefore, the peak EMG of TFL and VM can be further analysed with mixed sexes using Wilcoxon Sign Rank tests which showed a significant decrease in immediate post-tape for the peak EMG of TFL in both the KTT (p=0.048) and KTNT groups (p=0.04). In addition, there was a significant decrease in immediate post-tape for the peak EMG of VM in the KTNT group (p=0.037) but no significant difference was seen in the KTT group (p=0.204), Table 6-20.

Table 6-17 Mean (SD) and Mixed Methods ANOVA for normalised values from peak EMG signal analysis in each group during stance phase.

Peak Normalised EMG	KTT group				KTNT group				P-value (ηp^2)		
	Females (n=9)		Males (n=11)		Females (n=10)		Males (n=10)		Pre-Immediate post effect	Group effect	Sex effect
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape			
Gmax	0.535 (0.191)	0.527 (0.176)	0.683 (0.111)	0.625 (0.083)	0.580 (0.118)	0.517 (0.138)	0.626 (0.118)	0.571 (0.106)	0.114 (0.068)	0.538 (0.011)	0.008* (0.182)

* Significant main effect at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

Table 6-18 Pairwise comparison for sex differences of peak EMG.

Peak Normalised EMG	Mean Difference (Female vs Male)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Gmax	-0.086	0.008*	-0.148	-0.024

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

Table 6-19 Median (Q1, Q3) and Wilcoxon Sign Rank test within the two groups and two sexes separately, and Mann-Whitney U-tests for between group for normalised values from peak EMG signal analysis in each group during stance phase.

Peak Normalised EMG	KTT group				KTNT group				P-value	
	Females (n=9)		Males (n=11)		Females (n=10)		Males (n=10)		Between Group Pre-tape	Between Group Immediate post-tape
	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape	Pre-tape	Immediate post-tape		
Gmed [a]	0.653 (0.567, 0.748)	0.438 (0.293, 0.638)	0.675 (0.587, 0.753)	0.714 (0.579, 0.794)	0.668 (0.648, 0.746)	0.599 (0.463, 0.716)	0.654 (0.625, 0.726)	0.647 (0.472, 0.673)	0.957	0.829
Pre-post tape (p-value)	0.038*		0.929		0.047*		0.203			
TFL	0.690 (0.508, 0.753)	0.622 (0.534, 0.649)	0.787 (0.617, 0.815)	0.606 (0.499, 0.643)	0.643 (0.589, 0.749)	0.485 (0.354, 0.621)	0.691 (0.550, 0.759)	0.591 (0.524, 0.663)	0.291	0.279
Pre-immediate post tape (p-value)	0.374		0.075		0.028*		0.445			
VM	0.637 (0.516, 0.769)	0.637 (0.423, 0.712)	0.679 (0.597, 0.710)	0.652 (0.500, 0.734)	0.767 (0.706, 0.814)	0.606 (0.565, 0.736)	0.691 (0.621, 0.802)	0.689 (0.580, 0.787)	0.030*	0.372
Pre-immediate post tape (p-value)	0.441		0.131		0.022*		0.575			
VL [a]	0.734 (0.623, 0.785)	0.571 (0.499, 0.631)	0.629 (0.555, 0.768)	0.648 (0.550, 0.714)	0.704 (0.460, 0.751)	0.690 (0.608, 0.767)	0.682 (0.575, 0.772)	0.668 (0.594, 0.701)	0.685	0.048*
Pre-immediate post tape (p-value)	0.066		0.790		0.169		0.386			

* Significant difference at the 0.05 level. Normalised to 1 which represents the maximum observed signal.

[a] = significant between sexes at pre-tape in KTT group.

Table 6-20 The Wilcoxon Sign Rank tests results for pre-immediate post-tape in KTT and KTNT groups.

Peak Normalised EMG	KTT group		KTNT group	
	Median Difference	P-value	Median Difference	P-value
TFL	0.119	0.048*	0.127	0.040*
VM	0.029	0.108	0.075	0.037*

* Significant difference at the 0.05 level.

Normalised to 1 which represents the maximum observed signal.

6.3.10 Clinical Outcome Measures

6.3.10.1 Numerical Pain Rating scale (NPRS)

NPRS was found to be non-normally distributed. Therefore, the Friedman test was used to explore the differences between pre-tape, immediate post-tape, day 4, and day 7 of taping for the two groups for the NPRS. For the KTT group, there was a significant difference between pre-tape, immediate post-tape, day 4, and day 7 of taping for NPRS in both females ($p<0.001$, $W=0.896$) and males ($p<0.001$, $W=0.799$). In addition, for the KTNT group, a significant difference between pre-tape, immediate post-tape, day 4, and day 7 of taping was seen for NPRS in both females ($p<0.001$, $W=0.726$) and males ($p<0.001$, $W=0.582$).

The Mann-Whitney U tests demonstrated no significant difference between sexes for NPRS at pre-tape, immediate post-tape, day 4, and day 7 of taping in both KTT and KTNT groups ($p>0.05$), Table 6-21. Therefore, the comparison within groups for NPRS with mixed sexes can be further analysed using Friedman test. The Friedman test showed a significant difference for NPRS in the KTT group ($p<0.001$, $W=0.838$), and KTNT group ($p<0.001$, $W=0.650$) between pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping. The Wilcoxon Signed Rank test was used to further explore any differences between time points within the two groups separately. For the KTT group, the Wilcoxon Signed Rank test showed significantly lower NPRS scores immediately post-tape compared to pre-tape ($p<0.001$), day 4 of taping compared to pre-tape ($p<0.001$), day 7 compared to pre-tape ($p<0.001$), day 4 of taping compared to immediate post-tape

(p=0.008), and day 7 of taping compared to immediate post-tape (p=0.002). However, there was no significant difference between day 7 of taping compared to day 4 of taping (p=0.596). For the KTNT group, the Wilcoxon Signed Rank test showed significantly lower NPRS scores immediately post-tape compared to pre-tape (p<0.001), day 4 of taping compared to pre-tape (p<0.001), day 7 of taping compared to pre-tape (p<0.001), and day 7 of taping compared to immediate post-tape (p=0.005). There was no significant difference between day 4 of taping compared to immediate post-tape (p=0.212) and day 7 of taping compared to day 4 of taping (p=0.064), Table 6-22. Figure 6-11 presents the comparison between pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping for NPRS in both the KTT and KTNT groups.

The Mann-Whitney U tests showed a significant difference between the KTT and KTNT groups at pre-tape (p=0.006) and day 4 of taping (p=0.007). However, there was no significant difference immediately post-tape (p=0.128) and day 7 of taping (p=0.211), Table 6-21.

Table 6-21 Median (Q1, Q3), Friedman test for within the two groups and two sexes separately, and Mann-Whitney U-tests for between groups and between sexes for NPRS.

NPRS	KTT group		P-value	KTNT group		P-value	P-value
	Females (n=9)	Males (n=11)	Sex difference	Females (n=10)	Males (n=10)	Sex difference	Between Group
Pre-tape	6 (4.5, 7)	5 (4, 7)	0.290	4 (3, 4)	4 (3, 6.25)	0.334	0.006*
Immediate post-tape	2 (1.5, 3)	1 (0, 2)	0.160	2 (1.75, 3.25)	2.5 (0.75, 5.25)	0.817	0.128
Day 4	1 (0, 2)	0 (0, 2)	0.390	2 (1, 3.25)	2 (1, 4.25)	0.641	0.007*
Day 7	1 (0.5, 2.5)	0 (0, 1)	0.066	1 (0, 2.5)	1 (0, 3.5)	0.585	0.211
P value within sexes each group (W)	<0.001* (0.896)	<0.001* (0.799)		<0.001* (0.726)	<0.001* (0.582)		

* Significant difference at the 0.05 level.

Table 6-22 The Wilcoxon Sign Rank tests results for NPRS between pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping in KTT and KTNT groups.

NPRS	KTT group		KTNT group	
	Median Difference	P-value	Median Difference	P-value
Pre-tape vs Immediate post-tape	4	<0.001*	2	<0.001*
Pre-tape vs Day 4 of taping	5.5	<0.001*	2	<0.001*
Pre-tape vs Day 7 of taping	5	<0.001*	3	<0.001*
Immediate post-tape vs Day 4 of taping	1.5	0.008*	0	0.212
Immediate post-tape vs Day 7 of taping	1	0.002*	1	0.005*
Day 4 of taping vs Day 7 of taping	-0.5	0.596	1	0.064

* Significant difference at the 0.05 level.

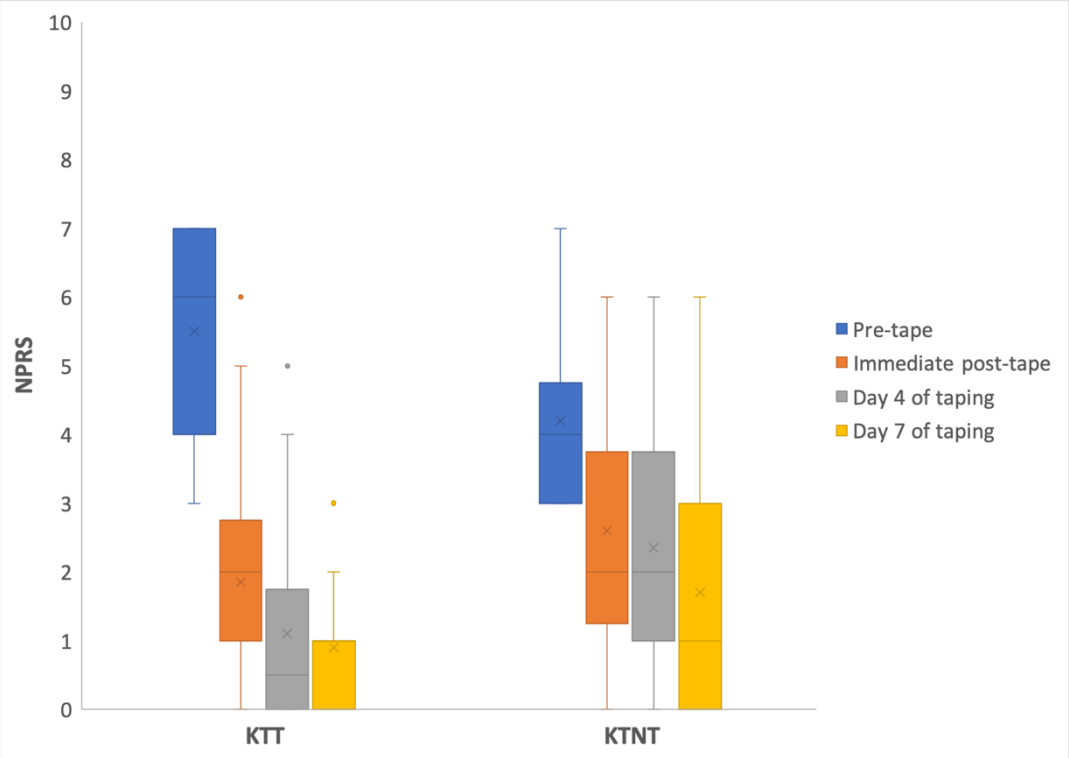


Figure 6-11 NPRS scores across time points for KTT and KTNT groups.

6.3.10.2 Knee Injury and Osteoarthritis Outcome Score (KOOS)

KOOS was found to be non-normally distributed. Differences between pre-tape and day 7 of taping for the two groups were explored using Wilcoxon Sign Rank tests. The Wilcoxon Sign Rank tests showed a significant increase in KOOS score from pre-tape to day 7 of taping in the KTT group for domains of pain in males (p=0.034), symptoms in females (p=0.035), ADL in both females and males (p=0.035, p=0.017), respectively, and sport and recreation in both females and males (p=0.028, p=0.007), respectively. However, there was no significant difference in the KOOS scores for domains of pain in females (p=0.080), symptoms in males (p=0.812), and knee-related quality of life in both females and males (p=0.065, p=0.088), respectively. For the KTNT group, there was a significant increase in the KOOS scores from pre-tape to day 7 of taping in the domains of ADL in females (p=0.007), however no significant difference was seen in males (p=0.394). In addition, no significant difference was seen for domains of pain, symptoms, sport and recreation, and knee-related quality of life in both females and males (p>0.05), Table 6-23. Figure 6-12 showed the comparison between pre-tape and day 7 of taping for the KOOS scores in the KTT and KTNT groups.

Mann-Whitney U tests showed no significant difference between the KTT and KTNT groups at pre-tape and day 7 of taping for all domains of the KOOS score (p>0.05), Table 6-23. In addition, the Mann-Whitney U tests demonstrated no significant difference between sexes for all domains of the KOOS score between pre-tape and day 7 of taping in both the KTT and KTNT groups (p>0.05). Therefore, the comparison for all domains of the KOOS score within groups with mixed sexes can be further analysed using Wilcoxon Signed Rank tests. These showed a significant increase in the KOOS score from pre-tape to day 7 of taping in the KTT group for the domains of pain (p=0.009), symptoms (p=0.046), ADL (p=0.002), sport and recreation (p=0.001), and knee-related quality of life (p=0.011). For the KTNT group, there was a significant increase in the KOOS score from pre-tape to day 7 of taping for ADL (p=0.022), but no significant differences were seen for the domains of pain (p=0.329), symptoms (p=0.285), sport and recreation (p=0.170), and knee-related quality of life (p=0.645), Table 6-24.

Table 6-23 Median (Q1, Q3) and Wilcoxon Sign Rank test within the two groups and two sexes separately, and Mann-Whitney U-tests for between groups and between sexes for KOOS scores.

KOOS scores	KTT group				KTNT group				P-value	
	Females (n=9)		Males (n=11)		Females (n=10)		Males (n=10)		Between Group Pre-tape	Between Group Day 7 of taping
	Pre-tape	Day 7 of taping	Pre-tape	Day 7 of taping	Pre-tape	Day 7 of taping	Pre-tape	Day 7 of taping		
Pain	88.89 (72.23, 98.61)	97.22 (93.06, 98.61)	88.89 (77.78, 100)	97.22 (86.11, 100)	87.50 (80.55, 97.22)	93.06 (84.72, 95.14)	90.28 (83.33, 95.83)	91.67 (82.64, 95.83)	0.989	0.062
Pre-tape- Day 7 of taping (p-value)	0.080		0.034*		0.207		0.833			
Symptoms	75 (67.86, 89.29)	92.86 (85.71, 100)	92.86 (71.43, 96.43)	89.29 (75.00, 96.43)	73.22 (66.97, 89.29)	83.93 (74.11, 92.86)	83.93 (81.25, 93.75)	83.93 (73.22, 97.32)	0.714	0.121
Pre-tape-Day 7 of taping (p-value)	0.035*		0.812		0.123		0.953			
ADL	95.59 (86.77, 97.06)	98.53 (95.59, 100)	95.59 (89.71, 98.53)	97.06 (94.12, 100)	95.59 (88.97, 98.53)	97.80 (95.22, 100)	97.06 (86.77, 98.90)	95.59 (94.12, 97.43)	0.521	0.196
Pre-tape-Day 7 of taping (p-value)	0.035*		0.017*		0.007*		0.394			
Sport and Recreation	80.00 (67.50, 85.00)	90.00 (82.50, 97.50)	70.00 (65.00, 80.00)	90.00 (75.00, 95.00)	77.50 (67.50, 96.25)	87.50 (78.75, 96.25)	80.00 (70.00, 91.25)	85.00 (75.00, 90.00)	0.230	0.273
Pre-tape-Day 7 of taping (p-value)	0.028*		0.007*		0.215		0.570			
Knee-related quality of life	62.50 (43.75, 78.13)	75.00 (59.38, 87.50)	68.75 (56.25, 87.50)	75.00 (68.75, 81.25)	68.75 (56.25, 76.56)	68.75 (59.38, 87.50)	65.63 (56.25, 75.00)	71.88 (48.44, 81.25)	0.859	0.340
Pre-tape-Day 7 of taping (p-value)	0.065		0.088		0.677		0.720			

* Significant difference at the 0.05 level.

Table 6-24 The Wilcoxon Sign Rank tests results for KOOS score between pre-tape and day 7 of taping in KTT and KTNT groups.

KOOS scores	KTT group		KTNT group	
	Median Difference (Day 7 of taping vs Pre-tape)	P-value	Median Difference (Day 7 of taping vs Pre-tape)	P-value
Pain	8.33	0.009*	2.78	0.329
Symptoms	7.15	0.046*	1.79	0.285
ADL	2.94	0.002*	1.47	0.022*
Sport and Recreation	15.00	0.001*	5.00	0.170
Knee-related quality of life	9.38	0.011*	6.25	0.645

* Significant difference at the 0.05 level.

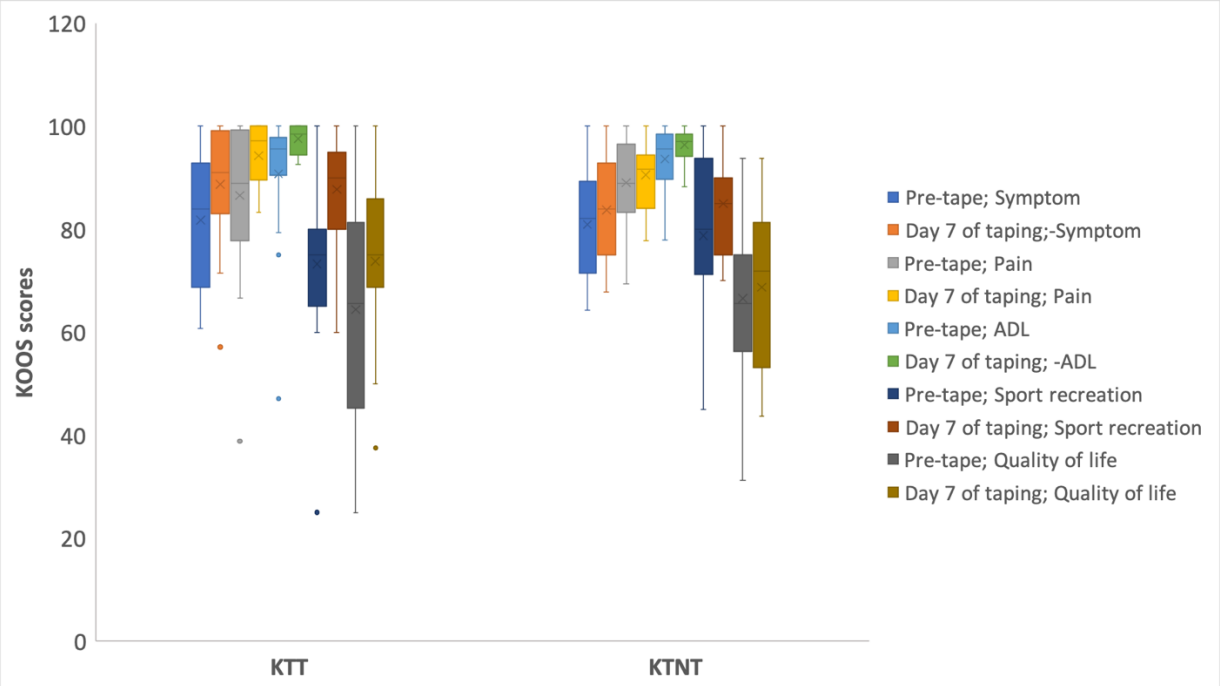


Figure 6-12 Comparison between pre-tape and day 7 of taping for KOOS scores in KTT and KTNT groups.

6.3.10.3 Tampa Scale for Kinesiophobia (TSK)

TSK was found to be non-normally distributed. Therefore, the Friedman test was used to explore the differences between pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping for the two groups for the TSK. Both the KTT and KTNT groups, there was no significant difference between pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping for TSK in both females and males ($p>0.05$), Table 6-25.

Mann-Whitney U tests showed no significant difference between KTT and KTNT group at pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping ($p>0.05$), Table 6-25. In addition, the Mann-Whitney U tests demonstrated no significant difference between sexes for TSK at pre-tape, immediate post-tape, day 4, and day 7 of taping in both KTT and KTNT groups ($p>0.05$), Table 6-25. Therefore, the comparison within groups for TSK with mixed sexes can be further analysed using Friedman test. However, the Friedman test showed no significant difference for TSK within both the KTT group ($p=0.138$) and KTNT group ($p=0.052$) between pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping.

Table 6-25 Median (Q1, Q3), Friedman test for within the two groups and two sexes separately, and Mann-Whitney U-tests for between groups and between sexes for TSK.

TSK	KTT group		P-value	KTNT group		P-value	P-value
	Females (n=9)	Males (n=11)	Sex difference	Females (n=10)	Males (n=10)	Sex difference	Between Group
Pre-tape	47 (41.5, 49)	43 (39, 43)	0.252	41.5 (40.75, 45.25)	43.5 (40.75, 45.5)	0.760	0.447
Immediate post-tape	45 (41.5, 48)	42 (37, 46)	0.169	42 (38.25, 46)	43.5 (41.25, 45.75)	0.568	0.892
Day 4	45 (39.5, 50.5)	41 (39, 44)	0.110	42.5 (39, 45.5)	41.5 (39, 45.75)	0.909	0.989
Day 7	42 (39, 47)	40 (36, 42)	0.194	40 (38.75, 46)	40.5 (36.5, 44.25)	0.909	0.871
P value within sexes each group (W)	0.670 (0.057)	0.194 (0.143)		0.422 (0.094)	0.074 (0.231)		

6.3.10.4 Global Rating Of Change Scale (GROC)

GROC was found to be non-normally distributed. Therefore, the Friedman test was used to explore the differences between immediate post-tape, day 4, and day 7 of taping for the two groups for the GROC. For the KTT group, there was a significant difference between immediate post-tape, day 4, and day 7 of taping for GROC in both females ($p<0.001$, $W=0.933$) and males ($p=0.013$, $W=0.396$). In addition, for the KTNT group, a significant difference between immediate post-tape, day 4, and day 7 of taping was seen for GROC in both females ($p<0.001$, $W=0.760$) and males ($p<0.001$, $W=0.663$), Table 6-26.

The Wilcoxon Signed Rank test was used to further explore to determine any differences between time points within the two groups separately. For females in the KTT group, the Wilcoxon Signed Rank test showed a significantly greater GROC score at day 4 of taping compared to immediate post-tape ($p=0.007$), and day 7 of taping compared to immediate post-tape ($p=0.007$). However, there was no significant difference between day 7 of taping compared to day 4 of taping ($p=0.083$), Table 6-27. For the males in the KTT group, the Wilcoxon Signed Rank test showed a significantly greater GROC score at day 4 of taping compared to immediate post-tape ($p=0.021$), and day 7 of taping compared to immediate post-tape ($p=0.020$). However, no significant difference was seen between day 7 of taping compared to day 4 of taping ($p=0.480$), Table 6-27. For the females in the KTNT group, the Wilcoxon Signed Rank test showed a significantly greater GROC score at day 4 of taping compared to immediate post-tape ($p=0.039$), day 7 of taping compared to immediate post-tape ($p=0.007$), and day 7 of taping compared to day 4 of taping ($p=0.014$), Table 6-28. For the males in the KTNT group, the Wilcoxon Signed Rank test showed a significantly greater GROC score at day 4 of taping compared to immediate post-tape ($p=0.026$), and day 7 of taping compared to immediate post-tape ($p=0.007$). However, no significant difference was seen between day 7 of taping compared to day 4 of taping ($p=0.292$), Table 6-28.

The Mann-Whitney U tests showed significant differences between the KTT and KTNT groups at immediate post-tape ($p=0.003$), day 4 of taping ($p<0.001$), and day 7 of taping ($p=0.004$), Table 6-26. Figure 6-13 presents the comparison between immediate post-tape, day 4 of taping, and day 7 of taping for GROC in the KTT and KTNT groups.

Moreover, the Mann-Whitney U tests demonstrated a significant difference between sexes for GROC at immediate post-tape ($p=0.021$) in KTT group but this was not seen in the KTNT group. In addition, there was no significant difference between sexes for the GROC score at day 4, and day 7 of taping in both KTT and KTNT groups ($p>0.05$), Table 6-26. Therefore, the GROC cannot be further analysed with mixed sexes.

The number of participants for each GROC score category for the KTT and KTNT groups are shown in Figure 6-14 and Figure 6-15. This study used a 15-point GROC score (-7 to +7), for the KTT group, 12 participants indicated a clinically important change (+5 or greater) at immediate post-tape with the remainder indicating no clinically important change (between -4 and +4), with one reporting a clinically important negative effect on GROC. At day 4 and day 7 of taping, 18 participants indicated a clinically important change, with no participant reporting any negative clinically important changes. For the KTNT group, three participants at immediate post-tape indicated a clinically important change (+5 or greater), while 7 and 11 participants reported a clinically important change at day 4 and day 7 of taping, respectively, with no participant reporting a clinically important negative effect on GROC at immediate post-tape, day 4 and day 7 of taping.

Table 6-26 Median (Q1, Q3), Friedman test for within the two groups and two sexes separately, and Mann-Whitney U-tests for between groups and between sexes for GROC.

GROC	KTT group		P-value	KTNT group		P-value	P-value
	Females (n=9)	Males (n=11)	Sex difference	Females (n=10)	Males (n=10)	Sex difference	Between Group
Immediate post-tape	4 (2, 5)	5 (5, 6)	0.021*	1.5 (0, 4.25)	2.5 (0, 3.25)	0.847	0.003*
Day 4	6 (5, 6)	6 (5, 7)	0.204	4 (2.75, 6)	3.5 (2.5, 5)	0.465	<0.001*
Day 7	6 (5, 6.5)	6 (6, 7)	0.303	5.5 (3.75, 6.25)	4 (3, 5.25)	0.178	0.004*
P value within sexes each group (W)	<0.001* (0.933)	0.013* (0.396)		<0.001* (0.760)	0.001* (0.663)		

* Significant difference at the 0.05 level.

Table 6-27 The Wilcoxon Sign Rank tests results for GROC between immediate post-tape, day 4 of taping, and day 7 of taping for females and males in KTT group.

GROC	Females		Males	
	Median Difference	P-value	Median Difference	P-value
Day 4 of taping vs Immediate post-tape	2	0.007*	1	0.021*
Day 7 of taping vs Immediate post-tape	2	0.007*	1	0.020*
Day 7 of taping vs Day 4 of taping	0	0.083	0	0.480

* Significant difference at the 0.05 level.

Table 6-28 The Wilcoxon Sign Rank tests results for GROC between immediate post-tape, day 4 of taping, and day 7 of taping for females and males in KTNT group.

GROC	Females		Males	
	Median Difference	P-value	Median Difference	P-value
Day 4 of taping vs Immediate post-tape	2.5	0.039*	1	0.026*
Day 7 of taping vs Immediate post-tape	4	0.007*	1.5	0.007*
Day 7 of taping vs Day 4 of taping	1.5	0.014*	0.5	0.292

* Significant difference at the 0.05 level.

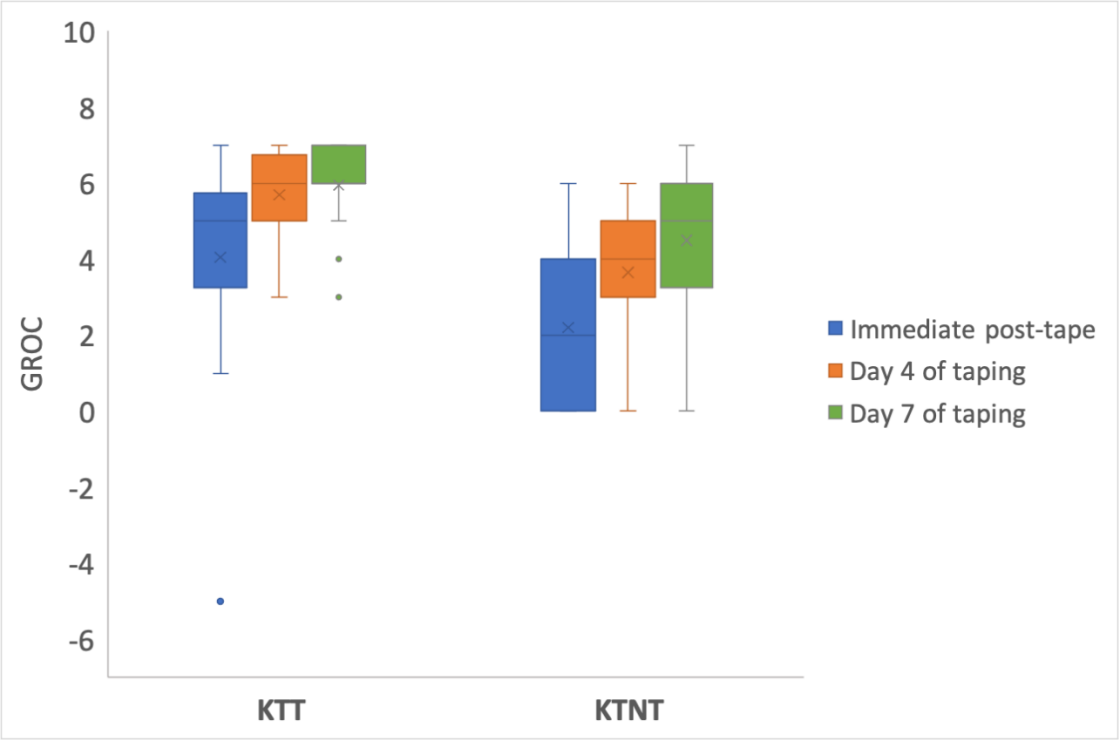


Figure 6-13 Comparison between immediate post-tape, day 4 of taping, and day 7 of taping for GROC scores in KTT and KTNT groups.

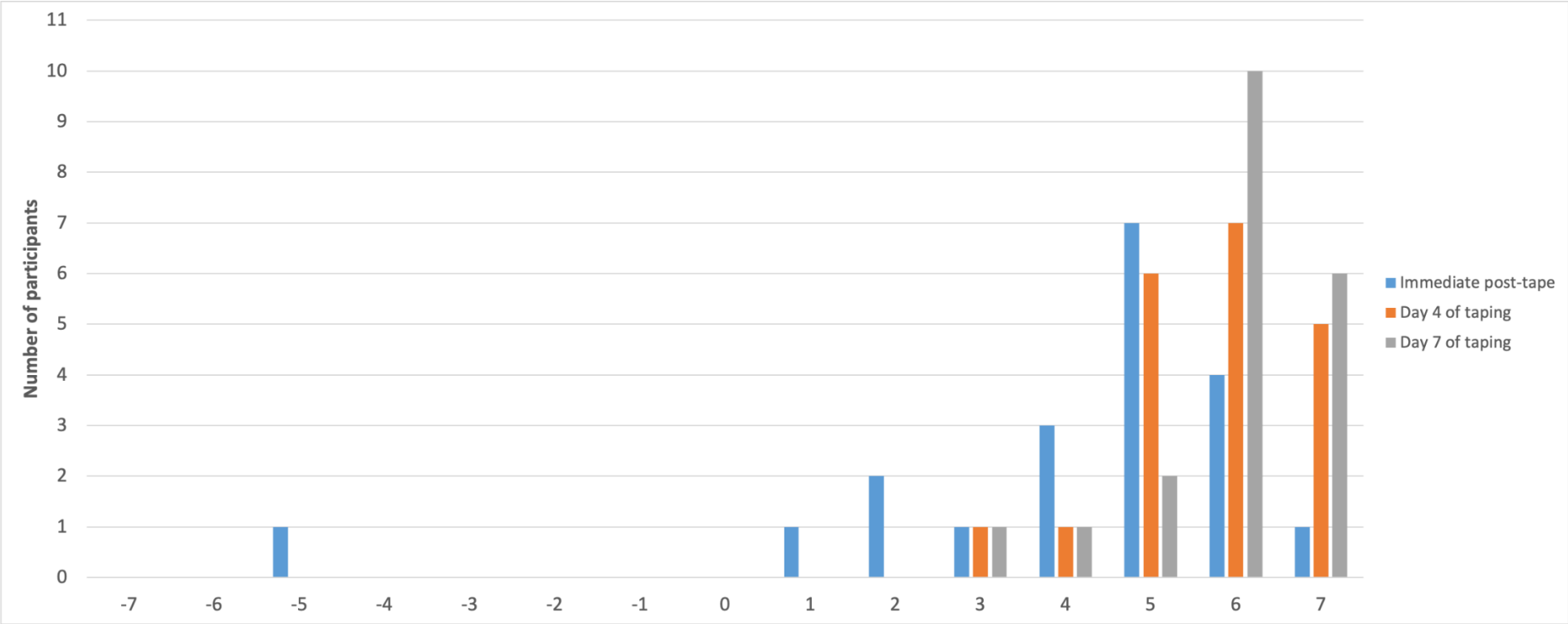


Figure 6-14 Number of participants in each GROC score category in the KTT group between immediate post-tape, day 4 of taping, and day 7 of taping compared to pre-tape. A score of 7 represents a very great deal better, 0 represents no change and -7 represents a very great deal worse. The question asked was "Please rate the overall condition of your iliotibial band syndrome from the time that you began taping until now".

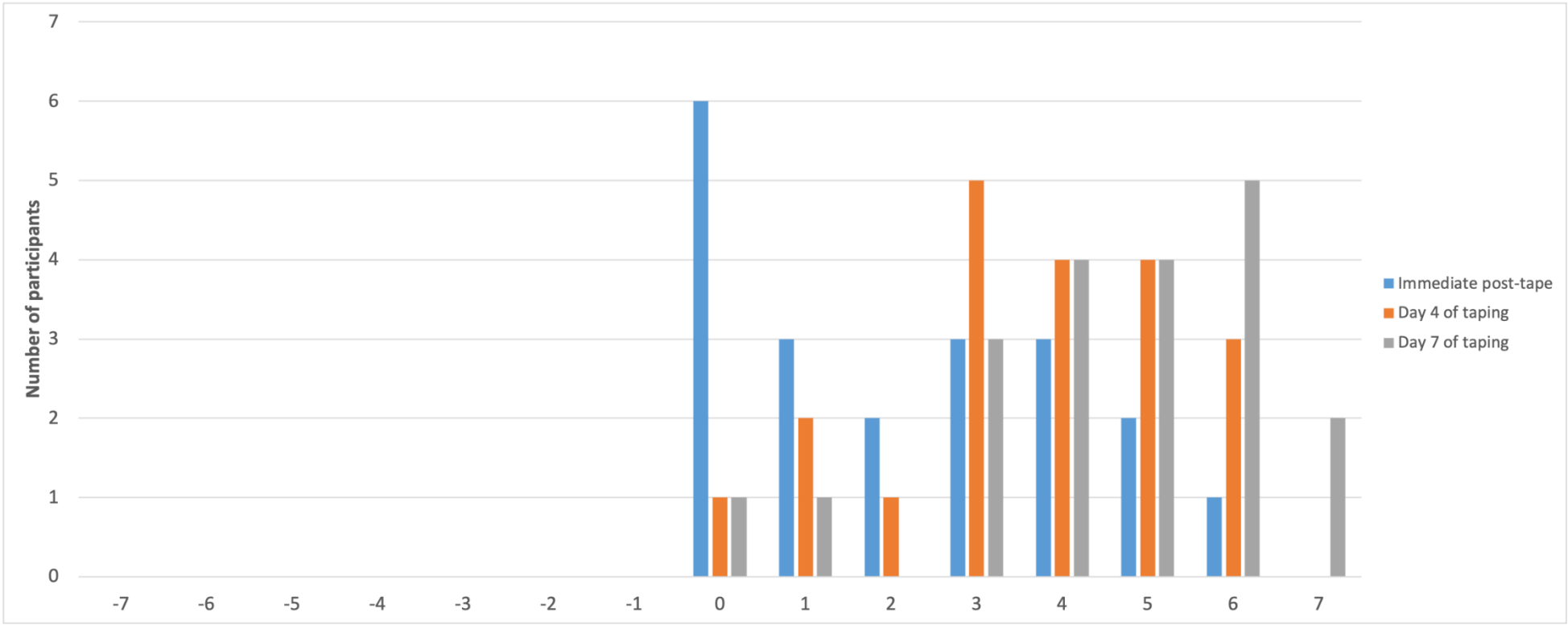


Figure 6-15 Number of participants in each GROC score category in the KTNT group between immediate post-tape, day 4 of taping, and day 7 of taping compared to pre-tape. A score of 7 represents a very great deal better, 0 represents no change and -7 represents a very great deal worse. The question asked was "Please rate the overall condition of your iliotibial band syndrome from the time that you began taping until now".

6.3.10.5 Perceived comfort, stability of the knee joint, and running performance outcomes

6.3.10.5.1 Comfort Scores

Comfort score was found to be non-normally distributed. Therefore, the Friedman test was used to explore the differences between immediate post-tape, day 4 of taping, and day 7 of taping for the two groups for the comfort score. For the KTT group, there was no significant difference between immediate post-tape, day 4 of taping, and day 7 of taping for comfort score in both females ($p=0.289$) and males ($p=0.141$). For the KTNT group, a significant difference between immediate post-tape, day 4 of taping, and day 7 of taping was seen for comfort score in females ($p=0.005$, $W=0.521$) but no significant difference was seen in males ($p=0.196$), Table 6-29.

The Wilcoxon Signed Rank test was used to further explore to determine any differences between time points for the females in the KTNT group. The Wilcoxon Signed Rank test showed a significantly greater comfort score at day 4 of taping compared to immediate post-tape ($p=0.047$), and day 7 of taping compared to immediate post-tape ($p=0.006$). However, there was no significant difference between day 7 of taping compared to day 4 of taping ($p=0.083$), Table 6-30.

