

Central Lancashire Online Knowledge (CLoK)

Title	The effect of a home-based stretching exercise on the ground reaction force generation and absorption during walking in individuals with plantar fasciitis
Туре	Article
URL	https://clok.uclan.ac.uk/id/eprint/44183/
DOI	https://doi.org/10.1016/j.ptsp.2022.09.006
Date	2022
Citation	Boonchum, Hataitip, Sinsurin, Komsak, Kunanusornchai, Wanlop, Richards, James and Bovonsunthonchai, Sunee (2022) The effect of a home-based stretching exercise on the ground reaction force generation and absorption during walking in individuals with plantar fasciitis. Physical Therapy in Sport, 58. pp. 58-67. ISSN 1466853X
Creators	Boonchum, Hataitip, Sinsurin, Komsak, Kunanusornchai, Wanlop, Richards, James and Bovonsunthonchai, Sunee

It is advisable to refer to the publisher's version if you intend to cite from the work. https://doi.org/10.1016/j.ptsp.2022.09.006

For information about Research at UCLan please go to http://www.uclan.ac.uk/research/

All outputs in CLoK are protected by Intellectual Property Rights law, including Copyright law. Copyright, IPR and Moral Rights for the works on this site are retained by the individual authors and/or other copyright owners. Terms and conditions for use of this material are defined in the <u>http://clok.uclan.ac.uk/policies/</u>

1	Title
2	
3	The effect of a home-based stretching exercise on the ground reaction
4	force generation and absorption during walking in individuals with
5	plantar fasciitis
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	

Title

1 Abstract

- 2 **Objectives:** This study aimed to investigate the effect of a home-based stretching exercise
- 3 program in individuals with plantar fasciitis (PF), and to compare its effect on ground
- 4 reaction force (GRF)-time variables between the mild, moderate, and severe pain subgroups
- 5 as well as between before and after in each subgroup.
- 6 **Design:** A single cohort with pre-and post-test design.
- 7 Interventions: Twenty individuals with PF received 3 weeks of home-based stretching
- 8 exercise program for calf muscles and plantar fascia. The data were compared between
- 9 before and after exercise in a whole number of participants and were compared among
- 10 the mild (n = 7), moderate (n = 7), and severe (n = 6) pain subgroups.
- 11 Main Outcome Measures: Force data were collected during walking using two force
- 12 plates. GRF-time variables included the force and time at; first peak (F1 and TF1), valley
- 13 (F2 and TF2), second peak (F3 and TF3) for the vertical forces, peak breaking (F4 and
- 14 TF4) and propulsive (F5 and TF5) forces, first peak (F6 and TF6) and second peak lateral
- 15 (F7 and TF7) forces. Additionally, worst pain was assessed using the visual analog scale.
- 16 **Results:** Significant reductions were seen in F2, TF2, TF3, TF5 and worst pain after
- 17 exercise in individuals with PF (P < 0.05). No differences were seen between the three
- 18 subgroups. For the within subgroup analysis, only the mild subgroup showed significant
- 19 changes in F2, TF2, F4, TF6, and TF7 after exercise (P < 0.05).
- 20 Conclusion: A home-based stretching exercise program was effective in reducing pain and
- some GRF-time variables, with the most noticeable response seen in the mild subgroup.
- 22 Keywords: Ground reaction force, Stretching exercise, Plantar fasciitis, Gait
- 23

1 1. Introduction

2 Plantar fasciitis (PF) is one of the most common foot and lower extremity pathologies (Lopes, Hespanhol Junior, Yeung, & Costa, 2012). The occurrence of PF was 3 reported to be slightly higher in females and those with intermediate or routine manual 4 5 occupations (Thomas et al., 2019). PF pathogenesis is characterized by a chronic 6 degenerative process within the plantar fascia, causing a repetitive overload, poor lower 7 extremity biomechanics, and soft tissue microtrauma (Cutts, Obi, Pasapula, & Chan, 2012; Waclawski, Beach, Milne, Yacyshyn, & Dryden, 2015). Clinical symptoms of PF present 8 with heel pain while standing or walking for a long time. Pain usually presents at the first 9 10 few steps in the morning after waking up and will be disappeared after rest (Karagounis, 11 Tsironi, Prionas, Tsiganos, & Baltopoulos, 2011). Decreased gait ability is the most 12 important functional limitation in daily life for individuals with PF. If individuals are not treated appropriately, condition can become more severe and develop into a chronic stage 13 14 (Beeson, 2014). From the current knowledge, the exact etiology of PF is still unclear. However, 15 several intrinsic and extrinsic risk factors have been proposed to be contributing causes 16 including obesity, prolonged weight-bearing activities, or sports training with high impact 17 forces such as running and jumping. In addition, abnormal biomechanics such as excessive 18 foot pronation, decreased ankle dorsiflexion, and incorrect foot placement are also 19 20 suspected to be related causes of PF (Beeson, 2014; Wearing, Smeathers, Urry, Hennig, & Hills, 2006). Increasing the Ground Reaction Force (GRF), which directly transmits and 21 potentially damages the plantar fascia during walking, has been highlighted as an important 22 biomechanical factor of PF progression. Persistent heel pain results in alterations of 23

1	temporospatial gait and foot kinematic variables (Bovonsunthonchai et al., 2019; Thong-On
2	et al., 2019), which in turn could affect the GRF-time variables during the stance phase of
3	gait through pain avoiding strategies (Phillips & McClinton, 2017). A previous study
4	(Johnson, Tenforde, Outerleys, Reilly, & Davis, 2020), compared the impact-related GRF
5	variables between two groups of runners with and without PF. Impact-related GRF
6	variables included vertical average and instantaneous load rates, posterior and
7	medial/lateral instantaneous load rates, vertical stiffness, and ratio of peak vertical ground
8	reaction force (vGRF) to vertical center of mass (vCOM) displacement at initial loading.
9	The results showed higher vertical average loading rates and vertical instantaneous loading
10	rates in runners with PF. The authors also reported that runners who had a vertical stiffness
11	during loading response of \geq 73.1 kN/m were 15 times more likely to have PF than those
12	with a lower vertical stiffness. This suggests that therapists may need to focus on reducing
13	the GRF during the management of injured runners, especially in those with PF. Therefore,
14	GRF variables could be used to represent the abnormal mechanics of plantar fascia loading
15	associated with the risk of injury on the soft tissue, fascia, and other related foot structures.
16	Alteration of the GRF-time variables in individuals with PF is still ambiguous due
17	to the difference in methodology and variability of participants' characteristics between
18	studies. Comparing the data to those of healthy controls, Chang et al. (Chang, Rodrigues,
19	Van Emmerik, & Hamill, 2014) found the reduced 2 nd peak of vertical GRF (v-GRF) and
20	delayed time to midstance in individuals with PF. Consistent with this finding, Katoh et al.
21	(Katoh, Chao, Morrey, & Laughman, 1983) and Wearing et al. (Wearing, Smeathers, &
22	Urry, 2003) also reported the increased 1st peak v-GRF in the same population. However,
23	when controlling the speed of walking, a study conducted by Bovonsunthonchai et al.

