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

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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.

Keywords: Kinesio tape, running biomechanics, Electromyography, Running, Iliotibial band syndrome.

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 and Iliotibial band syndrome (ITBS) is frequently reported in long-distance runners [8] with an incidence as high as 22.2% of all lower extremity injuries [9, 10]. There are many factors influencing the development of ITBS including worn out running shoes, training program errors, tightness of the Iliotibial band (ITB) and Tensor Fascia Lata (TFL), and weakness of the gluteus medius (Gmed) [9, 11] and hip external rotators [12]. Furthermore, past research comparing individuals with ITBS compared to a sex-matched group highlighted that males with ITBS demonstrate greater internal hip rotation and knee adduction [12], whereas females demonstrate increased hip adduction, knee internal rotation and femoral external rotation [13].

Guner et al [14] demonstrated that an inhibition KT technique showed significantly lower maximum knee flexion, and greater maximum knee extension when using inhibition and facilitation KT techniques compared to a no tape condition in stance phase of walking. However, past research on asymptomatic participants has shown that KT did not change hip or knee kinematics or kinetics [15] or the magnitudes of peak knee extensor or flexor moments [16]. Despite the proposal by Kase [2] that KT may assist individuals with ITBS, to the authors' knowledge, there is no scientific evidence to support the usefulness of KT as a treatment for runners with ITBS. Therefore, more work is required exploring if running biomechanics can be modified using KT, specifically those parameters that have been associated with ITBS including; hip adduction and internal rotation, and decrease knee internal rotation.

Before examining the effect of KT on individuals with ITBS, it is important to understand the effect of KT on lower limb kinematics in healthy runners. Therefore, 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 participants. It was hypothesized that the KT would increase peak hip external rotation, decrease peak hip adduction and internal rotation, and decrease peak knee internal rotation, and show perceived improvements.

Methods

Healthy participants were recruited from a University staff and student population and local running clubs. The inclusion criteria were; aged between 18 to 45 years old, regularly run a minimum of 10 kilometres a week, no physical limitations which may interfere with the testing protocol such as fatigue, illness, or dizziness. Exclusion criteria were; history of lower limb musculoskeletal injuries in the past six months, previous lower limb surgery, or a skin allergy to KT. This study was approved by the University of Central Lancashire ethics committee (STEMH 966), and all participants provided written informed consent prior to testing.

All participants ran along a 20-meter runway and were instructed to run at a similar self-selected speed under three taping conditions: no tape (NT), Kinesio Tape with tension (KTT) and Kinesio Tape with no tension (KTNT), following a three minute habituation period. All participants performed the NT condition first, the other conditions were randomised in blocks of 10 trials. After both taping conditions, participants were asked to assess their perceived comfort, knee joint stability and running performance using a seven-point Likert scale. Specific questions “Do you think kinesio tape is comfortable?”, “Do you think kinesio tape helps the stability of your knee?” and “Do you think kinesio tape offers benefits to your running performance?”. A threshold of 2 was used to determine if a minimum clinically important change had been reached [17].

The KT (Kinesio Tex^{TM} Tape) was applied by a certified KT practitioner to the participants' dominant limb whilst the participants lay on their non-dominant side. The KTT consisted of three layers of KT; a 'Y' shape with approximately 15-25% stretch applied on the ITB covering the TFL referred to as an inhibition technique, an 'I' shape line with approximately 25-35% stretch referred to as a space correction technique, and two 'I' shape lines with approximately 50-75% stretch referred to as a functional correction technique (Figure 1). The KTNT condition consisted of the same tape application but with no stretch or tension applied.

Retroreflective markers were positioned on the right and left anterior superior iliac spine, posterior superior iliac spine, the greater trochanter, the medial and lateral femoral epicondyles, and the medial and lateral malleoli. Four retroreflective markers were attached directly on the shoe over the calcaneus, first and fifth metatarsal heads, and midfoot, which were modelled as a single segment. Tracking clusters comprising of four non-orthogonal retroreflective markers were placed on the lateral thigh and shank segments. Kinematic data were collected at 100 Hz using ten Oqus cameras (Qualisys medical AB, Sweden), and kinetic data were collected at 500 Hz using four AMTI BP400600 force platforms (AMTI, USA). In addition, surface electromyography (EMG) data were recorded using five Trigno wireless sensors sampling at 1925 Hz (Delsys Inc, USA) which were positioned over the Gluteus Maximus (Gmax), Gmed, TFL, Vastus Medialis (VM), and Vastus Lateralis (VL) muscles following the SENIAM guidelines [18].