The Mann-Whitney U tests showed significant difference between the KTT and KTNT groups at immediate post-tape ($p<0.001$). However, there were no significant differences at day 4 of taping ($p=0.129$) and day 7 of taping ($p=0.068$), Table 6-29. The Mann-Whitney U tests demonstrated a significant difference between sexes for comfort score at day 4 of taping ($p=0.012$) in KTT group and at day 7 of taping ($p=0.015$) in the KTNT group. No significant differences between sexes were seen for comfort score at immediate post-tape and day 7 of taping in the KTT group, and at immediate post-tape and day 4 of taping in the KTNT group ($p>0.05$), Table 6-29. Therefore, the comfort score cannot be further analysed with mixed sexes.

The number of participants for each comfort score category for the KTT and KTNT groups among immediate post-tape, day 4 of taping, and day 7 of taping is shown in Figure 6-16. For the KTT group, 14 participants indicated a clinically important change (+2 or greater)

at immediate post-tape and day 4 of taping, with 16 participants at day 7 of taping revealed a clinically important change, with the remainder indicating no clinically important change (between -1 and +1), with no participant reporting a clinically important negative effect on comfort score (-2 or less). For the KTNT group, one participant at immediate post-tape indicated a clinically important change (+2 or greater), while 9 and 13 participants reported a clinically important change at day 4 and day 7 of taping, respectively, with one participant reporting a clinically important negative effect on comfort score at day 4 and day 7 of taping.

Table 6-29 Median (Q1, Q3), Friedman test for within the two groups and two sexes separately, and Mann-Whitney U-tests for between groups and between sexes for comfort scores.

Comfort scores	KTT group		P-value	KTNT group		P-value	P-value
	Females (n=9)	Males (n=11)	Sex difference	Females (n=10)	Males (n=10)	Sex difference	Between Group
Immediate post-tape	2 (0, 2.5)	2 (1, 2)	0.900	0.5 (0, 1)	0 (0, 0.25)	0.148	<0.001*
Day 4 of taping	1 (0, 2)	2 (2, 3)	0.012*	2 (0.75, 2)	0 (0, 2)	0.123	0.129
Day 7 of taping	2 (1.5, 2)	3 (2, 3)	0.153	2 (2, 2.25)	0.5 (0, 2)	0.015*	0.068
P value within sexes each group (W)	0.289 (0.138)	0.141 (0.178)		0.005* (0.521)	0.196 (0.163)		

* Significant difference at the 0.05 level.

Table 6-30 The Wilcoxon Sign Rank tests results for comfort scores between Immediate post-tape, day 4 of taping, and day 7 of taping for females in KTNT groups.

Comfort scores	Median Difference	P-value
Day 4 of taping vs Immediate post-tape	1.5	0.047*
Day 7 of taping vs Immediate post-tape	1.5	0.006*
Day 7 of taping vs Day 4 of taping	0	0.260

* Significant difference at the 0.05 level.

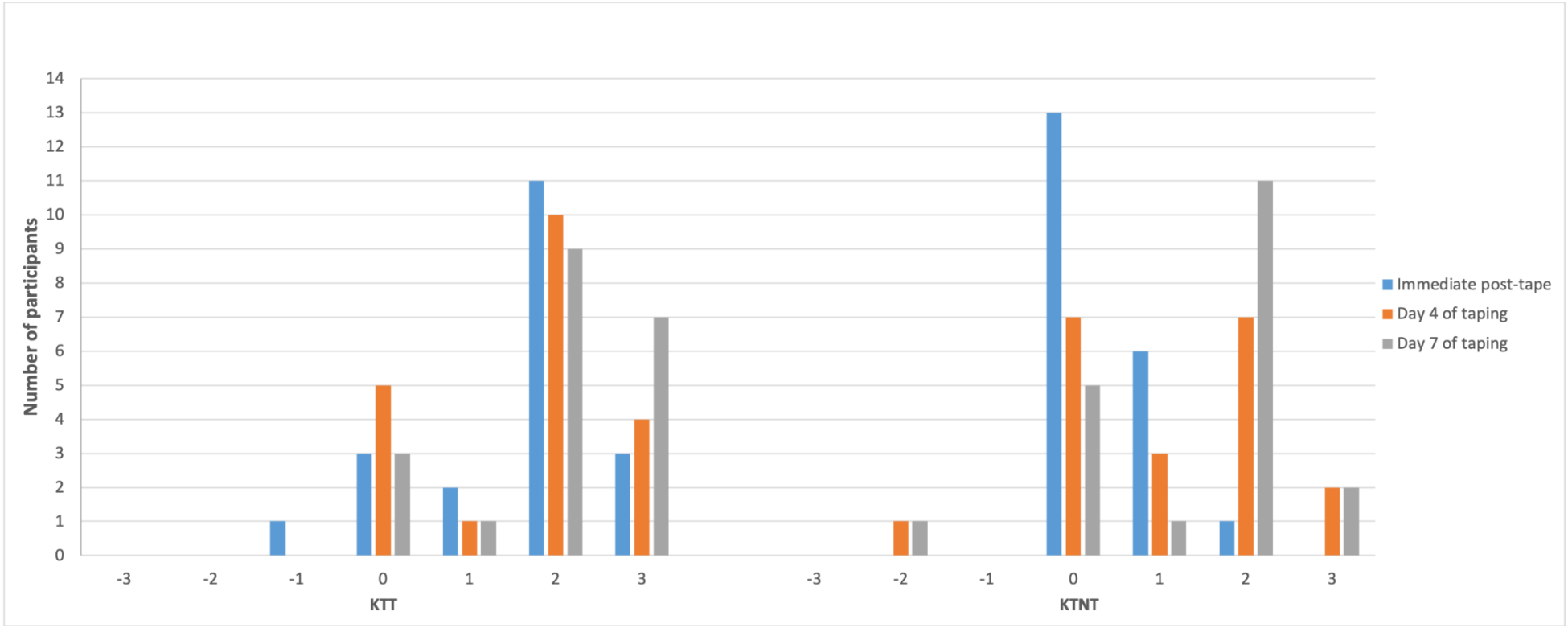


Figure 6-16 Number of participants in each comfort score category in KTT and KTNT groups between immediate post-tape, day 4 of taping, and day 7 of taping compared to pre-tape. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree. The question asked was "Do you think this kinesio tape is comfortable compared to pre-tape?".

6.3.10.5.2 Knee stability scores

The knee stability scores were found to be non-normally distributed. Therefore, the Friedman test was used to explore the differences between immediate post-tape, day 4 of taping, and day 7 of taping for the two groups. For the KTT group, there were significant differences between immediate post-tape, day 4 of taping, and day 7 of taping in both females ($p=0.050$, $W=0.333$) and males ($p=0.013$, $W=0.396$). For the KTNT group, a significant difference between immediate post-tape, day 4 of taping, and day 7 of taping was seen in the females ($p=0.028$, $W=0.358$), but no significant difference was seen in the males ($p=0.554$), Table 6-31.

The Wilcoxon Signed Rank test was used to further explore any differences between time points for both sexes in the KTT group and the females in the KTNT group. For the females in the KTT group, the Wilcoxon Signed Rank test showed a significantly greater knee stability score at day 4 of taping compared to immediate post-tape ($p=0.046$), and day 7 of taping compared to day 4 of taping ($p=0.034$). However, there was no significant difference between day 7 of taping compared to immediate post-tape ($p=0.034$), Table 6-32. For the males in the KTT group, the Wilcoxon Signed Rank test showed a significantly greater knee stability score at day 7 of taping compared to immediate post-tape ($p=0.020$), and day 7 of taping compared to day 4 of taping ($p=0.014$). However, no significant difference was seen between day 4 of taping compared to immediate post-tape ($p=0.655$), Table 6-32. For the females in the KTNT group, the Wilcoxon Signed Rank test showed a significantly greater knee stability score at day 4 of taping compared to immediate post-tape ($p=0.047$), day 7 of taping compared to immediate post-tape ($p=0.026$). However, no significant difference was seen between day 7 of taping compared to day 4 of taping ($p=0.564$), Table 6-33.

The Mann-Whitney U tests showed significant differences between the KTT and KTNT groups at immediate post-tape ($p<0.001$) and day 7 of taping ($p<0.001$). However, there was no significant difference at day 4 of taping ($p=0.690$), Table 6-31. The Mann-Whitney U test demonstrated a significant difference between sexes for knee stability scores at day 7 of taping ($p=0.048$) in the KTT group. No significant difference between sexes was seen for comfort score at immediate post-tape and day 4 of taping in KTT group, and at immediate post-tape, day 4 of taping, and day 7 of taping in KTNT group ($p>0.05$), Table 6-31. Therefore, the knee stability scores cannot be further analysed with mixed sexes.

The number of participants for each knee stability scores category for the KTT and KTNT groups between immediate post-tape, day 4 of taping, and day 7 of taping is shown in Figure 6-17. For the KTT group, 17 participants at immediate post-tape indicated a clinically important change (+2 or greater), while 13 and 20 participants reported a clinically important change at day 4 and day 7 of taping, respectively, with the remainder indicating no clinically important change (between -1 and +1), with no participant reporting a clinically important negative effect on knee stability score (-2 or less). For the KTNT group, 5 participants at immediate post-tape indicated a clinically important change (+2 or greater), while 13 and 14 participants reported a clinically important change at day 4 and day 7 of taping, respectively. No participant reported negative important changes in stability of the knee joint perception at any time point.

Table 6-31 Median (Q1, Q3), Friedman test for within the two groups and two sexes separately, and Mann-Whitney U-tests for between groups and between sexes for knee stability scores.

Knee stability scores	KTT group		P-value	KTNT group		P-value	P-value
	Females (n=9)	Males (n=11)	Sex difference	Females (n=10)	Males (n=10)	Sex difference	Between Group
Immediate post-tape	2 (1.5, 2.5)	2 (2, 2)	0.963	1 (0, 1.25)	1 (0.75, 2)	0.372	<0.001*
Day 4 of taping	2 (1, 2)	2 (1, 3)	0.148	2 (1, 2)	2 (0.75, 2)	0.647	0.690
Day 7 of taping	2 (2, 2)	3 (2, 3)	0.048*	2 (2, 2)	1.5 (1, 2)	0.091	<0.001*
P value within sexes each group (W)	0.050* (0.333)	0.013* (0.396)		0.028* (0.358)	0.554 (0.059)		

* Significant difference at the 0.05 level.

Table 6-32 The Wilcoxon Sign Rank tests results for knee stability scores between immediate post-tape, day 4 of taping, and day 7 of taping for females and males in KTT groups.

Knee stability scores	Females		Males	
	Median Difference	P-value	Median Difference	P-value
Day 4 of taping vs Immediate post-tape	0	0.046*	0	0.655
Day 7 of taping vs Immediate post-tape	0	0.480	1	0.020*
Day 7 of taping vs Day 4 of taping	0	0.034*	1	0.014*

* Significant difference at the 0.05 level.

Table 6-33 The Wilcoxon Sign Rank tests results for knee stability scores between immediate post-tape, Day 4 of taping, and day 7 of taping for females in KTNT groups.

Knee stability scores	Median Difference	P-value
Day 4 of taping vs Immediate post-tape	1	0.047*
Day 7 of taping vs Immediate post-tape	1	0.026*
Day 7 of taping vs Day 4 of taping	0	0.564

* Significant difference at the 0.05 level.

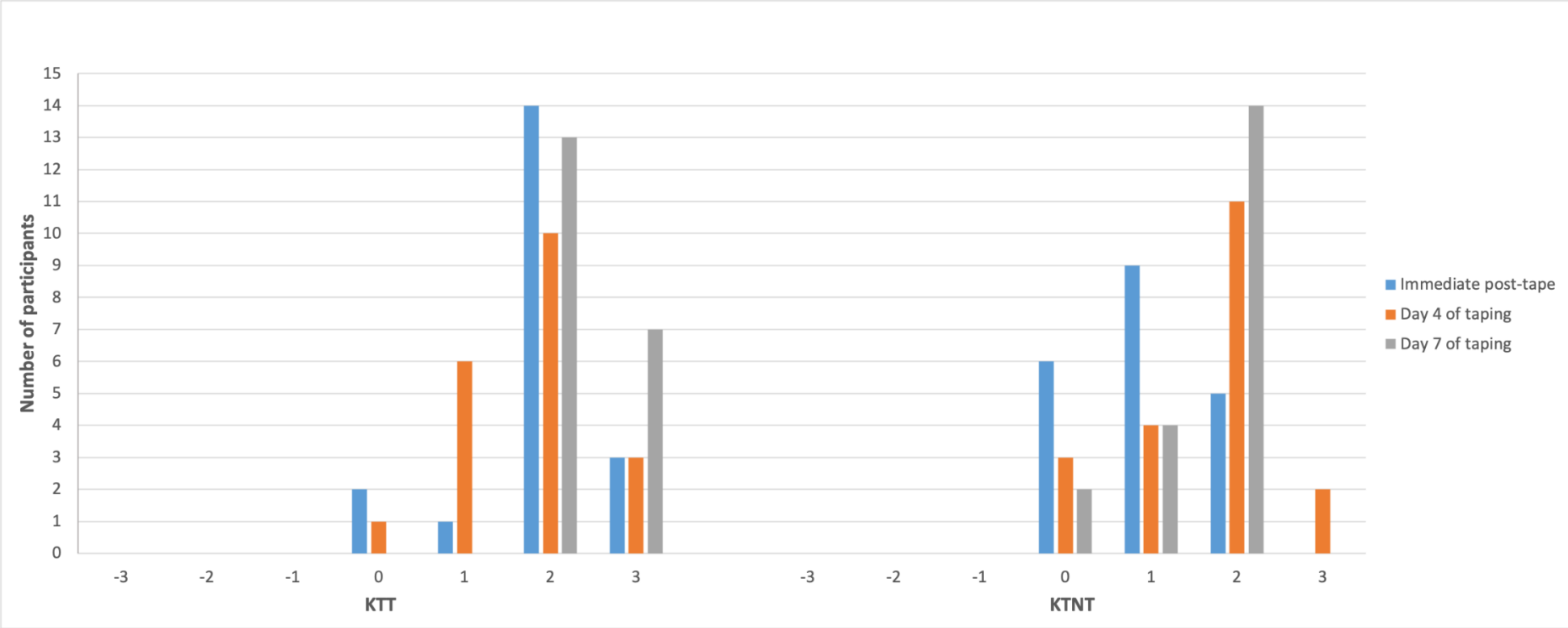


Figure 6-17 Number of participants in each knee stability score category in KTT and KTNT groups between immediate post-tape, day 4 of taping, and day 7 of taping compared to pre-tape. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree. The question asked was "Do you think this kinesio tape helps the stability of your knee compared to pre-tape?".

6.3.10.5.3 Running performance scores

Running performance scores were found to be non-normally distributed. Therefore, the Friedman test was used to explore the differences between immediate post-tape, day 4 of taping, and day 7 of taping for the two groups. For the KTT group, there were significant differences between immediate post-tape, day 4 of taping, and day 7 of taping in both females (p=0.012, W=0.493) and males (p=0.018, W=0.364). For the KTNT group, a significant difference between immediate post-tape, day 4 of taping, and day 7 of taping was seen for running performance scores in females (p=0.018, W=0.400) but no significant difference was seen in males (p=0.317), Table 6-34.

The Wilcoxon Signed Rank test was used to further explore to determine any differences between time points for both sexes in the KTT group and the females in the KTNT group. For females in the KTT group, the Wilcoxon Signed Rank test showed a significantly greater running performance score at day 7 of taping compared to immediate post-tape (p=0.009). However, there was no significant difference between day 4 of taping compared to immediate post-tape (p=0.248), and day 7 of taping compared to day 4 of taping (p=0.131). For males in the KTT group, the Wilcoxon Signed Rank test showed a significantly greater running performance score at day 7 of taping compared to immediate post-tape (p=0.020). However, no significant difference was seen between day 4 of taping compared to immediate post-tape (p=0.059), and day 7 of taping compared to day 4 of taping (p=0.317), Table 6-35. For the females in the KTNT group, the Wilcoxon Signed Rank test showed a significantly greater running performance score at day 4 of taping compared to immediate post-tape (p=0.038), day 7 of taping compared to immediate post-tape (p=0.041). However, no significant difference was seen between day 7 of taping compared to day 4 of taping (p=0.785), Table 6-36.

The Mann-Whitney U tests showed a significant difference between the KTT and KTNT groups at Day 7 of taping (p=0.024) with KTT showing greater running performance scores than KTNT group. However, no significant difference was observed at immediate post-tape (p=0.169) and day 4 of taping (p=0.231), Table 6-34. In addition, the Mann-Whitney U tests demonstrated a significant difference between sexes for running performance scores at immediate post-tape (p=0.022) in the KTT group. No significant

difference between sexes was seen running performance scores at day 4 of taping and day 7 of taping in KTT group, and at immediate post-tape, day 4 of taping, and day 7 of taping in KTNT group ($p>0.05$), Table 6-34. Therefore, the running performance scores cannot be further analysed with mixed sexes.

The number of participants for each running performance scores category for the KTT and KTNT groups between immediate post-tape, day 4 of taping, and day 7 of taping is shown in Figure 6-18. For the KTT group, 9 participants at immediate post-tape indicated a clinically important change (+2 or greater), while 15 and 17 participants reported a clinically important change at day 4 and day 7 of taping, respectively, with the remainder indicating no clinically important change (between -1 and +1), with no participant reporting a clinically important negative effect on benefits to running performance (-2 or less). For the KTNT group, 5 participants at immediate post-tape indicated a clinically important change (+2 or greater), while 12 participants reported a clinically important change at day 4 and day 7 of taping. No participants reporting any negative important changes in perceived running performance at any time point.

Table 6-34 Median (Q1, Q3), Friedman test for within the two groups and two sexes separately, and Mann-Whitney U-tests for between groups and between sexes for running performance scores.

Running performance scores	KTT group		P-value	KTNT group		P-value	P-value
	Females (n=9)	Males (n=11)	Sex difference	Females (n=10)	Males (n=10)	Sex difference	Between Group
Immediate post-tape	0 (0, 1.5)	2 (1, 2)	0.022*	0.5 (0, 2)	1 (0.75, 1.25)	0.519	0.169
Day 4 of taping	2 (0.5, 2)	2 (2, 3)	0.054	2 (1, 2)	1.5 (1, 2.25)	0.870	0.231
Day 7 of taping	2 (1.5, 2.5)	3 (2, 3)	0.148	2 (0.75, 2.25)	1.5 (0.75, 2)	0.447	0.024*
P value within sexes each group (W)	0.012* (0.493)	0.018* (0.364)		0.018* (0.400)	0.317 (0.115)		

* Significant difference at the 0.05 level.

Table 6-35 The Wilcoxon Sign Rank tests results for running performance scores between immediate post-tape, day 4 of taping, and day 7 of taping for females and males in KTT groups.

Running performance scores	Females		Males	
	Median Difference	P-value	Median Difference	P-value
Day 4 of taping vs Immediate post-tape	2	0.248	0	0.059
Day 7 of taping vs Immediate post-tape	2	0.009*	1	0.020*
Day 7 of taping vs Day 4 of taping	0	0.131	1	0.317

* Significant difference at the 0.05 level.

Table 6-36 The Wilcoxon Sign Rank tests results for running performance between immediate post-tape, day 4 of taping, and day 7 of taping for females in KTNT groups.

Running performance scores	Median Difference	P-value
Day 4 of taping vs Immediate post-tape	1.5	0.038*
Day 7 of taping vs Immediate post-tape	1.5	0.041*
Day 7 of taping vs Day 4 of taping	0	0.785

* Significant difference at the 0.05 level.

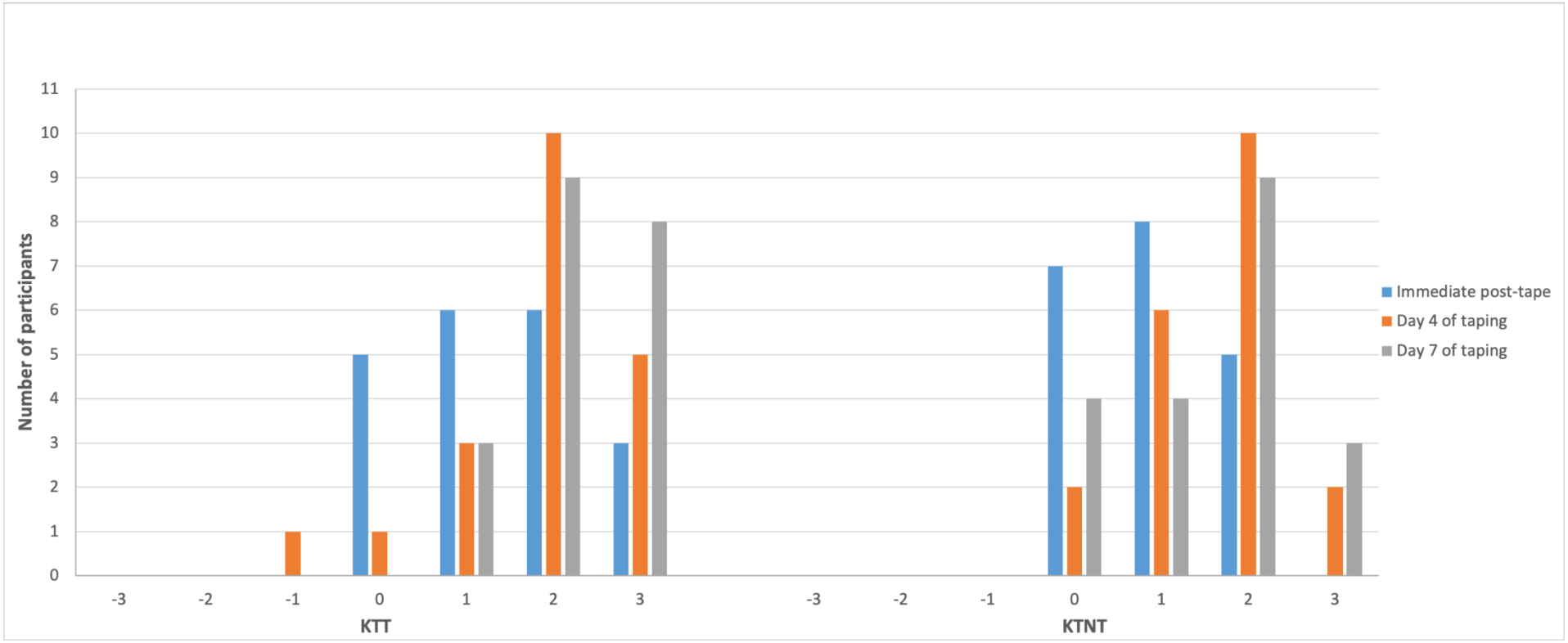


Figure 6-18 Number of participants in each running performance score category in KTT and KTNT groups between immediate post-tape, day 4 of taping, and day 7 of taping compared to pre-tape. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree. The question asked was "Do you think this kinesio tape offers benefits to your running performance compared to pre tape?".

6.3.11 Clinical Assessments

6.3.11.1 Muscle strength test

The hip isometric strength for both hip abduction and hip external rotation of the study limb were found to be normally distributed. Unpaired t-tests showed no pre-tape differences between groups ($p>0.05$).

The Mixed Methods ANOVA tests showed no significant interactions between group and pre-immediate post-tape, and between sex and pre-immediate post-tape in both hip abduction and hip external rotation isometric strength test ($p>0.05$), Table 6-37. The Mixed Methods ANOVA showed no significant main effects for pre-immediate post-tape for both hip abduction and hip external rotation isometric strength test ($p=0.177$, $p=0.205$), respectively. In addition, no significant main effects for group were observed for both the hip abduction and hip external rotation isometric strength test ($p=0.601$, $p=0.760$), respectively, and no significant main effects for sex ($p=0.410$, $p=0.728$), respectively, Table 6-37.

Table 6-37 Mean (SD) and repeated measures ANOVA for hip isometric strength of affected side in each group.

Hip isometric strength (Nm/kg)	KTT group		KTNT group		P-value (η_p^2)		
	Females (n=9)	Males (n=11)	Females (n=10)	Males (n=10)	Pre-Immediate post effect	Group effect	Sex effect
Hip abduction							
Pre-tape	9.38 (4.11)	10.24 (4.48)	9.90 (4.90)	12.40 (6.09)	0.177 (0.05)	0.601 (0.008)	0.410 (0.019)
Immediate post-tape	10.49 (4.87)	11.01 (3.85)	10.43 (4.45)	11.53 (5.18)			
Hip external rotation							
Pre-tape	6.69 (1.04)	6.53 (2.00)	6.67 (1.31)	6.62 (1.71)	0.205 (0.044)	0.760 (0.003)	0.728 (0.003)
Immediate post-tape	6.69 (1.11)	7.25 (1.62)	6.48 (1.19)	6.80 (2.10)			

6.3.11.2 Assessment of the length of tensor fascia latae (TFL) and Iliotibial Band (ITB)

The TFL and ITB length test of the affected side was found to be normally distributed. Unpaired t-tests showed no pre-tape differences between groups in the TFL and ITB length test ($p>0.05$).

The Mixed Methods ANOVA tests results showed a significant interaction between group and pre-immediate post-tape for TFL and ITB length test, Table 6-38. Post hoc paired t-tests showed a significant increase in the TFL and ITB length test after taping in both the KTT group by 4.95 degrees ($p<0.001$) and the KTNT group ($p=0.006$) by 1.31 degrees, Table 6-39. However, no significant difference was seen between sex and pre-immediate post-tape ($p>0.05$). The Mixed Methods ANOVA showed a significant main effect for pre-immediate post-tape for the TFL and ITB length test ($p<0.001$, $\eta_p^2=0.570$), Table 6-38. The LSD post hoc test showed that there was a significant increase in the TFL and ITB length test with 3.09 degrees after taping in affected side, Table 6-40. In addition, a significant main effect was seen for group ($p=0.007$, $\eta_p^2=0.183$), Table 6-38. The LSD post hoc test showed that the KTT group had a significantly greater TFL and ITB length test in the affected side compared to the KTNT group with 3.10 degrees, Table 6-41. However, the Mixed Methods ANOVA showed no significant main effect for sex ($p=0.174$), Table 6-38.

Table 6-38 Mean (SD) and repeated measures ANOVA for TFL and ITB length of affected side in each group.

ITB and TFL muscle length $^{\lambda}$ (degrees)	KTT group		KTNT group		P-value (ηp^2)		
	Females (n=9)	Males (n=11)	Females (n=10)	Males (n=10)	Pre-Immediate post effect	Group effect	Sex effect
Pre-tape	11.64 (4.20)	9.67 (3.56)	10.00 (2.55)	8.67 (2.76)	<0.001 *	0.007*	0.174
Immediate post-tape	15.76 (3.98)	15.30 (5.69)	11.80 (2.69)	9.48 (3.14)	(0.570)	(0.183)	(0.051)

* Significant main effect at the 0.05 level.

$^{\lambda}$ = significant interaction between Group x Pre-Immediate post-tape.

Table 6-39 The Pair t–test for TFL and ITB length of affected side in each group separately.

Group	Mean Difference (Pre-tape vs Immediate post-tape)	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT	-4.95	<0.001*	-6.60	-3.30
KTNT	-1.31	0.006*	-2.18	-0.43

* Significant difference at the 0.05 level.

Table 6-40 Pairwise comparisons of main pre-immediate post-tape effect for TFL and ITB length of affected side.

ITB and TFL muscle length (degrees)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
Pre-tape vs Immediate post-tape	-3.09	<0.001*	-4.00	-2.18

* Significant difference at the 0.05 level.

Table 6-41 Pairwise comparisons of main group effect for TFL and ITB length of affected side.

ITB and TFL muscle length(degrees)	Mean Difference	P-value	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
KTT vs KTNT	3.10	0.007*	0.89	5.32

* Significant difference at the 0.05 level.

6.4 Discussion

6.4.1 Summary of the effect of KT in ITBS Participants

The aim of this study was to investigate the efficacy and effectiveness of the application of KT in the short-term management of ITBS in an exploratory RCT in runners with ITBS that received either KTT or KTNT. The main finding in this study showed increased peak hip external rotation angle in the KTT group during the stance phase of running. There was also a decrease in average TFL muscle activity but no main effects for group were seen, and there was a significant increase in TFL and ITB length in both the KTT and KTNT groups. In addition, there was a significant decrease in the average Gmax, Gmed, and VM muscle activities but again no main effect for group was seen, although a trend towards a group effect was seen for VM ($p=0.073$). Additionally, there was a significant decrease for peak Gmed muscle activity in females in both groups. Participants in the KTT group reported improvements in clinical outcome measures (NPRS, all domains of KOOS, and Global Rating Of Change Scale (GROC)), and also no participant reported any negative important changes in comfort perception, stability of knee joint, and benefit on running performance after using KTT. However, there was no significant difference in the Tampa Scale for Kinesiophobia (TSK) after using KT.

Patient characteristics such as age and weight can affect outcome measurements and imbalance groups and can bias statistical tests (Roberts and Torgerson, 1999). In the present study, there were no significant differences in age, weight, height, BMI and average running distance between the KTT and KTNT groups. In addition, there was no significant differences in running speed between groups. Therefore, it these findings would suggest that both taping groups are similar in characteristics and it is plausible that any difference in outcome measures could be due to the effect of taping.

6.4.2 The effect of KT on Transverse Plane Hip Kinematics and Moments

To the author's knowledge, this is the first RCT to examine the effect of KT on ITBS. Overall, the results of the present study showed that there were no differences in the peak hip internal rotation angle, but significant differences were seen in the peak hip external rotation angle immediately post-tape compared to pre-tape. However, there

were no significant differences between groups for pre-tape and immediate post-tape in the peak hip internal and external rotation angle. These results are partially consistent with the thesis hypothesis that taping with tension would increase the peak hip external rotation angle and decrease the peak hip internal rotation angle. In addition, there was no statistically significant difference in peak hip external and internal rotation moments immediately post-tape compared to pre-tape.

There is a lack of research studying the effect of KT on the biomechanics associated with ITBS in runners. However, the present study was similar to Mackay et al. (2020) who investigated the effect of Mulligan Knee Taping using both KT and rigid Tape on pain and lower limb biomechanics in female patients with patellofemoral pain (PFP). They found that both taping techniques significantly increased hip external rotation angles at initial contact during running and decreased transverse hip ROM compared to a no tape condition. In addition, both taping techniques showed no statistically significant difference in hip moments compared to no tape during running. The significant increase in peak hip external rotation angle of the present study is potentially due to the tension of taping as a significant increase was only seen in immediate post taping compared to pre-tape in the KTT group, although there was no significant difference between group immediately post taping. The increase in the peak hip external rotation angle may help to improve pain during the stance phase of running in individuals with ITBS. This is supported by (Noehren et al., 2014) who showed that runners with ITBS demonstrate increased hip internal rotation compared to healthy participants which can shorten the ITB. When considering the KT method used in this study, one possible mechanism for altered hip external rotation was the somatosensory stimulations of the KT which facilitated the hip to externally rotate. However, this observed change was small in magnitude for the female runners with ITBS ($\leq$ 2 degrees) whereas the male runners with ITBS showed greater changes (~4 degrees) in immediate post-tape compared to pre-tape in the KTT group. This could suggest that KT techniques in this study may have more benefit in male runners with ITBS than female runners with ITBS. This may be due to males having more hair than females which may have increase the somatosensory stimulation from the KT application. Alternatively, the females have more hip internal rotation than males in this study and therefor may need more tension or stretch in the

KT in order to gain the same level of somatosensory stimulation. Although male runners showed a greater magnitude change of hip external rotation angle compared to female runners in this study, the KT application used in this study helped to decrease pain during running in both females and males. However, there is limited evidence to support the differences in response to tape in the male and female runners with ITBS which requires further study in the future.

For the peak hip internal rotation angle, there were no significant differences in the KTT or KTNT groups and no significant differences between groups for pre-tape and immediate post-tape. The findings of the present study are consistent with Song et al. (2015) who demonstrated that there was no significant difference in hip internal rotation angle when using femoral rotational taping in PFP compared to no tape or sham tape during single-leg squat. In addition, Song et al. (2017) showed no significant difference in hip internal rotation angle when using femoral rotational taping in females with PFP compared to no tape or sham tape on dynamic postural stability. However, Hickey et al. (2016) investigated the effect of the Mulligan Knee Taping technique on lower limb biomechanics during a single-legged squat in adult females with PFP, and showed that the peak hip internal rotation was significantly reduced using Mulligan knee tape compared to the control group. This finding contrast to the present study maybe because the difference in the taping material and technique which may explain the between study differences that need to further investigation.

Both rigid and elastic tape have been used in the management of knee pain (Barton et al., 2014, Mackay et al., 2020). However, there are differences in the materials and properties between rigid tape and KT. Rigid tape is constructed with a strong rayon backing and rubber zinc oxide with adhesive whereas KT is an elastic adhesive tape which is a cotton-based woven fabric with a high degree of elasticity (Tunakova et al., 2017, Masters et al., 2018). In addition, elastic tape has been reported to be associated with fewer skin allergies than rigid tape and allows stretching significantly beyond its original length (Mackay et al., 2020, Kase et al., 2003). A previous study demonstrated that MT using both KT and rigid tape significantly increased hip external rotation angle at initial contact during running (Mackay et al., 2020). Both rigid and KT revealed a good

level of perceived comfort, however, KT has been reported to be more comfortable to wear than rigid tape (Mackay et al., 2020). The greater comfort when wearing KT compared to rigid tape has been suggested to be due to its mechanical properties (Tunakova et al., 2017). Therefore, when considering the similar effects reported in terms of pain reduction when using either rigid or KT tape, Mackay et al. (2020) stated that many clinicians choose KT especially when treating running related injuries due to its minimal restriction and greater comfort compared to rigid tape. Mackay et al. (2020) used KT at 100% of stretch, which is greater than the general clinical guideline to reduce any irritation on the skin especially during running (Andrýsková and Lee, 2020). However, there is little evidence to support the efficacy and effectiveness of one taping tension over another when using KT tape.

6.4.3 The effect of KT on TFL Muscle Activity

One plausible reason for the result in the transverse plane hip kinematics in the present study could be due to a significant decrease in the TFL muscle activity between pre and immediate post-tape, as the function of the TFL is to contribute to hip internal rotation (Richard et al., 2009), and a decrease in average TFL muscle activity may be associated with an increase hip external rotation (Akbaş et al., 2011).

The present study showed significantly lower values for the average and peak TFL muscle activity between pre and immediate post-tape, but no significant main effect was observed for group. In addition, the increased ITB stiffness may increase compression or friction forces along the LFE (Tateuchi et al., 2015), and lead to ITB tissue irritation (Jelsing et al., 2013). Therefore, the decrease in TFL muscle activity seen in the present study may help to improve the TFL and ITB muscle length in ITBS and lead to decrease pain from the compression between the ITB and LFE (Fairclough et al., 2006).

6.4.4 The effect of KT on TFL and ITB Muscle Length

The TFL tightness is one of the main risk factors for ITBS as it connects to the ITB (Baker et al., 2011, Richard et al., 2009). The tightness in the TFL can cause hip internal rotation, which is a commonly reported presentation in runners with ITBS (Baker and Fredericson,

2016) and previous research has reported that ITBS participants exhibited decreased TFL and ITB length compared to a healthy control group (Noehren et al., 2014, Miller et al., 2007, Foch et al., 2015). The TFL tightness can increase the tension in the ITB which can cause high compression to the LFE and lead to the development of ITBS (Fairclough et al., 2006). Therefore, the increase in the TFL muscle length would potentially help to decrease the compression between ITB and LFE and help to decrease pain in runners with ITBS.

The present study showed that there was a significant interaction between the group and pre-immediate post-tape for TFL and ITB length tests. A significant increase was seen in the TFL and ITB length test immediate post-tape in both the KTT group by 4.95 degrees and the KTNT group by 1.31 degrees. These results suggest that the KT application used in the present study can help to improve TFL and ITB length, and that KTT can increase the TFL more than KTNT. This may be one mechanism by which KT may help runners with ITBS decrease the tension of ITB and lead to a decrease in pain. One plausible reason why the KT method used in this thesis can help to increase muscle length is an inhibition effect on TFL that KT may inhibit TFL muscle tension leading to an increase TFL muscle length (Yeung and Yeung, 2016). To the author's knowledge, this is the first time the effect of KT on TFL and ITB length has been explored in runners with ITBS. However, this is supported by previous studies which investigated the changes in TFL and ITB length in PFP participants when combining KT and an exercise program compared to a control group of exercise only (Akbaş et al., 2011). In addition, the result of the present study was similar to other intervention studies, Fredericson et al. (2002) demonstrated that there was a statistically significant increase in the TFL and ITB length after stretching the ITB. However, Pepper et al. (2021) showed that foam rolling and ITB stretching did not change ITB stiffness which may be due to the intervention not affecting ITB stiffness. Therefore, the KT technique in the current study may be one tool to help for improving the TFL and ITB length and symptoms during running in the rehabilitation programme for runners with ITBS.