1	(Bovonsunthonchai et al., 2019) reported no difference in the v-GRF and mediolateral GRF
2	(ML-GRF) between individuals with PF and healthy controls, but larger variability was
3	found as observed by the greater standard deviation in individuals with PF when compared
4	to healthy controls.

5 Tightness of the ankle plantarflexors has been suggested to be the most important 6 impairment associated with biomechanical changes in PF (Riddle, Pulisic, Pidcoe, & Johnson, 2003). The tension of ankle plantarflexors decreases the ankle dorsiflexion angle 7 at heel strike and results in the increased force transmission on the plantar fascia during the 8 stance phase of gait. Force overload on plantar fascia may cause tissue damage, and may 9 also be associated with the inability of GRF absorption function over foot flat to midstance 10 period, which results in altered GRF patterns, creates a risk of injury, and inhibits the tissue 11 healing process (Liddle, Rome, & Howe, 2000). 12 Non-operative interventions are suggested as an effective treatment in PF. 13 14 Stretching exercise is the most popular recommendation supported by moderate to high levels of evidence (DiGiovanni et al., 2003; Digiovanni et al., 2006; Porter, Barrill, 15 Oneacre, & May, 2002). Stretching exercise is a low-cost treatment that everyone can 16 easily perform by themselves. Individuals with PF could gain many benefits from exercise, 17 as shown with improvements in clinical symptoms and activities of daily living 18 (Boonchum, Bovonsunthonchai, Sinsurin, & Kunanusornchai, 2020; DiGiovanni et al., 19 20 2003; Digiovanni et al., 2006; Thong-On et al., 2019). Importantly, exercise may help with some of the limitations including treatment time, cost of treatment, health-profession 21

22 consultation demand, and treatment accessibility.

1	Home-based stretching exercise programs have been suggested as a sustainable
2	management option for this condition (Boonchum et al., 2020), with reported
3	improvements in pain and muscle strength, however no changes in multi-segment foot
4	motion after performing a home-based stretching exercise program were seen. Boonchum
5	et al. demonstrated both the direct and indirect benefits of stretching, i.e, reduced pain.
6	increased muscle strength, increased muscle length, leading to increases in the isometric
7	contraction force through changes in the length-tension relationship. A pilot study was
8	carried out in 39 individuals with PF who were classified into three groups. The first group
9	received manual treatment, exercises, and insoles, the second group received exercises and
10	insoles, and the last group received insoles only. The findings showed moderate
11	improvement in pain and function when compared to baseline in all the three groups but no
12	inter-group difference was found {Yildiz, 2022 #65}. The efficacy of home-based exercise
13	was further supported by a prospective randomized controlled study of Kaiser et al.
14	{Kaiser, 2022 #64}. They compared physical therapy with home-based stretching exercises
15	and found that both groups had significant improvements in visual analog scale (VAS) pain
16	scores, Foot and Ankle Ability Measure (FAAM), and Short Form Health Survey (SF-36)
17	scores at 6 months relative to baseline, but no notable differences in all outcomes were seen
18	between groups {Kaiser, 2022 #64}.
19	The verifiable response to treatment in this group of patients may be influenced in
20	part by patient characteristics such as severity, pain, duration of disease, etc. Therefore,
21	choosing the appropriate form of treatment should take into account these factors. A
22	previous study has shown a statistically significat correlation between gastrocnemius

muscle tightness and heel pain severity in patients with PF {Pearce, 2021 #62}. Factors

1	contributing to the failure of conservative treatment, such as stretching and custom foot
2	orthosis, were also reported. The study found that the first-step pain, ankle dosiflexion
3	limitation, and heel valgus in a relaxed position could predict the treatment failure for
4	patients with PF {Wrobel, 2016 #63}. However, to date, no study has shown the efficacy
5	and effectivenes of such exercises in PF patients with varying degrees of severity.
6	Therefore, this study aimed to investigate the effect of a home-based stretching
7	exercise program on GRF-time variables and pain, and to determine if the exercise effect
8	varied according to the different pain severity levels in individuals with PF. We
9	hypothesized that the home-based stretching exercise program would produce significantly
10	different GRF-time variables and significant reductions in pain, and that similar effects
11	would be seen in a group with less pain severity.
12	
13	2. Methods

14 2.1 Study design and ethical consideration

This was a single cohort with a pre-and post-test design. Data were collected in a
3D motion analysis laboratory, at the Faculty of Physical Therapy, XXX University,
COUNTRY. The study was approved by XXX University Central Institutional Research
Board (COA no: MU-CIRB 2019/018.2801). The study was conducted in accordance with
the Declaration of Helsinki. Participants were informed about the research objectives,
benefits and details and signed an informed consent form before participating in the study.

22 2.2 Participants

7

1	The inclusion criteria were; age between $40 - 65$ years, ≥ 1 -month duration of clinical
2	symptoms, resting pain \leq 4 points, decreased active ankle dorsiflexion of < 30 degrees
3	assessed using a hand-held goniometer with the knee flexed in sitting position, tightness of
4	achilles tendon assessed by passive movement, and negative tarsal tunnel test. Exclusion
5	criteria were; a history of neuromuscular disorders, lower extremity surgery, systemic
6	disease, rheumatoid arthritis, ankylosing spondylitis, Reiter's syndrome, generalized
7	osteoarthrosis, tingling or numbness in the foot, inflammation sign at the ankle, flatfoot
8	deformity assessed by footprint method, peripheral vascular disease, and receiving other
9	physical therapy or treatment during the study.
10	A flow chart diagram of the recruitment is presented in Fig. 1. Fifty-four individuals
11	with PF were recruited from social media and posters advertised within the Physical
12	Therapy Center, Faculty of Physical Therapy, Mahidol University. After screening
13	following the criteria, twenty-six individuals with PF were included in the study. During
14	participation, three individuals withdrew from the program due to sudden pain at the knee
15	(n = 1) and lumbar $(n = 1)$, and admission to the hospital with an unrelated medical
16	problem $(n = 1)$, with the remaining twenty participants completing the study. Age, weight,
17	height, body mass index (BMI), and gender were recorded for demographic data.
18	Additional measures included; disease onset, worst pain score, symptomatic side, physical
19	activity level, gait speed, and cadence. The worst pain was determined using scores
20	between $0 - 100$ with a higher value representing greater severity. Physical Activity level
21	was assessed using the Thai version of the International Physical Activity
22	Questionnaire (IPAQ).