Marker, force and EMG data were then exported to C3D and imported into Visual 3D (C-Motion, USA) for further analysis. Kinematic and kinetic data were filtered using cut-off frequencies of 8 Hz and 50 Hz, respectively, using a low-pass Butterworth 4th order zero lag filter [13]. The last five trials with clear foot contacts within the boundaries of the force platform under each condition were analysed during the stance phase of running. Heel strike and toe-off were determined using vertical force thresholds of 20 N. The hip and knee joint kinematics were calculated using an XYZ cardan sequence of rotations, equivalent to the joint coordinate system [19], and lower limb kinematics were calculated using a six degrees of freedom model [20]. External joint moments were computed using inverse-dynamics relative to the proximal coordinate system, and data were normalized to 100% of stance phase. The EMG signals were high-pass filtered using a 20 Hz cut off frequency to reduce movement artefacts [21, 22], and then rectified and low-pass filtered with a 15 Hz cut off frequency. The maximum observed EMG signal from the filtered data across all trials and conditions for each muscle was then used to normalized the average and peak EMG signals [22].

Shapiro-Wilk tests were performed to determine the distribution of the data. For normally distributed data, 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 tests. For non-normally distributed data, 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. Likert scale data were analysed using descriptive statistics to describe any perceived changes due to the taping conditions. All statistical analyses were performed using SPSS version 26 (IBM, USA), with the alpha value set to 0.05.

Results

Twenty healthy participants (10 males and 10 females) were recruited, aged 30.6±7.8 years, height 173.0±11.3 cm, weight 70.8±13.4 kg, and BMI 23.6±3.1 kg/m^2. No significant differences were seen for running speed ($p=0.326$) which 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. The RM ANOVA showed no significant interactions between sex and taping conditions ($p>0.05$). Figure 2 shows the effects of taping conditions on the three dimensional hip and knee joint angles and moments.

Hip kinematics and moments between taping conditions

Descriptive statistics and main effects for hip kinematics and moments are shown in Table 1. The RM ANOVA showed significant differences between taping conditions for peak hip flexion angle ($p=0.016$). Post-hoc pairwise comparisons showed a significantly greater hip flexion angle in the KTT and KTNT conditions compared to the NT condition ($p=0.029$, $p=0.007$), respectively. Friedman tests revealed a significant difference in peak hip abduction and peak hip external rotation angle for males ($p=0.025$, $p=0.025$), respectively. Post-hoc Wilcoxon tests showed the KTT condition had a significantly greater peak hip abduction angle compared to the NT condition (p=0.022). No significant differences were seen between the KTNT and NT conditions, or between the KTNT and KTT conditions (p=0.139, p=0.878), respectively. In addition, the KTT condition showed significantly greater peak hip external rotation compared to the NT and KTNT conditions (p=0.047, p=0.037), respectively. However, no significant differences were seen between the KTNT and NT conditions (p=0.508).

Knee kinematics and moments between conditions

Descriptive statistics and main effects for knee kinematics and moments are shown in Table 2. The RM ANOVA showed significant differences between conditions for peak knee flexion angle (p=0.042) and peak knee flexion moments (p=0.012). Pairwise comparisons showed a significantly greater peak knee flexion angle in the KTNT condition compared to the NT condition (p<0.001), and significantly lower peak knee flexion moments in the KTNT condition compared to the NT condition (p=0.010), and lower moments in the KTNT condition compared to the KTT condition (p=0.027).