6.4.5 The effect of KT on Coronal Plane Hip Kinematics and Moments

For the hip in the coronal plane, previous studies showed an increase in hip adduction angle in runners with ITBS (Grau et al., 2011, Ferber et al., 2010b, Noehren et al., 2007). Grau et al. (2011) indicated that there was less hip adduction angle and frontal ROM at the hip joint in runners with ITBS compared to healthy runners. Ferber et al. (2010b) demonstrated significant increases in the peak hip adduction in the stance phase in the ITBS group compared to a control group. Similarly, Noehren et al. (2007) reported that female runners who developed ITBS had greater hip adduction angles compared to healthy runners. Additionally, it has been reported that runners with ITBS may have increased compression from the ITB to the LFE due to increased hip adduction and knee internal rotation (Noehren et al., 2007). Therefore, the decrease in the peak hip adduction angle or increase hip abduction angle may help to improve the ITBS symptoms by decreasing the compression between the ITB and the LFE.

The present study showed that there was a significant decrease in the coronal plane hip ROM immediate post-tape compared to pre-tape in the KTT group. There was no statistically significant difference in peak hip abduction and adduction moments immediately post-tape compared to pre-tape. The findings of the present study were similar to Song et al. (2015) who studied the effect of femoral rotational taping, and indicated that there was no statistically significant difference in the hip adduction angle between the PFP group compared with a control group during a single-leg squat task. By contrast, Song et al. (2017) investigated the effects of femoral rotational taping in PFP found that there was a decreased hip adduction excursion when performing the star excursion balance test in femoral rotational taping compared with no tape group.

6.4.6 The effect of KT on Sagittal Plane Hip Kinematics and Moments

For the hip in the sagittal plane, the present study showed that there were no significant interactions, main effects for pre-immediate post-tape or between group differences in peak hip flexion angle, peak hip extension angle, and sagittal plane hip ROM. The findings of the present study were similar to Mackay et al. (2020) who showed that Mulligan knee taping using rigid tape and KT had no significant effect on hip sagittal

plane kinematics in PFP participants. In addition, the findings of the present study were similar to the study of Pelletier et al. (2019) who investigated the effects of patellar taping and KT in runners with and without PFP. Their result showed that there was no significant difference between the hip flexion angles at initial contact for the KT and no tape conditions, whereas the patellar taping resulted in greater hip flexion than the KT condition and NT condition. This means that the KT application in this study can affect the transverse and coronal plane hip kinematics without changing the sagittal plane in ITBS participants.

6.4.7 The effect of KT on Knee Kinematics and Moments

Abnormal knee biomechanics has been reported in runners with ITBS. Noehren et al. (2014) showed increased knee adduction in male runners with ITBS in a comparison with controls. In addition, previous studies showed runners with ITBS demonstrating an increase in knee internal rotation compared to healthy controls (Fredericson and Wolf, 2005, Noehren et al., 2007, Baker and Fredericson, 2016, Shen et al., 2019, Baker et al., 2011, Foch et al., 2015).

Based on the KT technique used in this study, it was hypothesised the KT would decrease knee internal rotation. However, the findings of the present study demonstrated that there was no significant difference in knee kinematics within or between KTT and KTNT in all three planes, but there was a trend towards a significant difference between group at pre-tape ($p=0.083$) for peak internal knee rotation angle. In addition, no significant differences were seen within groups or between KTT and KTNT in sagittal and coronal planes. Nevertheless, the KTT group had a significantly lower peak knee external rotation moment compared to the KTNT group for immediate post-tape, but there was no significant differences between groups for pre-tape.

The current study findings for the coronal and transverse knee angles and moments are in contrast to Mackay et al. (2020) who indicated that both rigid taping and KT reduced the knee adduction angle, increased internal rotation angle, and no statistically significant difference in knee moments at initial contact during running compared to no

tape, however the taping used by Mackay et al. was at the knee whereas this current study, the KT was applied to the thigh. Conversely, the knee sagittal plane result was similar to Mackay et al. (2020) and demonstrated that both rigid and KT had no significant effect on knee sagittal plane kinematics during a running task.

During the running, first half of stance phase, the knee is internally rotating and the knee external rotation moment work to decelerate the internal rotation movement (Noehren et al., 2007). Noehren et al. (2007) indicated that the ITBS group had 25% greater knee external rotation moment compared to healthy controls, although it was not statistically significant. Therefore, a decrease in the knee external rotation moment would decrease the ITB strain, as this structure plays an important role in resisting this (Hutchinson et al., 2022). However, this effect was only present between groups immediate post-tape and there was no significant difference within group. It maybe because the KT application in the present study was not applied directly to the knee.

6.4.8 The effect of KT on Gmax Muscle Activity

The Gmax is a muscle that connects to the ITB and the main function is hip extension, and also stabilizes the knee and hip joints via the ITB (Richard et al., 2009, Agur et al., 2017). An increase in Gmax muscle activity could lead to an increase in the tension in the ITB which can increase the strain or compression of the ITB against the LFE, and may lead to the development of ITBS (Hutchinson et al., 2022). Additionally, a previous study showed that Gmax muscle activity was more active in the runners with ITBS compared to healthy control runners, although this was not statistically significant (Baker et al., 2018). Therefore, decreasing the Gmax muscle activity may help to decrease the tension in the ITB and reduce the compression between the ITB and the LFE, and may be associated with a decrease in pain in runners with ITBS.

In this present study the runners with ITBS showed a significant decrease in average Gmax muscle activity immediate post-tape compared to pre-tape. This indicates that the KT application in this study can affect the Gmax muscle activity without changing the hip sagittal plane kinematics and moments in ITBS participants. This is in contrast to

Song et al. (2015) who showed no effect of KT on Gmax muscle activity, however, Song et al. considered the effect of KT during a single-leg squat.

6.4.9 The effect of KT on Gmed Muscle Activity

The Gmed muscle is the major hip abductor muscle and its function during stance phase is to provide eccentric control into hip adduction (Lenhart et al., 2014). Previous studies demonstrated the Gmed muscle activity showed an increase in the runners with ITBS compared to healthy runners, although this was not statistically significant (Baker et al., 2018, Foch et al., 2020). The increase in Gmed muscle activity may be due to runners with ITBS attempting to control hip movement.

The present study showed that average Gmed muscle activity was significantly lower immediate post-tape compared to pre-tape, but no main effect for group was seen. In addition, both the KTT and KTNT groups demonstrating a significantly lower peak muscle activity immediate post-tape compared to pre-tape, however, there was no significant difference between the two groups at pre-tape and immediate post-tape for peak Gmed muscle activity. The findings of the present study was supported by Ataullah et al. (2021) who examined the effects of KT on muscle strength and Gmed muscle activity in athletes with chronic ankle instability. They found a significant increase in the Gmed strength, and a significant decrease in Gmed muscle activity in the KT group, while the control group had a significant increase in Gmed strength but no decrease in the Gmed muscle activity. In addition, Ataullah et al. (2021) showed an increase in the Gmed strength and a significant decrease in Gmed muscle activity in a KT group compared to a control group. In contrast Hickey et al. (2016) showed that there were no significant differences in the peak Gmed muscle activity when using Mulligan knee taping compared to a control group. Shams et al. (2021) considered the onset of Gmed muscle activity and showed that after plyometric training with Mulligan knee taping in women with dynamic knee valgus, Gmed was activated earlier and they hypothesised that this may help prevent knee valgus during landing. The decrease in the Gmed muscle activity in the present study may imply that KT might change the activation of the Gmed muscle during the running task (Glaviano et al., 2020). Therefore, changes in the Gmed muscle may be

associated with improved frontal plane control, and help to minimize hip adduction which has been indicated as a risk factor during running in individuals with ITBS, although the present study did not find any changes in the hip adduction angle.

6.4.10 The effect of KT on VM Muscle Activity

The present study showed lower VM muscle activity immediate post-tape compared to pre-tape, and also a trend towards group significance for average VM activity at pre-tape. In addition, the peak VM muscle activity showed a significant decrease in immediate post-tape for the peak muscle activity of VM in the KTNT group but no significant difference was seen in the KTT group compared to pre-tape. This is supported by previous studies, including Lee et al. (2012) who considered the effect of KT around the knee joint in PFP participants and demonstrated reduced VM and VL muscle activity during stair climbing. Similarly, Keet et al. (2007) reported significant decreases in VM and VL muscle activity in both healthy and PFP groups during a closed chain step test compared to a NT condition. This may indicate the effect of KT to modify the muscle forces around the knee. Therefore, KT may be a useful tool in the rehabilitation of people with ITBS. However, the present study only found differences in the KTNT group.

6.4.11 The effect of KT on Hip Abduction and Hip External Rotator Strength

Hip strength is usually part of the ITBS assessment of an injured runner. It has been suggested that hip abductor muscle weakness may result in increased hip adduction angle during the stance phase of running (Fredericson et al., 2000, Noehren et al., 2007). In addition, hip abductor weakness has been demonstrated in track athletes with ITBS (Fredericson et al., 2000), with weakness of the external rotators also have been reported in the runners with ITBS that can increase the load on the ITB (Noehren et al., 2014). Furthermore, a significant decrease in hip adduction strength was seen in runners previously suffering from ITBS compared to runners currently suffering from ITBS and healthy controls (Foch et al., 2015). Nevertheless, this contrasts with a study which reported no differences in abductor hip strength in people with ITBS (Grau et al., 2008a). Therefore, it is interesting to look at the hip muscle strength of both the hip abductor

and external rotators in runners with ITBS immediately post-tape, with an increase in hip muscle strength being associated with possible improvements in ITBS symptoms.

However, the present study showed no effects of KT on hip abduction or hip external rotation isometric strength. This finding is consistent with previous studies that also demonstrated no differences in muscle strength between KT and no tape conditions in healthy volunteers (Vercelli et al., 2012, Cai et al., 2016, Poon et al., 2015) or in individuals with lateral epicondylitis (Au et al., 2017), or in individuals with chronic ankle instability (Fereydounnia et al., 2019). However, in contrast Rajasekar et al. (2018) reported that KT over Gmed can correct exaggerated dynamic knee valgus and improve hip abductor strength immediately after taping compared to sham KT. The present study differed in the measurement method used by Rajasekar et al. (2018) who used the Donatelli drop leg test, whereas the present study used an isometric strength test which may be get the different result. In addition, Rajasekar et al. (2018) applied KT directly over the hip abductor muscle arguably providing a greater proprioceptive effect and associated muscle response. The findings of the present study that showed no significant difference may be because the KT application used in this thesis was not applied directly over the hip abductor or hip external rotator muscles and therefore may not offer sufficient proprioceptive effect.

6.4.12 Sex differences in Running Biomechanics

The consideration of sex differences has been highlighted in ITBS research as females who have been diagnosed with ITBS are reported to have larger hip adduction and knee internal rotation angles compared to healthy controls. The studies of Noehren et al. (2007) and Ferber et al. (2010b) concluded that larger hip adduction angles could cause a greater demand on the hip abductor muscles during eccentric loading, which could lead to overuse during running (McCarthy et al., 2015). This can cause the ITB to compress against the greater trochanter or lateral femoral condyle causing female runners to develop ITBS symptoms more often than their male counterparts (Taunton et al., 2002a).

In the present study sex differences were seen in kinematics and moments showing that females demonstrated a significantly greater peak hip flexion, sagittal plane hip ROM, peak hip adduction angle, coronal plane hip ROM, peak hip internal rotation, and peak knee flexion angle, whilst males demonstrated a significantly greater peak hip external rotation and peak knee flexion moment, peak hip adduction moments, and peak hip internal rotation moments. These findings are partially supported by Phinyomark et al. (2015) who studied the differences between males and females in runners with ITBS, and between healthy runners compared with their ITBS counterparts. They found that female runners with ITBS exhibited significantly greater hip external rotation compared with male runners with ITBS. In addition, female runners with ITBS also showed trends toward increased knee internal rotation, and hip adduction angles in comparison to their male counterparts. However, the study of Phinyomark et al. (2015) was only one studied that investigated the sex differences in running biomechanics in individuals with ITBS, which need more research in the future. The present study showed that females with ITBS demonstrated significantly greater peak hip adduction angle and peak hip internal rotation compared to males with ITBS. Results in the present study was similar to sex differences reported in healthy cohort studies (Phinyomark et al., 2014, Chumanov et al., 2008), who reported greater peak hip adduction, hip internal rotation and knee abduction angles in healthy female runners when compared with male runners. Ferber et al. (2010b) reported that females who had previously sustained ITBS demonstrated a significantly increase peak rearfoot invertor moment, peak knee internal rotation angle, and peak hip adduction angle compared to healthy controls. Therefore, the sex differences observed in lower limb biomechanics in individuals with ITBS of the previous and the present studies indicate that further research should take sex into account when exploring the biomechanics in individuals with ITBS. In addition, the results of the present study imply that females have a greater risk of ITBS compared to males with greater peak hip adduction angle and peak hip internal rotation which is associated with a greater load on the ITB and presentation of ITBS (Charles and Rodgers, 2020). Females had a greater sagittal plane hip ROM, coronal plane hip ROM, peak hip adduction angle, and peak hip internal rotation compared to males which may have increased the tension or stretch of the KT during running. This may increase the stimulation of the mechanoreceptors on the skin and could lead to a greater biomechanical effect in the

females in this study. However, there was a similar response with an increase in peak hip external rotation angle in both males and females in the KTT group, and no change in peak hip adduction angle, peak hip internal rotation, sagittal plane hip ROM for both males and females in both the KTT and KTNT groups. Additionally, there was a decrease in the coronal plane hip ROM in the KTT group but not in the KTNT group, and no significant interactions between sex and pre-immediate post-tape. This suggested that females and males in this study showed a similar response to KT application in biomechanical parameters, although females had the same amount of stretch of KT at the point of application as the males in this study. Nevertheless, no previous studies have examined the difference of the amount of KT stretch for males and females during dynamic tasks and any associated effectiveness of altering lower limb running mechanics which may be interesting to explore in more detail in future studies.

When considering muscle activity, males demonstrated significantly greater peak Gmax, Gmed and VL muscle activity compared to females. A significant decrease for average TFL muscle activity was also seen for females immediately post-tape but no difference was seen in the males. This means that females with ITBS may have a response to decreasing the average TFL muscle activity immediately post-tape than the males. Additionally, the present study observed sex differences in peak Gmed muscle activity with females in both the KTT and KTNT groups demonstrating a significantly lower peak muscle activity immediate post-tape compared to pre-tape. These findings are consistent with the female Thai healthy participants who demonstrated significantly lower average and peak Gmed muscle activity in the KTNT condition compared to the NT and KTT conditions. To the author's knowledge, there is a lack of research exploring differences in muscle activation between sexes, in particular the activation associated with the effect of taping in the management of ITBS. However, previous studies on healthy participants have reported contrasting findings to the present study that showed greater Gmax muscle activity in females compared to males and no differences in Gmed muscle activity due to sex in running (Chumanov et al., 2008, Willson et al., 2012). Furthermore, Baker et al. (2018) indicated that the Gmed and Gmax muscle activity were more active in runners with ITBS compared to healthy runners. Therefore, based on previous studies and the present study both Gmax and Gmed muscle activity

may be associated with a greater risk of ITBS in males compared with females. For the VL, the present result contrasted with Landry et al. (2007) who indicated that VM and VL muscle activity during running was greater in female than in male athletes. However, little or no research has been conducted exploring the VL muscle activity in individuals with ITBS, therefore further study is warranted to understand the relationship between VL muscle activity and ITBS.

6.4.13 The effect of KT on Pain

The 11-point NPRS was used to assess the effect of KT on self-reported pain over a one-week period at the pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping. A MCIC (for within group) and MCID (for between group) of 2 points was used to represent a clinically important change for NPRS scores (Farrar et al., 2001, Michener et al., 2011, Childs et al., 2005). The present study showed that there was a reduction in the NPRS scores in runners with ITBS in both KTT and KTNT groups.

For the KTT group, there was a significant decrease in the NPRS scores from pre-tape to immediate post-tape, day 4 of taping, and day 7 of taping by 4, 5.5, and 5 points, respectively. In addition, a significant decreased was seen on day 4 of taping compared to immediate post-tape, and day 7 of taping compared to immediate post-tape by 1.5, and 1 point, respectively. For the KTNT group, there was a significant decrease in the NPRS scores from pre-tape to immediate post-tape, day 4 of taping, and day 7 of taping by 2, 2, and 3 points, respectively. In addition, a significant decreased was seen on day 7 of taping compared to immediate post-tape by 1 point. Therefore, both the KTT and KTNT groups in this study met the MCIC for the immediate effect, at day 4 of taping, and at day 7 of taping compared to pre-tape. When considering the between groups in the values of the NPRS changes scores from pre-tape to each time, there was a greater improvement in NPRS scores in the KTT group compared to KTNT group at immediate post-tape, day 4 of taping, and day 7 of taping by 2, 3.5, and 2 points, respectively. These findings indicate that the KT can help to decrease the self-reported pain in both KTT and KTNT groups, however the KTT group had a greater reduction in self-reported pain than

the KTNT group, although the KTT group reported significantly higher self-reported pain than the KTNT group at pre-tape (KTT = 6; KTNT = 4).

There are a number of studies that support the findings that KT can help to decrease pain levels. Mackay et al. (2020) demonstrated that Mulligan knee taping applied with rigid tape or KT at 100% tension significantly decreased self-reported pain during a self-selected pain provocative task, a moderately paced running task, and a single leg squat task in female patients with PFP. Similarly, Kakar et al. (2020) demonstrated KT and sham taping significantly decreased self-reported pain using a visual analogue scale during a squat task compared to NT condition during squats. Similarly in patients with knee osteoarthritis, Donec and Kubilius (2019) showed that the majority (>70%) of patients in both the KT group and sham tape group reported a decrease in knee pain. Additionally, Mulligan knee taping technique significantly reduced perceived pain during the single-legged squat compared to the non-taped condition (Hickey et al., 2016). Furthermore, Song et al. (2015) who investigated femoral rotational taping, showed that KT could alter patellofemoral kinematics and decrease pain compared to NT condition in the treatment of young female participants with PFP during single-leg squat. In addition, Song et al. (2017) indicated a significantly decreased pain during the star excursion balance test applying femoral rotational tape and sham tape compared to no tape. However, there was no significant difference in the pain level between these 2 taping conditions. These results support the use of femoral rotation KT to improve dynamic postural control and reduce pain during the star excursion balance test.

One explanation why taping decrease self-reported pain is the stimulating the skin and promoting pain-relieving mechanisms. However, the underlying mechanism of the KT effect observed in the present study may be multifactorial. Any reductions in pain may be as a result of the effect of KT to improve the previously reported abnormal biomechanics associated with ITBS and TFL muscle tension. The effect of KT with tension may facilitate hip external rotation during running through somatosensory stimulation. In addition, this study used an inhibition KT technique which is purported to inhibit TFL muscle activity through stretching of the Golgi tendon organs (Yeung and Yeung, 2016). Therefore, the increase hip external rotation angle and the decrease in TFL muscle

activity seen in the present study may lead to decrease pain from the compression between the ITB and LFE in runners with ITBS (Fairclough et al., 2006). Additionally, the KT is thought to increase proprioceptive feedback during functional activities by stimulating the skin and promoting pain-relieving mechanisms through gate control theory by decreasing the pressure on nociceptors receptors, thereby achieving pain relief (Melzack and Wall, 1965). Melzack and Wall (1965) proposed the gate control theory mechanism to explain how the stimulation of non-painful sensations such as touch, pressure, and vibration can help to reduce painful sensations. The gate control theory is related to the area in the spinal cord which has a neurological gating system that controls pain transmission to the brain by either blocking or allowing pain signals to the brain (Moayedi and Davis, 2013). When there is more activation of the large sensory nerve fibres associated with non-painful sensations from mechanoreceptors to the spinal cord in comparison to pain signals transmitted by small sensory nerve fibres at the gating area in the spinal cord. These can help to block or decrease the pain signals, which this phenomenon is defined as gate control theory (Coffey and Mahon, 1982). It has been proposed that the application of KT on the skin stimulates the mechanoreceptors located in the skin which helps to block pain by stimulating the mechanoreceptors and transmitting those mechanical inputs through the large sensory nerve fibres, which inhibit pain signals transmitted by the small sensory nerve fibres (Thelen et al., 2008, Pamuk and Yucesoy, 2015). When considering KT, it is plausible to suggest that the application of KT which pulling on the skin can induce the gate control theory by inhibiting the transmission of pain. However, many previous studies of KT proposed this mechanism for reducing pain (Kakar et al., 2020, Song et al., 2017, Park et al., 2019), but the exact mechanisms of pain reduction as a result of KT application is still unknown and future research is required.

6.4.14 The effect of KT on The Knee Injury and Osteoarthritis Outcome Score (KOOS)

The KOOS was used in this study as this allows a short-term assessment of patient outcomes relevant to treatment using KT applied for 7 days. The MCIC and MCID of KOOS used in this thesis was 10 points (Roos and Lohmander, 2003). The result of this study demonstrated that the KTT group reported significantly improvement KOOS

across all domains whereas the KTNT group reported significantly improvement only ADL domain from pre-tape to day 7 of taping.

For the KTT group, there was a significant increase in the KOOS scores from pre-tape to day 7 of taping for domains of pain by 8.33 points, symptoms by 7.15 points, ADL by 2.94 points, sport and recreation by 15 points, and knee-related quality of life by 9.38 points. Therefore, only the sport and recreation domain of KOOS reached the MCIC threshold. This indicates that runners with ITBS have some benefits of KTT during sport and recreation but the effects under the other domains were not clinically important. For the KTNT group, although there was a significant increase in the KOOS scores from pre-tape to day 7 of taping in the ADL by 1.47 points, no domains reached the MCIC threshold. When considering the between group differences in response, the changes in KOOS scores from pre-tape to day 7 of taping, only the sport and recreation domain showed a greater improvement and reached the MCID in KOOS scores in the KTT group compared to KTNT group (KTT = 15, KTNT =5). This confirms that runners with ITBS have a perceived greater benefit when using KTT during sport and recreation when compared to KTNT.

No previous research has reported the KOOS score to explore taping in runners with ITBS, however, there were studies on the effect of taping or bracing on KOOS scores in other knee conditions. The result of the current study was similar to the study of Sinclair et al. (2016) who showed that a proprioceptive knee brace intervention can improve the KOOS scores in all domains in recreational athletes who suffer from patellofemoral pain during jogging, cutting movement and single leg hop. Similarly, Khadavi et al. (2015) showed a significant improvement of KOOS scores in the domains of symptoms, pain, sports and recreation, and quality of life when using a knee brace. Furthermore, Aydoğdu et al. (2017) showed a significant improvement in all subscales of KOOS after treatment with a combined conventional rehabilitation method and KT in knee osteoarthritis patients, however, this study did not consider the use of sham taping or KTNT. Donec and Kubilius (2020) showed that after four weeks of KT application on the knee joint, a significant improvement was found in all KOOS subscales in patients with knee osteoarthritis who received a specific KT application. Therefore, previous studies

show agreement with the present study with reported improvements in KOOS scores after using taping or bracing.

6.4.15 The effect of KT on Tampa Scale for Kinesiophobia (TSK)

The phenomenon of post-traumatic injury, later described as a fear of movement/re-injury, refers to the idea of having a fragile and vulnerable body, where movement can lead to re-injury (Vlaeyen et al., 1995a). The TSK was used to assess the kinesiophobia or fear of movement in this study as ITBS is a musculoskeletal injury with chronic pain where athletes have reported fear and insecurity towards returning to the sport in which they experienced their injury (Heijne et al., 2008). The result of this study showed that there was no significant difference for TSK within and between KTT and KTNT groups between pre-tape, immediate post-tape, day 4 of taping, and day 7 of taping.

The MCIC and MCID for the current study was set at scores of 1 and 2 respectively (Huang et al., 2019). For the KTT group, there was a decrease in the TSK scores from pre-tape to immediate post-tape by 0.5 points, pre-tape to day 4 of taping by 1 point, and pre-tape to day 7 of taping by 3.5 points. For the KTNT group, there was an increase in the TSK score from pre-tape to immediate post-tape of 1 point. There was a decrease in the TSK scores from pre-tape to day 4 of taping by 0.5 scores, pre-tape to day 7 of taping by 2.5 scores. Although there were not any significant differences, TSK score changes reached the MCIC in day 4 and day 7 of taping in the KTT group, and in immediate post-tape and day 7 of taping in the KTNT group.

Based on previous research, there is inconsistency on the effect of KT to decrease kinesiophobia in patients with musculoskeletal pain (Hoffman et al., 2018). The results of the present study are similar to those reported by Alahmari et al. (2020) who showed that there was no significant reduction of kinesiophobia for both immediate and short-term differences with the application of KT compared with a control group. Similarly, Castro-Sánchez et al. (2012) demonstrated no significant differences in TSK scores between KT and sham taping after one and four weeks. In contrast, Kurt et al. (2016) investigated the short-term effects of KT in patients with PFP and showed a significant

improvement in TSK score in the KT group compared to the placebo KT group. In addition, Gholami et al. (2020) showed that KT and placebo KT groups had a significant decrease in the TSK score but did not show significant differences between groups in athletes after anterior cruciate ligament reconstruction.

Considering the total TSK scores, the scale ranged from 17- 68, and the cut off score was developed by Vlaeyen et al. (1995a) where a score of 37 or over is considered as a high score indicating a high degree of kinesiophobia, while scores below that are considered as low scores. The TSK scores in the current study were 43 points for the KTT group and 42.5 points for the KTNT group at pre-tape. At day 7 of taping, the TSK scores were reduced but were still high with 40.5 points for the KTT group and 40 points for the KTNT group. These values were similar to Castro-Sánchez et al. (2012) who reported TSK scores of 39 in a KT group after applying KT for one week in people with chronic non-specific back pain. Similarly, Alahmari et al. (2020) reported that a KT group had a mean TSK score of 38.93 and 37.60 scores in immediate post-tape and day 3 of taping, respectively. Therefore, the KT application used in the present study suggests that kinesiophobia is not decreased within a week following tape application. This maybe because ITBS is a chronic musculoskeletal problem and requires a longer time period to reduce the fear of movement.

6.4.16 The effect of KT on Global Rating Of Change Scale (GROC)

The Global Rating Of Change Scale (GROC) was used to assess the overall condition of ITBS at immediate post-tape, day 4 of taping, and day 7 of taping compared to pre-tape. The MCIC and MCID of GROC used in this thesis was $\pm$ 5 points (Stratford et al., 1994). Interestingly, for the KTT group, there was only one participant who reported negative important changes in GROC score and 12 out of 20 participants indicated a positive clinically important change at immediate post-tape. At day 4 and day 7 of taping, no participant reported any negative important changes, and 18 out of 20 participants indicated a positive clinically important change. For the KTNT group, no participant reported any negative important changes in GROC score at immediate post-tape, day 4 and day 7 of taping, with 3, 7, and 11 participants indicating a positive clinically

important change at immediate post-tape, day 4 and day 7 of taping, respectively. These results suggest that as the KTT perceived greater change than KTNT this could explain why the participants' GROC scores were higher with KTT than KTNT.

Sex differences were seen with males demonstrating a significantly greater GROC score immediately post-tape than females in the KTT group. For females in the KTT group, GROC scores reached the MCIC at day 4 and day 7 of taping. For males in the KTT group, GROC scores reached the MCIC at immediate post-tape, day 4 and day 7 of taping. In the KTNT group, GROC scores only reached the MCIC at day 7 of taping in females, and did not reach the MCIC in males. In the comparison between the two groups, there was a significantly greater change in the KTT at immediate post-tape by 3 points, day 4 of taping by 2 points, and day 7 of taping by 1 point compared to the KTNT group. These GROC scores confirm that the KTT group showed a perceived greater improvement than the KTNT group.

This is supported by Harput et al. (2016) who investigated the effects of knee brace and KT on functional performance and self-reported function in individuals six months post anterior cruciate ligament reconstruction. They used the GROC score to assess the effect of knee brace and KT and found that the knee brace showed improved knee function compared to no intervention and KT, and KT showed better knee function compared with no intervention. In addition, Crossley et al. (2015) examined the efficacy of a patellofemoral joint targeted exercise, with education, manual-therapy and taping (intervention condition) compared to education alone (control condition) over 12 weeks. They found that both groups showed superior outcomes for GROC scores. In contrast Araujo et al. (2018) investigated the effectiveness of KT in patients with chronic low back pain after 6 months and found that there was no effect of KT versus sham on GROC. They indicated that improvements over time in both groups may be due to the natural course of the disease, regression to the mean, and/or non-specific effects of treatment. Moreover, Pinheiro et al. (2020) examined the short-term effects of KTT and KTNT in older women with knee osteoarthritis, compared with controls that did not receive KT. They found no differences between groups, however from the descriptive analysis participants in both KTT and KTNT groups reported better perception of change,

with the latter unchanged compared to controls. Although no statistical differences were observed, most older women in the KTT and KTNT groups showed signs of improvement, with the control group reporting little change. Therefore, previous studies show agreement with the present study with reported improvements in GROC scores after using taping which KTT group showed a greater improvement than the KTNT group.

6.4.17 The effect of KT on Perception of Comfort

The comfort score was used to assess the effects at immediate post-tape, day 4 of taping, and day 7 of taping compared to pre-tape, and the MCIC and MCID used was ± 2 points (Kamper et al., 2009). For the KTT group, no participant reported negative important changes in comfort perception at immediate post-tape, at day 4 and day 7 of taping. The 14 out of 20 participants indicated a positive clinically important change at immediate post-tape and day 4 of taping, with 16 out 20 participants reporting a positive clinically important change at day 7. For the KTNT group, one participant reported negative important changes in comfort perception at day 4 and day 7 of taping, with 1, 9, and 13 participants indicating a positive clinically important change at immediate post-tape, day 4 and day 7 of taping, respectively. The only significant between group finding occurred immediate post-tape, with KTT reporting significantly greater perceived comfort (by 2 points) compared to the KTNT group, which is a clinically important difference. This means that the immediate effect has been the most comfort perception in the present study.

There is lack of research on the perception of comfort when using KT in patients, especially those with ITBS. However, there are other studies that explored the effects of rigid tape or bracing on other regions of the body. Mackay et al. (2020) highlighted that female patient with PFP who performed a self-selected pain provocative task, single-leg squat task, and running task while wearing Mulligan knee taping applied with rigid tape, KT at 100% of stretch, showed that both rigid and KT show a good level of perceived comfort, but with KT being more comfortable to wear than rigid tape. It has been suggested that the greater comfort in wearing the KT is due to its mechanical properties (Tunakova et al., 2017). Similarly, Hébert-Losier et al. (2019) indicated that elite cyclists

show a good level of perceive comfort to KTT application, with perceived improvements in knee stability and performance. In other region of KT application, Guner and Alsancak (2020) investigated the effect of KT application on participant with foot pronation using the laser postural alignment system. The result revealed that KT does not affect the weight load or load line of the ankle when standing, however, participants perceived an increase in comfort perception with KT. Therefore, previous studies show agreement with the present study that have been reported most participants had comfort perception after using KT compared to pre-tape which KTT group perceive more comfort than the KTNT group over one week.

6.4.18 The effect of KT on Perception of Knee Stability

The stability of the knee joint score was used to determine the effects immediate post-tape, and at day 4 of taping, and day 7 of taping compared to pre-tape. The MCIC and MCID used in this thesis was used at ±2 points (Kamper et al., 2009). For the KTT group, no participant reported any negative important changes in the stability of the knee joint perception. The 17 out of 20 participants indicated a positive clinically important change at immediate post-tape, 13 participants at day 4 of taping, and 20 participants at day 7. For the KTNT group, no participant reported negative important changes in stability, with 5, 13, and 14 participants indicating a positive clinically important change at immediate post-tape, day 4 and day 7 of taping, respectively. Although there was a significant difference between the two groups for perceived knee stability immediate post-tape and day 7 of taping, the only MCID was immediate post-tape.

This is supported by Guner and Alsancak (2020) who showed an increase in perceived support perception when using KT on participant with foot pronation. Correspondingly, the result of Sawkins et al. (2007) investigated the effect of ankle taping in three conditions including real tape, placebo tape and no tape in a hopping test and a modified star excursion balance test in participants with ankle instability. They found that participants perceptions of stability increased with both real and placebo ankle taping when performing the functional tasks, with more participants reporting improvements in stability with the real tape condition than either the placebo or control condition on

both of the functional tests. They also claimed that the increased stability gave them more confidence and/or assurance that the tape would keep them safe from injury. Therefore, previous studies show agreement with the present study that reported the improvements in knee joint perception scores after using KT which KTT group perceive more knee support than the KTNT group over one week.

6.4.19 The effect of KT on Perception of Running Performance

A running performance score was used to determine the perceptions of the tape immediate post-tape, day 4 of taping, and day 7 of taping compared to pre-tape, and similar to comfort and knee stability a MCIC and MCID of ± 2 points was used (Kamper et al., 2009). For the KTT group, no participant reported negative important changes in the benefits to running performance, with 9 out of 20 participants perceived a clinically important benefit immediate post-tape, 15 participants at day 4 of taping, and 17 participants at day 7 of taping. For the KTNT group, no participants reported any negative important changes, with 5, 12, and 12 participants indicating a positive clinically important change at immediate post-tape, day 4 and day 7 of taping, respectively. Although there was a significant difference between the two groups for the running performance scores at day 7 of taping, the scores did not reach the MCID at immediate post-tape, day 4 of taping, and day 7 of taping.

This is supported by Chaney et al. (2015) who investigated the effects of gastrocnemius-soleus complex KT on power, speed, and self-perception of physical performance in basketball players. They found that there was no significant difference in the overall physical performance under the taped condition for both vertical jump and 20-meter sprint. However, there was a significant difference in self-perceptions of taping benefits for vertical jump but not for 20-meter sprint. By contrast, Mak et al. (2019) investigated the facilitatory KT on the wrist extensors in healthy participants and reported no significant difference perceived performance compared to the NT condition.

CHAPTER 7 Synthesis and Conclusion

7.1 General discussion and clinical implications

When comparing the response to KT in the healthy individuals and runners with ITBS, there was a similar response to KT with an increase in peak hip external rotation angle and a decrease in the average TFL muscle activity, which both have been previously identified as key biomechanical factors in runners with ITBS, Table 7-1. There was a similar response with a decrease in average Gmax muscle activity and average and peak Gmed muscle activity with Gmed muscle activity showing a similar response in the runners with ITBS and the Thai healthy participants, although this was not seen in the UK healthy participants, Table 7-1. This may be a beneficial effect as a decrease in the Gmax and Gmed muscle activity may help to reduce pain in runners with ITBS because previous studies showed an increase in the Gmax and Gmed muscle activity in runners with ITBS compared to healthy runners (Baker et al., 2018, Foch et al., 2020).

However, not all parameters showed the same response to taping in the runners with ITBS and healthy participants. The runners with ITBS showed no difference in the sagittal plane hip kinematics and moments whereas the UK healthy participants showed a greater peak hip flexion angle and sagittal plane hip ROM, and The Thai healthy participants showed a greater peak hip extension angle, Table 7-1. The clinical implications of these changes are unclear as these parameters have not been previously identified as key biomechanical factors associated in runners with ITBS. Runners with ITBS showed no difference in the coronal plane hip kinematics and moments with the exception of a decreased coronal plane hip ROM whereas both healthy cohorts showed a similar increase in the peak hip abduction angle, however there was no decrease in hip adduction angle, which has been purported to decrease pain in runners with ITBS and has been previously identified as one of the key factors associated with pain in runners with ITBS (Grau et al., 2011, Ferber et al., 2010b, Noehren et al., 2007). For knee kinematics and moments, the runners with ITBS demonstrated no difference in the knee kinematics and moments with the exception of knee moments with the KTT group showing a lower peak knee external rotation moment compared to the KTNT group for immediate post-taping (Table 7-1), however as above, the clinical implications of these

changes are unclear as these parameters have not been previously identified as key biomechanical factors associated in runners with ITBS. Also observed was a greater knee flexion angle and lower peak knee flexion moment in the UK healthy participants, whereas the Thai healthy participants showed an increase in peak knee internal rotation angle and a decrease in peak knee abduction moments, Table 7-1. The clinical implications of these changes are unclear as these parameters have not been previously identified as key biomechanical factors associated in runners with ITBS, except peak knee internal rotation angle that previous studied showed an increase peak knee internal rotation angle in runners with ITBS compared to runner healthy control (Ferber et al., 2010b, Noehren et al., 2007).

Table 7-1 Comparison of the biomechanical response to all taping conditions for UK healthy, Thai healthy, and Thai runners with ITBS. Significant changes are represented as solid green, red and amber represent a significant response decrease, increases and no change, trends towards significance to decrease (green hashed), and trend to increase (red hashed). Increased peak hip abduction and external rotation angles have been purported to help to reduce the ITB tension, which may help to decrease the symptoms of ITBS. Decreased peak hip internal rotation angle, peak knee internal rotation angle, and changes in muscle activity indicate to reduce the ITB tension, which may help to reduce the symptoms of ITBS (Ferber et al., 2010b, Noehren et al., 2007, Baker et al., 2018, Baker and Fredericson, 2016).