1	The GRF-time variables and worst pain score were evaluated at two-time points,	
2	before and after the exercise program. In addition, data were classified according to three	
3	subgroups of worst pain score {Turner, 2004 #69}; mild (between 0 to 40, $n = 7$), moderate	
4	(between 41 to 70, $n = 7$), and severe pain (between 71 to 100, $n = 6$), and outcome	
5	measures were compared between and within these subgroups.	
6		
7	2.3 Data collection protocol	
8		
9	2.3.1 The ground reaction force (GRF)-time	
10	GRF-time data during walking were collected before and after 3 weeks of exercise	
11	from two force plates (AMTI-OR67, Advance Mechanical Technologies Inc., USA) which	
12	were positiond in the middle of the walkway and synchronized with two video cameras	
13	(Vicon TM Bonita, UK) placed infront and at the side of the participants. Before data	
14	collection the force plates were zeroed to reduce noise.	
15	Participants walked with bare feet along the 8 m walkway at a self-selected speed.	
16	Participants were allowed 2 to 3 practice trials to familiarise themselves with the walkway,	
17	and then walking trials were collected. Force data were collected at a sampling rate of	
18	1,000 Hz and were filtered using a fourth-order Butterworth low pass filter with a cut-off	
19	frequency of 15. The motion picture obtained by the video cameras was used for inspection	
20	along with the force information generated during walking. All data were processed using	
21	the Nexus software (version 2.8.1). The averaged successful data of 3 walking trials with	
22	the most painful foot of each participant was selected for analysis.	

1	The GRF data were normalized to body weight and the force and time parameters
2	over the stance phase of gait included; 1) vertical (v)-GRF comprised of F1, F2, F3 (N/kg)
3	and TF1, TF2, TF3 (% stance phase), 2) Antero-posterior (AP)-GRF comprised of F4 and
4	F5 (N/kg) and TF4 and TF5 (% stance phase), and 3) Medio-lateral (ML)-GRF comprised
5	of F6 and F7 (N/kg) and TF6 and TF7 (% stance phase) (Fig. 2).

6

7 2.3.2 Worst pain score

8 The worst pain score was verbally rated using the numeric rating scale (NRS) by the 9 participants. The scale ranging from 0 (no pain) to 100 (unimaginary pain) scores over the 10 past week. The more painful side data was used in the analysis for the individuals who had 11 bilateral PF symptoms.

12

13 2.4 Intervention program

14 The home-based exercise program in this study comprised of stepwise progressive stretching exercises for calf and plantar fascia. To ensure individuals with PF were able to 15 follow the program properly, a physiotherapist demonstrated the exercise program until 16 they were able to reproduce the exercises accurately, and participants also received a 17 handbook and video clips of the exercise program. The program consisted of static 18 stretching exercises of the gastrocnemius, soleus, and plantar fascia for 20-30 s, resting 19 20 between exercises for 10 s. for 10 sets. The total time for each session was 20 min per day, 5 days per week for 3 weeks. Participants were re-checked and were assigned progressive 21 exercises after the 5th and 10th day of the intervention program. Stretching exercise was 22 progressed depending on individual perception of the gastrocnemius and soleus tension to 23

prevent injury and maximize efficiency. The tension during stretching was re-assessed
 every week to ensure a sequential rehabilitation program was provided. Further details of
 the exercise program have been previously published (Boonchum et al., 2020).

4

5 2.5 Statistical analyses

6 Non-parametric statistics were used in this study due to the small number of 7 participants recruited. Wilcoxon signed rank tests were used to compare the GRF-time and pain measures between before and after exercise for all participants (n = 20). Further 8 analysis using Kruskal Wallis tests compared the differences of GRF-time variables 9 10 between mild (n = 7), moderate (n = 7), and severe (n = 6) subgroups before and after exercise, and Wilcoxon signed rank tests were used to compare the data between before and 11 after exercise within each subgroup. The alpha level was set at 0.05 for all comparisons. 12 For the data that showed significant differences, effect sizes were calculated based 13 on the formula $(r = |z|/\sqrt{N})$ {Fritz, 2012 #70}. The Cohen's guideline for r indicates that 14 a large effect is 0.5 or greater, a medium effect is between 0.3 and 0.49, and a small effect 15 16 is less than 0.1 {Cohen, 1988 #71}. All data were analyzed using SPSS version 23.0 (SPSS 17 Inc, Chicago, IL, USA).

18

19 2.6 Sample size calculation

Sample size was estimated based on the first objective which was to determine the
effect of a home-based exercise program in individuals with PF. The G*Power program
version 3.1.9.4 was used to determine the sample size based on our own pilot data (n = 5)

on the F2 variable. A priori method using the Wilcoxon signed rank test (match paired) 1 function was selected with alpha set to 0.05 and power of 0.80. The effect size obtained 2 was calculated using the formula {Fritz, 2012 #70}: $r = |z| / \sqrt{N} = 0.78$, and the resulting 3 estimated total sample size required was found to be 16. 4 5 3. Results 6 7 3.1 Characteristics of the participants 8 9 Table 1 shows the characteristics of all participants and in each severity subgroup. 10 Twenty individuals with PF completed the research protocol, who were classified into a mild (n = 7), moderate (n = 7), and severe (n = 6) pain subgroup. The total participants' 11 median and interqualtile range (IQR) of age, weight, height, and BMI were 58(53-61)12 years, 61.8 (53.2 – 72.3) kg, 159.0 (153.2 – 169.9) cm, and 24.6 (21.8 – 27.5) kg/m², 13 14 respectively. Seventy percent of the participants were female (n = 14) and 60% (n = 12) had chronic onset of PF for more than 12 months, with a median and IQR of worst pain at 15 baseline of 50.0 (40.0 - 77.7). The majority of participants (n = 11) fell into the high level 16 of physical activity category using the Thai IPAQ. No significant differences were seen 17 between the three pain subgroups in all variables at baseline, except for the worst pain 18 19 score. Further Bonferroni correction for multiple test revealed significant differences (P 20 <0.001) in the worst pain score between mild vs severe subgroups only.