Muscle Activity between conditions

Descriptive statistics and main effects for average and peak muscle activity are shown in Table 3. The RM ANOVA showed significant differences between conditions for average Gmax EMG (p=0.003), TFL (p=0.042), and peak Gmax EMG (p=0.007). Post-hoc pairwise comparisons showed significantly lower average Gmax EMG in the KTNT condition compared to the NT condition (p=0.003), significantly lower average TFL EMG in the KTT condition compared to the NT condition (p=0.005), and significantly lower peak Gmax EMG in the KTNT condition when compared to the NT and KTT conditions (p=0.007, p=0.033), respectively (Table 3).

Perceived comfort, knee stability and running performance outcomes

Figure 3 shows the participants' scores for perceived comfort, knee stability and running performance for the KTT and KTNT conditions. For the comfort score, ten and thirteen participants indicated an important improvement (+2 or greater) in the KTT and KTNT conditions, respectively, with the remainder indicating no important change (between +1 and -1). For the knee stability score, six participants indicated an important improvement in the KTT and KTNT conditions, with the remainder indicating no important change. For the running performance score, seven participants indicated an important improvement in the KTT and

KTNT conditions, with the remainder in the KTNT indicating no important change. Two participants reported an important negative effect in the KTT condition (-2 or lower) for running performance.

Sex differences

Females demonstrated a significantly greater peak hip adduction angle (p=0.037) and coronal plane hip ROM (p=0.026), whilst males demonstrated a significantly greater peak hip extension moment (p=0.022), and a greater peak knee abduction moment (p=0.048).

Discussion

This study showed a significantly greater peak hip external rotation angle in the KTT compared to the NT and the KTNT conditions, with no significant difference 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 and could be explained by the decrease in TFL muscle activity in the KTT condition compared to the NT condition, as TFL is associated with hip internal rotation [23]. Additionally, the coronal plane hip kinematics showed a significant decrease in peak hip abduction angle in the KTT compared to the NT condition in male participants. This is supported by Masters et al [24] who showed a significant decrease in hip adduction and internal rotation angles throughout stance when a rigid tape was applied to the hip.

The findings of our study showed a significantly greater peak hip flexion angle in KTT and KTNT compared to the NT condition, which was associated with a significant decrease in the average and peak Gmax EMG in the KTNT compared to the NT and KTT conditions. As the Gmax muscle contributes to hip extension, a decrease in Gmax muscle activity may lead to an increase in hip flexion during the initial loading phase. These findings contrast previous studies that demonstrated no significant difference in peak hip angle between KT with or without tension and no tape conditions, however the taping techniques used in this study were not just associated with the knee as used in previous studies [15, 25], but continued more proximally as far as the hip joint.

The changes seen in the hip in the transverse plane under the KTT condition in this study are particularly interesting. The hip transverse plane 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 increase strain on the ITB [13] and significantly weaker external hip rotators [12]. Therefore, the increase in peak hip external rotation under the KTT condition could help to increase the hip external rotation and reduce the hip internal rotation during stance phase within individuals with ITBS. Additionally, the TFL activation should be considered as previous studies have shown that the TFL muscle activation in runners with ITBS was increased compared to control runners [21]. The effects due to the taping seen in this study may help to reduce the tension in the TFL in individuals with ITBS, which may in turn help to reduce pain when running, but this requires further exploration.

One explanation for the effect of KT with tension to facilitate hip external rotation is somatosensory stimulation. In addition, a larger surface area for the proprioceptive effect of the tape as the hip externally rotates and flexes during running may provide cutaneous stimulation leading to a change in movement strategy [26]. This is supported by Yeung and Yeung [27] who proposed that KT may stimulate skin mechanoreceptors, increase motor unit excitability and elicit a muscle spindle reflex. Additionally, they proposed that KT's 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 leading to an increase in hip external rotation. This effect has also been shown at the shoulder by Hsu et al [28] who reported that KT can improve scapular upward rotation and posterior tilt patterns in baseball players with shoulder impingement.

Past research examining sex differences in running biomechanics have reported that healthy female runners demonstrate greater peak hip adduction, hip internal rotation and knee abduction angles compared with male runners [29, 30]. The results of the present study support these previous findings and suggest that male and female movement patterns may be classifiable. In addition, our results showed significantly greater peak hip extension and peak knee abduction moments in males compared to females. These result are in contrast to Ferber et al who showed similar peak hip extension and peak knee abduction moments between males and females [29]. The sex differences observed in lower limb biomechanics in this study indicate that further research is warranted to explore if males and females with ITBS respond differently to KT.