	UK Healthy			Thai Healthy			Thai ITBS		
	KTT vs NT	KTNT vs NT	KTT vs KTNT	KTT vs NT	KTNT vs NT	KTT vs KTNT	KTT vs NT	KTNT vs NT	KTT vs KTNT
Hip Kinematics									
Peak flexion									
Peak extension									
Sagittal plane Hip ROM									
Peak abduction									
Coronal plane Hip ROM									
Peak internal rotation									
Peak external rotation									

	UK Healthy			Thai Healthy			Thai ITBS		
	KTT vs NT	KTNT vs NT	KTT vs KTNT	KTT vs NT	KTNT vs NT	KTT vs KTNT	KTT vs NT	KTNT vs NT	KTT vs KTNT
Knee Kinematics									
Peak flexion									
Peak internal rotation									
Knee Moments									
Peak flexion									
Peak abduction									
Peak external rotation									
Average muscle activities									
Gmax									
Gmed									
TFL									
Peak muscle activities									
Gmax									
Gmed									
TFL									
VM									

The findings that KTT significantly increased peak hip external rotation angle and significantly decreased TFL muscle activity compared to NT in runners with ITBS is largely consistent with the results found in the UK and Thai healthy studies, although there were no significant differences between the KTT and KTNT groups in the runners with ITBS. This supports the hypothesis that the application of KT with tension used in this thesis can help to increase the peak hip external rotation angle and decrease TFL muscle activity. A decrease TFL muscle activity would decrease the loading on the ITB (Hamill et al., 2008, Meardon et al., 2012), as this structure is formed by the TFL and Gmax. An increased activation of the TFL muscle may be related to unusual tension of the ITB (Stecco et al., 2013). In addition, an increase in the hip external rotation or reduced hip internal rotation during the stance phase may help to decrease pain or symptoms in runners with ITBS, this is supported by previous studies which have reported that

individuals with ITBS have an increased hip internal rotation angle during running (Noehren et al., 2014). This suggests that the result of pain reduction in the runners with ITBS may be associated with an increased peak hip external rotation angle and decrease TFL muscle activity. However, for the peak hip internal rotation angle, there were no significant differences seen within and between groups in runners with ITBS which contrasted with the UK and Thai healthy studies. This means that the KT used in this thesis did not provide a mechanism to decrease the hip internal rotation angle in runners with ITBS during running, although there was a decrease in the peak hip internal rotation angle in the Thai healthy participants and a trend towards a decrease in the UK healthy participant in the KTT compared to the NT. This may be due to a different response of KT between healthy runners and runners with ITBS, which the runners with ITBS having greater hip internal rotation than the healthy runners (Noehren et al., 2014).

An increased hip abduction angle or decreased hip adduction angle would help to improve symptoms in runners with ITBS which is supported by previous studies which reported a greater peak hip adduction angle in runners with ITBS when compared to healthy controls (Grau et al., 2011, Ferber et al., 2010b, Noehren et al., 2007). However, the peak hip abduction and adduction angle in runners with ITBS showed no significant differences in the KTT or KTNT groups and no significant differences between groups for pre-tape and immediate post-tape. This result was in contrast to the healthy cohort studies, which showed a significant increase in the peak hip abduction angle in the KTT compared to the NT condition in the UK healthy cohort, and a trend towards increased ($p=0.054$) peak hip abduction angle in the KTT condition compared to the NT condition in the Thai healthy cohort. In addition, the result of the peak hip adduction angle in runners with ITBS was similar in both UK and Thai healthy cohort studies. These results suggested that there was a difference in response to KT in the healthy cohorts and ITBS cohort, which is supported by previous studies which have shown that there was a difference between healthy runners and runners with ITBS, which the runners with ITBS having greater hip adduction angles than healthy runners (Noehren et al., 2007).

The sagittal plane hip kinematics is not one of the key biomechanical factors that has been associated in runners with ITBS (Baker and Fredericson, 2016). Therefore, a

decrease or increase in sagittal plane hip kinematics is of unknown clinical value in any improvements in the symptoms in runners with ITBS. There was no significant difference in peak hip extension and flexion angles immediately post-taping compared to pre-taping in runners with ITBS. However, the Thai healthy participants showed no significant effect of taping for the peak hip flexion angle while the UK healthy participants showed a significantly greater peak hip flexion angle in the KTT and KTNT compared to the NT condition. For the peak hip extension angle, The Thai healthy participants showed a significantly greater peak hip extension angle in both KTT and KTNT conditions compared to the NT condition, and a significantly greater angle in the KTT condition compared to the KTNT condition while the UK healthy participants showed no significant effect of taping for the peak hip extension angle. The difference in sagittal plane hip kinematics between The UK and Thai healthy participants may be due to the greater running speeds in the UK healthy participants. When considering the running speed, runners with ITBS were tested in the same laboratory as the Thai healthy participants and there were no significant differences in the running speed between the two cohorts (Appendix 20). This suggested that the KT application used in this thesis may help the sagittal plane hip kinematics for healthy participants, but this effect was not seen in the runners with ITBS. In addition, these results suggested that there was a different response to the taping between Thai healthy participants and Thai runners with ITBS, which may be worthy of further analysis in the future.

For knee kinematics and moments, the runners with ITBS showed only a significant decrease in peak knee external rotation moment in the KTT group compared to the KTNT group for immediate post-tape. A decrease in the knee external rotation moment would decrease the ITB strain, as this structure plays an important role in resisting the knee external rotation moment (Hutchinson et al., 2022), however, there was only a significant difference in the main effect for group and there was no significant difference within group. It may be because the KT application in the present study was not applied directly to the knee. In addition, this change was not seen in the two healthy cohort studies. Therefore, this suggested that there was a different response to KT between the healthy cohorts and ITBS cohort. For other differences in knee kinematics and moments, although the runners with ITBS showed no significant differences in all three

planes, both healthy cohorts showed a significant difference, but there was a different response between the two healthy cohorts. The UK healthy participants showed a significantly greater peak knee flexion angle in the KTNT condition compared to the NT condition, and lower peak knee flexion moments in the KTNT condition compared to the NT condition and lower moments in the KTNT condition compared to the KTT condition. Whereas the Thai healthy participants presented an increase in peak knee internal rotation angle in the KTT condition compared to the NT condition, and a decrease in peak knee abduction moments in the KTT condition compared to the NT and KTNT conditions. An increase in peak knee internal rotation angle is in contrast to the hypothesis that the peak knee internal rotation angle would significantly decrease. In addition, a decrease in the knee abduction moments would also decrease ITB strain and could reduce pain in runners with ITBS, as the ITB plays an important role in resisting knee abduction moments (Hutchinson et al., 2022). However, these were not seen in the Thai runners with ITBS.

The different response between the two healthy cohorts for knee kinematics and moments may be due to the difference in running speed between the two healthy cohort studies. The UK cohort had faster running speeds and had a greater peak knee flexion angle, peak knee internal rotation, and knee abduction moments which have all been associated with faster running speeds (Fukuchi et al., 2017). This suggests that KT may benefit to increase running performance from a greater knee flexion angle over taping without tension in the faster running speeds in the UK healthy cohort, however, this was not seen in KTT condition. This result may be due to the running speed was not controlled and effect of a small sample size, and happened by chance. In addition, the results suggest the slower running speeds in the Thai healthy cohort of taping with tension might have an effect on knee internal rotation angle or knee abduction moments and the ability of the tape to have a meaningful effect which is not seen at the faster running speeds. This may suggest the proprioceptive effect of the tape is diminished at faster running speeds when greater knee internal rotation or knee abduction moments are present. This may be because the KT application used in this thesis was not applied directly to the knee, and could also be due to associations between other factors which can also influence the lower limb kinematics and moments,

such as foot posture (Powell et al., 2016), footwear (Lewinson et al., 2013), but the consideration of these factors were outside the scope of this thesis.

For Gmax and Gmed muscle activity, there was a significant decrease in both Gmax and Gmed muscle activity immediate post-tape compared to pre-tape in runners with ITBS, although there was only a significant difference in the main effect for pre-immediate post-tape. This was similar to the findings in the UK and Thai healthy participants which also showed significantly decreased Gmax muscle activity in the KTNT condition compared to the NT condition. Similarly, the Thai healthy participants showed that the Gmed muscle activity was significantly decreased in both KTT and KTNT conditions compared to the NT conditions, although no significant difference was observed in the UK healthy participants. Decreasing the Gmax and Gmed muscle activity may be associated with a decrease in pain in runners with ITBS. The Gmax is a muscle that connects to the ITB (Richard et al., 2009, Agur et al., 2017), a decrease Gmax muscle activity could lead to a decrease in the tension in the ITB which can reduce the strain or compression of the ITB against the LFE, and may lead to decrease in pain in runners with ITBS. Furthermore, the Gmed is the major hip abductor muscle, and provide eccentric control into hip adduction during stance phase (Lenhart et al., 2014), therefore, changes in the Gmed muscle may be associated with minimize hip adduction which has been indicated as a risk factor during running with ITBS (Baker and Fredericson, 2016). These are supported by Baker et al. (2018) who demonstrated that there was an increase in the Gmax and Gmed muscle activity in runners with ITBS compared to healthy runners. Additionally, the results of this thesis would indicate that the KT application used in this thesis may help to decrease the Gmax and Gmed muscle activity when running at slower speeds, and reduce only the Gmax muscle activity when running at faster speeds.

For the perception of comfort, knee stability, and running performance the runners with ITBS reported more positive responses when running under the KTT than the Thai and UK healthy participants, with the KTNT producing similar responses to a lesser extent. This supports that there may be a subjective difference in the KT application between runners with ITBS and healthy participants in the perception of comfort, knee stability, and running performance. One explanation for this difference was that runners with

ITBS have pain and altered lower limb biomechanics during running. Therefore, runners with ITBS may benefit to a greater extent when considering the perception of comfort, knee stability, and running performance when using KT.

When considering the clinical implications, this thesis investigated the immediate effect of KT on the biomechanics of running and the short-term effect on clinical outcome measures. The results of the study on Thai runners with ITBS showed that there was altered biomechanics in the KTT group, which may relate to the reductions in pain in both the KTT and KTNT groups, with the greatest effect seen in the KTT group. The results of this study support the hypothesis that the KT application in this thesis has short-term benefits for runners with ITBS, which can help them to run with reduced pain. This may allow runners to continue training, or possibly return to competition without time-off running participation during the rehabilitation period.

This study did not investigate the medium-term effects of KT, and further studies are needed to confirm whether KT produces a continued effect and whether there is a latent effect after the tape is removed on both the clinical and biomechanical outcome measures. When considering the removal of the tape, pain may return or may result in a lack of confidence and kinesiophobia when running without tape. In the author's view, therapists may gradually decrease the tension or use the KT with no tension before removing the KT. Nevertheless, there are a limited number of studies that have reported on the rate of removal of KT and therefore, future research is required to investigate this.

The therapist may need to consider the KT application for individualisation in terms of tension of tape, location of tape, and number of lines of KT applied, which may be different from the thesis in clinical implication. This thesis successfully used KT to help improve the biomechanics and muscle activity which have been associated with ITBS in both runners with and without ITBS. In addition, the application of KT in this thesis can also help to decrease pain in runners with ITBS, therefore, the KT technique used in this thesis may be used as a guideline for runners with ITBS. However, the biomechanical changes seen in this thesis were mostly at the hip joint with a lesser effect at the knee joint, which could be due to the KT application in the present study being not applied

directly to the knee but applied more proximally, hence a greater effect at the hip joint. In addition, the taping technique used in this thesis was not applied directly over the hip abductor or hip external rotator muscles, therefore, KT may not offer sufficient proprioceptive effect to increase hip abductor or hip external rotator muscle's function. It may be necessary for the therapist to apply KT directly to the hip or knee to see direct improvements in knee biomechanics or hip abductor and/or external rotator muscle's function (Mackay et al., 2020, Rajasekar et al., 2018), however, this was outside the scope of this thesis.

When considering the KT technique used in this thesis, four lines of KT were used. One line is commonly referred to as the "inhibition" technique, 1 line as "space correction", and 2 lines as "functional correction". Although there is little evidence to support the proposed actions of these individual or combined techniques, the results of this thesis suggest that these techniques provide a level of therapeutic benefit by encouraging self-reported outcome measures. Furthermore, the amount of KT tension could have been adapted for each participant depending on their assessment, however, there is a lack of evidence to support a differential taping treatment plan, but this could be an interesting future investigation. Moreover, this thesis showed the biomechanical effects of taping in running and further investigation of other dynamic movements such as single leg squat, drop jump, and pivot turns used in different sports and patient groups may also provide greater insight into the effect of such taping techniques.

One explanation for the effect of KTT to facilitate hip external rotation is somatosensory stimulation. However, when considering the changes seen in the significant parameters, some parameters show similar changes in KTNT and KTT compared to the NT condition such as average Gmax and Gmed, which were observed in both healthy cohort studies and the participants with ITBS, Table 7-1. This was in contrast to a systematic review concluding that KT had no benefit over taping without tension (Parreira Pdo et al., 2014). In addition, one factor that could be associated with the improvement in some parameters was the psychological effect of KT, however there was no significant change in kinesiophobia which was a psychological parameter considered in the Thai ITBS study.

Nonetheless, the principal mechanism of the effect of KT is likely multifactorial and needs further investigation in future research.

7.2 Contributions to Knowledge

To the authors knowledge, this is the first study to investigate the effect of KT on running biomechanics and perceived outcome measures in individuals with and without ITBS. The KT technique used in this thesis has been hypothesised to increase peak hip external rotation, decrease peak hip adduction and internal rotation and may also decrease peak knee internal rotation, all of which have been previously associated with runners with symptoms of ITBS.

The results of this thesis help our understanding of the immediate effects of KT on running biomechanics and perceived comfort, knee stability, running performance and short-term clinical effects. The first two studies investigated healthy participants recruited from UK and Thai runners, with the KT with tension showing modified running biomechanics including increased hip external rotation and abduction angles, with a positive effect on perception of comfort, knee stability, and running performance when using KT. These changes in running biomechanics may be associated with the problems experienced in runners with ITBS. The final study was, to the author's knowledge, the first RCT to investigate the effect of KT in runners with ITBS, which aimed to explore the possible mechanisms by which KT may reduce pain through changes in lower limb biomechanics. The results of the ITBS study help our understanding of the immediate effects of KT on running biomechanics, muscle activity, hip abductor and external rotator muscle strength, and TFL muscle and ITB length. This thesis also showed that the application of KT can help to decrease pain, improve all domains of KOOS, improve GROC, with no participant reporting any negative important changes in perceive comfort, knee joint stability, and running performance in the short term, although there was no change in the fear of movement over the 7 days considered. Therefore, KT may help runners with ITBS during rehabilitation and training and may subsequently reduce the time away from running participation.

7.3 Research Limitations

This study countered many of the potential limitations by conducting rigorous literature reviews and pilot studies, but it was not possible to control all variables. The first would be the small sample size when examining sex differences, which could be viewed as a limitation. However, the reporting of the effect of taping with both sexes combined, allows for the overall effects to be considered. Future larger studies on the effect of taping on the different sexes should be conducted. The runners were instructed to run at the same self-selected speed under the different conditions and no significant differences were seen in running speed between the conditions except between the KTNT condition compared to NT condition for males in the Thai healthy cohort. However, running speed was not controlled and could have varied between participants. This is a limitation as speed induced changes could appear, however the researcher took this approach to allow the participants to run at their most comfortable speed. Furthermore, not accurately measuring the amount of stretch of the tape is a limitation. Although the application of the KT was applied by a single certified KT practitioner and the proportional increase in KT length visually assessed, variations in the amount of KT stretch could possibly influence the amount of sensory stimulus which could change the level of response to the tape. Each participant wore their own footwear which could be viewed as a limitation as different types of running shoe may have been used during testing, for example minimal and maximal running shoes, however this was not recorded and could not be considered within the analysis.

The exact nature of the perception of comfort and running performance in this thesis were not well defined which are another limitation. A greater understanding may have been achieved if this was specific to, for example comfortable when moving, or no irritation, and what running performance is such as increasing the running speed or agility. This would improve understanding of the question for participants and help the interpretation.

In all studies in this thesis, there was an additional limitation in the data collection protocol, as some markers had to be removed and reattached after the tape was

applied. The effect of this was assessed by checking the repositioning of the anatomical markers by creating virtual markers based on the markers that remained attached (Chapter 3, section 3.4.3). However, any effect of the taping should be considered in light of this marker removal and reattachment which introduced a possible source of test/retest error in the biomechanical measures.

In addition, the KT was re-applied on day 4, and there could have been variations in the tape tension compared to the first day as this was not objectively assessed and recorded. Further work is required on the quantification of the effect of different amounts of KT stretch to determine the optimum tape and whether this should be varied in relation to the individual's presentation.

7.4 Recommendations for future research

The findings from this work have shown the immediate effect of KT on the biomechanics of running, muscle activity, and muscle length, and also shows positive effects in the majority of the clinical outcome measures, most noteworthy being a decrease in pain level in runners with ITBS over the 7 days.

To the author's knowledge, there is little or no research on the medium- and long-term effects of KT in the management of symptoms of ITBS in runners. Current evidence from clinical trials on pain outcomes is controversial and insufficient to draw any conclusions about the effects of KT (Luo and Li, 2021). Future studies should explore the short-, medium- and longer-term effect of KT on the biomechanics of running, muscle activity, muscle strength and muscle length and whether any changes observed are maintained after the removal of the KT, as well as the medium and longer-term benefits in the clinical outcome measures. This absence of literature was highlighted by a previous systematic review and meta-analysis on the use of KT for knee osteoarthritis which stated that evidence exists for the short-term effectiveness but is not available for long-term treatment (Luo and Li, 2021). Based on the findings within this thesis that KT may help to reduce pain and improve function in the short-term, these effects are worthy of further investigation in the medium and longer term in runners with ITBS.

One aspect not considered within this thesis is the effects on the biomechanics of the ankle joints and any association with the changes seen at the knee and hip joints. In addition, further exploration of the comparisons in the biomechanics between healthy and ITBS participants in the no tape condition could be conducted, as could additional analysis of estimates of forces on the structures associated with ITBS. Although current work was specific to runners with ITBS, the findings suggest similar explorations would be applicable in other patient population groups who suffer from knee pain such as patellofemoral pain or knee osteoarthritis to help our understanding of the biomechanics and the association with changes in clinical outcome measures.

The findings presented would suggest that the KT has a positive effect on knee and hip biomechanics and short-term clinical outcomes, therefore exploring other interventions such as neoprene sleeves, knee braces and/or rigid tape, interventions such as stretching or strengthening exercises, or a combination of KT with other interventions may provide interesting and complimentary insights. Although previous effects of KT as an adjunct to exercise in the treatment of PFP showed a similar improvement in pain and functional performance compared to the control group who received only an exercise programme (Akbaş et al., 2011), there has been little or no research on the combination of KT with rehabilitation programmes such as stretching or strengthening exercises in runners with ITBS. Some studies have reported that increases in Gmed muscle strength from a 6-week rehabilitation program can alleviate symptoms and facilitate a return to running in runners with ITBS (Fredericson et al., 2000, Beers et al., 2008). Additionally, stretching of the TFL and ITB is frequently considered as part of ITBS rehabilitation programs and may reduce the friction between the ITB and the LFE during flexion and extension of the knee joint (Fairclough et al., 2006). When considering a combination of treatments various studies have shown that this can be more beneficial for runners with ITBS then single interventions such as taping (Fredericson et al., 2000, Beers, 2008, Ferber et al., 2010b). Therefore, it may be worthy to investigate a combination of KT with the stretching of TFL and ITB and/or the strengthening of the Gmed muscle, as well as other risk factors such as patient education about ITBS, running shoes, and running technique (Fredericson and Weir, 2006, Barber and Sutker, 1992).

7.5 Final Conclusions

The results of this thesis help our understanding of the effect of KT in healthy participants and in runners with ITBS. The results from the healthy studies showed that this KT technique appeared to increase peak hip external rotation in both the UK and Thai healthy cohorts. Additionally, there was a decrease in peak hip internal rotation angle in the Thai healthy participants, and there was a trend towards a decrease in peak hip adduction and internal rotation angle in the UK healthy participants. Furthermore, TFL activity showed a decrease with KTT compared with NT, and Gmax activity reduced with KTNT when compared with NT in the UK healthy participants. Whereas the Thai healthy participants showed Gmax activity decreased with KTNT compared with NT and there was a trend toward a decrease in TFL activity in the KTT condition compared to the NT condition. These results suggest that a significant change in biomechanics of running and muscle activity can be achieved with the application of KT, with the greatest effect seen with the application of KT with tension, with no participants reporting any negative important changes in comfort and perception of stability of the knee joint.

The results of the Thai ITBS study showed that this KT application has a similar biomechanical effect in symptomatic runners with ITBS. There was an increase in the peak hip external rotation in the KTT group, with decrease in average TFL activity but no main effect for group was seen, with an increase in the TFL and ITB length in both the KTT and KTNT groups. In addition, the KTT group had a significantly lower peak knee external rotation moment compared to the KTNT group at immediate post-taping, with no significant differences seen between groups for pre-tape. Furthermore, a decrease in the average Gmax, Gmed, and VM muscle activity was seen with tape but no differences were seen between the groups. Clinical outcome measures in the KTT group showed improvements in NPRS, all domains of KOOS, GROC, and also no participant reported any negative important changes in perceive comfort, stability of knee joint, and running performance, although no changes were seen in TSK. All of these results suggest that changes in running biomechanics previously associated with ITBS may be ameliorated by the use of KT and are most effective with kinesio tape with tension. In addition, with the exception of TSK, there was an improvement in all clinical outcome measures.

Appendices

Appendix 1. Certified Kinesio Taping Practitioner

KTAI • SINCE 1984

Kinesio Taping® Association International

This is to certify that

Mr.Pongchai Watcharakhueankhan,

has successfully completed the course requirements of the CKTP® program for proficiency in the Kinesio Taping® Method.

Certified Kinesio Taping Practitioner®

DR. KENZO KASE, FOUNDER OF THE KINESIO TAPING® METHOD

KINESIO TAPING® ASSOCIATION INTERNATIONAL

The course content is not intended for use outside the scope of practice of the learner's license or regulation.

Certified Kinesio Taping Practitioner KTA INTERNATIONAL KINESIO® CKTP

This Certificate is only valid in conjunction with a valid KTAI membership. 1/9/2021

KTAI • SINCE 1984

Kinesio Taping® Association International

This is to certify that

Mr.Pongchai Watcharakhueankhan

Physiotherapist

has successfully completed the course requirements of the CKTP® program for proficiency in the Kinesio Taping® Method.

Certified Kinesio Taping Practitioner®

DR. KENZO KASE, FOUNDER OF THE KINESIO TAPING® METHOD

KINESIO TAPING® ASSOCIATION INTERNATIONAL

The course content is not intended for use outside the scope of practice of the learner's license or regulation.

Certified Kinesio Taping Practitioner KTA INTERNATIONAL KINESIO® CKTP

This Certificate is only valid in conjunction with a valid KTAI membership. 1/13/2022

Appendix 2. Likert Scale Questionnaire of UK Healthy study

Likert Scale Questionnaire - Please answer the following questions.

Tape 1

1. Do you think kinesio tape is comfortable?

Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6	7

2. Do you think kinesio tape helps the stability of your knee?

Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6	7

3. Do you think kinesio tape offers benefits to your running performance?

Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6	7

Tape 2

1. Do you think kinesio tape is comfortable?

Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6	7

2. Do you think kinesio tape helps the stability of your knee?

Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6	7

3. Do you think kinesio tape offers benefits to your running performance?

Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6	7

Appendix 3. UK Healthy Study Publication

UK healthy study was published as an article in the Gait and Posture journal.

Gait & Posture 91 (2022) 179–185

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

The immediate effects of Kinesio Taping on running biomechanics, muscle activity, and perceived changes in comfort, stability and running performance in healthy runners, and the implications to the management of Iliotibial band syndrome☆

P. Watcharakhueankhan[a,b,*], G.J. Chapman[a], K. Sinsurin[b], T. Jaysrichai[c], J. Richards[a]

[a] Allied Health Research Unit, University of Central Lancashire, UK
[b] Faculty of Physical Therapy, Mahidol University, Nakhon Pathom, Thailand
[c] Faculty of Physical Therapy, Srinakharinwirot University, Nakhon Nayok, Thailand

ARTICLE INFO

Keywords:
Kinesio tape
Running biomechanics
Electromyography
Running
Iliotibial band syndrome

ABSTRACT

Background: Kinesio Taping is frequently used in the management of lower limb injuries, and has been shown to improve pain, function, and running performance. However, little is known about the effects of Kinesio Taping on running biomechanics, muscle activity, and perceived benefits.
Research question: This study aimed to explore the immediate effects of Kinesio Taping on lower limb kinematics, joint moments, and muscle activity, as well as perceived comfort, knee joint stability, and running performance in healthy runners.
Methods: Twenty healthy participants ran at a self-selected pace along a 20-metre runway under three conditions; no tape (NT), Kinesio Tape with tension (KTT), and Kinesio tape without tension (KTNT). Comparisons of peak hip, knee angles and moments, and EMG were analysed during the stance phase of running.
Results: KTT exhibited significant increases in peak hip flexion, peak hip abduction and hip external rotation compared to NT. Moreover, the KTT condition showed a trend towards a decrease in peak hip internal rotation and adduction angle compared to the NT condition. EMG results showed that Tensor Fascia Latae activity decreased with KTT compared with NT, and Gluteus Maximus activity reduced with KTNT when compared with NT. Ten of the 20 participants indicated important improvements in the comfort score, six participants in the knee stability score, and seven participants in the running performance score when using KTT.
Significance: These results suggest that changes in running biomechanics previously associated with ITBS can be improved with the application of kinesio tape, with the greatest effect seen with the application of kinesio tape with tension. Perceived improvements were seen in comfort, stability and running performance, however these benefits were only seen in half the participants. Further work is required to explore the biomechanical effects and perceived benefits in different patient groups.

1. Introduction

Kinesio Taping (KT) is a common treatment technique in physical therapy and rehabilitation in the treatment of musculoskeletal problems [1–5]. Although, the therapeutic effects of KT are still unclear, the hypothesised therapeutic effects include; facilitating muscle activity, providing a sensory stimulus to the skin, muscle, or fascial structures, and limiting range of motion (ROM) [2]. A systematic review concluded that KT was more effective compared to active or sham taping, although the differences were small and may not be clinically important, in addition many of the studies were of low quality [6]. However, there is some evidence to suggest KT may be a useful treatment option for lower limb musculoskeletal problems [3,4] with a systematic review suggesting KT may be recommended to relieve pain intensity and increase ROM for patients with myofascial pain syndrome [5].

Despite the many health benefits of running [7], injuries are common

☆ This research was funded by the Ministry of Science and Technology, Thailand.
* Correspondence to: 322 Sathupradit Road, Yannawa District, Bangpongpang Sub-District, Bangkok 10120, Thailand.
E-mail address: PWatcharakhueankhan@uclan.ac.uk (P. Watcharakhueankhan).

https://doi.org/10.1016/j.gaitpost.2021.10.025
Received 27 May 2021; Received in revised form 22 September 2021; Accepted 15 October 2021
Available online 26 October 2021

Appendix 4. Participant Information Sheet of UK Healthy study

PARTICIPANT INFORMATION SHEET

Version 1 – 14/12/18

The Effects of Kinesio Taping on Biomechanical and Clinical Outcomes in Runners with Iliotibial Band Friction Syndrome

Ph.D Student: Pongchai Watcharakhueankhan

Director of Studies: Prof Jim Richards, School of Health Sciences

Invitation: You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Please do not hesitate to ask if there are any areas of the study you are unclear about or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?
The purpose of this study is to explore the immediate effects of Kinesio Taping application on your thigh. This has been suggested to be effective in reducing pain and improve performance in runner patients who have a lateral knee pain (iliotibial band friction syndrome). In addition, this will determine any perceived changes in the stability of the knee joint, comfort and benefits of kinesio taping.

Aims of the study
The aim of the study is to collect data on the movement of your legs during running and to determine if this affects muscle activity.

Who will conduct the research?
The research will be conducted by a team of researchers made up of experts in human movement and physiotherapists in the Allied Health Research Unit at the University of Central Lancashire. The team is made up of male and female researchers.

Why have I been chosen?
Your aged is between 18 to 45 years, regularly run a minimum of 10 -20 kilometres a week, and no physical limitations which may interfere with the testing protocol such as fatigue, illness, or dizziness. No history of musculoskeletal injury to the lower limbs in the past 6 months, history of taking any anti-inflammatory or analgesic drugs for 72 hours prior to testing, previous surgery to the lower limbs, and skin allergy to kinesio tape.

What we will ask you to do?
You will be asked to wear your normal sports shirt, sports shorts, and running shoes. Then, your skin will be prepared with alcohol wipes and sensors will then be attached to

the skin using hypoallergenic double-sided adhesive tape. After that, sensors will be attached to the skin on the pelvis and lower limbs to record the quality of movement. In addition, EMG sensors which will be placed over key muscles of the lower limb in order to record muscle activity.

After attachment of the sensors you will be asked to perform running tasks. Before testing, you will be allowed to practice in order to become accustom to the testing environment. After that, you will be asked to run at a self-selected speed along a 10m walkway. Three completed trials i.e. good foot strikes on the force plates will be collected and analysed.

You will be tested during running in pre-tape (no-tape), and then kinesio tape and kinesio sham tape, the order of which will be randomised. This study will take approximately one hour to complete.

Kinesio Tape Application

You will be received Kinesio tape application in two conditions; including kinesio tape and kinesio sham tape. Kinesio tape, you will receive an actual therapeutic Kinesio Tape application which consisted of 4 kinesio tape lines. The first tape will be applied over the lateral thigh in Y shape (figure 1). The second tape will be applied across the lower of thigh in half circle (figure 2), and the third and fourth tapes will be applied over the thigh in spiral shape (figure 3-4). These four kinesio tape lines of actual therapeutic Kinesio Tape application will be applied in stretch muscle position and various percent of kinesio tape stretch. The sham taping consists of the same techniques and material as the real application but will be applied with no tension in a neutral position.

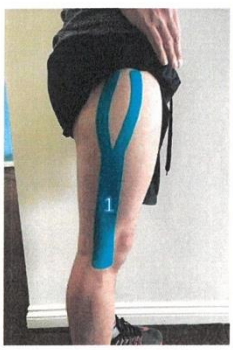


Figure 1

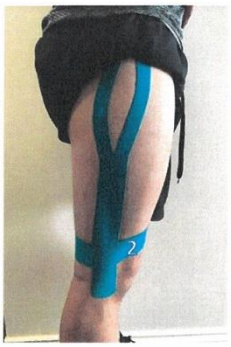


Figure 2

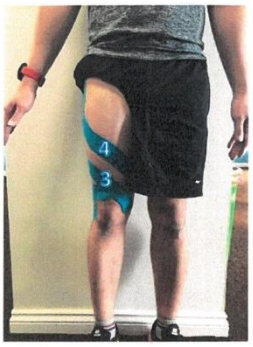


Figure 3

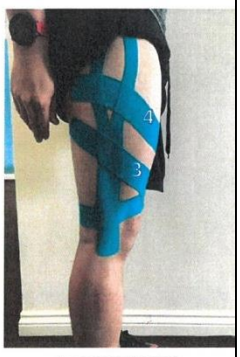


Figure 4

Do I have to take part?

No. It is up to you to decide whether or not you take part. If you do wish to participate, you will be given this information sheet to keep and given the opportunity to ask the researchers any questions you have regarding the study. During the study, if there is any aspect you are unhappy with, you have the right to withdraw at any point without giving any reasons and without any negative consequences, this will include the withdrawal of any data collected from you.

What we will ask you to do?

If having read this information sheet you wish to participate in this study you will be asked to attend for one visit for approximately 1 hour.

What are the possible disadvantages or risks of taking part?
You may have some slight discomfort when we remove the kinesio tape and sensors.

What are the possible benefits of taking part?
You will have a chance to know about your running biomechanics. Moreover, after this study, we can further understand the effects of Kinesio tape on biomechanics in runners.

What happens when the research study stops?
You will not be contacted or required to complete any further assessments regarding this study.

Will information about me be kept confidential?
All the information that we collect about you during the course of this research will be kept strictly confidential. When we write about the results of the study your name and details will be removed completely.

What if there is a problem?
Any complaint about the way you have been dealt with during the study or any possible harm you might suffer will be addressed. If you have any complaints about the study or how you have been treated in the study, please in the first instance contact the researchers using the details provided, they will do their best to answer your questions. If you do not receive a satisfactory response, concerns should be addressed to the University Officer for Ethics at OfficerForEthics@uclan.ac.uk. Information provided should include the study name or description (so that it can be identified), the principal investigator and the substance of the complaint.

What will happen to the results of the research study?
The findings of the study will be submitted to a journal and for conference presentations.

Who is organising the research?
The Allied Health Research Unit in the School of Health Sciences at the University of Central Lancashire are organising the research.

Who is funding this study?
There is not any funding in this study.

Who has reviewed the study?
The University of Central Lancashire Ethics Committee have reviewed and approved this study.

Thank you for taking the time to read about the study, if you have any questions please do not hesitate to ask.

Contact Details

PhD Student
Pongchai Watcharakhueankhan
PWatcharakhueankhan@uclan.ac.uk
Brook Building (Room 121)
University of Central Lancashire
Tel: 0784926313

Director of Studies
Prof Jim Richards
Brook Building (Room 118)
University of Central Lancashire
Preston, PR1 2HE.
JRichards@uclan.ac.uk
Tel: 01772 894575

Appendix 5. PAR-Q+ 2018

2018 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** _____	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** _____	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** _____	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

☑ **If you answered NO to all of the questions above, you are cleared for physical activity.**
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness centre may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

01-11-2017

2018 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm*

If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes*

If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

01-11-2017

2018 PAR-Q+

6. **Do you have any Mental Health Problems or Learning Difficulties?** *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. **Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. **Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. **Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. **Do you have any other medical condition not listed above or do you have two or more medical conditions?**

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: _____

_____

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

01-11-2017

2018 PAR-Q+

If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References
1. Jamnik VK, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.
3. Chisholm DM, Collis ML, Kulak LL, Davenport W, and Gruber N. Physical activity readiness. British Columbia Medical Journal. 1975;17:375-378.
4. Thomas S, Reading J, and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Science 1992;17:4 338-345.

01-11-2017

Appendix 6. UCLan Research Ethics Committee approval

uclan
University of Central Lancashire

13 February 2019

James Richards / Pongchai Watcharakhueankhan
School of Health Sciences
University of Central Lancashire

Dear James / Pongchai

Re: STEMH Ethics Committee Application
Unique Reference Number: STEMH 966

The STEMH ethics committee has granted approval of your proposal application 'The Effects of Kinesio Taping on Biomechanical and Clinical Outcomes in Runners with Iliotibial Band Friction Syndrome'. Approval is granted up to the end of project date*.

It is your responsibility to ensure that

- the project is carried out in line with the information provided in the forms you have submitted
- you regularly re-consider the ethical issues that may be raised in generating and analysing your data
- any proposed amendments/changes to the project are raised with, and approved, by Committee
- you notify EthicsInfo@uclan.ac.uk if the end date changes or the project does not start
- serious adverse events that occur from the project are reported to Committee
- a closure report is submitted to complete the ethics governance procedures (Existing paperwork can be used for this purposes e.g. funder's end of grant report; abstract for student award or NRES final report. If none of these are available use e-Ethics Closure Report Proforma).

Yours sincerely

Emma Bray
Deputy Vice Chair
STEMH Ethics Committee

* for research degree students this will be the final lapse date

NB - Ethical approval is contingent on any health and safety checklists having been completed and necessary approvals gained as a result.

Appendix 7.Consent Form of UK Healthy study

uclan

CONSENT FORM

The Effects of Kinesio Taping on Biomechanical and Clinical Outcomes in Runners with Iliotibial Band Friction Syndrome

Ph.D Student: Pongchai Watcharakhueankhan
Director of Studies: Prof Jim Richards

School of Health Sciences

The following test will require you to have sensors attached to your legs to determine your muscle activity and movements whilst you perform running test. Moreover, kinesio tape will be applied to your thigh during running test. There will be breaks between the test so these should not cause any fatigue. Only data from the sensors will be collected, no photographic images. This will also prevent you from being identified in any report/publication. Before any of the tests are conducted the University of Central Lancashire Ethics Committee require written consent, please complete if you agree to the terms of the research.

Please initial box

I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions	☐
I agree to wear your normal sports shirt, sports shorts, and running shoes and understand why this is required	☐
I confirm I have no physical limitations which may interfere with the testing protocol such as fatigue, illness, or dizziness. No history of musculoskeletal injury to the lower limbs in the past 6 months, previous surgery to the lower limbs, and skin allergy to kinesio tape.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my rights being affected. I understand that I will be able to withdraw my data from the study up until all the tests have been completed.	☐
I agree to take part in the above study.	☐

_____	_____	_____
Name of Participant	Date	Signature
_____	_____	_____
Name of Person taking consent (if different from researcher)	Date	Signature
_____	_____	_____
Researcher	Date	Signature

1 for participant; 1 for researcher

Appendix 8. Participant Information Sheet of Thai Healthy Study

เอกสารชี้แจงผู้เข้าร่วมวิจัย สำหรับผู้เข้าร่วมวิจัยที่มีอายุ 18 ปีบริบูรณ์ขึ้นไป
(Participant Information Sheet)

☐ ต้นฉบับ ☑การปรับเปลี่ยนครั้งที่.....2..... วันที่....11...../.... มี.ค...../.....2563...