21

1	3.2 Comparisons of GRF-time variables and worst pain between before and after 3 weeks
2	of exercise in individuals with PF and sub-group analysis
3	Table 2 shows the comparisons of GRF-time variables and worst pain between
4	before and after 3 weeks of exercise in all participants. The results revealed significant
5	differences in F2 ($P = 0.019$, effect size (r) = 0.53) and TF2 ($P = 0.026$, $r = 0.50$), TF3 ($P =$
6	0.035, $r = 0.47$), TF5 ($P = 0.032$, $r = 0.48$) and worst pain ($P = 0.001$, $r = 0.78$) while the
7	other GRF-time variables showed no difference ($P > 0.05$).
8	Tables 3 and 4 show the effect of a home-based exercise on the vertical and the
9	shear GRF-time variables between the three pain subgroups and within group comparison.
10	The findings demonstrated no significant differences between the three subgroups before
11	nor after exercise ($P > 0.05$) in all GRF-time variables. However, the within-group
12	comparison showed significant differences were seen for F2 ($P = 0.043$, $r = 0.77$), TF2 ($P =$
13	0.006, <i>r</i> = 0.89), F4 (<i>P</i> = 0.018, <i>r</i> = 0.77), TF6 (<i>P</i> = 0.018, <i>r</i> = 0.89) and TF7 (<i>P</i> = 0.043, <i>r</i>
14	= 0.77) between before and after exercise in mild subgroup.
15	
16	4. Discussion
17	
18	4.1 Comparisons of GRF-time variables and worst pain between before and after 3 weeks
19	of exercise in individuals with PF
20	Our results showed that the combined stretching exercise program for
21	gastrocnemius, soleus, and plantar fascia in individuals with heel pain reduced the worst
22	pain scores, F2, and TF2 with a large effects size and reduced TF3 and TF5 with a medium
23	effect size, with the force during midstance F2 being higher than that previously reported in

1	healthy individuals (Katoh et al., 1983), which could be an indication of a cause or
2	compensation as a result of PF (Wearing et al., 2006). A study done by Erdemir et al.
3	(Erdemir, Hamel, Fauth, Piazza, & Sharkey, 2004), investigated the effect of achilles
4	tendon stimulation on plantar fascia load during gait in cadaver feet. They found the
5	increase of achilles tendon load had a strong association with increasing tension in the
6	plantar fascia over the stance phase of gait ($r = 0.76$). This association yielded greater
7	forces in late midstance in order to counterbalance the higher midstance v-GRF in
8	preparation for the change from stance to swing phase (Dananberg, 1993). This strategy
9	may produce a higher tension in gastrocnemius and soleus muscles, as well as plantar
10	fascia. The changes of these soft tissue properties resulted in higher forces during
11	midstance and were attributed to overload stress on the plantar facia in individuals with PF
12	(Katoh et al., 1983).
13	Physiological effect of stretching exercise can reduce muscle stiffness and enhance
14	appropriate actin-myosin attachment leading to improvement of viscoelastic property of the
15	muscles (Malliaropoulos, Papalexandris, Papalada, & Papacostas, 2004). Consequently,
16	responsiveness to gain normal movement and appropriate muscle force production (Herzog,
17	Joumaa, & Leonard, 2010). A possible explanation for the lower F2 and slightly earlier
18	timing of TF2 in our study may indicate an improvement in the progression of the body
19	over the stance leg as a result of the stretching exercise program. A stretching exercise
20	program for gastrocnemius and soleus in the closed chain position with weekly progression
21	by increasing the body load position may enhance the absorbing and loading function

23 stiffness as well as allowing the calf muscles to generate an appropriate force to stabilize

22

during gait. Stretching the plantar fascia in the open-chain position could also reduce joint

1	the arch of the foot during midstance. Another explanation for the relationship between	
2	muscle and fascia function after the stretching exercises was the reduction in the worst pain	
3	which may lead to less compensatory movements. This finding was comparable to a	
4	previous RCT study (Hsu, Lai, Chang, & Hsu, 2013), that reported a significant reduction	
5	in F2 after 3 weeks of receiving shockwave therapy in individuals with PF. The authors	
6	explained that the reduction of force was partly due to the pain being decreased. For the	
7	delayed time to the minimum v-GRF at midstance or TF2 in individuals with PF, we found	
8	similar results of a previous study (Wearing et al., 2003). It was suspected that individuals	
9	with PF had a delayed timing of movement over the stance limb due to pain in the plantar	
10	fascia which interrupted loading and weight transfer.	
11	For the TF3 or time to the second peak v-GRF and TF5 or time to peak propulsive	
12	force, both occurring over the push-off phase. Nevertheless, none of the previous studies	
13	directly determined these variables in individuals with PF before. However, alteration of	
14	these timings may be implied from previous studies which investigated the peak v-GRF	l
15	during push-off (Chang et al., 2014; Katoh et al., 1983; Wearing et al., 2003). As the	
16	operational definition of the timing of this force is the percentage of stance time related to	
17	v-GRF during push-off phase. Many studies reported significant reductions in the peak v-	
18	GRF during push-off in individuals with PF (Chang et al., 2014; Katoh et al., 1983;	
19	Wearing et al., 2003). This has been previously hypothesized to be associated with the	
20	reduction of stress and strain within the plantar fascia (Phillips & McClinton, 2017). Fessel	
21	et al. (Fessel et al., 2014), used elongation measurement in vivo during the stance phase of	
22	gait, in combination with measurement of mechanical properties in vitro, to explore the	
23	mechanical function of the plantar aponeurosis. They found elongation of the fascia was	