There are a limited number of studies that have reported perceived comfort, knee stability and running performance when using KT. Hébert-Losier et al [22] demonstrated that most elite cyclists perceived the KTT to be comfortable, increase knee stability, and improve performance, despite no significant effects on any physiological and kinematic measures. 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 performance although these benefits were only seen in half the participants. These findings, in combination with the kinematics and kinetics, demonstrate some effect of KTT on running mechanics and perceptions, which may be useful in the management of individuals with running related injuries.

A limitation within this study is the length of the habituation period and length of time each taping intervention was worn for, which may have influenced the findings. A longer habituation period and normal treatment time should be considered in the future. The small sample size when examining sex differences could be viewed as a limitation and should be interpreted with care. Future larger studies on the effect of taping on the different sexes should be conducted. Our approach not to control running speed between conditions could be viewed as a limitation as speed induced changes could appear. We took this approach to allow the participants to run at their comfortable speed which could have varied between participants, however taping did not change running speed through restriction or enhancement. Despite the application of the tape being applied by a single certified practitioner the accuracy of the tape stretch could potentially influence findings. Future research should consider accurately measuring the stretch of the applied tape.

Conclusion

These results suggest that changes in the biomechanics of running that were previously associated with ITBS can be achieved with the application of kinesio tape, with the greatest effect seen with the application of kinesio taping with tension. However, this was only perceived as beneficial in less than half the healthy participants. Further work is required to determine if kinesio tape has the same biomechanical effect in symptomatic runners with ITBS, and whether it can offer any improvements in pain and function.

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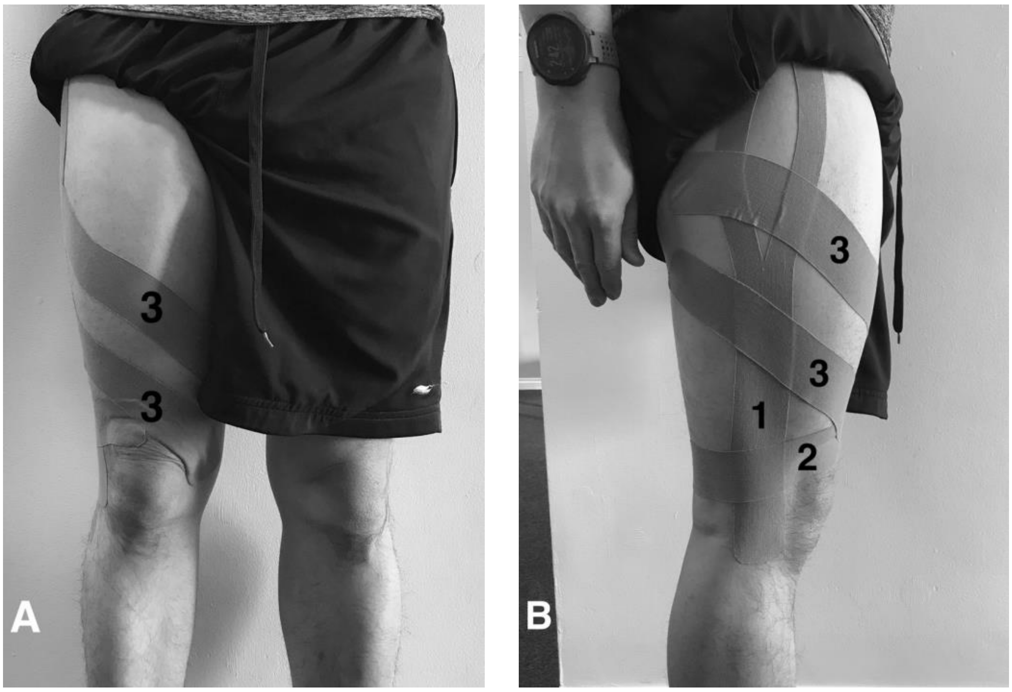

Figure 1. (A) anterior view of Kinesio Tape Application and (B) lateral view of Kinesio Tape Application. 1) Inhibition technique, 2) Space correction technique, 3) Functional correction technique.