ในเอกสารนี้อาจมีข้อความที่ท่านอ่านแล้วยังไม่เข้าใจ โปรดสอบถามหัวหน้าโครงการวิจัย หรือผู้แทนให้ช่วยอธิบาย จนกว่าจะเข้าใจดี ท่านจะได้รับเอกสารนี้ 1 ฉบับ นำกลับไปอ่านที่บ้านเพื่อปรึกษาหารือกับญาติพี่น้อง เพื่อนสนิท แพทย์ประจำตัว ของท่าน หรือผู้อื่นที่ท่านต้องการปรึกษา เพื่อช่วยในการตัดสินใจเข้าร่วมการวิจัย

ชื่อโครงการ (ภาษาไทย) ผลการใช้คิเนซิโอเทปต่อผลลัพธ์ทางชีวกลศาสตร์และคลินิกในนักวิ่งสุขภาพดี

ชื่อผู้วิจัย นายพงษ์ชัย วัชรเขื่อนขันธ์

สถานที่วิจัย

1. คณะกายภาพบำบัด มหาวิทยาลัยมหิดล ศาลายา เลขที่ 999 ถนนพุทธมณฑลสาย 4 ต.ศาลายา อ.พุทธมณฑล จ. นครปฐม 73170

2. ศูนย์กายภาพบำบัด (เชิงสะพานสมเด็จพระปิ่นเกล้า) คณะกายภาพบำบัด มหาวิทยาลัยมหิดล
198/2 ถนนสมเด็จพระปิ่นเกล้า แขวงบางยี่ขัน เขตบางพลัด กรุงเทพฯ 10700
โทรศัพท์ : 02-441-5450
โทรศัพท์ 086-326-8162

โครงการวิจัยนี้ทำขึ้นเพื่อศึกษาผลการใช้คิเนซิโอเทป (เทปสีเพื่อการบำบัดรักษา) ต่อขาในนักวิ่งสุขภาพดี ซึ่งประโยชน์ที่คาดว่าจะได้รับคือ ช่วยให้เข้าใจผลการใช้เทปสีเพื่อการบำบัดรักษาในคนสุขภาพดีและเป็นแนวทางการใช้เทปสีเพื่อการบำบัดรักษา ในคนไข้นักวิ่งที่มีอาการปวดเข่าทางด้านนอก เพื่อที่จะช่วยให้นักวิ่งเหล่านี้สามารถวิ่งได้ไม่ต้องหยุดพักขณะทำการรักษาและฟื้นฟูได้

ท่านได้รับเชิญให้เข้าร่วมวิจัยนี้ เพราะท่านเป็นผู้ที่มีคุณสมบัติครบถ้วน ตามเกณฑ์ที่ผู้วิจัยกำหนด คือมีอายุระหว่าง 18 ถึง 45 ปี มีระยะทางการวิ่งเฉลี่ยรวมอย่างน้อย 10 กิโลเมตรต่อสัปดาห์ ไม่มีการจำกัดการเคลื่อนไหวทางกายซึ่งอาจจะส่งผลต่อการทดสอบได้ เช่น การอ่อนล้า การเจ็บป่วย หรือการวิงเวียนศีรษะ ไม่มีประวัติการบาดเจ็บทางระบบกระดูกและกล้ามเนื้อของขาภายใน 6 เดือนก่อนเริ่มการศึกษา ไม่มีประวัติเคยได้รับการผ่าตัดต่อบริเวณขา ไม่มีการรับประทานยาคลายกล้ามเนื้อหรือยาแก้อักเสบก่อนการทดสอบ 72 ชั่วโมงและไม่มีการแพ้ต่อเทปสีเพื่อการบำบัดรักษา

ประโยชน์ที่ท่านได้รับ คือ ท่านจะได้มีโอกาสทราบชีวกลศาสตร์การวิ่งของท่าน และหากงานวิจัยนี้ได้ผลดีจะเป็นประโยชน์สำหรับผู้ป่วยที่มีการปวดเข่าด้านนอกในอนาคตได้

โครงการวิจัยนี้จะมีผู้เข้าร่วมการวิจัยทั้งสิ้นประมาณ 20 คน ระยะเวลาที่ใช้ในเข้าร่วมการวิจัยประมาณ 1 ชั่วโมง ถึง 1 ชั่วโมง 30 นาที

หากท่านตัดสินใจเข้าร่วมการวิจัยแล้ว จะมีขั้นตอนการวิจัยดังต่อไปนี้คือ

ขั้นตอนการเตรียมการ

ผู้วิจัยทำการอธิบายวัตถุประสงค์ ขั้นตอนการศึกษา ประโยชน์ของการศึกษา ความเสี่ยงในการวิจัย รวมทั้งการป้องกันและความปลอดภัยของการศึกษานี้ จากนั้นผู้วิจัยสัมภาษณ์ประวัติทั่วไปและประวัติความเจ็บป่วย เช่น โรคประจำตัว และการบาดเจ็บ และหากท่านผ่านเกณฑ์การเข้าร่วมงานวิจัย ผู้วิจัยจะให้ท่านลงนามในใบยินยอมเข้าร่วมวิจัย

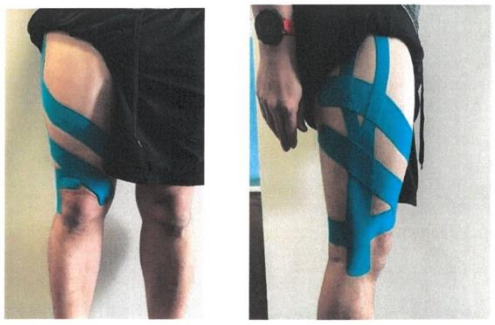
ท่านจะได้รับการทดสอบความถนัดของขา โดยการให้เตะลูกฟุตบอล เอาปลายขาวาดเป็นรูปเลขแปดบนพื้น

ท่านจะใส่ชุดเสื้อกล้าม กางเกงขาสั้น ถุงเท้าและรองเท้ากีฬาในการทดสอบของท่านเอง จากนั้นผู้วิจัยจะใช้แอลกอฮอล์เช็ดผิวหนังและทำการติดขั้วรับสัญญาณการทำงานของกล้ามเนื้อที่กล้ามเนื้อก้นและต้นขาของขาทั้งสองข้าง รวมทั้งจะได้รับการติดเครื่องหมายทรงกลมสะท้อนแสงบริเวณขาและกระดูกเชิงกรานของท่าน

ขั้นตอนการเก็บข้อมูล

ท่านจะได้รับการทดสอบความยืดหยุ่นและการตึงตัวของกล้ามเนื้อต้นขาด้านนอก การทดสอบความแข็งแรงของกล้ามเนื้อสะโพก การทดสอบด้วยการย่อขาข้างเดียว และทดสอบด้วยการวิ่งเป็นระยะทาง 10 เมตร ก่อนการติดเทปสีเพื่อการบำบัดรักษาและจากนั้นทดสอบการวิ่งหลังติดเทปสีเพื่อการบำบัดรักษาแบบมีแรงตึงตัว และไม่มีแรงตึงตัวโดยการสุ่มลำดับการทดสอบ โดยท่านจะวิ่ง 5-10 รอบในแต่ละเงื่อนไข โดยแต่ละรอบของการทดสอบจะมีระยะเวลาพักนานอย่างน้อย 60 วินาทีหรือจนกว่าท่านจะหายเหนื่อยและพร้อมที่จะทำการทดสอบครั้งต่อไป ซึ่งก่อนการทดสอบ ท่านจะได้ทดลองซ้อมวิ่งเพื่อให้เกิดความคุ้นเคยกับสิ่งแวดล้อมและการทดสอบ

หลังการทดสอบการวิ่งที่มีการติดเทปสีเพื่อการบำบัดรักษาแบบมีแรงตึงตัวและไม่มีแรงตึงตัว ท่านจะได้รับการทำแบบสอบถามความรู้สึกหลังการเทปสีเพื่อการบำบัดรักษาในเรื่องความสะดวกสบาย ความมั่นคงของเข่าและสมรรถภาพการวิ่งหลังการใช้เทปสีเพื่อการบำบัดรักษา



รูปภาพแสดงการติดเทปสีเพื่อบำบัดรักษาด้านหน้าและด้านข้าง

ความเสี่ยงที่อาจจะเกิดขึ้นเมื่อเข้าร่วมการวิจัย งานวิจัยนี้มีความเสี่ยงน้อยมากเนื่องจากเป็นการวิ่งระยะสั้น 10 เมตร และหยุดพักไม่ใช่การวิ่งต่อเนื่องระยะยาว รวมถึงผู้วิจัยทำการศึกษาในกลุ่มประชากรที่มีสุขภาพร่างกายสมบูรณ์แข็งแรง และไม่มีอาการเจ็บปวดหรือบาดเจ็บใด ๆ ขณะเข้าร่วมงานวิจัย อย่างไรก็ตาม ผู้วิจัยได้จัดเตรียมแผ่นเย็น สำหรับประคบบริเวณกล้ามเนื้อ ที่อาจเกิดอาการปวด เมื่อยล้าได้ เพื่อป้องกันและลดความรุนแรงของอาการเจ็บปวดที่อาจจะเกิดขึ้นได้ และถ้าท่านมีความผิดปกติเกิดขึ้นจากการเข้าร่วมการวิจัยในครั้งนี้ เช่น มีอาการปวด เมื่อยล้าอย่างรุนแรง ผู้วิจัยจะให้ท่านหยุดทันทีและผู้วิจัยจะคอยสังเกตอาการ ให้การรักษา และรับผิดชอบค่าใช้จ่ายในการรักษาทั้งหมด จนกว่าอาการผิดปกตินั้นจะหายไปและจะขอให้ท่านยุติการเข้าร่วมโครงการวิจัยต่อไป

หากมีอาการผิดปกติ รู้สึกไม่สบายกาย หรือมีผลกระทบต่อจิตใจของท่านเกิดขึ้นระหว่างการวิจัย ท่านจะแจ้งผู้วิจัยโดยเร็วที่สุด และหากท่านมีข้อข้องใจที่จะสอบถามที่เกี่ยวข้องกับการวิจัย หรือหากเกิดการบาดเจ็บ/เจ็บป่วย หรือหากเกิดเหตุการณ์ไม่พึงประสงค์จากการวิจัยกับท่าน ท่านสามารถติดต่อได้ที่ อาจารย์พงษ์ชัย วัชรเขื่อนขันธ์ หมายเลขโทรศัพท์ 086-326-8162 ได้ตลอด 24 ชั่วโมง

หากเกิดเหตุการณ์ไม่พึงประสงค์จากการวิจัย ท่านจะได้รับการรักษาที่ ศูนย์การแพทย์กาญจนาภิเษก มหาวิทยาลัยมหิดล เลขที่ 999 ถ.บรมราชชนนี ต.ศาลายา อ.พุทธมณฑล จ.นครปฐม 73170 หรือ โรงพยาบาลศิริราช เลขที่ 2 ถนนวังหลัง แขวงศิริราช เขตบางกอกน้อย กรุงเทพฯ 10700 และอาจารย์พงษ์ชัย วัชรเขื่อนขันธ์ จะเป็นผู้รับผิดชอบค่าใช้จ่ายในการแก้ไขเหตุไม่พึงประสงค์ สามารถติดต่อหมายเลขโทรศัพท์ 086-326-8162 ได้ตลอด 24 ชั่วโมง

การวิจัยนี้ไม่มีค่าตอบแทนที่จะได้รับ ไม่มีค่าใช้จ่ายใด ๆ ที่ท่านจะต้องรับผิดชอบและไม่มีค่าเดินทาง

หากมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ทราบโดยรวดเร็วไม่ปิดบัง

ข้อมูลส่วนตัวของท่านจะถูกเก็บรักษาไว้เป็นระยะเวลา 5 ปีหลังเสร็จสิ้นงานวิจัย ไม่เปิดเผยต่อสาธารณะเป็นรายบุคคล แต่จะรายงานผลการวิจัยเป็นข้อมูลส่วนรวม และจะทำลายเอกสารโดยลบไฟล์ข้อมูลและใช้เครื่องทำลายเอกสารเพื่อทำลายเอกสาร ข้อมูลของท่านเป็นรายบุคคลอาจมีคณะบุคคลบางกลุ่มเข้ามาตรวจสอบได้ เช่น ผู้ให้ทุนวิจัย สถาบันหรือองค์กรของรัฐที่มีหน้าที่ตรวจสอบ คณะกรรมการจริยธรรมฯ เป็นต้น

ท่านมีสิทธิ์ถอนตัวออกจากโครงการการวิจัยเมื่อใดก็ได้ โดยไม่ต้องแจ้งให้ทราบล่วงหน้าและการไม่เข้าร่วมการวิจัยหรือถอนตัวออกจากโครงการวิจัยนี้จะไม่มีผลกระทบต่อการบริการและการรักษาที่ สมควรจะได้รับแต่ประการใด

โครงการวิจัยนี้ได้รับการพิจารณารับรองจาก คณะกรรมการจริยธรรมการวิจัยในคนส่วนกลาง มหาวิทยาลัยมหิดล ซึ่งมีสำนักงานอยู่ที่ สำนักงานอธิการบดีมหาวิทยาลัยมหิดล ถนนพุทธมณฑล สาย 4 ตำบลศาลายา อำเภอพุทธมณฑล

จังหวัดนครปฐม 73170 หมายเลขโทรศัพท์ 02-849-6224 ,6225 โทรสาร 02-849-6224 หากท่านได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ ท่านสามารถติดต่อกับประธานคณะกรรมการฯ หรือผู้แทน ได้ตามสถานที่และหมายเลขโทรศัพท์ข้างต้น

ข้าพเจ้าได้อ่านรายละเอียดในเอกสารนี้ครบถ้วนแล้ว

ลงชื่อ.....ผู้เข้าร่วมวิจัย

(.....)

วันที่...../...../.....

Appendix 9. Screening Questionnaire (Thai Version)

SCREENING QUESTIONNAIRE (IN THAI)

(แบบสัมภาษณ์ข้อมูลผู้เข้าร่วมการวิจัย)

ส่วนที่ 1 ข้อมูลทั่วไปของผู้เข้าร่วมการวิจัย

รหัสผู้เข้าร่วมวิจัย.....เพศ.....อายุ.....ปี.....เดือน

น้ำหนัก.....กิโลกรัม ส่วนสูง.....เซนติเมตร

โทรศัพท์..... ระยะทางการวิ่งเฉลี่ยใน 1 สัปดาห์.....

สำหรับผู้วิจัย

ขาข้างที่ถนัด.....

ส่วนที่ 2 ข้อมูลทางด้านสุขภาพ

แบบประเมินความพร้อมก่อนการออกกำลังกาย (PAR-Q)

1. ท่านเคยได้รับการบอกกล่าวจากแพทย์ว่าเป็นโรคหัวใจ☐ หรือความดันโลหิตสูง☐หรือไม่

☐ ใช่ ☐ ไม่ใช่ ☐ ไม่ทราบ

2. ท่านมีอาการปวดหรือเจ็บแน่นหน้าอกขณะพัก ระหว่างทำกิจวัตรประจำวัน หรือ ขณะออกกำลังกายหรือไม่

☐ ใช่ ☐ ไม่ใช่ ☐ ไม่ทราบ

3. ท่านเคยอาการหน้ามืด วิงเวียนศีรษะหรือหมดสติใน ระยะเวลา 12 เดือนที่ผ่านมาหรือไม่ (กรุณาตอบ ไม่ใช่ ถ้าอาการนี้เกิดขึ้นขณะหายใจเร็วมากเกินไปหรือออกกำลังกายหนักเกินไป)

☐ ใช่ ☐ ไม่ใช่ ☐ ไม่ทราบ

4. ท่านเคยได้รับการวินิจฉัยว่าเป็นโรคเรื้อรังอื่น ๆ (นอกจากโรคหัวใจหรือความดันโลหิตสูง)

☐ ใช่ ☐ ไม่ใช่ ☐ ไม่ทราบ

ถ้ามี โปรดระบุ.....

5. ปัจจุบันท่านได้รับประทานยาสำหรับสภาวะโรคเรื้อรังหรือไม่

☐ ใช่ ☐ ไม่ใช่ ☐ ไม่ทราบ

ถ้ามี

โปรดระบุชื่อสภาวะโรคเรื้อรังและชื่อยา.....

.....

6. ปัจจุบันหรือภายใน 12 เดือนที่ผ่านมาท่านมีปัญหาโรคกระดูก ข้อต่อ กล้ามเนื้อเส้นเอ็น หรือเส้นเอ็นกระดูกและการออกกำลังกายจะทำให้ให้อาการหนักขึ้นหรือไม่ (กรุณาตอบ ไม่ใช่ ถ้าอาการนี้เกิดขึ้นในอดีตแต่ไม่ได้จำกัดการออกกำลังกายปัจจุบัน)

☐ ใช่ ☐ ไม่ใช่ ☐ ไม่ทราบ

ถ้ามี โปรดระบุ.....

7. ท่านเคยได้รับการบอกกล่าวจากแพทย์ว่าควรออกกำลังกายภายใต้คำแนะนำของแพทย์หรือไม่

☐ ใช่ ☐ ไม่ใช่ ☐ ไม่ทราบ

<u>คำถามเพิ่มเติม</u>

1. ท่านเคยได้รับบาดเจ็บหรือได้รับการผ่าตัดรยางค์ขาหรือไม่

☐ ใช่ ☐ ไม่ใช่ ☐ ไม่ทราบ

ถ้ามี โปรดระบุ.....

2. ท่านมีการรับประทานยาคลายกล้ามเนื้อหรือยาแก้อักเสบก่อนการทดสอบ 72 ชั่วโมง

☐ ใช่ ☐ ไม่ใช่ ☐ ไม่ทราบ

Appendix 10. Informed Consent Sheet of Thai Healthy Study

MU-CIRB	คณะกรรมการจริยธรรมการวิจัยในคนส่วนกลาง มหาวิทยาลัยมหิดล	แก้ไข ณ วันที่ 02/08/2015
หนังสือแสดงเจตนายินยอมเข้าร่วมการวิจัยโดยได้รับการบอกกล่าวและเต็มใจ สำหรับผู้เข้าร่วมวิจัยที่มีอายุ 18 ปีบริบูรณ์ขึ้นไป (Informed Consent Sheet)		หน้าที่ 1 ของ 2 หน้า

หนังสือแสดงเจตนายินยอมเข้าร่วมการวิจัยโดยได้รับการบอกกล่าวและเต็มใจ
สำหรับผู้เข้าร่วมวิจัยที่มีอายุ 18 ปีบริบูรณ์ขึ้นไป (Informed Consent Sheet)

วันที่..... เดือน..... พ.ศ.....

ข้าพเจ้า.....อายุ.....ปี อาศัยอยู่บ้านเลขที่.....

ถนน.....ตำบล.....อำเภอ.....

จังหวัด..... รหัสไปรษณีย์..... โทรศัพท์.....

ขอแสดงเจตนายินยอมเข้าร่วมโครงการวิจัยเรื่องผลการใช้คิเนซิโอเทปต่อผลลัพธ์ทางชีวกลศาสตร์และคลินิกในนักวิ่งที่มีสุขภาพดี

โดยข้าพเจ้าได้รับทราบรายละเอียดเกี่ยวกับที่มาและจุดมุ่งหมายในการทำวิจัยรายละเอียดขั้นตอนต่าง ๆ ที่จะต้องปฏิบัติหรือได้รับการปฏิบัติ ประโยชน์ที่คาดว่าจะได้รับของการวิจัยและความเสี่ยงที่อาจจะเกิดขึ้นจากการเข้าร่วมการวิจัย รวมทั้งแนวทางป้องกันและแก้ไขหากเกิดอันตรายขึ้น ค่าตอบแทนที่จะได้รับ ค่าใช้จ่ายที่ข้าพเจ้าจะต้องรับผิดชอบจ่ายเอง โดยได้อ่านข้อความที่มีรายละเอียดอยู่ในเอกสารชี้แจงผู้เข้าร่วมการวิจัยโดยตลอด อีกทั้งยังได้รับคำอธิบายและตอบข้อสงสัยจากหัวหน้าโครงการวิจัยเป็นที่เรียบร้อยแล้ว โดยไม่มีสิ่งใดปิดบังซ่อนเร้น

ข้าพเจ้าจึงสมัครใจเข้าร่วมในโครงการวิจัยนี้ :

ข้าพเจ้าได้ทราบถึงสิทธิ์ที่ข้าพเจ้าจะได้รับข้อมูลเพิ่มเติมทั้งทางด้านประโยชน์และโทษจากการเข้าร่วมการวิจัย และสามารถถอนตัวหรืองดเข้าร่วมการวิจัยได้ทุกเมื่อ โดยจะไม่มีผลกระทบต่อการบริการและการรักษาพยาบาลที่ข้าพเจ้าจะได้รับต่อไปในอนาคต และยินยอมให้ผู้วิจัยใช้ข้อมูลส่วนตัวของข้าพเจ้าที่ได้รับจากการวิจัย แต่จะไม่เผยแพร่ต่อสาธารณะเป็นรายบุคคล โดยจะนำเสนอเป็นข้อมูลโดยรวมจากการวิจัยเท่านั้น

หากข้าพเจ้ามีอาการผิดปกติ รู้สึกไม่สบายกาย หรือมีผลกระทบต่อจิตใจของข้าพเจ้าเกิดขึ้นระหว่างการวิจัย ข้าพเจ้าจะแจ้งผู้วิจัยโดยเร็วที่สุด และหากข้าพเจ้ามีข้อข้องใจเกี่ยวกับขั้นตอนของการวิจัย หรือหากเกิดผลข้างเคียงที่ไม่พึงประสงค์จากการวิจัยขึ้นกับข้าพเจ้า ข้าพเจ้าจะสามารถติดต่อกับ อ.พงษ์ชัย วัชรเขื่อนขันธ์ หมายเลขโทรศัพท์ 086-326-8162 ได้ตลอด 24 ชั่วโมง

/หากข้าพเจ้า ได้รับการปฏิบัติ.....

1

หากข้าพเจ้า ได้รับการปฏิบัติไม่ตรงตามที่ได้ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย ข้าพเจ้าจะสามารถติดต่อกับประธานคณะกรรมการจริยธรรมการวิจัยในคนหรือผู้แทน ได้ที่สำนักงานคณะกรรมการจริยธรรมการวิจัยในคนส่วนกลาง สำนักงานอธิการบดี มหาวิทยาลัยมหิดล หมายเลขโทรศัพท์ 02-849-6224 ,6225 โทรสาร 02-849-6224

ข้าพเจ้าเข้าใจข้อความในเอกสารชี้แจงผู้เข้าร่วมการวิจัย และหนังสือแสดงเจตนายินยอมนี้โดยตลอดแล้ว จึงลงลายมือชื่อไว้

ลงชื่อ.....
(.....)
ผู้เข้าร่วมการวิจัย/ผู้แทนโดยชอบธรรม
วันที่...../...../.....

ลงชื่อ.....
(.....)
ผู้ให้ข้อมูลและขอความยินยอม/หัวหน้าโครงการวิจัย
วันที่...../...../.....

ในกรณีผู้เข้าร่วมการวิจัยไม่สามารถอ่านหนังสือได้ผู้ที่อ่านข้อความทั้งหมดแทนผู้เข้าร่วมการวิจัยคือ..... ..... จึงได้ลงลายมือชื่อไว้เป็นพยาน

ลงชื่อ.....พยาน
(.....)
วันที่...../...../.....

Appendix 11. Likert scale Thai version

รหัสผู้ตอบแบบประเมิน.....

วันที่ประเมิน .....

แบบสอบถามความความพึงพอใจในการใช้คิเนซิโอเทป (Kinesio Tape)

กรุณาตอบคำถามต่อไปนี้

1. คุณคิดว่าหลังการใช้คิเนซิโอเทป (kinesio tape) คุณมีความสะดวกสบายในการเคลื่อนไหวหรือไม่

ไม่เห็นด้วยอย่างยิ่ง	ไม่เห็นด้วย	ไม่เห็นด้วยเล็กน้อย	ปกติ	เห็นด้วยเล็กน้อย	เห็นด้วย	เห็นด้วยอย่างยิ่ง
1	2	3	4	5	6	7

2. คุณคิดว่าหลังการใช้คิเนซิโอเทป (kinesio tape) ช่วยเพิ่มความมั่นคงให้กับข้อเข่าคุณหรือไม่

ไม่เห็นด้วยอย่างยิ่ง	ไม่เห็นด้วย	ไม่เห็นด้วยเล็กน้อย	ปกติ	เห็นด้วยเล็กน้อย	เห็นด้วย	เห็นด้วยอย่างยิ่ง
1	2	3	4	5	6	7

3. คุณคิดว่าคิเนซิโอเทป (kinesio tape) มีประโยชน์ต่อสมรรถภาพการวิ่งของคุณหรือไม่

ไม่เห็นด้วยอย่างยิ่ง	ไม่เห็นด้วย	ไม่เห็นด้วยเล็กน้อย	ปกติ	เห็นด้วยเล็กน้อย	เห็นด้วย	เห็นด้วยอย่างยิ่ง
1	2	3	4	5	6	7

Appendix 12. Mahidol University Central Institutional Review Board Certificate of Approval

COA No. MU-CIRB 2019/224.1912

Mahidol University Central Institutional Review Board (MU-CIRB)

Certificate of Approval

Protocol No.: MU-CIRB 2019/282.2510

Title of Project: The Effects of Kinesio Taping on Biomechanical and Clinical Outcomes in Runners with Iliotibial Band Friction Syndrome

Approval Includes:

1) Principal Investigator: Mr. Pongchai Watcharakhueankhan
   Affiliation: Faculty of Physical Therapy, Mahidol University
   Research Site: Faculty of Physical Therapy, Mahidol University
2) Submission Form Version Received Date 28 November 2019
3) Protocol Version Received Date 25 October 2019
4) Participant Information Sheet Version Received Date 28 November 2019
5) Informed Consent Form Version Received Date 28 November 2019
6) Screening Questionnaire Version Received Date 28 November 2019
7) Questionnaire Version Received Date 25 October 2019
8) Knee and Osteoarthritis Outcome Score Version Received Date 25 October 2019
9) Thai version of Tampa Scale for Kinesiophobia Version Received Date 25 October 2019
10) Recruitment Material Version Received Date 25 October 2019

MU-CIRB is in Full Compliance with International Guidelines for Human Research Protection such as Declaration of Helsinki, The Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP)

Date of Approval: *19 / December / 2019*

Date of Expiration: *18 / December / 2020*

Signature of Chairperson: .....

(Professor Dr. Rutja Phuphaibul)

MU-CIRB Chair

Signature of Institute Representative: .....

(Professor Wachira Kochakarn)

Acting Vice President for Research and Scientific Affairs

** See list of Co-Investigators at the back page*

Page 1 of 2

List of Co – Investigators

1. Prof. Dr. Jim Richards
2. Dr. Graham Chapman
3. Asst. Prof. Dr. Komsak Sinsurin

All MU-CIRB Approved Investigators must comply with the Following:

1. Conduct the research according to the approved protocol.
2. Conduct the informed consent process without coercion or undue influence, and provide the potential subjects sufficient time to consider whether or not to participate.
3. Use only the Consent Form bearing the MU-CIRB Approval stamp.
4. Obtain approval of any changes in research activity before commencing and informed research participants about the changes for their consideration in pursuing the research.
5. Timely report of serious adverse events to MU-CIRB and any new information that may adversely affect the safety of the subjects or the conduct of the trial.
6. Provide MU-CIRB the progress reports at least annually or as requested.
7. Provide MU-CIRB the final reports when completed the study procedures.

.....

MU-CIRB Address: Office of the President, Mahidol University, 4th Floor, Room Number 411
999 Phuttamonthon 4 Road, Salaya, Nakhonpathom 73170, Thailand
Tel: 66 (0) 2849 6224, 6225 Fax: 66 (0) 2849 6224
E-mail: mucirb@gmail.com
Website: http://www.sp.mahidol.ac.th

COA No. MU-CIRB 2019/224.1912

Mahidol University Central Institutional Review Board (MU-CIRB)

Certificate of Approval

Protocol No.: MU-CIRB 2019/282.2510

Title of Project: The Effects of Kinesio Taping on Biomechanical and Clinical Outcomes in Runners with Iliotibial Band Friction Syndrome

Approval Includes:

1) Principal Investigator: Mr. Pongchai Watcharakhueankhan
   Affiliation: Faculty of Physical Therapy, Mahidol University
   Research Site: Faculty of Physical Therapy, Mahidol University
2) Submission Form Version Date 11 March 2020
3) Protocol Version Date 16 March 2020
4) Participant Information Sheet Version Received Date 11 March 2020
5) Informed Consent Form Version Received Date 28 November 2019
6) Screening Questionnaire Version Received Date 28 November 2019
7) Questionnaire Version Received Date 25 October 2019
8) Data Collection Form Version Date 2 July 2020
9) Knee and Osteoarthritis Outcome Score Version Received Date 25 October 2019
10) Thai version of Tampa Scale for Kinesiophobia Version Received Date 25 October 2019
11) Recruitment Material Version Received Date 25 October 2019

MU-CIRB is in Full Compliance with International Guidelines for Human Research Protection such as Declaration of Helsinki, The Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP)

Date of Approval: *19 / December / 2020*

Date of Expiration: *18 / December / 2021*

Signature of Chairperson: .....

(Professor Dr. Rutja Phuphaibul)

MU-CIRB Chair

** See list of Co-Investigators at the back page*

List of Co – Investigators

1. Prof. Dr. Jim Richards
2. Dr. Graham Chapman
3. Asst. Prof. Dr. Komsak Sinsurin

All MU-CIRB Approved Investigators must comply with the Following:

1. Conduct the research according to the approved protocol.
2. Conduct the informed consent process without coercion or undue influence, and provide the potential subjects sufficient time to consider whether or not to participate.
3. Use only the Consent Form bearing the MU-CIRB Approval stamp.
4. Obtain approval of any changes in research activity before commencing and informed research participants about the changes for their consideration in pursuing the research.
5. Timely report of serious adverse events to MU-CIRB and any new information that may adversely affect the safety of the subjects or the conduct of the trial.
6. Provide MU-CIRB the progress reports at least annually or as requested.
7. Provide MU-CIRB the final reports when completed the study procedures.

.....

MU-CIRB Address: Office of the President, Mahidol University, 4th Floor, Room Number 411
999 Phuttamonthon 4 Road, Salaya, Nakhonpathom 73170, Thailand
Tel: 66 (0) 2849 6224, 6225 Fax: 66 (0) 2849 6224
E-mail: mucirb@gmail.com
Website: http://www.sp.mahidol.ac.th

Appendix 13. Unpaired t-tests and Mann-Whitney U tests for comparisons between the UK and Thai healthy participants under the NT condition

Shapiro-Wilk tests were performed to determine the distribution of the data. The result found that there were parameters that showed non-normal distributed including peak hip flexion moment, peak hip abduction moment, peak hip adduction moment, peak hip internal rotation moment, peak knee flexion angle, minimum knee flexion angle, peak knee abduction angle, peak knee adduction moment, peak knee external rotation moment, coronal plane knee ROM, peak VM muscle activity, and running speed. For normally distributed data, Unpaired t-tests were used to compare between the UK and Thai healthy participants under the NT condition whereas Mann-Whitney U tests were used in non-normally distributed data. Table Appendix 13-0-1 showed mean (SDs) and Unpaired t-tests results, median (Q1/Q3) and Mann-Whitney U tests of peak hip kinematics and moments in the sagittal, coronal and transverse plane. Table Appendix 13-0-2 showed mean (SDs) and Unpaired t-tests results, median (Q1/Q3) and Mann-Whitney U tests of peak knee kinematics and moments in the sagittal, coronal and transverse plane. Table Appendix 13-0-3 showed mean (SDs) and Unpaired t-tests results, median (Q1/Q3) and Mann-Whitney U tests of normalised values from EMG signal analysis during stance phase.

For running speed, the Mann-Whitney U tests showed a significant greater in the UK healthy participants compared to the Thai healthy participants ($p<0.001$). The mean (Q1, Q3) running speed in the UK healthy participants was 3.87 (3.32, 4.27) m/s and for the Thai healthy participants was 2.79 (2.56, 3.16) m/s.

Table Appendix 13-0-1 Mean (SDs) and Unpaired t-tests results, median (Q1/Q3) and Mann-Whitney U tests of peak hip kinematics and moments in the sagittal, coronal and transverse plane.

Parameter	UK healthy	Thai healthy	P value
Hip Kinematics (degrees)			
Peak flexion	34.78 (7.40)	34.76 (7.12)	0.993
Peak extension	-7.30 (5.93)	-3.39 (5.19)	0.032*
Peak adduction	13.59 (4.13)	9.32 (2.85)	<0.001*
Peak abduction	0.16 (3.30)	-1.05 (3.21)	0.248
Peak internal rotation	1.57 (4.34)	1.26 (6.58)	0.864
Peak external rotation	-6.77 (4.91)	-6.70 (7.21)	0.971
Sagittal plane ROM	42.08 (6.11)	38.14 (5.42)	0.038*
Coronal plane ROM	13.44 (2.72)	10.37 (2.89)	0.001*
Transverse plane ROM	8.34 (2.85)	7.97 (3.34)	0.704
Hip Moments (Nm/kg)			
Peak extension	2.22 (0.70)	1.54 (0.49)	0.002*
Peak external rotation	0.60 (0.22)	0.58 (0.18)	0.799
Peak flexion	-1.02 (-1.34, -0.66)	-0.72 (-0.81, -0.64)	0.181
Peak abduction	2.00 (1.44, 2.22)	1.56 (1.50, 1.76)	0.045*
Peak adduction	-0.33 (-0.43, -0.22)	-0.15 (-0.22, -0.13)	<0.001*
Peak internal rotation	-0.08 (-0.14, -0.02)	-0.07 (-0.15, -0.04)	0.849

* Significant difference at the 0.05 level.

Table Appendix 13-0-2 Mean (SDs) and Unpaired t-tests results, median (Q1/Q3) and Mann-Whitney U tests of peak knee kinematics and moments in the sagittal, coronal and transverse plane.

Parameter	UK healthy	Thai healthy	P value
Knee Kinematics (degrees)			
Peak adduction	0.27 (2.83)	2.92 (3.49)	0.012*
Peak internal rotation	10.64 (5.08)	3.26 (5.33)	<0.001*
Peak external rotation	-5.22 (4.79)	-10.12 (5.71)	0.005*
Sagittal plane ROM	29.71 (5.16)	27.27 (4.01)	0.103
Transverse plane ROM	15.86 (4.13)	13.38 (3.02)	0.037*
Peak flexion	38.88 (34.99, 42.37)	42.29 (40.36, 45.23)	0.037*
Minimum flexion	9.60 (7.61, 10.91)	14.47 (12.21, 17.00)	<0.001*
Peak abduction	-5.32 (-6.85, -4.04)	-2.51 (-3.48, -0.08)	0.002*
Coronal plane ROM	5.67 (4.52, 7.06)	4.56 (3.85, 6.68)	0.245
Knee Moments (Nm/kg)			
Peak extension	2.80 (0.57)	2.65 (0.47)	0.403
Peak flexion	-0.27 (0.18)	-0.25 (0.13)	0.771
Peak abduction	0.41 (0.26)	0.64 (0.32)	0.024*
Peak internal rotation	-0.42 (0.19)	-0.35 (0.12)	0.233
Peak adduction	-0.16 (-0.31, -0.12)	-0.10 (-0.15, -0.06)	0.003*
Peak external rotation	0.04 (0.02, 0.05)	0.03 (0.02, 0.05)	0.750

* Significant difference at the 0.05 level.

Table Appendix 13-0-3 Mean (SDs) and Unpaired t-tests results, median (Q1/Q3) and Mann-Whitney U tests of normalised values from EMG signal analysis during stance phase.

Parameter	UK healthy	Thai healthy	P value
Average Activity			
Gmax	0.12 (0.03)	0.11 (0.03)	0.448
Gmed	0.12 (0.05)	0.12 (0.04)	0.926
TFL	0.12 (0.04)	0.12 (0.03)	0.681
VM	0.11 (0.04)	0.11 (0.03)	0.568
VL	0.08 (0.03)	0.11 (0.03)	0.009*
Peak Activity			
Gmax	0.61 (0.09)	0.58 (0.15)	0.469
Gmed	0.64 (0.10)	0.67 (0.12)	0.318
TFL	0.57 (0.16)	0.60 (0.18)	0.632
VL	0.50 (0.19)	0.65 (0.14)	0.008*
VM	0.66 (0.57, 0.73)	0.57 (0.47, 0.72)	0.185

* Significant difference at the 0.05 level.

Appendix 14. Participant Information Sheet of Thai ITBS Study

เอกสารชี้แจงผู้เข้าร่วมวิจัย สำหรับผู้เข้าร่วมวิจัยที่มีอายุ 18 ปีบริบูรณ์ขึ้นไป
(Participant Information Sheet)

☐ ต้นฉบับ ☑การปรับเปลี่ยนครั้งที่.....2..... วันที่....11...../.....มี.ค...../.....2563...