Commented [JR<oS&HS1]: Sorry I don't know what point you are trying to make here

1	associated with F3 or the peak v-GRF during push-off. Consistent with Chen et al.'s study
2	(Chen, Chang, Li, Chang, & Lin, 2015), who reported that peak plantar fascia tension
3	correlated with F3 in healthy subjects. Individuals with PF may have a delay of TF3 to
4	avoid excessive force, which causes stress and pain within the fascia. Thus, an earlier TF3
5	after stretching exercises may come from a decrease in plantar fascia tension and pain
6	response to the treatment program, which is also likely to be associated with the alterations
7	of TF5 or time to peak propulsive force during push-off.
8	This current study found no significant differences in F1 and F3 or the 1st and 2nd
9	peak of the v-GRF after completing the exercise program in individuals with PF. According
10	to a previous report (Wearing et al., 2003), individuals with PF showed an increase in F1
11	when compared to healthy controls. The changes in force generation in the early phase can
12	have a lasting effect on the propulsive forces that occur at the end of the stance phase.
13	Some supporting data showed a reduction of F3 in individuals with PF compared to healthy
14	(Chang et al., 2014; Katoh et al., 1983; Wearing et al., 2003). Hence, we expected to
15	observe a decrease in F1 and an increase in F3 after exercise in individuals with PF.
16	Possible explanations of no change may be attributed to the diversity of sample selection
17	criteria, experimental protocol, testing tool, and computation method between studies.
18	
19	4.2 Sub-group analysis
20	When considering the pain severity subgroup analysis, the results showed no

21 difference in all variables between the mild, moderate, and severe subgroups both at before 22 and after exercise (P > 0.05). However, for within-group analysis, significant differences 1 were seen in F2, TF2, F4, TF6, and TF7 with large effect sizes in a mild pain subgroup

2 only.

Demographic and clinical characteristics could affect the comparative results among 3 subgroups, however, no differences were seen in those data, except pain which was used as 4 5 a segmentation factor to assign groups. From the results, it could be implied that a home-6 based stretching exercise in our study was appropriate for individuals with PF who had a 7 mild pain level only. This may be due to a stretching program that was progressive by using the body weight in a closed chain position, which may be too difficult for individuals with 8 moderate to severe pain levels and led to poor adherence. Another possible reason to 9 10 support this issue may relate to the fear. Pain catastrophizing and kinesiophobia were 11 believed to be associated with pain severity in individuals with PF (Cotchett, Lennecke, Medica, Whittaker, & Bonanno, 2017). Pain catastrophizing and kinesiophobia may act as 12 the threads and made individuals avoid weight bearing on the symptomatic foot and 13 14 resulting in the stretching exercise being not effective. However, this fear issue was not documented in this study. In addition, the exercise program was designed as a home-based. 15 Weekly phone calls were performed to check symptoms and encouraged participants to 16 follow the protocol. So, the position and degree of stretching was properly or not cannot be 17 checked in this situation. 18 The significant reduction of F2 and TF2 in a mild group found in this study could 19 20 be explained similarly to those of the overall analysis. The results emphasized the exercise effect on the arch of foot improvement to protect load on the fascia over midstance. For the 21 significant increase in F4 after exercise in our study, this may in part be explained by the 22

23 previous finding (Katoh et al., 1983). This aberrant walking pattern links with a

compensatory mechanism to avoid excessive anterior shear force on the symptomatic side 1 2 during heel strike. So, the effect of stretching exercise could alleviate pain symptoms which potentially allow improvement in braking function. Both time reductions of TF6 and TF7 3 may be due to the improvement of plantar fascia and gastrosoleus flexibility along with 4 5 reduced pain. It can be seen that the within group analysis showed the changes only in the 6 mild subgroup, while the moderate and severe subgroups had no change after performing 7 the home-based stretching exercise for 3 weeks. This may be implied that the duration of exercise may not be sufficient to alter the soft tissues, resulting in no visible changes for the 8 9 moderate and severe subgroups.

10 No significant differences were seen in all GRF-time variables between the three subgroups. The possible reasons may relate to a small number of participants in our study 11 and the duration of the exercise program being too short to induce any change. A previous 12 study (Engkananuwat et al., 2018), investigated the combined gastrocnemius and plantar 13 14 fascia stretching exercise with the same intensity dose as our study but provided a longer duration of 4 weeks in the mild stage of individuals with unilateral PF. The results showed 15 significant reductions in pain and ankle dorsiflexion ROM. In addition, a shorter time of 16 calf muscle stretching exercise of 2 weeks could improve pain and function in individuals 17 with PF but not differ from the control group (Radford, Landorf, Buchbinder, & Cook, 18 2007). 19

This study has a number of limitations. Firstly, there was no healthy control group, or untreated control group, which could have been used to compare with individuals with PF who received the intervention. Secondly, the exercise program should include gait training section to correct movement patterns, restore normal muscle function, and prevent

injuries caused by repetitive force impact onto the ground when walking, thirdly, 1 2 considering exercise adherence and kinesiophobia may have helped to understand the nonresponse of the moderate and severe groups. In addition, a long-term follow-up assessment 3 or longer duration of exercise program may have revealed if a more delayed response was 4 5 present in the moderate and severe groups. Finally, this study is limited by a small sample 6 size, and future study should include a greater number of participants to increase power, 7 generalizability and treatment effects in different subgroups of people with PF. 8 5. Conclusion 9 10 A home-based stretching exercise program of gastrocnemius and soleus muscles 11 and plantar fascia provided beneficial effects on pain relief and improved gait parameters 12 including some GRF-time variables. A sub-group analysis revealed that a 3 week stretching exercise provided benefits in a mild pain subgroup only. Therapists should take into 13 14 account the pain severity in order to design an exercise program that is appropriate for different pain subgroups. 15 16 References 17 Beeson, P. (2014). Plantar fasciopathy: revisiting the risk factors. Foot Ankle Surg, 20(3), 18 160-165. doi:10.1016/j.fas.2014.03.003 19 20 Boonchum, H., Bovonsunthonchai, S., Sinsurin, K., & Kunanusornchai, W. (2020). Effect of a home-based stretching exercise on multi-segmental foot motion and clinical 21

22 outcomes in patients with plantar fasciitis. J Musculoskelet Neuronal Interact,

23 20(3), 411-420.