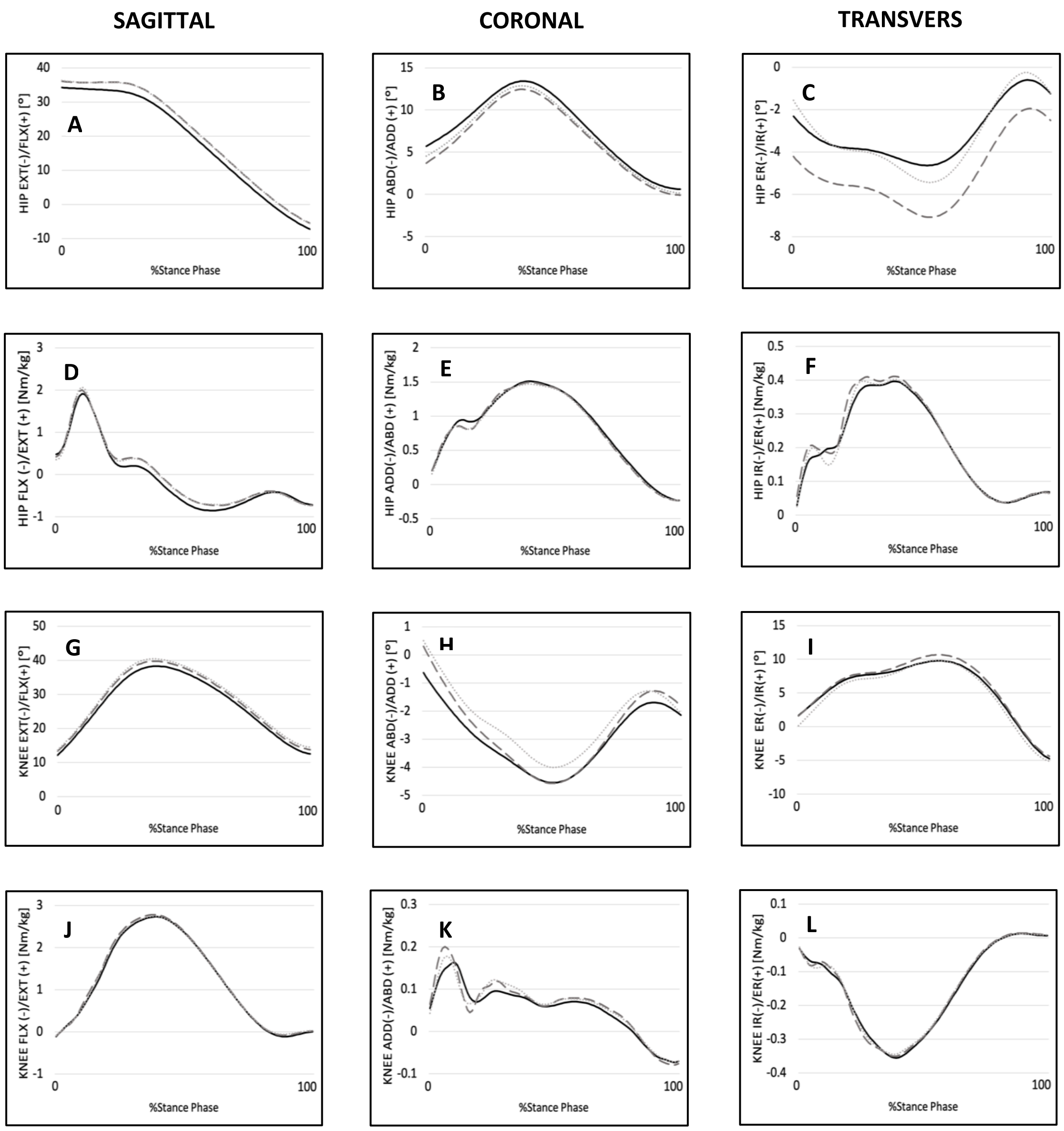

Figure 2. Time series graph of 3D hip joint angles (A-C), hip joint moments (D-F), knee joint angles (G-I), and knee joint moments (J-L) across three kinesio taping conditions with NT (solid black), KTT (dashed dark grey), and KTNT (dotted light grey).