ในเอกสารนี้อาจมีข้อความที่ท่านอ่านแล้วยังไม่เข้าใจ โปรดสอบถามหัวหน้าโครงการวิจัย หรือผู้แทนให้ช่วยอธิบาย จนกว่าจะเข้าใจดี ท่านจะได้รับเอกสารนี้ 1 ฉบับ นำกลับไปอ่านที่บ้านเพื่อปรึกษาหารือกับญาติพี่น้อง เพื่อนสนิท แพทย์ประจำตัว ของท่าน หรือผู้อื่นที่ท่านต้องการปรึกษา เพื่อช่วยในการตัดสินใจเข้าร่วมการวิจัย

ชื่อโครงการ (ภาษาไทย) ผลการใช้คิเนซิโอเทปต่อผลลัพธ์ทางชีวกลศาสตร์และคลินิกในนักวิ่งที่เป็น Iliotibial Band Friction Syndrome

ชื่อผู้วิจัย นายพงษ์ชัย วัชรเขื่อนขันธ์

สถานที่วิจัย

1. คณะกายภาพบำบัด มหาวิทยาลัยมหิดล ศาลายา เลขที่ 999 ถนนพุทธมณฑลสาย 4 ต.ศาลายา อ.พุทธมณฑล จ. นครปฐม 73170

2. ศูนย์กายภาพบำบัด (เชิงสะพานสมเด็จพระปิ่นเกล้า) คณะกายภาพบำบัด มหาวิทยาลัยมหิดล 198/2 ถนนสมเด็จพระปิ่นเกล้า แขวงบางยี่ขัน เขตบางพลัด กรุงเทพฯ 10700

โทรศัพท์ : 02-441-5450

โทรศัพท์ 086-326-8162

โครงการศึกษานี้ทำขึ้นเพื่อศึกษาผลการใช้คิเนซิโอเทป (เทปสีเพื่อการบำบัดรักษา) ต่อขาในนักวิ่งที่มีปัญหาปวดเข่าทางด้านนอก ซึ่งประโยชน์ที่คาดว่าจะได้รับคือ ช่วยให้เข้าใจผลการใช้เทปสีเพื่อการบำบัดรักษาในนักวิ่งที่มีปัญหาปวดเข่าทางด้านนอก และเป็นแนวทางการใช้เทปสีเพื่อการบำบัดรักษาในคนไข้นักวิ่งที่มีปัญหาปวดเข่าทางด้านนอก เพื่อที่จะช่วยให้นักวิ่งเหล่านี้สามารถวิ่งได้ไม่ต้องหยุดพักขณะทำการรักษาและฟื้นฟูได้

ท่านได้รับเชิญให้เข้าร่วมวิจัยนี้ เพราะท่านเป็นผู้ที่มีคุณสมบัติครบถ้วน ตามเกณฑ์ที่ผู้วิจัยกำหนด คือมีอายุระหว่าง 18 ถึง 45 ปี มีระยะทางการวิ่งเฉลี่ยรวมอย่างน้อย 10 กิโลเมตรต่อสัปดาห์ ไม่มีการจำกัดการเคลื่อนไหวทางกายซึ่งอาจจะส่งผลต่อการทดสอบได้ เช่น การอ่อนล้า การเจ็บป่วย หรือการวิงเวียนศีรษะ ไม่มีประวัติเคยได้รับการผ่าตัดต่อบริเวณขา ไม่มีอาการหรืออาการสำคัญของพยาธิสภาพทางข้อเข่าอื่น ๆ ได้แก่ การเจ็บเข่าทางด้านหน้า, เข่าเสื่อม, การบาดเจ็บหมอนรองกระดูกเข่าด้านนอก, การบาดเจ็บเส้นประสาทบริเวณเข่า, การเจ็บเข่าที่มาจากหลัง, มีการบาดเจ็บของข้อเข่า, และการอักเสบของกล้ามเนื้อหลังข้อพับหรือเส้นเอ็นกล้ามเนื้อด้านหลังต้นขา ไม่มีการรับประทานยาคลายกล้ามเนื้อหรือยาแก้อักเสบก่อนการทดสอบ 72 ชั่วโมงและไม่มีการแพ้ต่อเทปสีเพื่อการบำบัดรักษา

ประโยชน์ที่ท่านได้รับ คือ ท่านจะได้มีโอกาสทราบชีวกลศาสตร์การวิ่งของท่าน ได้รับโอกาสการตรวจร่างกายทั้งความแข็งแรงกล้ามเนื้อ ความยืดหยุ่นกล้ามเนื้อ และได้รับโอกาสใช้เทปสีเพื่อการบำบัดรักษาต่ออาการปวดเข่าทางด้านนอกของท่านและหากงานวิจัยนี้ได้ผลดีจะเป็นประโยชน์สำหรับผู้ป่วยที่มีการปวดเข่าด้านนอก ในอนาคตได้

โครงการศึกษานี้จะมีผู้เข้าร่วมการวิจัยทั้งสิ้นประมาณ 44 คน ระยะเวลาที่ใช้ในเข้าร่วมการวิจัยประมาณ 2 ชั่วโมง ถึง 2 ชั่วโมง 30 นาที

หากท่านตัดสินใจเข้าร่วมการวิจัยแล้ว จะมีขั้นตอนการวิจัยดังต่อไปนี้คือ

ขั้นตอนการเตรียมการ

ผู้วิจัยทำการอธิบายวัตถุประสงค์ ขั้นตอนการศึกษา ประโยชน์ของการศึกษา ความเสี่ยงในการวิจัย รวมทั้งการป้องกันและความปลอดภัยของการศึกษานี้ จากนั้นผู้วิจัยสัมภาษณ์ประวัติทั่วไปและประวัติความเจ็บป่วย เช่น โรคประจำตัวและการบาดเจ็บ และหากท่านผ่านเกณฑ์การเข้าร่วมงานวิจัย ผู้วิจัยจะให้ท่านลงนามในใบยินยอมเข้าร่วมวิจัย

ผู้เข้าร่วมการวิจัยทุกคน จะได้รับการทดสอบความถนัดของขา โดยการให้เตะลูกฟุตบอล เอาปลายขาวาดเป็นรูปเลขแปดบนพื้น

ขั้นตอนการเก็บข้อมูล

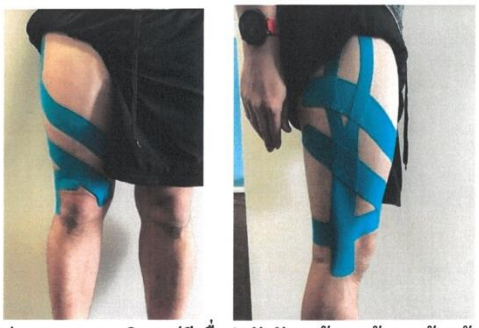
วันที่หนึ่ง – ท่านจะใส่ชุดเสื้อกล้าม กางเกงขาสั้น ถุงเท้าและรองเท้ากีฬาของท่านเองในการทดสอบ จากนั้นผู้วิจัยจะใช้แอลกอฮอล์เช็ดผิวหนังและและทำการติดขั้วรับสัญญาณการทำงานของกล้ามเนื้อที่กล้ามเนื้อก้นและต้นขาของขาข้างที่มีอาการปวดเข่าทางด้านนอก รวมทั้งจะได้รับการติดเครื่องหมายทรงกลมสะท้อนแสงบริเวณขาและกระดูกเชิงกรานของท่าน

หลังจากนั้น ท่านจะได้รับการทดสอบด้วยการวิ่งเป็นระยะทาง 10 เมตรก่อนและหลังการเทปสีเพื่อการบำบัดรักษา ทั้งนี้ท่านจะวิ่ง 5-10 รอบทั้งก่อนและหลังติดเทปสีเพื่อการบำบัดรักษาโดยแต่ละรอบของการทดสอบจะมีระยะเวลาพักนานอย่างน้อย 60 วินาทีหรือจนกว่าท่านจะหายเหนื่อยและพร้อมที่จะทำการทดสอบครั้งต่อไป ซึ่งก่อนการทดสอบท่านจะได้ทดลองซ้อมวิ่งเพื่อให้เกิดความคุ้นเคยกับสิ่งแวดล้อมและการทดสอบ

นอกจากนี้ ก่อนทดสอบการวิ่งท่านจะได้รับการวัดในทางคลินิกได้แก่ การสอบถามระดับความเจ็บปวดของอาการปวดเข่าทางด้านนอก การทดสอบความยืดหยุ่นและการตึงตัวของกล้ามเนื้อต้นขาด้านนอก การทดสอบความแข็งแรงของกล้ามเนื้อสะโพก การทดสอบด้วยการย่อขาข้างเดียว และทำแบบสอบถามการประเมินข้อเข่า แบบสอบถามประเมินการกลัวในการเคลื่อนไหว และหลังการทดสอบการวิ่งด้วยการติดเทปสีเพื่อการบำบัดรักษาท่านจะได้รับการสอบถามระดับความเจ็บปวดของอาการปวดเข่าทางด้านนอก แบบสอบถามความรู้สึกหลังการใช้เทปสีเพื่อการบำบัดรักษาในเรื่องความสะดวกสบาย ความมั่นคงของเข่าและสมรรถภาพการวิ่ง แบบสอบถามประเมินการกลัวในการเคลื่อนไหว และ แบบประเมินการเปลี่ยนแปลงอาการโดยรวม

วันที่สี่ ท่านจะได้รับการเปลี่ยนเทปสีเพื่อการบำบัดรักษาโดยผู้วิจัย และได้รับการสอบถามระดับความเจ็บปวดของอาการปวดเข่าทางด้านนอก ทำแบบสอบถามแบบความรู้สึกหลังการใช้เทปสีเพื่อการบำบัดรักษาในเรื่องความสะดวกสบาย ความมั่นคงของเข่าและสมรรถภาพการวิ่ง แบบสอบถามประเมินการกลัวในการเคลื่อนไหว และ แบบประเมินการเปลี่ยนแปลงอาการโดยรวม

วันที่เจ็ด ท่านจะได้รับการสอบถามระดับความเจ็บปวดของอาการปวดเข่าทางด้านนอก แบบสอบถามความรู้สึกหลังการใช้เทปสีเพื่อการบำบัดรักษาในเรื่องความสะดวกสบาย ความมั่นคงของเข่าและสมรรถภาพการวิ่ง แบบสอบถามประเมินการกลัวในการเคลื่อนไหว แบบสอบถามความรู้สึกหลังการใช้เทปสีเพื่อการบำบัดรักษาในเรื่องความสะดวกสบาย ความมั่นคงของเข่าและสมรรถภาพการวิ่ง และแบบประเมินการเปลี่ยนแปลงอาการ โดยรวม ทางโทรศัพท์



รูปภาพแสดงการติดเทปสีเพื่อบำบัดรักษาด้านหน้าและด้านข้าง

ความเสี่ยงที่อาจจะเกิดขึ้นเมื่อเข้าร่วมการวิจัย งานวิจัยนี้มีความเสี่ยงน้อยมากเนื่องจากเป็นการวิ่งระยะสั้น 10 เมตร และหยุดพักไม่ใช่การวิ่งต่อเนื่องระยะยาว รวมถึงผู้วิจัยทำการศึกษาในกลุ่มประชากรที่มีปัญหาปวดเข่าทางด้านนอกแต่ไม่มีการจำกัดเคลื่อนไหวทางกายขณะเข้าร่วมงานวิจัย อย่างไรก็ตาม ผู้วิจัยได้จัดเตรียมแผ่นเย็น สำหรับประคบบริเวณกล้ามเนื้อที่อาจเกิดอาการปวด เมื่อยล้าได้ เพื่อป้องกันและลดความรุนแรงของอาการเจ็บปวดที่อาจจะเกิดขึ้นได้ และถ้าท่านมีความผิดปกติเกิดขึ้นจากการเข้าร่วมการวิจัยในครั้งนี้ เช่น มีอาการปวด เมื่อยล้าอย่างรุนแรง ผู้วิจัยจะให้ท่านหยุดทันทีและผู้วิจัยจะคอยสังเกตอาการ ให้การรักษา และรับผิดชอบค่าใช้จ่ายในการรักษาทั้งหมด จนกว่าอาการผิดปกตินั้นจะหายไปและ จะขอให้ท่านยุติการเข้าร่วมโครงการวิจัยต่อไป

หากมีอาการผิดปกติ รู้สึกไม่สบายกาย หรือมีผลกระทบต่อจิตใจของท่านเกิดขึ้นระหว่างการวิจัย ท่านจะแจ้งผู้วิจัยโดยเร็วที่สุด และหากท่านมีข้อข้องใจที่จะสอบถามที่เกี่ยวข้องกับการวิจัย หรือหากเกิดการบาดเจ็บ/เจ็บป่วย หรือหากเกิดเหตุการณ์ไม่พึงประสงค์จากการวิจัยกับท่าน ท่านสามารถติดต่อได้ที่ อาจารย์พงษ์ชัย วัชรเชื่อนขันธ์ หมายเลขโทรศัพท์ 086-326-8162 ได้ตลอด 24 ชั่วโมง

หากเกิดเหตุการณ์ไม่พึงประสงค์จากการวิจัย ท่านจะได้รับการรักษาที่ ศูนย์การแพทย์กาญจนาภิเษก มหาวิทยาลัยมหิดล เลขที่ 999 ถ.บรมราชชนนี ต.ศาลายา อ.พุทธมณฑล จ.นครปฐม 73170 หรือ โรงพยาบาลศิริราช เลขที่ 2 ถนนวังหลัง แขวงศิริราช เขตบางกอกน้อย กรุงเทพฯ 10700 และอาจารย์พงษ์ชัย วัชรเชื่อนขันธ์ จะเป็นผู้รับผิดชอบค่าใช้จ่ายในการแก้ไขเหตุไม่พึงประสงค์สามารถติดต่อหมายเลขโทรศัพท์ 086-326-8162 ได้ตลอด 24 ชั่วโมง

การวิจัยนี้ท่านจะได้รับค่าเดินทางเป็นจำนวนเงิน 300 บาท และไม่มีค่าใช้จ่ายใด ๆ ที่ท่านจะต้องรับผิดชอบ

หากมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ทราบโดยรวดเร็วไม่ปิดบัง

ข้อมูลส่วนตัวของท่านจะถูกเก็บรักษาไว้เป็นระยะเวลา 5 ปีหลังเสร็จสิ้นงานวิจัย ไม่เปิดเผยต่อสาธารณะเป็นรายบุคคล แต่จะรายงานผลการวิจัยเป็นข้อมูลส่วนรวม และจะทำลายเอกสารโดยลบไฟล์ข้อมูลและใช้เครื่องทำลายเอกสารเพื่อทำลายเอกสาร ข้อมูลของท่านเป็นรายบุคคลอาจมีคณะบุคคลบางกลุ่มเข้ามาตรวจสอบได้ เช่น ผู้ให้ทุนวิจัย สถาบันหรือองค์กรของรัฐที่มีหน้าที่ตรวจสอบ คณะกรรมการจริยธรรมฯ เป็นต้น

ท่านมีสิทธิ์ถอนตัวออกจากโครงการการวิจัยเมื่อใดก็ได้ โดยไม่ต้องแจ้งให้ทราบล่วงหน้าและการไม่เข้าร่วมการวิจัยหรือถอนตัวออกจากโครงการวิจัยนี้จะไม่มีผลกระทบต่อการบริการและการรักษาที่ สมควรจะได้รับแต่ประการใด

โครงการวิจัยนี้ได้รับการพิจารณารับรองจาก คณะกรรมการจริยธรรมการวิจัยในคนส่วนกลาง มหาวิทยาลัยมหิดล ซึ่งมีสำนักงานอยู่ที่ สำนักงานอธิการบดีมหาวิทยาลัยมหิดล ถนนพุทธมณฑล สาย 4 ตำบลศาลายา อำเภอพุทธมณฑล จังหวัดนครปฐม 73170 หมายเลขโทรศัพท์ 02-849-6224 ,6225 โทรสาร 02-849-6224 หากท่านได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ ท่านสามารถติดต่อกับประธานคณะกรรมการฯ หรือผู้แทน ได้ตามสถานที่และหมายเลขโทรศัพท์ข้างต้น

ข้าพเจ้าได้อ่านรายละเอียดในเอกสารนี้ครบถ้วนแล้ว

ลงชื่อ.....ผู้เข้าร่วมวิจัย

(.....)

วันที่...../...../.....

Appendix 15. Informed Consent Sheet of Thai ITBS Study

MU-CIRB	คณะกรรมการจริยธรรมการวิจัยในคนส่วนกลาง มหาวิทยาลัยมหิดล	แก้ไข ณ วันที่ 02/08/2015
หนังสือแสดงเจตนายินยอมเข้าร่วมการวิจัยโดยได้รับการบอกกล่าวและเต็มใจ สำหรับผู้เข้าร่วมวิจัยที่มีอายุ 18 ปีบริบูรณ์ขึ้นไป (Informed Consent Sheet)		หน้าที่ 1 ของ 2 หน้า

หนังสือแสดงเจตนายินยอมเข้าร่วมการวิจัยโดยได้รับการบอกกล่าวและเต็มใจ
สำหรับผู้เข้าร่วมวิจัยที่มีอายุ 18 ปีบริบูรณ์ขึ้นไป (Informed Consent Sheet)

วันที่..... เดือน..... พ.ศ.....

ข้าพเจ้า.....อายุ.....ปี อาศัยอยู่บ้านเลขที่.....

ถนน.....ตำบล.....อำเภอ.....

จังหวัด..... รหัสไปรษณีย์..... โทรศัพท์.....

ขอแสดงเจตนายินยอมเข้าร่วมโครงการวิจัยเรื่องผลการใช้คิเนซิโอเทปต่อผลลัพธ์ทางชีวกลศาสตร์และคลินิกในนักวิ่งที่เป็น Iliotibial Band Friction Syndrome

โดยข้าพเจ้าได้รับทราบรายละเอียดเกี่ยวกับที่มาและจุดมุ่งหมายในการทำวิจัยรายละเอียดขั้นตอนต่างๆ ที่จะต้องปฏิบัติหรือได้รับการปฏิบัติ ประโยชน์ที่คาดว่าจะได้รับของการวิจัยและความเสี่ยงที่อาจจะเกิดขึ้นจากการเข้าร่วมการวิจัย รวมทั้งแนวทางป้องกันและแก้ไขหากเกิดอันตรายขึ้น ค่าตอบแทนที่จะได้รับ ค่าใช้จ่ายที่ข้าพเจ้าจะต้องรับผิดชอบจ่ายเอง โดยได้อ่านข้อความที่มีรายละเอียดอยู่ในเอกสารชี้แจงผู้เข้าร่วมการวิจัยโดยตลอด อีกทั้งยังได้รับคำอธิบายและตอบข้อสงสัยจากหัวหน้าโครงการวิจัยเป็นที่เรียบร้อยแล้ว โดยไม่มีสิ่งใดปิดบังซ่อนเร้น

ข้าพเจ้าจึงสมัครใจเข้าร่วมในโครงการวิจัยนี้ :

ข้าพเจ้าได้ทราบถึงสิทธิ์ที่ข้าพเจ้าจะได้รับข้อมูลเพิ่มเติมทั้งทางด้านประโยชน์และโทษจากการเข้าร่วมการวิจัย และสามารถถอนตัวหรือองค์เข้าร่วมการวิจัยได้ทุกเมื่อ โดยจะไม่มีผลกระทบต่อการบริการและการรักษาพยาบาลที่ข้าพเจ้าจะได้รับต่อไปในอนาคต และยินยอมให้ผู้วิจัยใช้ข้อมูลส่วนตัวของข้าพเจ้าที่ได้รับจากการวิจัย แต่จะไม่เผยแพร่ต่อสาธารณะเป็นรายบุคคล โดยจะนำเสนอเป็นข้อมูลโดยรวมจากการวิจัยเท่านั้น

หากข้าพเจ้ามีอาการผิดปกติ รู้สึกไม่สบายกาย หรือมีผลกระทบต่อจิตใจของข้าพเจ้าเกิดขึ้นระหว่างการวิจัย ข้าพเจ้าจะแจ้งผู้วิจัยโดยเร็วที่สุด และหากข้าพเจ้ามีข้อข้องใจเกี่ยวกับขั้นตอนของการวิจัย หรือหากเกิดผลข้างเคียงที่ไม่พึงประสงค์จากการวิจัยขึ้นกับข้าพเจ้า ข้าพเจ้าจะสามารถติดต่อกับ อ.พงษ์ชัย วัชรเขื่อนขันธ์ หมายเลขโทรศัพท์ 086-326-8162 ได้ตลอด 24 ชั่วโมง

/หากข้าพเจ้า ได้รับการปฏิบัติ.....

1

หากข้าพเจ้า ได้รับการปฏิบัติไม่ตรงตามที่ได้ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย ข้าพเจ้าจะสามารถติดต่อกับประธานคณะกรรมการจริยธรรมการวิจัยในคนหรือผู้แทน ได้ที่สำนักงานคณะกรรมการจริยธรรมการวิจัยในคนส่วนกลาง สำนักงานอธิการบดี มหาวิทยาลัยมหิดล หมายเลขโทรศัพท์ 02-849-6224 ,6225 โทรสาร 02-849-6224

ข้าพเจ้าเข้าใจข้อความในเอกสารชี้แจงผู้เข้าร่วมการวิจัย และหนังสือแสดงเจตนายินยอมนี้โดยตลอดแล้ว จึงลงลายมือชื่อไว้

ลงชื่อ.....
(.....)
ผู้เข้าร่วมการวิจัย/ผู้แทนโดยชอบธรรม
วันที่...../...../.....

ลงชื่อ.....
(.....)
ผู้ให้ข้อมูลและขอความยินยอม/หัวหน้าโครงการวิจัย
วันที่...../...../.....

ในกรณีผู้เข้าร่วมการวิจัยไม่สามารถอ่านหนังสือได้ผู้ที่อ่านข้อความทั้งหมดแทนผู้เข้าร่วมการวิจัยคือ..... ..... จึงได้ลงลายมือชื่อไว้เป็นพยาน

ลงชื่อ.....พยาน
(.....)
วันที่...../...../.....

Appendix 16. Numerical Pain Rating Scale (Thai Version)

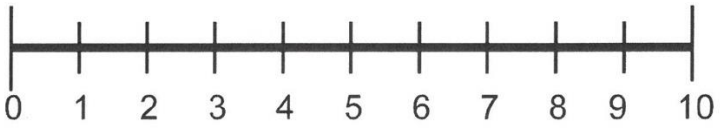
รหัสผู้ตอบแบบประเมิน.....

วันที่ประเมิน .....

แบบสอบถามการบอกความรู้สึกปวดเป็นตัวเลข

(Numerical Pain Rating Scale; NPRS)

โปรดเลือกตัวเลขที่แสดงถึงระดับความรู้สึกความปวดเข่าด้านนอกของท่านขณะที่ท่านวิ่ง จาก 0 ถึง 10 โดย เลข 0 คือความรู้สึกที่ท่านไม่ปวดเลย และเลข 10 คือความรู้สึกปวดมากจนทนไม่ได้



ไม่ปวด

ปวดมากจน
ทนไม่ได้

Appendix 17. Thai version of KOOS

แบบประเมินข้อเข่า Knee and Osteoarthritis Outcome Score (KOOS)

รหัสผู้ตอบแบบประเมิน_____

อายุ _____ปี เพศ ☐ ชาย ☐ หญิง วันที่ประเมิน_____

คำชี้แจง แบบประเมินนี้เป็นการสำรวจความคิดเห็นของท่านเกี่ยวกับข้อเข่า ข้อมูลนี้จะช่วยในการติดตามอาการที่เกิดขึ้น และประเมินระดับความสามารถในการเคลื่อนไหวของท่าน

โปรดตอบทุกคำถามโดยเลือกตอบข้อที่เหมาะสมที่สุดเพียงข้อเดียวในแต่ละคำถาม
โดยทำเครื่องหมายที่ตัวเลือกนั้น ☑ หากไม่แน่ใจกรุณาเลือกคำตอบที่ใกล้เคียงที่สุด

1. อาการ คำถามต่อไปนี้เกี่ยวข้องกับอาการที่เกิดขึ้นกับท่านในช่วงสัปดาห์ที่ผ่านมา

S1 ข้อเข่าของท่านมีอาการบวมหรือไม่

ไม่มี	ไม่ค่อยมี	บางครั้ง	มีอาการบ่อยๆ	บวมตลอดเวลา
☐	☐	☐	☐	☐

S2 ท่านรู้สึกว่าข้อเข่ามีการเสียดสีกัน หรือมีเสียงเกิดขึ้นในข้อขณะเคลื่อนไหวหรือไม่

ไม่มี	ไม่ค่อยมี	บางครั้ง	เป็นบ่อยๆ	เป็นตลอดเวลา
☐	☐	☐	☐	☐

S3 ข้อเข่าของท่านมีอาการติด หรือยึดในขณะเคลื่อนไหวหรือไม่

ไม่มี	ไม่ค่อยมี	บางครั้ง	เป็นบ่อยๆ	เป็นตลอดเวลา
☐	☐	☐	☐	☐

S4 ท่านสามารถเหยียดเข่าได้สุดหรือไม่

ทำได้ทุกครั้ง	ทำได้เป็นส่วนใหญ่	ทำได้บางครั้ง	ทำไม่ค่อยได้	ทำไม่ได้เลย
☐	☐	☐	☐	☐

S5 ท่านสามารถงอเข่าได้สุดหรือไม่

ทำได้ทุกครั้ง	ทำได้เป็นส่วนใหญ่	ทำได้บางครั้ง	ทำไม่ค่อยได้	ทำไม่ได้เลย
☐	☐	☐	☐	☐

2. การฝืดขัดของข้อ คำถามต่อไปนี้เกี่ยวข้องกับการฝืดขัดของข้อเข่าที่ท่านรู้สึกในช่วงสัปดาห์ที่ผ่านมานี้ การฝืดขัดของข้อเข่าเป็นความรู้สึกถึงการจำกัดการเคลื่อนไหวของข้อเข่า หรือเคลื่อนไหวข้อเข่าในทิศทางต่างๆ ได้ช้าลง

S6 เมื่อท่านตื่นนอนตอนเช้า ระดับความรุนแรงของการฝืดขัดของข้อเข่าเป็นอย่างไร

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

S7 ระดับความรุนแรงของการฝืดขัดของข้อเข่าหลังจากนั่ง นอน หรือพักการใช้ขาในช่วงเวลากลางวันเป็นอย่างไร

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

1

3. อาการปวด

P1 ท่านรู้สึกว่ามีอาการปวดข้อเข่าบ่อยครั้งเพียงใด

ไม่มีอาการ	ทุกเดือน	ทุกสัปดาห์	ทุกวัน	ตลอดเวลา
☐	☐	☐	☐	☐

โปรดระบุระดับความปวดข้อเข่าที่เกิดขึ้นในช่วงสัปดาห์ที่ผ่านมานี้
ในขณะที่เคลื่อนไหวข้อเข่าในลักษณะต่อไปนี้

P2 หมุนบิดขาบนเข่าข้างที่ปวดขณะยืน

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

P3 เหยียดเข่าจนสุด

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

P4 งอเข่าจนสุด

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

P5 เดินบนพื้นราบ

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

P6 เดินขึ้น หรือลงบันได

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

P7 ขณะนอนอยู่บนเตียงตอนกลางคืน

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

P8 นั่งหรือนอน

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

P9 ยืนตรง

ไม่มีอาการ	มีอาการเล็กน้อย	มีอาการปานกลาง	มีอาการรุนแรง	มีอาการรุนแรงมาก
☐	☐	☐	☐	☐

4. การเคลื่อนไหวในกิจวัตรประจำวัน คำถามต่อไปนี้เกี่ยวข้องกับความสามารถในการเคลื่อนไหวที่เป็นส่วนประกอบของการทำกิจวัตรประจำวัน ซึ่งหมายถึงการเคลื่อนไหวและดูแลตนเอง

โปรดเลือกคำตอบที่แสดงระดับความยากลำบากของการเคลื่อนไหวต่อไปนี้
<u>ที่ท่านรู้สึกในช่วงสัปดาห์ที่ผ่านมา</u>

A1 เดินลงบันได

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A2 เดินขึ้นบันได

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A3 ลุกขึ้นจากเก้าอี้

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A4 ยืนตรง

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A5 ก้มหยิบของจากพื้น

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A6 เดินบนพื้นราบ

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A7 ก้าวขึ้นหรือลงจากรถ

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A8 เดินไปซื้อของระยะใกล้ ๆ

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A9 สวมถุงน่องหรือถุงเท้า

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A10 ลุกขึ้นจากเตียง

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A11 ถอดถุงน่องหรือถุงเท้า

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A12 นอนพลิกตัวบนเตียงโดยไม่ขยับเข่าก่อน

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A13 ก้าวขาเข้าและออกจากห้องน้ำ

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A14 นั่ง

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A15 นั่งลง และลุกจากโถส้วม โปรดระบุหากเป็นส้วมแบบนั่งยองๆไม่ใช่แบบโถนั่ง

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A16 ทำงานบ้านหนัก ๆ เช่นเคลื่อนย้ายสิ่งของ ขัดพื้น

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

A17 ทำงานบ้านเบา ๆ เช่น ทำกับข้าว กวาดบ้าน

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

5. การเคลื่อนไหวในการออกกำลังกาย และการทำกิจกรรมอื่น ๆ คำถามต่อไปนี้เกี่ยวข้องกับการเคลื่อนไหวที่เป็นส่วนประกอบของการออกกำลังกาย และการทำกิจกรรมอื่นๆ นอกเหนือจากการทำกิจวัตรประจำวัน **โปรดเลือกคำตอบที่แสดงระดับความยากลำบากของการเคลื่อนไหวต่อไปนี้ที่ท่านรู้สึกในช่วงสัปดาห์ที่ผ่านมา**

SP1 ย่อเข่า/ นั่งยอง ๆ

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

SP2 วิ่ง

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

SP3 กระโดด

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

SP4 หมุนบิดขาบนเข่าข้างที่ปวด

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

SP5 คุกเข่า

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

6. คุณภาพชีวิต

Q1 ท่านรู้สึกว่าเข่าของท่านมีปัญหาบ่อยเพียงใด

ไม่มีปัญหาเลย	ทุกเดือน	ทุกสัปดาห์	ทุกวัน	ตลอดเวลา
☐	☐	☐	☐	☐

Q2 ท่านได้ปรับเปลี่ยนวิถีชีวิตหรือกิจวัตรประจำวันเพื่อหลีกเลี่ยงไม่ให้เกิดการบาดเจ็บของข้อเข่ามากขึ้นหรือไม่

ไม่เลย	เล็กน้อย	ปานกลาง	มาก	มากที่สุด
☐	☐	☐	☐	☐

Q3 ท่านรู้สึกไม่มั่นใจต่อสภาพของข้อเข่ามากน้อยเพียงใด

ไม่รู้สึกเลย	ไม่มั่นใจเล็กน้อย	ไม่มั่นใจปานกลาง	ไม่มั่นใจมาก	ไม่มั่นใจมากที่สุด
☐	☐	☐	☐	☐

Q4 โดยทั่วไปแล้ว ท่านคิดว่าข้อเข่าของท่านทำให้เกิดความยากลำบากต่อท่านมากน้อยเพียงใด

ไม่ลำบากเลย	ลำบากเล็กน้อย	ลำบากปานกลาง	ลำบากมาก	ลำบากมากที่สุด
☐	☐	☐	☐	☐

ขอขอบคุณที่กรุณาตอบคำถามในแบบประเมินนี้ครบทุกข้อ

Appendix 18. Thai version of Tampa Scale for Kinesiophobia

รหัสผู้ตอบแบบประเมิน.....
วันที่ประเมิน .....

Thai version of Tampa Scale for Kinesiophobia

แบบสอบถามสเกลของแทมพาสาหรับการกลัวในการเคลื่อนไหว ฉบับภาษาไทย

โดย พัฒนสิน อารีอุดมวงศ์ และวิศรุต บุตราภาศ

		ไม่เห็นด้วยอย่างยิ่ง	ไม่เห็นด้วย	เห็นด้วย	เห็นด้วยอย่างยิ่ง
1.	ฉันเกรงว่า ฉันอาจจะได้รับบาดเจ็บ หากออกกำลังกาย	1	2	3	4
2.	ถ้าฉันฝืนที่จะเคลื่อนไหวให้ได้ อาการปวดของฉันน่าจะเพิ่มขึ้น	1	2	3	4
3.	ร่างกายของฉันกำลังบอกฉันว่า อาการปวดที่มีอยู่นี้ น่าจะเป็นสัญญาณอันตราย	1	2	3	4
4.	อาการปวดของฉันน่าจะลดลง หากฉันออกกำลังกาย	1	2	3	4
5.	คนอื่นมักไม่เข้าใจว่า ฉันปวดจริง ๆ	1	2	3	4
6.	อุบัติเหตุที่เกิดขึ้นทำให้ตัวฉันตกอยู่ในอันตรายไปตลอดชีวิต	1	2	3	4
7.	อาการปวดมีความหมายเสมอ ๆ ว่า ร่างกายของฉันได้รับบาดเจ็บ	1	2	3	4
8.	สิ่งที่กระตุ้นอาการปวดของฉันไม่ได้หมายความว่ามันจะเป็นอันตราย	1	2	3	4
9.	ฉันเกรงว่า ฉันอาจจะทำให้ตนเองได้รับบาดเจ็บโดยไม่ได้ตั้งใจ	1	2	3	4
10.	วิธีที่ปลอดภัยที่สุดที่ป้องกันไม่ให้ปวดมากขึ้นคือ อย่าเคลื่อนไหวโดยไม่จำเป็น	1	2	3	4
11.	ฉันไม่น่าจะปวดมากเช่นนี้ หากไม่มีบางอย่างที่อันตรายเกิดขึ้นกับร่างกายของฉัน	1	2	3	4
12.	แม้ว่าฉันจะปวด แต่ฉันน่าจะมีอาการดีขึ้น หากได้เคลื่อนไหวร่างกาย	1	2	3	4
13.	อาการปวดทำให้ฉันรู้ว่า เมื่อไรควรหยุดออกกำลังกาย เพื่อหลีกเลี่ยงการบาดเจ็บ	1	2	3	4
14.	มันไม่ปลอดภัยเลยสำหรับคนที่มีอาการคล้ายกับฉันที่จะไปออกกำลังกาย	1	2	3	4
15.	ฉันไม่สามารถทำทุกอย่างที่คนปกติทำได้ เพราะว่าฉันจะได้รับบาดเจ็บได้ง่ายกว่าคนอื่น	1	2	3	4
16.	ฉันไม่คิดว่าสิ่งที่ทำให้ฉันปวดมาก นั้นจะเป็นอันตรายเสมอไป	1	2	3	4
17.	คนที่กำลังมีอาการเจ็บปวด ไม่ควรออกกำลังกาย	1	2	3	4

Appendix 19. Thai Version of Global Rating Of Change Scale

รหัสผู้ตอบแบบประเมิน.....

วันที่ประเมิน .....

แบบประเมินการเปลี่ยนแปลงอาการโดยรวม (**GLOBAL RATING OF CHANGE SCALE**) (**GROC**)

กรุณาประเมินสภาพโดยรวมของอาการปวดเข่าด้านนอกของคุณ (iliotibial band syndrome) จากเวลาที่คุณเริ่มทำการรักษาจนถึงตอนนี้ (เลือกเพียงข้อเดียว)

☐ แย่ลงอย่างมาก (-7)	☐ เท่าเดิม (0)	☐ ดีขึ้นอย่างมาก (7)
☐ แย่ลงมาก (-6)		☐ ดีขึ้นมาก (6)
☐ ค่อนข้างแย่ลง (-5)		☐ ค่อนข้างดีขึ้น(5)
☐ แย่ลงปานกลาง (-4)		☐ ดีขึ้นปานกลาง (4)
☐ แย่ลงบางส่วน (-3)		☐ ดีขึ้นบางส่วน (3)
☐ แย่ลงเล็กน้อย (-2)		☐ ดีขึ้นเล็กน้อย (2)
☐ แย่ลงเพียงเล็กน้อย (-1)		☐ ดีขึ้นเพียงเล็กน้อย (1)

From: Jaeschke R, Singer J, Guyatt GH. Measurement of health status. Ascertaining the minimal clinically important difference. Control Clin Trials 1989: 407-15.

Appendix 20. The comparisons of the running speed between the Thai healthy and Thai ITBS participants under the NT condition

Descriptives

Running_speed

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Healthy	20	2.9099	.42383	.09477	2.7115	3.1082	2.47	4.20
ITBS_KTT	20	2.6987	.30055	.06720	2.5580	2.8393	2.04	3.35
ITBS_KTNT	20	2.8149	.41786	.09344	2.6193	3.0104	2.00	3.61
Total	60	2.8078	.38827	.05013	2.7075	2.9081	2.00	4.20

ANOVA

Running_speed

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.448	2	.224	1.510	.230
Within Groups	8.447	57	.148		
Total	8.894	59			

Multiple Comparisons

Dependent Variable: Running_speed

LSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Healthy	ITBS_KTT	.21121	.12173	.088	-.0326	.4550
	ITBS_KTNT	.09502	.12173	.438	-.1487	.3388
ITBS_KTT	Healthy	-.21121	.12173	.088	-.4550	.0326
	ITBS_KTNT	-.11619	.12173	.344	-.3600	.1276
ITBS_KTNT	Healthy	-.09502	.12173	.438	-.3388	.1487
	ITBS_KTT	.11619	.12173	.344	-.1276	.3600

References

Abián-Vicén, J., Alegre, L. M., Fernández-Rodríguez, J. M. & Aguado, X. (2009). Prophylactic ankle taping: elastic versus inelastic taping. *Foot Ankle Int,* 30**,** 218-25.

Aderem, J. & Louw, Q. A. (2015). Biomechanical risk factors associated with iliotibial band syndrome in runners: a systematic review. *BMC Musculoskeletal Disorders,* 16**,** 356.

Agur, A., M.R. & Dalley, A. F. (2017). *Grant's Atlas of Anatomy,* China, Lippincott Williams and Wilkins.

Akbaş, E., Atay, A. O. & Yüksel, I. (2011). The effects of additional kinesio taping over exercise in the treatment of patellofemoral pain syndrome. *Acta Orthop Traumatol Turc,* 45**,** 335-41.

Alahmari, K. A., Rengaramanujam, K., Reddy, R. S., Samuel, P. S., Tedla, J. S., Kakaraparthi, V. N. & Ahmad, I. (2020). The immediate and short-term effects of dynamic taping on pain, endurance, disability, mobility and kinesiophobia in individuals with chronic non-specific low back pain: A randomized controlled trial. *PLoS One,* 15**,** e0239505.