1	Bovonsunthonchai, S., Thong-On, S., Vachalathiti, R., Intiravoranont, W., Suwannarat, S.,
2	& Smith, R. (2019). Alteration of the multi-segment foot motion during gait in
3	individuals with plantar fasciitis: a matched case-control study. Acta Bioeng
4	Biomech, 21(4), 73-82. doi:10.37190/ABB-01426-2019-02
5	Chang, R., Rodrigues, P. A., Van Emmerik, R. E., & Hamill, J. (2014). Multi-segment foot
6	kinematics and ground reaction forces during gait of individuals with plantar
7	fasciitis. J Biomech, 47(11), 2571-2577. doi:10.1016/j.jbiomech.2014.06.003
8	Chen, Y. N., Chang, C. W., Li, C. T., Chang, C. H., & Lin, C. F. (2015). Finite element
9	analysis of plantar fascia during walking: a quasi-static simulation. Foot Ankle Int,
10	36(1), 90-97. doi:10.1177/1071100714549189
11	Cotchett, M., Lennecke, A., Medica, V. G., Whittaker, G. A., & Bonanno, D. R. (2017).
12	The association between pain catastrophising and kinesiophobia with pain and
13	function in people with plantar heel pain. Foot (Edinb), 32, 8-14.
14	doi:10.1016/j.foot.2017.03.003
15	Cutts, S., Obi, N., Pasapula, C., & Chan, W. (2012). Plantar fasciitis. Ann R Coll Surg Engl,
16	94(8), 539-542. doi:10.1308/003588412X13171221592456
17	Dananberg, H. J. (1993). Gait style as an etiology to chronic postural pain. Part I.
18	Functional hallux limitus. J Am Podiatr Med Assoc, 83(8), 433-441.
19	doi:10.7547/87507315-83-8-433
20	DiGiovanni, B. F., Nawoczenski, D. A., Lintal, M. E., Moore, E. A., Murray, J. C.,
21	Wilding, G. E., & Baumhauer, J. F. (2003). Tissue-specific plantar fascia-stretching

exercise enhances outcomes in patients with chronic heel pain. A prospective, 22

1	randomized study. J Bone Joint Surg Am, 85(7), 1270-1277. doi:10.2106/00004623-	
2	200307000-00013	
3	Digiovanni, B. F., Nawoczenski, D. A., Malay, D. P., Graci, P. A., Williams, T. T.,	
4	Wilding, G. E., & Baumhauer, J. F. (2006). Plantar fascia-specific stretching	
5	exercise improves outcomes in patients with chronic plantar fasciitis. A prospective	
6	clinical trial with two-year follow-up. J Bone Joint Surg Am, 88(8), 1775-1781.	
7	doi:10.2106/JBJS.E.01281	
8	Engkananuwat, P., Kanlayanaphotporn, R., & Purepong, N. (2018). Effectiveness of the	
9	simultaneous stretching of the achilles tendon and plantar fascia in Individuals with	
10	plantar fasciitis. Foot Ankle Int, 39(1), 75-82. doi:10.1177/1071100717732762	
11	Erdemir, A., Hamel, A. J., Fauth, A. R., Piazza, S. J., & Sharkey, N. A. (2004). Dynamic	
12	loading of the plantar aponeurosis in walking. J Bone Joint Surg Am, 86(3), 546-	
13	552. doi:10.2106/00004623-200403000-00013	
14	Fessel, G., Jacob, H. A., Wyss, C., Mittlmeier, T., Muller-Gerbl, M., & Buttner, A. (2014).	
15	Changes in length of the plantar aponeurosis during the stance phase of gaitan in	
16	vivo dynamic fluoroscopic study. Ann Anat, 196(6), 471-478.	
17	doi:10.1016/j.aanat.2014.07.003	
18	Herzog, W., Joumaa, V., & Leonard, T. R. (2010). The force-length relationship of	
19	mechanically isolated sarcomeres. Adv Exp Med Biol, 682, 141-161.	
20	doi:10.1007/978-1-4419-6366-6_8	
21	Hsu, W. H., Lai, L. J., Chang, H. Y., & Hsu, R. W. (2013). Effect of shockwave therapy on	
22	plantar fasciopathy. A biomechanical prospective. Bone Joint J, 95-B(8), 1088-	

23 1093. doi:10.1302/0301-620X.95B8.31497

1	Irving, D. B., Cook, J. L., Young, M. A., & Menz, H. B. (2008). Impact of chronic plantar	
2	heel pain on health-related quality of life. J Am Podiatr Med Assoc, 98(4), 283-289.	
3	doi:10.7547/0980283	
4	Johnson, C. D., Tenforde, A. S., Outerleys, J., Reilly, J., & Davis, I. S. (2020). Impact-	
5	related ground reaction forces are more strongly associated with some running	
6	injuries than others. Am J Sports Med, 48(12), 3072-3080.	
7	doi:10.1177/0363546520950731	
8	Karagounis, P., Tsironi, M., Prionas, G., Tsiganos, G., & Baltopoulos, P. (2011). Treatment	
9	of plantar fasciitis in recreational athletes: two different therapeutic protocols. Foot	
10	Ankle Spec, 4(4), 226-234. doi:10.1177/1938640011407320	
11	Katoh, Y., Chao, E. Y., Morrey, B. F., & Laughman, R. K. (1983). Objective technique for	
12	evaluating painful heel syndrome and its treatment. Foot Ankle, 3(4), 227-237.	
13	doi:10.1177/107110078300300410	
14	Liddle, D., Rome, K., & Howe, T. (2000). Vertical ground reaction forces in patients with	
15	unilateral plantar heel pain - a pilot study. Gait Posture, 11(1), 62-66.	
16	doi:10.1016/s0966-6362(99)00053-3	
17	Lopes, A. D., Hespanhol Junior, L. C., Yeung, S. S., & Costa, L. O. (2012). What are the	
18	main running-related musculoskeletal injuries? A systematic review. Sports Med,	
19	42(10), 891-905. doi:10.1007/BF03262301	
20	Malliaropoulos, N., Papalexandris, S., Papalada, A., & Papacostas, E. (2004). The role of	
21	stretching in rehabilitation of hamstring injuries: 80 athletes follow-up. Med Sci	
22	Sports Exerc, 36(5), 756-759. doi:10.1249/01.mss.0000126393.20025.5e	