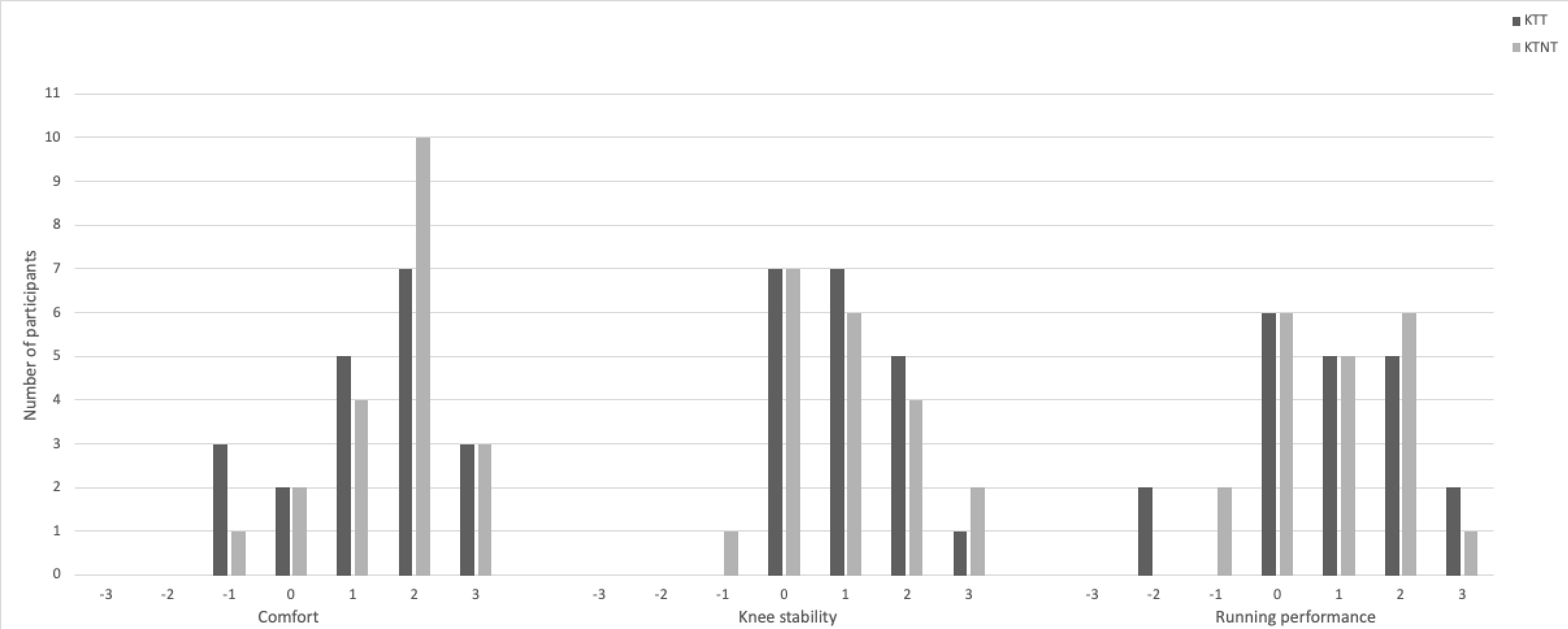

Figure 3. Number of participants in each comfort, knee stability and running performance score category in KTT (dark grey) and KTNT (light grey) taping conditions. A score of 3 represents strongly agree, 0 represents neutral and -3 represents strongly disagree.

Table 1. Mean (SDs) and repeated measures ANOVA results, median (Q1/Q3) and Friedman test of peak hip kinematics and moments in the sagittal, coronal and transverse plane.