Alenezi, F., Herrington, L., Jones, P. & Jones, R. (2016). How reliable are lower limb biomechanical variables during running and cutting tasks. *J Electromyogr Kinesiol,* 30**,** 137-42.

Amis, A. A. (2017). Anterolateral knee biomechanics. *Knee Surg Sports Traumatol Arthrosc,* 25**,** 1015-1023.

Anandkumar, S., Sudarshan, S. & Nagpal, P. (2014). Efficacy of kinesio taping on isokinetic quadriceps torque in knee osteoarthritis: a double blinded randomized controlled study. *Physiother Theory Pract,* 30**,** 375-83.

Andrýsková, A. & Lee, J. H. (2020). The Guidelines for Application of Kinesiology Tape for Prevention and Treatment of Sports Injuries. *Healthcare (Basel),* 8.

Araujo, A. C., Do Carmo Silva Parreira, P., Junior, L. C. H., Da Silva, T. M., Da Luz Junior, M. A., Da Cunha Menezes Costa, L. & Pena Costa, L. O. (2018). Medium term effects of kinesio taping in patients with chronic non-specific low back pain: a randomized controlled trial. *Physiotherapy,* 104**,** 149-151.

Areeudomwong, P. & Buttagat, V. (2017). Reliability and Validity of the Cross-Culturally Adapted Thai Version of the Tampa Scale for Kinesiophobia in Knee Osteoarthritis Patients. *Malays J Med Sci,* 24**,** 61-67.

Ataullah, M. G., Kapoor, G., Alghadir, A. H. & Khan, M. (2021). Effects of kinesio taping on hip abductor muscle strength and electromyography activity in athletes with chronic ankle instability: A randomized controlled trial. *J Rehabil Med*.

Aydoğdu, O., Sari, Z., Yurdalan, S. U. & Polat, M. G. (2017). Clinical outcomes of kinesio taping applied in patients with knee osteoarthritis: A randomized controlled trial. *J Back Musculoskelet Rehabil,* 30**,** 1045-1051.

Baker, R. L. & Fredericson, M. (2016). Iliotibial Band Syndrome in Runners: Biomechanical Implications and Exercise Interventions. *Phys Med Rehabil Clin N Am,* 27**,** 53-77.

Baker, R. L., Souza, L. B. & Fredericson, M. (2011). Iliotibial Band Syndrome: Soft Tissue and Biomechanical Factors in Evaluation and Treatment. *PM&R,* 3**,** 550-561.

Baker, R. L., Souza, R. B., Rauh, M. J., Fredericson, M. & Rosenthal, M. D. (2018). Differences in Knee and Hip Adduction and Hip Muscle Activation in Runners With and Without Iliotibial Band Syndrome. *PM&R,* 10**,** 1032-1039.

Barber, F. A. & Sutker, A. N. (1992). Iliotibial band syndrome. *Sports Med,* 14**,** 144-8.

Bartlett, R. (2007). *Introduction to Sports Biomechanics: Analysing Human Movement Patterns*, Routledge.

Barton, C., Balachandar, V., Lack, S. & Morrissey, D. (2014). Patellar taping for patellofemoral pain: a systematic review and meta-analysis to evaluate clinical outcomes and biomechanical mechanisms. *Br J Sports Med,* 48**,** 417-24.

Basmajian, J. V. L. C. J. D. (1985). *Muscles Alive : their functions revealed by electromyography,* Baltimore, Williams & Wilkins.

Beals, C. & Flanigan, D. (2013). A Review of Treatments for Iliotibial Band Syndrome in the Athletic Population. *Journal of Sports Medicine,* 2013**,** 367169.

Beers, A. (2008). Effects of multi- modal physiotherapy, including hip abductor strengthening, in patients with iliotibial band friction syndrome. *Physiother Can,* 60.

Beers, A., Ryan, M., Kasubuchi, Z., Fraser, S. & Taunton, J. E. (2008). Effects of Multi-modal Physiotherapy, Including Hip Abductor Strengthening, in Patients with Iliotibial Band Friction Syndrome. *Physiother Can,* 60**,** 180-8.

Bell, A. L., Pedersen, D. R. & Brand, R. A. (1990). A comparison of the accuracy of several hip center location prediction methods. *J Biomech,* 23**,** 617-21.

Bendig, A. W. (1954). Reliability of short rating scales and the heterogeneity of the rated stimuli. *Journal of Applied Psychology,* 38**,** 167-170.

Besomi, M., Maclachlan, L., Mellor, R., Vicenzino, B. & Hodges, P. W. (2020). Tensor Fascia Latae Muscle Structure and Activation in Individuals With Lower Limb Musculoskeletal Conditions: A Systematic Review and Meta-Analysis. *Sports Medicine,* 50**,** 965-985.

Björklund, M., Wiitavaara, B. & Heiden, M. (2017). Responsiveness and minimal important change for the ProFitMap-neck questionnaire and the Neck Disability Index in women with neck-shoulder pain. *Qual Life Res,* 26**,** 161-170.

Bobos, P., Macdermid, J., Nazari, G. & Furtado, R. (2019). Psychometric properties of the global rating of change scales in patients with neck disorders: a systematic review with meta-analysis and meta-regression. *BMJ Open,* 9**,** e033909.

Bolia, I. K., Gammons, P., Scholten, D. J., Weber, A. E. & Waterman, B. R. (2020). Operative Versus Nonoperative Management of Distal Iliotibial Band Syndrome-Where Do We Stand? A Systematic Review. *Arthrosc Sports Med Rehabil,* 2**,** e399-e415.

Bonaldi, V. M., Chhem, R. K., Drolet, R., Garcia, P., Gallix, B. & Sarazin, L. (1998). Iliotibial band friction syndrome: sonographic findings. *J Ultrasound Med,* 17**,** 257-60.

Briem, K., Eythorsdottir, H., Magnusdottir, R. G., Palmarsson, R., Runarsdottir, T. & Sveinsson, T. (2011). Effects of kinesio tape compared with nonelastic sports tape and the untaped ankle during a sudden inversion perturbation in male athletes. *J Orthop Sports Phys Ther,* 41**,** 328-35.

Brindle, R. A., Milner, C. E., Zhang, S. & Fitzhugh, E. C. (2014). Changing step width alters lower extremity biomechanics during running. *Gait Posture,* 39**,** 124-8.

Brown, A. M., Zifchock, R. A., Lenhoff, M., Song, J. & Hillstrom, H. J. (2019). Hip muscle response to a fatiguing run in females with iliotibial band syndrome. *Hum Mov Sci,* 64**,** 181-190.

Buist, I., Bredeweg, S. W., Van Mechelen, W., Lemmink, K. A., Pepping, G. J. & Diercks, R. L. (2008). No effect of a graded training program on the number of running-related injuries in novice runners: a randomized controlled trial. *Am J Sports Med,* 36**,** 33-9.

Burns, S. A., Mintken, P. E., Austin, G. P. & Cleland, J. (2011). Short-term response of hip mobilizations and exercise in individuals with chronic low back pain: a case series. *J Man Manip Ther,* 19**,** 100-7.

Cahalan, T. D., Johnson, M. E., Liu, S. & Chao, E. Y. (1989). Quantitative measurements of hip strength in different age groups. *Clin Orthop Relat Res***,** 136-45.

Cai, C., Au, I. P., An, W. & Cheung, R. T. (2016). Facilitatory and inhibitory effects of Kinesio tape: Fact or fad? *J Sci Med Sport,* 19**,** 109-12.

Callaghan, M. J., Selfe, J., Bagley, P. J. & Oldham, J. A. (2002). The Effects of Patellar Taping on Knee Joint Proprioception. *J Athl Train,* 37**,** 19-24.

Callaghan, M. J., Selfe, J., Mchenry, A. & Oldham, J. A. (2008). Effects of patellar taping on knee joint proprioception in patients with patellofemoral pain syndrome. *Man Ther,* 13**,** 192-9.

Campolo, M., Babu, J., Dmochowska, K., Scariah, S. & Varughese, J. (2013). A comparison of two taping techniques (kinesio and mcconnell) and their effect on anterior knee pain during functional activities. *Int J Sports Phys Ther,* 8**,** 105-10.

Cappozzo, A., Catani, F., Croce, U. D. & Leardini, A. (1995). Position and orientation in space of bones during movement: anatomical frame definition and determination. *Clin Biomech (Bristol, Avon),* 10**,** 171-178.

Carson, M. C., Harrington, M. E., Thompson, N., O'connor, J. J. & Theologis, T. N. (2001). Kinematic analysis of a multi-segment foot model for research and clinical applications: a repeatability analysis. *J Biomech,* 34**,** 1299-307.

Castro-Sánchez, A. M., Lara-Palomo, I. C., Matarán-Peñarrocha, G. A., Fernández-Sánchez, M., Sánchez-Labraca, N. & Arroyo-Morales, M. (2012). Kinesio Taping reduces disability and pain slightly in chronic non-specific low back pain: a randomised trial. *J Physiother,* 58**,** 89-95.

Chaipinyo, K. & Karoonsupcharoen, O. (2009). No difference between home-based strength training and home-based balance training on pain in patients with knee osteoarthritis: a randomised trial. *Aust J Physiother,* 55**,** 25-30.

Chaney, C., Hirayama, G. M., Mendoza, T. E., Schmitt, D. M. & Janini, S. (2015). The effects of Kinesio™ tape on vertical jump, 20-m sprint, and self-perception of performance in high school basketball players. *Current Orthopaedic Practice,* 26**,** 420-424.

Charles, D. & Rodgers, C. (2020). A LITERATURE REVIEW AND CLINICAL COMMENTARY ON THE DEVELOPMENT OF ILIOTIBIAL BAND SYNDROME IN RUNNERS. *Int J Sports Phys Ther,* 15**,** 460-470.

Chiari, L., Della Croce, U., Leardini, A. & Cappozzo, A. (2005). Human movement analysis using stereophotogrammetry. Part 2: instrumental errors. *Gait Posture,* 21**,** 197-211.

Childs, J. D., Piva, S. R. & Fritz, J. M. (2005). Responsiveness of the numeric pain rating scale in patients with low back pain. *Spine (Phila Pa 1976),* 30**,** 1331-4.

Chowdhury, R. H., Reaz, M. B., Ali, M. A., Bakar, A. A., Chellappan, K. & Chang, T. G. (2013). Surface electromyography signal processing and classification techniques. *Sensors (Basel),* 13**,** 12431-66.

Chuang, T. D. & Acker, S. M. (2019). Comparing functional dynamic normalization methods to maximal voluntary isometric contractions for lower limb EMG from walking, cycling and running. *J Electromyogr Kinesiol,* 44**,** 86-93.

Chumanov, E. S., Wall-Scheffler, C. & Heiderscheit, B. C. (2008). Gender differences in walking and running on level and inclined surfaces. *Clin Biomech (Bristol, Avon),* 23**,** 1260-8.

Clansey, A. C., Hanlon, M., Wallace, E. S. & Lake, M. J. (2012). Effects of fatigue on running mechanics associated with tibial stress fracture risk. *Med Sci Sports Exerc,* 44**,** 1917-23.

Cleland, J. A., Childs, J. D., Fritz, J. M., Whitman, J. M. & Eberhart, S. L. (2007). Development of a clinical prediction rule for guiding treatment of a subgroup of patients with neck pain: use of thoracic spine manipulation, exercise, and patient education. *Phys Ther,* 87**,** 9-23.

Cleland, J. A., Childs, J. D. & Whitman, J. M. (2008). Psychometric properties of the Neck Disability Index and Numeric Pain Rating Scale in patients with mechanical neck pain. *Arch Phys Med Rehabil,* 89**,** 69-74.

Cleland, J. A., Fritz, J. M., Whitman, J. M. & Palmer, J. A. (2006). The reliability and construct validity of the Neck Disability Index and patient specific functional scale in patients with cervical radiculopathy. *Spine (Phila Pa 1976),* 31**,** 598-602.

Clement, D. B., Taunton, J. E., Smart, G. W. & Mcnicol, K. L. (1981). A Survey of Overuse Running Injuries. *Phys Sportsmed,* 9**,** 47-58.

Coffey, G. H. & Mahon, M. V. (1982). Pain: theories and a new approach to treatment. *J Natl Med Assoc,* 74**,** 147-53.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences,* New York, Routledge Academic.

Collins, N., Crossley, K., Beller, E., Darnell, R., Mcpoil, T. & Vicenzino, B. (2009). Foot orthoses and physiotherapy in the treatment of patellofemoral pain syndrome: randomised clinical trial. *Br J Sports Med,* 43**,** 169-71.

Cook, C., Lawrence, J., Michalak, K., Dhiraprasiddhi, S., Donaldson, M., Petersen, S. & Learman, K. (2014). Is there preliminary value to a within- and/or between-session change for determining short-term outcomes of manual therapy on mechanical neck pain? *J Man Manip Ther,* 22**,** 173-80.

Costa, L. O., Maher, C. G., Latimer, J., Ferreira, P. H., Ferreira, M. L., Pozzi, G. C. & Freitas, L. M. (2008). Clinimetric testing of three self-report outcome measures for low back pain patients in Brazil: which one is the best? *Spine (Phila Pa 1976),* 33**,** 2459-63.

Crossley, K. M., Bennell, K. L., Cowan, S. M. & Green, S. (2004). Analysis of outcome measures for persons with patellofemoral pain: which are reliable and valid? *Arch Phys Med Rehabil,* 85**,** 815-22.

Crossley, K. M., Vicenzino, B., Lentzos, J., Schache, A. G., Pandy, M. G., Ozturk, H. & Hinman, R. S. (2015). Exercise, education, manual-therapy and taping compared to education for patellofemoral osteoarthritis: a blinded, randomised clinical trial. *Osteoarthritis Cartilage,* 23**,** 1457-64.

Cupler, Z. A., Alrwaily, M., Polakowski, E., Mathers, K. S. & Schneider, M. J. (2020). Taping for conditions of the musculoskeletal system: an evidence map review. *Chiropr Man Therap,* 28**,** 52.

D'mello, R. & Dickenson, A. H. (2008). Spinal cord mechanisms of pain. *Br J Anaesth,* 101**,** 8-16.

David, E. M. & Peter, C. (1994). *Better Training for Distance Runners* Human Kinetics.

Davison, E. A., Anderson, C. T., Ponist, B. H., Werner, D. M., Jacobs, M. E., Thompson, A. J. & Cook, M. R. (2016). Inhibitory Effect of the Kinesio Taping? Method on the Gastrocnemius Muscle. *American Journal of Sports Science and Medicine,* 4**,** 33-38.

De Luca, C. J., Gilmore, L. D., Kuznetsov, M. & Roy, S. H. (2010). Filtering the surface EMG signal: Movement artifact and baseline noise contamination. *J Biomech,* 43**,** 1573-9.

Della Croce, U., Leardini, A., Chiari, L. & Cappozzo, A. (2005). Human movement analysis using stereophotogrammetry. Part 4: assessment of anatomical landmark misplacement and its effects on joint kinematics. *Gait Posture,* 21**,** 226-37.

Devan, M. R., Pescatello, L. S., Faghri, P. & Anderson, J. (2004). A Prospective Study of Overuse Knee Injuries Among Female Athletes With Muscle Imbalances and Structural Abnormalities. *J Athl Train,* 39**,** 263-267.

Doma, K., Deakin, G. B. & Sealey, R. M. (2012). The reliability of lower extremity and thoracic kinematics at various running speeds. *Int J Sports Med,* 33**,** 364-9.

Donec, V. & Kriščiūnas, A. (2014). The effectiveness of Kinesio Taping® after total knee replacement in early postoperative rehabilitation period. A randomized controlled trial. *Eur J Phys Rehabil Med,* 50**,** 363-71.

Donec, V. & Kubilius, R. (2019). The effectiveness of Kinesio Taping® for pain management in knee osteoarthritis: a randomized, double-blind, controlled clinical trial. *Ther Adv Musculoskelet Dis,* 11**,** 1759720x19869135.

Donec, V. & Kubilius, R. (2020). The effectiveness of Kinesio Taping(®) for mobility and functioning improvement in knee osteoarthritis: a randomized, double-blind, controlled trial. *Clin Rehabil,* 34**,** 877-889.

Dworkin, R. H., Turk, D. C., Farrar, J. T., Haythornthwaite, J. A., Jensen, M. P., Katz, N. P., Kerns, R. D., Stucki, G., Allen, R. R., Bellamy, N., Carr, D. B., Chandler, J., Cowan, P., Dionne, R., Galer, B. S., Hertz, S., Jadad, A. R., Kramer, L. D., Manning, D. C., Martin, S., Mccormick, C. G., Mcdermott, M. P., Mcgrath, P., Quessy, S., Rappaport, B. A., Robbins, W., Robinson, J. P., Rothman, M., Royal, M. A., Simon, L., Stauffer, J. W., Stein, W., Tollett, J., Wernicke, J. & Witter, J. (2005). Core outcome measures for chronic pain clinical trials: IMMPACT recommendations. *Pain,* 113**,** 9-19.

Ekman, E. F., Pope, T., Martin, D. F. & Curl, W. W. (1994). Magnetic resonance imaging of iliotibial band syndrome. *Am J Sports Med,* 22**,** 851-4.

Ellis, R., Hing, W. & Reid, D. (2007). Iliotibial band friction syndrome—A systematic review. *Manual Therapy,* 12**,** 200-208.

Everhart, J. S., Kirven, J. C., Higgins, J., Hair, A., Chaudhari, A. & Flanigan, D. C. (2019). The relationship between lateral epicondyle morphology and iliotibial band friction syndrome: A matched case-control study. *Knee,* 26**,** 1198-1203.

Fairclough, J., Hayashi, K., Toumi, H., Lyons, K., Bydder, G., Phillips, N., Best, T. M. & Benjamin, M. (2006). The functional anatomy of the iliotibial band during flexion and extension of the knee: implications for understanding iliotibial band syndrome. *J Anat,* 208**,** 309-16.

Falvey, E. C., Clark, R. A., Franklyn-Miller, A., Bryant, A. L., Briggs, C. & Mccrory, P. R. (2010). Iliotibial band syndrome: an examination of the evidence behind a number of treatment options. *Scand J Med Sci Sports,* 20**,** 580-7.

Farooq, M. N., Mohseni-Bandpei, M. A., Gilani, S. A. & Hafeez, A. (2017). Urdu version of the neck disability index: a reliability and validity study. *BMC Musculoskelet Disord,* 18**,** 149.

Farquharson, C. & Greig, M. (2015). Temporal efficacy of kinesiology tape vs. Traditional stretching methods on hamstring extensibility. *Int J Sports Phys Ther,* 10**,** 45-51.

Farrar, J. T., Young, J. P., Jr., Lamoreaux, L., Werth, J. L. & Poole, R. M. (2001). Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain,* 94**,** 149-58.

Farrell, K. C., Reisinger, K. D. & Tillman, M. D. (2003). Force and repetition in cycling: possible implications for iliotibial band friction syndrome. *Knee,* 10**,** 103-9.

Ferber, R., Davis, I. M. & Williams, D. S., 3rd (2003). Gender differences in lower extremity mechanics during running. *Clin Biomech (Bristol, Avon),* 18**,** 350-7.

Ferber, R., Kendall, K. D. & Mcelroy, L. (2010a). Normative and critical criteria for iliotibial band and iliopsoas muscle flexibility. *J Athl Train,* 45**,** 344-8.

Ferber, R., Mcclay Davis, I., Williams, D. S., 3rd & Laughton, C. (2002). A comparison of within- and between-day reliability of discrete 3D lower extremity variables in runners. *J Orthop Res,* 20**,** 1139-45.

Ferber, R., Noehren, B., Hamill, J. & Davis, I. S. (2010b). Competitive female runners with a history of iliotibial band syndrome demonstrate atypical hip and knee kinematics. *J Orthop Sports Phys Ther,* 40**,** 52-8.

Fereydounnia, S., Shadmehr, A., Attarbashi Moghadam, B., Talebian Moghadam, S., Mir, S. M., Salemi, S. & Pourkazemi, F. (2019). Improvements in strength and functional

performance after Kinesio taping in semi-professional male soccer players with and without functional ankle instability. *Foot (Edinb),* 41**,** 12-18.

Ferraz, M. B., Quaresma, M. R., Aquino, L. R., Atra, E., Tugwell, P. & Goldsmith, C. H. (1990). Reliability of pain scales in the assessment of literate and illiterate patients with rheumatoid arthritis. *J Rheumatol,* 17**,** 1022-4.

Ferreira, M. L., Ferreira, P. H., Latimer, J., Herbert, R. D., Maher, C. & Refshauge, K. (2009). Relationship between spinal stiffness and outcome in patients with chronic low back pain. *Man Ther,* 14**,** 61-7.

Firth, B. L., Dingley, P., Davies, E. R., Lewis, J. S. & Alexander, C. M. (2010). The effect of kinesiotape on function, pain, and motoneuronal excitability in healthy people and people with Achilles tendinopathy. *Clin J Sport Med,* 20**,** 416-21.

Flato, R., Passanante, G. J., Skalski, M. R., Patel, D. B., White, E. A. & Matcuk, G. R., Jr. (2017). The iliotibial tract: imaging, anatomy, injuries, and other pathology. *Skeletal Radiol,* 46**,** 605-622.

Foch, E., Aubol, K. & Milner, C. E. (2020). Relationship between iliotibial band syndrome and hip neuromechanics in women runners. *Gait Posture,* 77**,** 64-68.

Foch, E. & Milner, C. (2013). Frontal plane running biomechanics in female runners with previous iliotibial band syndrome. *J Appl Biomech.,* 30.

Foch, E., Reinbolt, A., Zhang, S., Fitzhugh, C. & Milner, E. (2015). Associations between iliotibial band injury status and running biomechanics in women. *Gait & Posture,* 41**,** 706-710.

Ford, K. R., Myer, G. D. & Hewett, T. E. (2007). Reliability of landing 3D motion analysis: implications for longitudinal analyses. *Med Sci Sports Exerc,* 39**,** 2021-8.

Fredericson, M., Cookingham, C. L., Chaudhari, A. M., Dowdell, B. C., Oestreicher, N. & Sahrmann, S. A. (2000). Hip abductor weakness in distance runners with iliotibial band syndrome. *Clin J Sport Med,* 10**,** 169-75.

Fredericson, M. & Weir, A. (2006). Practical management of iliotibial band friction syndrome in runners. *Clin J Sport Med,* 16**,** 261-8.

Fredericson, M., White, J. J., Macmahon, J. M. & Andriacchi, T. P. (2002). Quantitative analysis of the relative effectiveness of 3 iliotibial band stretches. *Arch Phys Med Rehabil,* 83**,** 589-92.

Fredericson, M. & Wolf, C. (2005). Iliotibial band syndrome in runners : Innovations in Treatment. *Med Sport,* 35.

Freriks, B., Hermens, H., Diselhorst-Klug, C. & Rau, G. (1999). The recommendations for sensors and sensor placement procedures for surface electromyography. *In:* HJ, I. H. (ed.) *European Recommendations for Surface ElectroMyoGraphy* Enschede: Roessingh Research and Development.

Fukuchi, R. K., Fukuchi, C. A. & Duarte, M. (2017). A public dataset of running biomechanics and the effects of running speed on lower extremity kinematics and kinetics. *PeerJ,* 5**,** e3298.

Gholami, M., Kamali, F., Mirzeai, M., Motealleh, A. & Shamsi, M. (2020). Effects of kinesio tape on kinesiophobia, balance and functional performance of athletes with post anterior cruciate ligament reconstruction: a pilot clinical trial. *BMC Sports Sci Med Rehabil,* 12**,** 57.

Glaviano, N. R., Marshall, A. N., Mangum, L. C., Hart, J. M., Hertel, J., Russell, S. & Saliba, S. (2020). Improvements in Lower-Extremity Function Following a Rehabilitation Program With Patterned Electrical Neuromuscular Stimulation in Females With Patellofemoral Pain: A Randomized Controlled Trial. *J Sport Rehabil,* 29**,** 1075-1085.

Good, M., Stiller, C., Zauszniewski, J. A., Anderson, G. C., Stanton-Hicks, M. & Grass, J. A. (2001). Sensation and Distress of Pain Scales: reliability, validity, and sensitivity. *J Nurs Meas,* 9**,** 219-38.

Goubert, L., Crombez, G., Van Damme, S., Vlaeyen, J. W., Bijttebier, P. & Roelofs, J. (2004). Confirmatory factor analysis of the Tampa Scale for Kinesiophobia: invariant two-factor model across low back pain patients and fibromyalgia patients. *Clin J Pain,* 20**,** 103-10.

Grau, S., Krauss, I., Maiwald, C., Axmann, D., Horstmann, T. & Best, R. (2011). Kinematic classification of iliotibial band syndrome in runners. *Scand J Med Sci Sports,* 21**,** 184-9.

Grau, S., Krauss, I., Maiwald, C., Best, R. & Horstmann, T. (2008a). Hip abductor weakness is not the cause for iliotibial band syndrome. *Int J Sports Med,* 29**,** 579-83.

Grau, S., Maiwald, C., Krauss, I., Axmann, D. & Horstmann, T. (2008b). The influence of matching populations on kinematic and kinetic variables in runners with iliotibial band syndrome. *Res Q Exerc Sport,* 79**,** 450-7.

Grood, E. S. & Suntay, W. J. (1983). A joint coordinate system for the clinical description of three-dimensional motions: application to the knee. *J Biomech Eng,* 105**,** 136-44.

Guner, S. & Alsancak, S. (2020). Kinesiotaping Techniques to Alter Static Load in Patients With Foot Pronation. *J Chiropr Med,* 19**,** 175-180.

Guner, S., Alsancak, S. & Koz, M. (2015). Effect of two different kinesio taping techniques on knee kinematics and kinetics in young females. *J Phys Ther Sci,* 27**,** 3093-6.

Gunter, P. & Schwellnus, M. P. (2004). Local corticosteroid injection in iliotibial band friction syndrome in runners: a randomised controlled trial. *Br J Sports Med,* 38**,** 269-72; discussion 272.

Guyatt, G. H., Norman, G. R., Juniper, E. F. & Griffith, L. E. (2002). A critical look at transition ratings. *J Clin Epidemiol,* 55**,** 900-8.

Guzy, G., Vernon, H., Polczyk, R. & Szpitalak, M. (2013). Psychometric validation of the authorized Polish version of the Neck Disability Index. *Disabil Rehabil,* 35**,** 2132-7.

Hamill, J., Miller, R., Noehren, B. & Davis, I. (2008). A prospective study of iliotibial band strain in runners. *Clin Biomech (Bristol, Avon),* 23**,** 1018-25.

Han, J. T., Lee, J. H. & Yoon, C. H. (2015). The mechanical effect of kinesiology tape on rounded shoulder posture in seated male workers: a single-blinded randomized controlled pilot study. *Physiother Theory Pract,* 31**,** 120-5.

Harput, G., Ulusoy, B., Ozer, H., Baltaci, G. & Richards, J. (2016). External supports improve knee performance in anterior cruciate ligament reconstructed individuals with higher kinesiophobia levels. *Knee,* 23**,** 807-12.

Harrast, M. A. (2020). Clinical care of the runner : assessment, biomechanical principles, and injury management.

Hébert-Losier, K., Yin, N. S., Beaven, C. M., Tee, C. C. L. & Richards, J. (2019). Physiological, kinematic, and electromyographic responses to kinesiology-type patella tape in elite cyclists. *J Electromyogr Kinesiol,* 44**,** 36-45.

Heijne, A., Axelsson, K., Werner, S. & Biguet, G. (2008). Rehabilitation and recovery after anterior cruciate ligament reconstruction: patients' experiences. *Scand J Med Sci Sports,* 18**,** 325-35.

Hendry, D., Campbell, A., Ng, L., Grisbrook, T. L. & Hopper, D. M. (2015). Effect of Mulligan's and Kinesio knee taping on adolescent ballet dancers knee and hip biomechanics during landing. *Scand J Med Sci Sports,* 25**,** 888-96.

Heuts, P. H., Vlaeyen, J. W., Roelofs, J., De Bie, R. A., Aretz, K., Van Weel, C. & Van Schayck, O. C. (2004). Pain-related fear and daily functioning in patients with osteoarthritis. *Pain,* 110**,** 228-35.

Hewetson, T., Austin, K., Booth, L., Betser, J., Gwynn-Brett, K. A. & Marshall, S. C. (2010). *An illustrated guide to taping techniques : principles and practice,* Edinburgh ;, Mosby Elsevier.

Hickey, A., Hopper, D., Hall, T. & Wild, C. Y. (2016). The Effect of the Mulligan Knee Taping Technique on Patellofemoral Pain and Lower Limb Biomechanics. *Am J Sports Med,* 44**,** 1179-85.

Hillen, T., Davies, S., Rudd, A. G., Kieselbach, T. & Wolfe, C. D. (2003). Self ratings of health predict functional outcome and recurrence free survival after stroke. *J Epidemiol Community Health,* 57**,** 960-6.

Hing, W., Hall, T. & Mulligan, B. (2020). *The Mulligan Concept of Manual Therapy : textbook of techniques*.

Hjermstad, M. J., Fayers, P. M., Haugen, D. F., Caraceni, A., Hanks, G. W., Loge, J. H., Fainsinger, R., Aass, N. & Kaasa, S. (2011). Studies comparing Numerical Rating Scales, Verbal Rating Scales, and Visual Analogue Scales for assessment of pain intensity in adults: a systematic literature review. *J Pain Symptom Manage,* 41**,** 1073-93.

Hoffman, E., D'onofrio, A., Baez, S. & Cavallario, J. (2018). The Effectiveness of Kinesio Tape in Decreasing Kinesiophobia in Patients With Musculoskeletal Pain: A Critically Appraised Topic. *International Journal of Athletic Therapy and Training,* 23**,** 10-15.

Holmes, J. C., Pruitt, A. L. & Whalen, N. J. (1993). Iliotibial band syndrome in cyclists. *Am J Sports Med,* 21**,** 419-24.

Hood, S., Mcbain, T., Portas, M. & Spears, I. (2012). Measurement in Sports Biomechanics. *Measurement and Control,* 45**,** 182-186.

Hopper, D., Samsson, K., Hulenik, T., Ng, C., Hall, T. & Robinson, K. (2009). The influence of Mulligan ankle taping during balance performance in subjects with unilateral chronic ankle instability. *Phys Ther Sport,* 10**,** 125-30.

Hori, N., Newton, R. U., Kawamori, N., Mcguigan, M. R., Kraemer, W. J. & Nosaka, K. (2009). Reliability of performance measurements derived from ground reaction force data during countermovement jump and the influence of sampling frequency. *J Strength Cond Res,* 23**,** 874-82.

Howe, A., Campbell, A., Ng, L., Hall, T. & Hopper, D. (2015). Effects of two different knee tape procedures on lower-limb kinematics and kinetics in recreational runners. *Scand J Med Sci Sports,* 25**,** 517-24.

Huang, H., Nagao, M., Arita, H., Shiozawa, J., Nishio, H., Kobayashi, Y., Kaneko, H., Nagayama, M., Saita, Y., Ishijima, M., Takazawa, Y., Ikeda, H. & Kaneko, K. (2019). Reproducibility, responsiveness and validation of the Tampa Scale for Kinesiophobia in patients with ACL injuries. *Health and Quality of Life Outcomes,* 17**,** 150.

Hutchinson, L. A., Lichtwark, G. A., Willy, R. W. & Kelly, L. A. (2022). The Iliotibial Band: A Complex Structure with Versatile Functions. *Sports Med*.

Ireland, M. L., Willson, J. D., Ballantyne, B. T. & Davis, I. M. (2003). Hip strength in females with and without patellofemoral pain. *J Orthop Sports Phys Ther,* 33**,** 671-6.

Jaeschke, R., Singer, J. & Guyatt, G. H. (1989). Measurement of health status. Ascertaining the minimal clinically important difference. *Control Clin Trials,* 10**,** 407-15.

Jaramillo, J., Worrell, T. W. & Ingersoll, C. D. (1994). Hip isometric strength following knee surgery. *J Orthop Sports Phys Ther,* 20**,** 160-5.

Jelsing, E. J., Finnoff, J. T., Cheville, A. L., Levy, B. A. & Smith, J. (2013). Sonographic evaluation of the iliotibial band at the lateral femoral epicondyle: does the iliotibial band move? *J Ultrasound Med,* 32**,** 1199-206.

Jelsing, E. J., Maida, E., Finnoff, J. T. & Smith, J. (2014). The source of fluid deep to the iliotibial band: documentation of a potential intra-articular source. *Pm r,* 6**,** 134-8; quiz 138.

Jensen, M. P., Karoly, P. & Braver, S. (1986). The measurement of clinical pain intensity: a comparison of six methods. *Pain,* 27**,** 117-26.

Jorritsma, W., Dijkstra, P. U., De Vries, G. E., Geertzen, J. H. & Reneman, M. F. (2012). Detecting relevant changes and responsiveness of Neck Pain and Disability Scale and Neck Disability Index. *Eur Spine J,* 21**,** 2550-7.

Joshua, D. (2005). Evidence Based Treatment for Iliotibial Band Friction Syndrome. *BioMechanics*.

Kadaba, M. P., Ramakrishnan, H. K., Wootten, M. E., Gainey, J., Gorton, G. & Cochran, G. V. (1989). Repeatability of kinematic, kinetic, and electromyographic data in normal adult gait. *J Orthop Res,* 7**,** 849-60.

Kahl, C. & Cleland, J. A. (2005). Visual analogue scale, numeric pain rating scale and the McGill pain Questionnaire: an overview of psychometric properties. *Physical Therapy Reviews,* 10**,** 123-128.

Kakar, R. S., Greenberger, H. B. & Mckeon, P. O. (2020). Efficacy of Kinesio Taping and McConnell Taping Techniques in the Management of Anterior Knee Pain. *J Sport Rehabil,* 29**,** 79-86.

Kakouris, N., Yener, N. & Fong, D. T. P. (2021). A systematic review of running-related musculoskeletal injuries in runners. *J Sport Health Sci,* 10**,** 513-522.

Kamper, S. J., Maher, C. G. & Mackay, G. (2009). Global Rating of Change Scales: A Review of Strengths and Weaknesses and Considerations for Design. *Journal of Manual & Manipulative Therapy,* 17**,** 163-170.

Kamper, S. J., Ostelo, R. W., Knol, D. L., Maher, C. G., De Vet, H. C. & Hancock, M. J. (2010). Global Perceived Effect scales provided reliable assessments of health transition in people with musculoskeletal disorders, but ratings are strongly influenced by current status. *J Clin Epidemiol,* 63**,** 760-766.e1.

Kaplan, E. B. (1958). The iliotibial tract; clinical and morphological significance. *J Bone Joint Surg Am,* 40-A**,** 817-32.

Kase, K., Wallis, J. & Kase, T. (2003). *Clinical Therapeutic Applications of the Kinesio Taping Method*, Kinesio USA, LLC.

Kasemkijwattana, C., Kesprayura, S., Chaipinyo, K., Chanlalit, C. & Chansiri, K. (2009a). Autologous chondrocytes implantation for traumatic cartilage defects of the knee. *J Med Assoc Thai,* 92**,** 648-53.

Kasemkijwattana, C., Kesprayura, S., Chaipinyo, K., Chanlalit, C. & Chansiri, K. (2009b). Autologous chondrocytes implantation with three-dimensional collagen scaffold. *J Med Assoc Thai,* 92**,** 1282-6.

Keet, J. H. L., Gray, J., Harley, Y. & Lambert, M. I. (2007). The effect of medial patellar taping on pain, strength and neuromuscular recruitment in subjects with and without patellofemoral pain. *Physiotherapy,* 93**,** 45-52.

Kendall, F. P., Mccreary, E. K., Provance, P. G., Rodgers, M. M. & Romani, W. A. (2005). *Muscle testings and functions with posture and pain.,* Baltimore (MD), Williams & Wilkins.

Khadavi, M. J., Chen, Y. T. & Fredericson, M. (2015). A Novel Knee Orthosis in the Treatment of Patellofemoral Pain Syndrome. *Open Journal of Therapy and Rehabilitation,* Vol.03No.02**,** 6.

Khaund, R. & Flynn, S. H. (2005). Iliotibial band syndrome: a common source of knee pain. *Am Fam Physician,* 71**,** 1545-50.

Kim, B. J. & Lee, J. H. (2015). Effects of scapula-upward taping using kinesiology tape in a patient with shoulder pain caused by scapular downward rotation. *J Phys Ther Sci,* 27**,** 547-8.

Kim, B. J., Lee, J. H., Kim, C. T. & Lee, S. M. (2015). Effects of ankle balance taping with kinesiology tape for a patient with chronic ankle instability. *J Phys Ther Sci,* 27**,** 2405-6.

Kirk, K. L., Kuklo, T. & Klemme, W. (2000). Iliotibial band friction syndrome. *Orthopedics,* 23**,** 1209-14; discussion 1214-5; quiz 1216-7.

Koho, P., Aho, S., Kautiainen, H., Pohjolainen, T. & Hurri, H. (2014). Test-retest reliability and comparability of paper and computer questionnaires for the Finnish version of the Tampa Scale of Kinesiophobia. *Physiotherapy,* 100**,** 356-62.

Kori, S. H. (1990). Kinisophobia : A new view of chronic pain behavior. *Pain Manage***,** 35-43.

Kremer, E., Atkinson, J. H. & Ignelzi, R. J. (1981). Measurement of pain: patient preference does not confound pain measurement. *Pain,* 10**,** 241-8.