1	Patel, A., & DiGiovanni, B. (2011). Association between plantar fasciitis and isolated
2	contracture of the gastrocnemius. Foot Ankle Int, 32(1), 5-8.
3	doi:10.3113/FAI.2011.0005
4	Phillips, A., & McClinton, S. (2017). Gait deviations associated with plantar heel pain: A
5	systematic review. Clin Biomech (Bristol, Avon), 42, 55-64.
6	doi:10.1016/j.clinbiomech.2016.12.012
7	Pohl, M. B., Hamill, J., & Davis, I. S. (2009). Biomechanical and anatomic factors
8	associated with a history of plantar fasciitis in female runners. Clin J Sport Med,
9	19(5), 372-376. doi:10.1097/JSM.0b013e3181b8c270
10	Porter, D., Barrill, E., Oneacre, K., & May, B. D. (2002). The effects of duration and
11	frequency of Achilles tendon stretching on dorsiflexion and outcome in painful heel
12	syndrome: a randomized, blinded, control study. Foot Ankle Int, 23(7), 619-624.
13	doi:10.1177/107110070202300706
14	Radford, J. A., Landorf, K. B., Buchbinder, R., & Cook, C. (2007). Effectiveness of calf
15	muscle stretching for the short-term treatment of plantar heel pain: a randomised
16	trial. BMC Musculoskelet Disord, 8, 36. doi:10.1186/1471-2474-8-36
17	Riddle, D. L., Pulisic, M., Pidcoe, P., & Johnson, R. E. (2003). Risk factors for Plantar
18	fasciitis: a matched case-control study. J Bone Joint Surg Am, 85(5), 872-877.
19	doi:10.2106/00004623-200305000-00015
20	Siriphorn, A., & Eksakulkla, S. (2020). Calf stretching and plantar fascia-specific stretching
21	for plantar fasciitis: A systematic review and meta-analysis. J Bodyw Mov Ther,

22 24(4), 222-232. doi:10.1016/j.jbmt.2020.06.013

1	Thomas, M. J., Whittle, R., Menz, H. B., Rathod-Mistry, T., Marshall, M., & Roddy, E.	
2	(2019). Plantar heel pain in middle-aged and older adults: population prevalence,	
3	associations with health status and lifestyle factors, and frequency of healthcare use.	
4	BMC Musculoskelet Disord, 20(1), 337. doi:10.1186/s12891-019-2718-6	
5	Thong-On, S., Bovonsunthonchai, S., Vachalathiti, R., Intiravoranont, W., Suwannarat, S.,	
6	& Smith, R. (2019). Effects of strengthening and stretching exercises on the	
7	temporospatial gait parameters in patients with plantar fasciitis: A randomized	
8	controlled trial. Ann Rehabil Med, 43(6), 662-676. doi:10.5535/arm.2019.43.6.662	
9	Waclawski, E. R., Beach, J., Milne, A., Yacyshyn, E., & Dryden, D. M. (2015). Systematic	
10	review: plantar fasciitis and prolonged weight bearing. Occup Med (Lond), 65(2),	
11	97-106. doi:10.1093/occmed/kqu177	
12	Wearing, S. C., Smeathers, J. E., & Urry, S. R. (2003). The effect of plantar fasciitis on	
13	vertical foot-ground reaction force. Clin Orthop Relat Res(409), 175-185.	
14	doi:10.1097/01.blo.0000057989.41099.d8	
15	Wearing, S. C., Smeathers, J. E., Urry, S. R., Hennig, E. M., & Hills, A. P. (2006). The	
16	pathomechanics of plantar fasciitis. Sports Med, 36(7), 585-611.	



Fig. 1 Flow chart of the study.





posterior (AP)-GRF, and C) medio-lateral (ML)-GRF].

Variables Total Mild pai		Mild pain	Moderate pain	Severe pain	P-value
	(n = 20)	(n = 7)	(n = 7)	(n = 6)	
Age (years)	58.00 (53.00 - 61.00)	55.00 (52.00 - 59.00)	60.00 (53.00 - 65.00)	59.50 (50.00 - 64.25)	0.394 ^a
Weight (kg)	61.83 (53.21 – 72.31)	61.65 (53.00 - 63.85)	58.00 (52.40 - 77.00)	67.80 (58.24 - 96.89)	0.513 ^a
Height (cm)	159.00 (153.25 - 169.88)	154.00 (150.00 - 161.50)	158.00 (153.00 - 171.00)	166.40 (159.25 – 174.75)	0.100 ^a
BMI (kg/m ²)	24.63 (21.84 - 27.50)	24.48 (22.64 - 26.00)	24.78 (20.99 - 26.33)	26.07 (20.89 - 32.07)	0.833ª
Gender					
Male (n, %)	6, 30	2, 28.57	3, 42.86	2, 33.33	
Female (n, %)	14, 70	5, 71.34 4, 57.14 4, 66.67			
Disease onset (months)					
1-3 (n, %)	5, 25	3, 42.86	2.86 2, 28.57 1, 16.67		0.410 ^a
3-6 (n, %)	2, 10	-	1, 14.29	-	
6-9 (n, %)	1,5	1, 14.29	-	-	
>12 (n, %)	12, 60	3, 42.86	4, 57.14	5, 83.33	
Worst pain (scores)	50.00 (40.00 - 77.68)	35.00 (30.00 - 40.00)	50.00 (50.00 - 65.00)	80.00 (77.68 - 90.00)	<0.001 ^{a,b}
Туре					
Unilateral (n, %)	8,40	4, 57.14	2, 28.57	2, 33.33	0.527ª
Bilateral (n, %)	12, 60	3, 42.86	5, 71.43	4, 66.67	
Physical activity level					
High (n, %)	11, 55	3, 42.86	2, 28.57	2, 33.33	0.790 ^a
Moderate (n, %)	1,5	-	1, 14.29	-	
Low (n, %)	8,40	4, 57.15	4, 57.14	4, 66.67	
Arch of foot type					
Normal (n, %)	19, 95	7, 100	6, 85.70	6, 100	0.395ª
High (n, %)	1,5	-	1, 14.30	-	

Table 1 Baseline participant characteristics.

Gait speed (m/s)	0.98 (0.96 - 1.07)	0.97 (0.95 - 1.02)	0.98 (0.88 - 1.08)	1.03 (0.98 – 1.19)	0.254 ^a
Cadence (steps/min)	105.19 (100.76 - 109.26)	104.58 (106.83 - 97.07)	103.96 (102.72 - 105.81)	108.15 (100.00 - 118.76)	0.332 ^a

BMI: Body Mass Index; PF: Plantar Fasciitis. Data expressed as n, % or mean ± standard deviation.