	Males (n=10)			Females (n=10)				
Hip Kinematics (degrees)[a]	**NT**	**KTT**	**KTNT**	**NT**	**KTT**	**KTNT**	**Tape effect p value**	**Sex effect p value**
Peak flexion †,‡	36.0 (9.2)	38.8 (8.7)	38.6 (9.6)	33.6 (5.3)	35.2 (7.2)	35.3 (6.1)	0.016*	0.364
Peak extension	-6.1 (6.3)	-3.2 (6.7)	-3.2 (6.1)	-8.5 (5.6)	-7.9 (7.6)	-8.1 (7.1)	0.060	0.172
Sagittal plane ROM	42.0 (8.1)	42.1 (7.9)	41.9 (9.1)	42.1 (3.6)	43.1 (4.7)	43.4 (4.1)	0.537	0.765
Peak adduction	11.9 (3.4)	10.9 (4.2)	10.8 (3.9)	15.3 (4.3)	14.4 (3.0)	15.3 (4.9)	0.156	0.037*
Coronal plane ROM	12.0 (2.1)	12.0 (2.6)	12.1 (2.5)	14.8 (2.6)	14.8 (2.9)	14.9 (3.1)	0.931	0.026*
Peak internal rotation	1.0 (5.0)	-1.5 (5.8)	0.9 (5.4)	2.1 (3.8)	1.2 (4.2)	2.6 (5.2)	0.098	0.362
							Tape effect p value for Male	**Tape effect p value for Female**
Peak abduction †	1.2 (-1.8/2.0)	-0.4 (-1.9/1.0)	-1.4 (-2.4/1.2)	1.2 (-2.3/2.4)	-0.9 (-2.3/1.6)	0.5 (-2.3/ 2.5)	0.025*	0.273
Peak external rotation †,¥	-7.4 (-9.5/-4.3)	-8.7 (-17.6/-5.8)	-6.9 (-12.4/-2.3)	-5.0 (-9.6/-2.4)	-5.4 (-14.0/-3.6)	-7.7 (-12.3/-1.8)	0.025*	0.273
Transverse plane ROM	8.4 (6.3/10.2)	9.1 (7.0/10.7)	7.2 (6.5/10.1)	7.7 (6.0/12.2)	8.0 (7.3/10.9)	8.4 (6.2/11.9)	0.670	0.497
Hip Moments (Nm/kg)[b]							**Tape effect p value**	**Sex effect p value**
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	0.022*
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	0.760
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	0.983
							Tape effect p value for Male	**Tape effect p value for Female**
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	0.905
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	0.741
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	0.905

* The mean difference is significant 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 value indicate hip flexion/adduction/internal rotation and negative values indicated hip extension/abduction/external rotation.
[b] Positive value indicate hip extension/abduction/external rotation and negative values indicated hip flexion/adduction/internal rotation.

Table 2. Mean (SDs) and repeated measures ANOVA statistics results, median (Q1/Q3) and Friedman test of peak knee kinematics and moments in the sagittal, coronal and transverse plane.