Kristianslund, E., Krosshaug, T. & Van Den Bogert, A. J. (2012). Effect of low pass filtering on joint moments from inverse dynamics: implications for injury prevention. *J Biomech,* 45**,** 666-71.

Kurt, E. E., Büyükturan, Ö., Erdem, H. R., Tuncay, F. & Sezgin, H. (2016). Short-term effects of kinesio tape on joint position sense, isokinetic measurements, and clinical parameters in patellofemoral pain syndrome. *J Phys Ther Sci,* 28**,** 2034-40.

Kvist, J., Ek, A., Sporrstedt, K. & Good, L. (2005). Fear of re-injury: a hindrance for returning to sports after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc,* 13**,** 393-7.

Kvist, M. & Jarvinen, M. (1982). Clinical, histochemical and biomechanical features in repair of muscle and tendon injuries. *Int J Sports Med,* 3 Suppl 1**,** 12-4.

Landry, S. C., Mckean, K. A., Hubley-Kozey, C. L., Stanish, W. D. & Deluzio, K. J. (2007). Neuromuscular and lower limb biomechanical differences exist between male and female elite adolescent soccer players during an unanticipated run and crosscut maneuver. *Am J Sports Med,* 35**,** 1901-11.

Lavine, R. (2010). Iliotibial band friction syndrome. *Current Reviews in Musculoskeletal Medicine,* 3**,** 18-22.

Lee, C. R., Lee, D. Y., Jeong, H.-S. & Lee, M. H. (2012). The Effects of Kinesio Taping on VMO and VL EMG Activities during Stair Ascent and Descent by Persons with Patellofemoral Pain: a Preliminary Study. *Journal of Physical Therapy Science,* 24**,** 153-156.

Lee, K., Yi, C. W. & Lee, S. (2016). The effects of kinesiology taping therapy on degenerative knee arthritis patients' pain, function, and joint range of motion. *J Phys Ther Sci,* 28**,** 63-6.

Lee, S. M. & Lee, J. H. (2015). Ankle inversion taping using kinesiology tape for treating medial ankle sprain in an amateur soccer player. *J Phys Ther Sci,* 27**,** 2407-8.

Leibbrandt, D. C. & Louw, Q. A. (2018). The test retest reliability of gait outcomes in subjects with anterior knee pain. *J Bodyw Mov Ther,* 22**,** 476-481.

Lenhart, R., Thelen, D. & Heiderscheit, B. (2014). Hip muscle loads during running at various step rates. *J Orthop Sports Phys Ther,* 44**,** 766-74, a1-4.

Lethem, J., Slade, P. D., Troup, J. D. G. & Bentley, G. (1983). Outline of a fear-avoidance model of exaggerated pain perception—I. *Behaviour Research and Therapy,* 21**,** 401-408.

Levangie, P. K. & Norkin, C. C. (2011). *Joint structure and function : a comprehensive analysis,* Philadelphia, F.A. Davis Co.

Lewinson, R. T., Fukuchi, C. A., Worobets, J. T. & Stefanyshyn, D. J. (2013). The effects of wedged footwear on lower limb frontal plane biomechanics during running. *Clin J Sport Med,* 23**,** 208-15.

Lim, E. C. & Tay, M. G. (2015). Kinesio taping in musculoskeletal pain and disability that lasts for more than 4 weeks: is it time to peel off the tape and throw it out with the sweat? A systematic review with meta-analysis focused on pain and also methods of tape application. *Br J Sports Med,* 49**,** 1558-66.

Liu, K., Duan, Z., Chen, L., Wen, Z., Zhu, S., Qu, Q., Chen, W., Zhang, S. & Yu, B. (2020). Short-Term Effect of Different Taping Methods on Local Skin Temperature in Healthy Adults. *Front Physiol,* 11**,** 488.

Liu, K., Qian, J., Gao, Q. & Ruan, B. (2019). Effects of Kinesio taping of the knee on proprioception, balance, and functional performance in patients with anterior cruciate ligament rupture: A retrospective case series. *Medicine (Baltimore),* 98**,** e17956.

Logan, C. A., Bhashyam, A. R., Tisosky, A. J., Haber, D. B., Jorgensen, A., Roy, A. & Provencher, M. T. (2017). Systematic Review of the Effect of Taping Techniques on Patellofemoral Pain Syndrome. *Sports Health,* 9**,** 456-461.

Logan, S., Hunter, I., Jt, J. T. H., Feland, J. B. & Parcell, A. C. (2010). Ground reaction force differences between running shoes, racing flats, and distance spikes in runners. *J Sports Sci Med,* 9**,** 147-53.

Long, Z., Wang, R., Han, J., Waddington, G., Adams, R. & Anson, J. (2017). Optimizing ankle performance when taped: Effects of kinesiology and athletic taping on proprioception in full weight-bearing stance. *J Sci Med Sport,* 20**,** 236-240.

Louw, M. & Deary, C. (2014). The biomechanical variables involved in the aetiology of iliotibial band syndrome in distance runners - A systematic review of the literature. *Phys Ther Sport,* 15**,** 64-75.

Lüning Bergsten, C., Lundberg, M., Lindberg, P. & Elfving, B. (2012). Change in kinesiophobia and its relation to activity limitation after multidisciplinary rehabilitation in patients with chronic back pain. *Disabil Rehabil,* 34**,** 852-8.

Luo, W. H. & Li, Y. (2021). Current Evidence Does Support the Use of KT to Treat Chronic Knee Pain in Short Term: A Systematic Review and Meta-Analysis. *Pain Res Manag,* 2021**,** 5516389.

Lyman, K. J., Keister, K., Gange, K., Mellinger, C. D. & Hanson, T. A. (2017). INVESTIGATING THE EFFECTIVENESS OF KINESIO® TAPING SPACE CORRECTION METHOD IN HEALTHY ADULTS ON PATELLOFEMORAL JOINT AND SUBCUTANEOUS SPACE. *Int J Sports Phys Ther,* 12**,** 250-257.

Macintyre, J. G., Taunton, J. E., Clement, D. B., Lloyd-Smith, D. R., Mckenzie, D. C. & Morrell, R. W. (1991). Running Injuries: A Clinical Study of 4,173 Cases. *Clinical Journal of Sport Medicine,* 1.

Mackay, G. J. K., Stearne, S. M., Wild, C. Y., Nugent, E. P., Murdock, A. P., Mastaglia, B. & Hall, T. M. (2020). Mulligan Knee Taping Using Both Elastic and Rigid Tape Reduces Pain and Alters Lower Limb Biomechanics in Female Patients With Patellofemoral Pain. *Orthop J Sports Med,* 8**,** 2325967120921673.

Mak, D. N., Au, I. P., Chan, M., Chan, Z. Y., An, W. W., Zhang, J. H., Draper, D. & Cheung, R. T. (2019). Placebo effect of facilitatory Kinesio tape on muscle activity and muscle strength. *Physiother Theory Pract,* 35**,** 157-162.

Mason, D. L., Preece, S. J., Bramah, C. A. & Herrington, L. C. (2016). Reproducibility of kinematic measures of the thoracic spine, lumbar spine and pelvis during fast running. *Gait Posture,* 43**,** 96-100.

Masters, A., Netto, K. J., Brooker, S., Hopper, D. & Liew, B. (2018). Hip Taping Positively Alters Running Kinematics in Asymptomatic Females. *Int J Sports Med,* 39**,** 1068-1074.

Maykut, J. N., Taylor-Haas, J. A., Paterno, M. V., Dicesare, C. A. & Ford, K. R. (2015). Concurrent validity and reliability of 2d kinematic analysis of frontal plane motion during running. *Int J Sports Phys Ther,* 10**,** 136-46.

Mccarthy, C., Fleming, N., Donne, B. & Blanksby, B. (2015). Barefoot running and hip kinematics: good news for the knee? *Med Sci Sports Exerc,* 47**,** 1009-16.

Mcginley, J. L., Baker, R., Wolfe, R. & Morris, M. E. (2009). The reliability of three-dimensional kinematic gait measurements: a systematic review. *Gait Posture,* 29**,** 360-9.

Mcnicol, K., Taunton, J. E. & Clement, D. B. (1981). Iliotibial tract friction syndrome in athletes. *Can J Appl Sport Sci,* 6**,** 76-80.

Meardon, S. A., Campbell, S. & Derrick, T. R. (2012). Step width alters iliotibial band strain during running. *Sports Biomech,* 11**,** 464-72.

Melzack, R. & Wall, P. D. (1965). Pain mechanisms: a new theory. *Science,* 150**,** 971-9.

Menetrey, J. & Fritschy, D. (1999). Subtalar subluxation in ballet dancers. *Am J Sports Med,* 27**,** 143-9.

Mentiplay, B. F., Perraton, L. G., Bower, K. J., Adair, B., Pua, Y. H., Williams, G. P., Mcgaw, R. & Clark, R. A. (2015). Assessment of Lower Limb Muscle Strength and Power Using Hand-Held and Fixed Dynamometry: A Reliability and Validity Study. *PLoS One,* 10**,** e0140822.

Messier, S. P., Edwards, D. G., Martin, D. F., Lowery, R. B., Cannon, D. W., James, M. K., Curl, W. W., Read, H. M. & Hunter, D. M. (1995). Etiology of iliotibial band friction syndrome in distance runners. *Med Sci Sports Exerc,* 27**,** 951-60.

Messier, S. P. & Pittala, K. A. (1988). Etiologic factors associated with selected running injuries. *Med Sci Sports Exerc,* 20**,** 501-5.

Michener, L. A., Snyder, A. R. & Leggin, B. G. (2011). Responsiveness of the numeric pain rating scale in patients with shoulder pain and the effect of surgical status. *J Sport Rehabil,* 20**,** 115-28.

Miller, R. H., Lowry, J. L., Meardon, S. A. & Gillette, J. C. (2007). Lower extremity mechanics of iliotibial band syndrome during an exhaustive run. *Gait & Posture,* 26**,** 407-413.

Miller, R. P., Kori, S. H. & Todd, D. D. (1991). The Tampa Scale: a Measure of Kinisophobia. 7**,** 51.

Moayedi, M. & Davis, K. D. (2013). Theories of pain: from specificity to gate control. *J Neurophysiol,* 109**,** 5-12.

Montalvo, A. M., Cara, E. L. & Myer, G. D. (2014). Effect of kinesiology taping on pain in individuals with musculoskeletal injuries: systematic review and meta-analysis. *Phys Sportsmed,* 42**,** 48-57.

Monticone, M., Ambrosini, E., Vernon, H., Brunati, R., Rocca, B., Foti, C. & Ferrante, S. (2015). Responsiveness and minimal important changes for the Neck Disability Index and the Neck Pain Disability Scale in Italian subjects with chronic neck pain. *Eur Spine J,* 24**,** 2821-7.

Monticone, M., Frigau, L., Vernon, H., Rocca, B. & Mola, F. (2018). Responsiveness and minimal important change of the NeckPix© in subjects with chronic neck pain undergoing rehabilitation. *Eur Spine J,* 27**,** 1324-1331.

Mostafavifar, M., Wertz, J. & Borchers, J. (2012). A systematic review of the effectiveness of kinesio taping for musculoskeletal injury. *Phys Sportsmed,* 40**,** 33-40.

Mucha, M. D., Caldwell, W., Schlueter, E. L., Walters, C. & Hassen, A. (2017). Hip abductor strength and lower extremity running related injury in distance runners: A systematic review. *J Sci Med Sport,* 20**,** 349-355.

Munro, A., Herrington, L. & Carolan, M. (2012). Reliability of 2-dimensional video assessment of frontal-plane dynamic knee valgus during common athletic screening tasks. *J Sport Rehabil,* 21**,** 7-11.

Nakagawa, T. H., Moriya É, T., Maciel, C. D. & Serrão, F. V. (2014). Test-retest reliability of three-dimensional kinematics using an electromagnetic tracking system during single-leg squat and stepping maneuver. *Gait Posture,* 39**,** 141-6.

Nakajima, M. A. & Baldridge, C. (2013). The effect of kinesio® tape on vertical jump and dynamic postural control. *Int J Sports Phys Ther,* 8**,** 393-406.

Nederhand, M. J., Ijzerman, M. J., Hermens, H. J., Turk, D. C. & Zilvold, G. (2004). Predictive value of fear avoidance in developing chronic neck pain disability: consequences for clinical decision making. *Arch Phys Med Rehabil,* 85**,** 496-501.

Ngo, T., Stupar, M., Côté, P., Boyle, E. & Shearer, H. (2010). A study of the test-retest reliability of the self-perceived general recovery and self-perceived change in neck pain questions in patients with recent whiplash-associated disorders. *Eur Spine J,* 19**,** 957-62.

Nigg, B. M., Baltich, J., Maurer, C. & Federolf, P. (2012). Shoe midsole hardness, sex and age effects on lower extremity kinematics during running. *J Biomech,* 45**,** 1692-7.

Noble, C. A. (1979). The treatment of iliotibial band friction syndrome. *Br J Sports Med,* 13**,** 51-4.

Noble, C. A. (1980). Iliotibial band friction syndrome in runners. *Am J Sports Med,* 8**,** 232-4.

Noehren, B., Davis, I. & Hamill, J. (2007). ASB clinical biomechanics award winner 2006 prospective study of the biomechanical factors associated with iliotibial band syndrome. *Clin Biomech,* 22.

Noehren, B., Davis, I., Hamill, J. & Ferber, R. (2006). Secondary Plane Biomechanics of Iliotibial Band Syndrome in Competitive Female Runners: 2201Board #138 4:00 PM – 5:00 PM. *Medicine & Science in Sports & Exercise,* 38**,** S393.

Noehren, B., Schmitz, A., Hempel, R., Westlake, C. & Black, W. (2014). Assessment of strength, flexibility, and running mechanics in men with iliotibial band syndrome. *J Orthop Sports Phys Ther,* 44**,** 217-22.

Oliveira, A. S. & Pirscoveanu, C. I. (2021). Implications of sample size and acquired number of steps to investigate running biomechanics. *Sci Rep,* 11**,** 3083.

Orchard, J. W., Fricker, P. A., Abud, A. T. & Mason, B. R. (1996). Biomechanics of iliotibial band friction syndrome in runners. *Am J Sports Med,* 24**,** 375-9.

Orendurff, M. S., Kobayashi, T., Tulchin-Francis, K., Tullock, A. M. H., Villarosa, C., Chan, C., Kraus, E. & Strike, S. (2018). A little bit faster: Lower extremity joint kinematics and kinetics as recreational runners achieve faster speeds. *J Biomech,* 71**,** 167-175.

Ostelo, R. W., Swinkels-Meewisse, I. J., Knol, D. L., Vlaeyen, J. W. & De Vet, H. C. (2007). Assessing pain and pain-related fear in acute low back pain: what is the smallest detectable change? *Int J Behav Med,* 14**,** 242-8.

Osterhues, D. J. (2004). The use of Kinesio Taping® in the management of traumatic patella dislocation. A case study. *Physiotherapy Theory and Practice,* 20**,** 267-270.

Öztürk, G., Külcü, D. G., Mesci, N., Şilte, A. D. & Aydog, E. (2016). Efficacy of kinesio tape application on pain and muscle strength in patients with myofascial pain syndrome: a placebo-controlled trial. *J Phys Ther Sci,* 28**,** 1074-9.

Pamuk, U. & Yucesoy, C. A. (2015). MRI analyses show that kinesio taping affects much more than just the targeted superficial tissues and causes heterogeneous deformations within the whole limb. *J Biomech,* 48**,** 4262-70.

Park, J. S., Yoon, T., Lee, S. H., Hwang, N. K., Lee, J. H., Jung, Y. J. & Lee, G. (2019). Immediate effects of kinesiology tape on the pain and gait function in older adults with knee osteoarthritis. *Medicine (Baltimore),* 98**,** e17880.

Parreira Pdo, C., Costa Lda, C., Hespanhol, L. C., Jr., Lopes, A. D. & Costa, L. O. (2014). Current evidence does not support the use of Kinesio Taping in clinical practice: a systematic review. *J Physiother,* 60**,** 31-9.

Payton, C. & Bartlett, R. M. (2007). *Biomechanical evaluation of movement in sport and exercise: The British association of sport and exercise sciences guidelines*.

Pelletier, A., Sanzo, P., Kivi, D. & Zerpa, C. (2019). The effect of patellar taping on lower extremity running kinematics in individuals with patellofemoral pain syndrome. *Physiother Theory Pract,* 35**,** 764-772.

Pengel, L. H., Refshauge, K. M. & Maher, C. G. (2004). Responsiveness of pain, disability, and physical impairment outcomes in patients with low back pain. *Spine (Phila Pa 1976),* 29**,** 879-83.

Pepper, T. M., Brismée, J. M., Sizer, P. S., Jr., Kapila, J., Seeber, G. H., Huggins, C. A. & Hooper, T. L. (2021). The Immediate Effects of Foam Rolling and Stretching on Iliotibial Band Stiffness: A Randomized Controlled Trial. *Int J Sports Phys Ther,* 16**,** 651-661.

Phinyomark, A., Hettinga, B. A., Osis, S. T. & Ferber, R. (2014). Gender and age-related differences in bilateral lower extremity mechanics during treadmill running. *PLoS One,* 9**,** e105246.

Phinyomark, A., Osis, S., Hettinga, B. A., Leigh, R. & Ferber, R. (2015). Gender differences in gait kinematics in runners with iliotibial band syndrome. *Scand J Med Sci Sports,* 25**,** 744-53.

Pinheiro, Y. T., Barbosa, G. M., Fialho, H. R. F., Silva, C. a. M., Anunciação, J. O., Silva, H. J. A., Souza, M. C. & Lins, C. a. A. (2020). Does tension applied in kinesio taping affect pain or function in older women with knee osteoarthritis? A randomised controlled trial. *BMJ Open,* 10**,** e041121.

Piva, S. R., Gil, A. B., Moore, C. G. & Fitzgerald, G. K. (2009). Responsiveness of the activities of daily living scale of the knee outcome survey and numeric pain rating scale in patients with patellofemoral pain. *J Rehabil Med,* 41**,** 129-35.

Piva, S. R., Goodnite, E. A. & Childs, J. D. (2005). Strength around the hip and flexibility of soft tissues in individuals with and without patellofemoral pain syndrome. *J Orthop Sports Phys Ther,* 35**,** 793-801.

Pool, J. J., Hiralal, S., Ostelo, R. W., Van Der Veer, K., Vlaeyen, J. W., Bouter, L. M. & De Vet, H. C. (2009). The applicability of the Tampa Scale of Kinesiophobia for patients with sub-acute neck pain: a qualitative study. *Quality & quantity,* 43**,** 773-780.

Poon, K. Y., Li, S. M., Roper, M. G., Wong, M. K., Wong, O. & Cheung, R. T. (2015). Kinesiology tape does not facilitate muscle performance: A deceptive controlled trial. *Man Ther,* 20**,** 130-3.

Powell, D. W., Andrews, S., Stickley, C. & Williams, D. S. (2016). High- compared to low-arched athletes exhibit smaller knee abduction moments in walking and running. *Hum Mov Sci,* 50**,** 47-53.

Powers, C. M. (2010). The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. *J Orthop Sports Phys Ther,* 40**,** 42-51.

Preston, C. C. & Colman, A. M. (2000). Optimal number of response categories in rating scales: reliability, validity, discriminating power, and respondent preferences. *Acta Psychol (Amst),* 104**,** 1-15.

Queen, R. M., Gross, M. T. & Liu, H. Y. (2006). Repeatability of lower extremity kinetics and kinematics for standardized and self-selected running speeds. *Gait Posture,* 23**,** 282-7.

Rácz, K. & Kiss, R. M. (2021). Marker displacement data filtering in gait analysis: A technical note. *Biomedical Signal Processing and Control,* 70**,** 102974.

Rajasekar, S., Kumar, A., Patel, J., Ramprasad, M. & Samuel, A. J. (2018). Does Kinesio taping correct exaggerated dynamic knee valgus? A randomized double blinded sham-controlled trial. *J Bodyw Mov Ther,* 22**,** 727-732.

Reese, N. B. & Bandy, W. D. (2003). Use of an inclinometer to measure flexibility of the iliotibial band using the Ober test and the modified Ober test: differences in magnitude and reliability of measurements. *J Orthop Sports Phys Ther,* 33**,** 326-30.

Reischl, S. F., Powers, C. M., Rao, S. & Perry, J. (1999). Relationship between foot pronation and rotation of the tibia and femur during walking. *Foot Ankle Int,* 20**,** 513-20.

Richard, D. A., Wayne, V. & Adam, M. (2009). *Gray's Anatomy for Students,* London, United Kingdom, Churchill Livingstone.

Ridding, M. C., Brouwer, B., Miles, T. S., Pitcher, J. B. & Thompson, P. D. (2000). Changes in muscle responses to stimulation of the motor cortex induced by peripheral nerve stimulation in human subjects. *Exp Brain Res,* 131**,** 135-43.

Roberts, C. & Torgerson, D. J. (1999). Understanding controlled trials: baseline imbalance in randomised controlled trials. *Bmj,* 319**,** 185.

Roelofs, J., Goubert, L., Peters, M. L., Vlaeyen, J. W. & Crombez, G. (2004). The Tampa Scale for Kinesiophobia: further examination of psychometric properties in patients with chronic low back pain and fibromyalgia. *Eur J Pain,* 8**,** 495-502.

Roos, E. M. & Lohmander, L. S. (2003). The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. *Health Qual Life Outcomes,* 1**,** 64.

Roy, S. H., De Luca, C. J. & Schneider, J. (1986). Effects of electrode location on myoelectric conduction velocity and median frequency estimates. *J Appl Physiol (1985),* 61**,** 1510-7.

Rumball, J. S., Lebrun, C. M., Di Ciacca, S. R. & Orlando, K. (2005). Rowing injuries. *Sports Med,* 35**,** 537-55.

Sakaguchi, M., Ogawa, H., Shimizu, N., Kanehisa, H., Yanai, T. & Kawakami, Y. (2014). Gender differences in hip and ankle joint kinematics on knee abduction during running. *Eur J Sport Sci,* 14 Suppl 1**,** S302-9.

Sawkins, K., Refshauge, K., Kilbreath, S. & Raymond, J. (2007). The placebo effect of ankle taping in ankle instability. *Med Sci Sports Exerc,* 39**,** 781-7.

Schache, A. G., Blanch, P. D. & Murphy, A. T. (2000). Relation of anterior pelvic tilt during running to clinical and kinematic measures of hip extension. *Br J Sports Med,* 34**,** 279-83.

Schreiber, R. & Louw, Q. (2011). The effect of gluteus medius training on hip kinematics in a runner with iliotibial band syndrome. *South African Journal of Physiotherapy,* 67.

Schurr, S. A., Marshall, A. N., Resch, J. E. & Saliba, S. A. (2017). TWO-DIMENSIONAL VIDEO ANALYSIS IS COMPARABLE TO 3D MOTION CAPTURE IN LOWER EXTREMITY MOVEMENT ASSESSMENT. *Int J Sports Phys Ther,* 12**,** 163-172.

Schwartz, M. H., Trost, J. P. & Wervey, R. A. (2004). Measurement and management of errors in quantitative gait data. *Gait Posture,* 20**,** 196-203.

Seo, H.-D., Kim, M.-Y., Choi, J.-E., Lim, G.-H., Jung, S.-I., Park, S.-H., Cheon, S.-H. & Lee, H.-Y. (2016). Effects of Kinesio taping on joint position sense of the ankle. *Journal of Physical Therapy Science,* 28**,** 1158-1160.

Shaheen, A. A., Omar, M. T. & Vernon, H. (2013). Cross-cultural adaptation, reliability, and validity of the Arabic version of neck disability index in patients with neck pain. *Spine (Phila Pa 1976),* 38**,** E609-15.

Shams, F., Hadadnezhad, M., Letafatkar, A. & Hogg, J. (2021). Valgus Control Feedback and Taping Improves the Effects of Plyometric Exercises in Women With Dynamic Knee Valgus. *Sports Health***,** 19417381211049805.

Shannon, C. E. & Weaver, W. (1949). *The mathematical theory of communication,* Urbana,, University of Illinois Press.

Shen, P., Mao, D., Zhang, C., Sun, W. & Song, Q. (2019). Effects of running biomechanics on the occurrence of iliotibial band syndrome in male runners during an eight-week running programme—a prospective study. *Sports Biomechanics***,** 1-11.

Shen, P., Mao, D., Zhang, C., Sun, W. & Song, Q. (2021). Effects of running biomechanics on the occurrence of iliotibial band syndrome in male runners during an eight-week running programme-a prospective study. *Sports Biomech,* 20**,** 560-570.

Silva, R. O., Carlos, F. R., Morales, M. C., Emerick, V. S., Teruyu, A. I., Valadão, V. M. A., Carvalho, L. C. & Lobato, D. F. M. (2021). Effect of two Dynamic Tape™ applications on the electromyographic activity of the gluteus medius and functional performance in women: A randomized, controlled, clinical trial. *J Bodyw Mov Ther,* 25**,** 212-217.

Sinclair, J. & Selfe, J. (2015). Sex differences in knee loading in recreational runners. *J Biomech,* 48**,** 2171-5.

Sinclair, J. K. (2016). Effects of a 10 week footstrike transition in habitual rearfoot runners with patellofemoral pain. *Comparative Exercise Physiology,* 12**,** 141-150.

Sinclair, J. K., Selfe, J., Taylor, P. J., Shore, H. F. & Richards, J. D. (2016). Influence of a knee brace intervention on perceived pain and patellofemoral loading in recreational athletes. *Clin Biomech (Bristol, Avon),* 37**,** 7-12.

Słupik, A., Dwornik, M., Białoszewski, D. & Zych, E. (2007). Effect of Kinesio Taping on bioelectrical activity of vastus medialis muscle. Preliminary report. *Ortop Traumatol Rehabil,* 9**,** 644-51.

Song, C. Y., Huang, H. Y., Chen, S. C., Lin, J. J. & Chang, A. H. (2015). Effects of femoral rotational taping on pain, lower extremity kinematics, and muscle activation in female patients with patellofemoral pain. *J Sci Med Sport,* 18**,** 388-93.

Song, C. Y., Lin, J. J. & Chang, A. H. (2017). Effects of Femoral Rotational Taping on Dynamic Postural Stability in Female Patients With Patellofemoral Pain. *Clin J Sport Med,* 27**,** 438-443.

Sorenson, B., Kernozek, T. W., Willson, J. D., Ragan, R. & Hove, J. (2015). Two- and Three-Dimensional Relationships Between Knee and Hip Kinematic Motion Analysis: Single-Leg Drop-Jump Landings. *J Sport Rehabil,* 24**,** 363-72.

Souza, R. B. & Powers, C. M. (2009). Differences in hip kinematics, muscle strength, and muscle activation between subjects with and without patellofemoral pain. *J Orthop Sports Phys Ther,* 39**,** 12-9.

Stecco, A., Gilliar, W., Hill, R., Fullerton, B. & Stecco, C. (2013). The anatomical and functional relation between gluteus maximus and fascia lata. *J Bodyw Mov Ther,* 17**,** 512-7.

Steinwender, G., Saraph, V., Scheiber, S., Zwick, E. B., Uitz, C. & Hackl, K. (2000). Intrasubject repeatability of gait analysis data in normal and spastic children. *Clin Biomech (Bristol, Avon),* 15**,** 134-9.

Stewart, M., Maher, C. G., Refshauge, K. M., Bogduk, N. & Nicholas, M. (2007). Responsiveness of pain and disability measures for chronic whiplash. *Spine (Phila Pa 1976),* 32**,** 580-5.

Stewart, M. J., Maher, C. G., Refshauge, K. M., Herbert, R. D., Bogduk, N. & Nicholas, M. (2003). Advice or exercise for chronic whiplash disorders? Design of a randomized controlled trial. *BMC Musculoskelet Disord,* 4**,** 18.

Stratford, P. W., Binkley, J., Solomon, P., Gill, C. & Finch, E. (1994). Assessing change over time in patients with low back pain. *Phys Ther,* 74**,** 528-33.

Stratford, P. W., Binkley, J. M. & Riddle, D. L. (1996). Health status measures: strategies and analytic methods for assessing change scores. *Phys Ther,* 76**,** 1109-23.

Strauss, E. J., Kim, S., Calcei, J. G. & Park, D. (2011). Iliotibial band syndrome: evaluation and management. *J Am Acad Orthop Surg,* 19**,** 728-36.

Swanson, S. C. & Caldwell, G. E. (2000). An integrated biomechanical analysis of high speed incline and level treadmill running. *Med Sci Sports Exerc,* 32**,** 1146-55.

Swinkels-Meewisse, E. J., Swinkels, R. A., Verbeek, A. L., Vlaeyen, J. W. & Oostendorp, R. A. (2003). Psychometric properties of the Tampa Scale for kinesiophobia and the fear-avoidance beliefs questionnaire in acute low back pain. *Man Ther,* 8**,** 29-36.

Tateuchi, H., Shiratori, S. & Ichihashi, N. (2015). The effect of angle and moment of the hip and knee joint on iliotibial band hardness. *Gait Posture,* 41**,** 522-8.

Taunton, J. E., Ryan, M. B., Clement, D. B., Mckenzie, D. C., Lloyd-Smith, D. R. & Zumbo, B. D. (2002a). A retrospective case-control analysis of 2002 running injuries. *Br J Sports Med,* 36**,** 95-101.

Taunton, J. E., Ryan, M. B., Clement, D. B., Mckenzie, D. C., Lloyd-Smith, D. R. & Zumbo, B. D. (2002b). A retrospective case–control analysis of 2002 running injuries. *Br J Sports Med,* 36.

Tenforde, A. S., Sayres, L. C., Mccurdy, M. L., Collado, H., Sainani, K. L. & Fredericson, M. (2011). Overuse Injuries in High School Runners: Lifetime Prevalence and Prevention Strategies. *PM&R,* 3**,** 125-131.

Teng, H. L., Macleod, T. D., Link, T. M., Majumdar, S. & Souza, R. B. (2015). Higher Knee Flexion Moment During the Second Half of the Stance Phase of Gait Is Associated With the Progression of Osteoarthritis of the Patellofemoral Joint on Magnetic Resonance Imaging. *J Orthop Sports Phys Ther,* 45**,** 656-64.

Terry, G. C., Hughston, J. C. & Norwood, L. A. (1986). The anatomy of the iliopatellar band and iliotibial tract. *The American Journal of Sports Medicine,* 14**,** 39-45.

Thelen, M. D., Dauber, J. A. & Stoneman, P. D. (2008). The clinical efficacy of kinesio tape for shoulder pain: a randomized, double-blinded, clinical trial. *J Orthop Sports Phys Ther,* 38**,** 389-95.

Togo, K., Matsuoka, N., Hashigaki, S., Imai, K. & Moriya, T. (2011). Clinically Important Effects in New Drug Development. *Drug Information Journal,* 45**,** 805-810.

Tsai, Y. J., Huang, Y. C., Chen, Y. L., Hsu, Y. W. & Kuo, Y. L. (2020). A Pilot Study of Hip Corrective Taping Using Kinesio Tape for Pain and Lower Extremity Joint Kinematics in Basketball Players with Patellofemoral Pain. *J Pain Res,* 13**,** 1497-1503.

Tuite, M. J. (2010). Imaging of triathlon injuries. *Radiol Clin North Am,* 48**,** 1125-35.

Tunakova, V., Tunak, M., Mullerova, J., Kolinova, M. & Bittner, V. (2017). Material, structure, chosen mechanical and comfort properties of kinesiology tape. *The Journal of The Textile Institute,* 108**,** 2132-2146.

Van Der Worp, M. P., Van Der Horst, N., De Wijer, A., Backx, F. J. & Nijhuis-Van Der Sanden, M. W. (2012). Iliotibial band syndrome in runners: a systematic review. *Sports Med,* 42**,** 969-92.

Van Melick, N., Meddeler, B. M., Hoogeboom, T. J., Nijhuis-Van Der Sanden, M. W. G. & Van Cingel, R. E. H. (2017). How to determine leg dominance: The agreement between self-reported and observed performance in healthy adults. *PloS one,* 12**,** e0189876-e0189876.

Van Poppel, D., Van Der Worp, M., Slabbekoorn, A., Van Den Heuvel, S. S. P., Van Middelkoop, M., Koes, B. W., Verhagen, A. P. & Scholten-Peeters, G. G. M. (2021). Risk factors for overuse injuries in short- and long-distance running: A systematic review. *J Sport Health Sci,* 10**,** 14-28.

Vannatta, C. N., Heinert, B. L. & Kernozek, T. W. (2020). Biomechanical risk factors for running-related injury differ by sample population: A systematic review and meta-analysis. *Clin Biomech (Bristol, Avon),* 75**,** 104991.

Vannatta, C. N. & Kernozek, T. W. (2021). Sex differences in gluteal muscle forces during running. *Sports Biomech,* 20**,** 319-329.

Vanrenterghem, J., De Clercq, D. & Van Cleven, P. (2001). Necessary precautions in measuring correct vertical jumping height by means of force plate measurements. *Ergonomics,* 44**,** 814-8.

Vercelli, S., Sartorio, F., Foti, C., Colletto, L., Virton, D., Ronconi, G. & Ferriero, G. (2012). Immediate effects of kinesiotaping on quadriceps muscle strength: a single-blind, placebo-controlled crossover trial. *Clin J Sport Med,* 22**,** 319-26.

Verheul, J., Clansey, A. C. & Lake, M. J. (2017). Adjustments with running speed reveal neuromuscular adaptations during landing associated with high mileage running training. *J Appl Physiol (1985),* 122**,** 653-665.

Vlaeyen, J. W., Kole-Snijders, A. M., Rotteveel, A. M., Ruesink, R. & Heuts, P. H. (1995a). The role of fear of movement/(re)injury in pain disability. *J Occup Rehabil,* 5**,** 235-52.

Vlaeyen, J. W. S., Kole-Snijders, A. M. J., Boeren, R. G. B. & Van Eek, H. (1995b). Fear of movement/(re)injury in chronic low back pain and its relation to behavioral performance. *Pain,* 62**,** 363-372.

Wang, J., Tang, L. & Bronlund, J. (2013). Surface EMG Signal Amplification and Filtering. *International Journal of Computer Applications,* 82**,** 15-22.

Watanabe, K. (2019). Effect of taping and its conditions on electromyographic responses of knee extensor muscles. *Hum Mov Sci,* 63**,** 148-155.

Watson, C. J., Propps, M., Ratner, J., Zeigler, D. L., Horton, P. & Smith, S. S. (2005). Reliability and responsiveness of the lower extremity functional scale and the anterior

knee pain scale in patients with anterior knee pain. *J Orthop Sports Phys Ther,* 35**,** 136-46.

Willebrand, M., Andersson, G., Kildal, M., Gerdin, B. & Ekselius, L. (2006). Injury-related fear-avoidance, neuroticism and burn-specific health. *Burns,* 32**,** 408-15.

Williams, S., Whatman, C., Hume, P. A. & Sheerin, K. (2012). Kinesio taping in treatment and prevention of sports injuries: a meta-analysis of the evidence for its effectiveness. *Sports Med,* 42**,** 153-64.

Willson, J. D., Kernozek, T. W., Arndt, R. L., Reznichek, D. A. & Scott Straker, J. (2011). Gluteal muscle activation during running in females with and without patellofemoral pain syndrome. *Clin Biomech (Bristol, Avon),* 26**,** 735-40.

Willson, J. D., Petrowitz, I., Butler, R. J. & Kernozek, T. W. (2012). Male and female gluteal muscle activity and lower extremity kinematics during running. *Clin Biomech (Bristol, Avon),* 27**,** 1052-7.

Willy, R. W. & Davis, I. S. (2011). The effect of a hip-strengthening program on mechanics during running and during a single-leg squat. *J Orthop Sports Phys Ther,* 41**,** 625-32.

Winslow, J. (2014). Treatment of lateral knee pain using soft tissue mobilization in four female triathletes. *Int J Ther Massage Bodywork,* 7**,** 25-31.

Woodward, K. A., Unnithan, V. & Hopkins, N. D. (2015). Forearm Skin Blood Flow After Kinesiology Taping in Healthy Soccer Players: An Exploratory Investigation. *J Athl Train,* 50**,** 1069-75.

Worp, V. & Maarten, P. (2012). Iliotibial band syndrome in runners : A Systematic Review. *Sports Med,* 42.

Yam, M. L., Yang, Z., Zee, B. C. & Chong, K. C. (2019). Effects of Kinesio tape on lower limb muscle strength, hop test, and vertical jump performances: a meta-analysis. *BMC Musculoskelet Disord,* 20**,** 212.

Yang, Y., Zhang, X., Luo, Z., Wang, X., Ye, D. & Fu, W. (2020). Alterations in Running Biomechanics after 12 Week Gait Retraining with Minimalist Shoes. *Int J Environ Res Public Health,* 17.

Yeung, S. S. & Yeung, E. W. (2016). Acute Effects of Kinesio Taping on Knee Extensor Peak Torque and Stretch Reflex in Healthy Adults. *Medicine (Baltimore),* 95**,** e2615.

Yoshida, A. & Kahanov, L. (2007). The effect of kinesio taping on lower trunk range of motions. *Res Sports Med,* 15**,** 103-12.

Zhang, X. F., Liu, L., Wang, B. B., Liu, X. & Li, P. (2019). Evidence for kinesio taping in management of myofascial pain syndrome: a systematic review and meta-analysis. *Clin Rehabil,* 33**,** 865-874.