	Males (n=10)			Females (n=10)				
Knee Kinematics (degrees)[a]	**NT**	**KTT**	**KTNT**	**NT**	**KTT**	**KTNT**	**Tape effect p value**	**Sex effect p value**
Peak flexion ǂ	36.6 (7.0)	38.4 (6.5)	38.4 (7.3)	40.6 (3.4)	41.6 (3.5)	43.0 (3.6)	0.042*	0.103
Sagittal plane ROM	28.9 (6.5)	28.5 (5.0)	28.6 (6.0)	30.6 (3.5)	30.9 (3.0)	31.8 (3.7)	0.388	0.260
Coronal plane ROM	5.0 (1.2)	5.6 (1.6)	5.9 (1.5)	6.6 (2.1)	6.7 (2.4)	7.0 (2.3)	0.165	0.107
Peak internal rotation	9.4 (4.9)	11.7 (6.3)	10.3 (5.3)	11.9 (5.2)	11.1 (5.5)	10.8 (4.8)	0.369	0.743
Peak external rotation	-4.7 (4.1)	-3.8 (6.5)	-4.9 (5.7)	-5.7 (5.5)	-6.2 (5.7)	-6.7 (5.7)	0.514	0.461
							Tape effect p value for Male	**Tape effect p value for Female**
Minimum flexion	9.0 (3.8/11.2)	10.9 (5.4/13.8)	8.3 (6.9/13.8)	10.0 (8.1/11.0)	10.7 (6.8/13.6)	12.0 (8.5/13.1)	0.273	0.497
Peak adduction	1.3 (-1.4/2.8)	2.0 (0.5/2.8)	1.9 (-0.1/4.2)	-0.1 (-2.5/2.8)	0.9 (-1.6/3.7)	1.3 (-2.8/4.1)	0.202	0.122
Peak abduction	-4.8 (-5.7/-2.2)	-3.5 (-5.3/-1.9)	-4.4 (-5.8/-1.8)	-6.5 (-8.1/-4.8)	-4.7 (-7.5/-3.2)	-6.4 (-7.8/-4.0)	1.000	0.273
Transverse plane ROM	14.2 (11.2/17.6)	15.5 (13.2/18.1)	15.2 (12.9/17.3)	16.7 (14.0/20.0)	16.7 (13.4/19.3)	17.9 (12.5/21.1)	0.407	0.905
Knee Moments (Nm/kg)[b]	**NT**	**KTT**	**KTNT**	**NT**	**KTT**	**KTNT**	**Tape effect p value**	**Sex effect p value**
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	0.612
Peak flexion ǂ,¥	-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*	0.267
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	0.048*
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	0.965
							Tape effect p value for Male	**Tape effect p value for Female**
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	0.905
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	0.122

* The mean difference is significant at the 0.05 level.

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

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

Table 3. Mean (SDs) and repeated measures ANOVA statistics results, median (Q1/Q3) and Friedman test of normalised values from EMG signal analysis in each group during stance phase.

	Males (n=10)			Females (n=10)				
	NT	**KTT**	**KTNT**	**NT**	**KTT**	**KTNT**	**Tape effect p value**	**Sex effect p value**
Average Activity								
Gmax ‡	0.12 (0.03)	0.10 (0.03)	0.10 (0.03)	0.12 (0.03)	0.12 (0.05)	0.09 (0.04)	0.003*	0.799
TFL †	0.11 (0.04)	0.10 (0.03)	0.11 (0.03)	0.12 (0.05)	0.10 (0.04)	0.11 (0.05)	0.042*	0.703 (0.937)
VL	0.08 (0.02)	0.09 (0.03)	0.08 (0.03)	0.08 (0.04)	0.09 (0.04)	0.08 (0.04)	0.168 (0.173)	0.009* (0.751)
							Tape effect p value for Male	**Tape effect p value for Female**
Gmed	0.11 (0.09/0.14)	0.10 (0.08/0.11)	0.11 (0.07/0.13)	0.13 (0.08/0.15)	0.12 (0.09/0.13)	0.11 (0.09/0.13)	0.905	0.407(0.741)
VM	0.10 (0.09/ 0.13)	0.10 (0.08/0.13)	0.09(0.08/0.13)	0.11 (0.08/0.14)	0.09 (0.08/0.11)	0.10 (0.08/0.11)	0.045* (0.273)	0.273(0.150)
Peak Activity								
Gmax ‡,¥	0.62 (0.10)	0.53 (0.13)	0.52 (0.14)	0.61 (0.09)	0.56 (0.17)	0.45 (0.13)	0.007*	0.686
Gmed	0.63 (0.08)	0.59 (0.16)	0.61 (0.15)	0.64 (0.12)	0.58 (0.18)	0.64 (0.13)	0.321	0.820
TFL	0.56 (0.20)	0.53 (0.16)	0.55 (0.15)	0.59 (0.11)	0.51 (0.22)	0.54 (0.18)	0.446	0.996
VM	0.65 (0.11)	0.62 (0.10)	0.63 (0.09)	0.65 (0.12)	0.60 (0.17)	0.63 (0.18)	0.494	0.810
VL	0.53 (0.10)	0.62 (0.18)	0.61 (0.16)	0.48 (0.25)	0.58 (0.16)	0.55 (0.17)	0.120	0.348

* The mean difference is significant at the 0.05 level.

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