^aSignificant difference tested by the Kruskal-Wallis test at P < 0.05;

^bSignificant value adjusted by the Boferroni correction for multiple test at P < 0.05 between mild vs severe subgroups

Variables	Before exercise	After exercise	<i>P</i> -value*
	Median (IQR)	Median (IQR)	
Worst pain (scores)	50.00 (57.90 - 77.75)	31.00 (20.00 - 58.75)	0.001
F1 (N/kg)	101.52 (97.06 - 106.60)	101.47 (97.66 – 107.30)	0.351
F2 (N/kg)	81.34 (77.53 - 83.88)	77.88 (74.31 - 81.95)	0.019
F3 (N/kg)	105.69 (98.86 - 108.74)	106.15 (102.27 – 107.97)	0.575
TF1 (%)	19.10 (18.20 - 20.48)	18.10 (17.05 – 19.75)	0.080
TF2 (%)	33.60 (32.23 - 36.31)	32.96 (31.00 - 34.15)	0.026
TF3 (%)	52.58 (51.47 - 56.58)	51.70 (50.30 - 54.10)	0.035
F4 (N/kg)	14.43 (12.64 – 16.76)	15.20 (13.62 – 17.31)	0.135
F5 (N/kg)	-18.06 (-19.8915.28)	-18.27 (-19.9416.21)	0.100
TF4 (%)	12.53 (11.40 - 13.48)	12.30 (11.76 – 13.10)	0.778
TF5 (%)	62.10 (59.23 - 65.88)	60.77 (57.40 - 62.30)	0.032
F6 (N/kg)	-6.44 (-8.255.33)	-6.52 (-7.87 – -5.74)	0.841
F7 (N/kg)	-7.00 (-7.716.21)	-6.76 (-7.355.53)	0.247
TF6 (%)	19.90 (18.00 - 21.15)	17.78 (17.05 – 19.58)	0.073
TF7 (%)	55.45 (52.05 - 57.90)	54.60 (51.45 - 57.10)	0.059

Table 2 Comparison of the ground reaction force (GRF)-time variables and worst pain betweenbefore and after exercise in all participants (n = 20).

P-value* tested by the Wilcoxon signed ranks test; IQR: Interquatile range; F: peak force; TF:

time to peak force; N/kg: newton per kilogram; %: percent of stance phase

Variables	Plantar fasciitis severity, median (IQR)						Between-	Between-
	Mild (n = 7)		Moderate (n = 7)		Severe (n = 6)		group (B)	group (A)
	Before (B)	After (A)	Before (B)	After (A)	Before (B)	After (A)	<i>P</i> -value ^a	<i>P</i> -value ^a
F1 (N/kg)	100.97 (97.75 -	101.10 (98.14 -	101.22 (97.04 -	107.22 (100.73 -	107.15 (91.41 -	99.04 (95.91 -	0.542	0.357
	103.20)	106.75)	106.14)	107.49)	111.43)	109.82)		
P-value ^b	0.310		0.310		0.917			
F2 (N/kg)	82.56 (78.09 -	77.06 (74.28 -	81.31 (75.34 –	78.65 (74.18 –	79.91 (75.20 -	78.16 (72.28 –	0.909	0.999
	86.01)	82.24)	86.22)	82.49)	81.68)	82.49)		
<i>P</i> -value ^b	0.043		0.128		0.600			
F3 (N/kg)	107.55 (101.16 -	104.86 (101.56 -	102.62 (97.60 -	106.58 (104.58 -	106.26 (97.16 -	105.79 (97.61 –	0.346	0.255
	109.02)	108.06)	114.63)	107.40)	109.67)	111.95)		
<i>P</i> -value ^b	0.612		0.735		0.917			
TF1 (%)	18.80 (18.50 -	17.40 (16.60 -	19.20 (18.20 -	18.00 (17.20 -	18.85 (16.93 -	19.18 (17.48 –	0.639	0.677
	20.67)	19.80)	20.50)	19.60)	20.61)	20.63)		
<i>P</i> -value ^b	0.063		0.310		0.892			
TF2 (%)	33.40 (32.00 -	31.80 (30.25 -	34.40 (33.00 -	34.00 (31.00 -	34.00 (31.04 -	34.43 (31.48 -	0.459	0.671
	34.00)	33.33)	38.33)	34.00)	38.69)	37.74)		
<i>P</i> -value ^b	0.018		0.128		0.600			
TF3 (%)	51.80 (51.67 -	51.50 (50.67 -	56.33 (51.80 -	51.80 (49.67 -	51.90 (49.63 -	53.18 (48.65 -	0.422	0.176
	58.00)	52.40)	56.60)	49.67)	57.06)	55.04)		
<i>P</i> -value ^b	0.091		0.310		0.400			

Table 3 Comparison of the vertical ground reaction force (GRF)-time variables between the three pain subgroups (mild, moderate, and severe) and within-group (before and after) comparisons.

P-value^a tested by the Kruskall Wallis test; *P*-value^b tested by the Wilcoxon signed ranks test; N/kg: newton per kilogram; %: percent

of stance phase; B: Before exercise; A: After exercise

Variables	Plantar fasciitis severity, median (IQR)						Between-	Between-
	Mild (n = 7)		Moderate (n = 7)		Severe (n = 6)		group (B)	group (A)
	Before (B)	After (A)	Before (B)	After (A)	Before (B)	After (A)	<i>P</i> -value ^a	P-value ^a
F4 (N/kg)	13.76 (12.63 –	15.81 (13.57 –	14.24 (12.39 –	14.88 (12.42 –	16.36 (12.13 –	14.81 (12.64 –	0.748	0.662
	17.10)	17.63)	16.67)	19.06)	18.74)	16.66)		
<i>P</i> -value ^b	0.043		0.237		0.116			
F5 (N/kg)	-17.64 (-19.96 –	-18.76 (-19.95 –	-18.43 (-19.38 –	-17.40 (-20.87 –	-19.29 (-20.15 –	-18.85 (-20.59 –	0.542	0.357
	-14.76)	-16.17)	-15.27)	-16.27)	-15.79)	-16.03)		
<i>P</i> -value ^b	0.091		0.310		0.753			
TF4 (%)	13.00 (10.80 -	12.60 (11.80 -	12.25 (11.67 –	12.20 (11.80 -	11.60 (10.69 -	11.88 (11.37 –	0.909	0.999
	13.00)	12.75)	14.00)	13.80)	13.43)	13.50)		
<i>P</i> -value ^b	0.204		0.463		0.463			
TF5 (%)	59.75 (59.20 -	60.00 (57.60 -	63.50 (62.20 -	60.33 (57.20 -	60.20 (56.51 -	62.20 (56.47 -	0.346	0.255
	67.00)	61.80)	64.75)	61.80)	66.75)	63.44)		
<i>P</i> -value ^b	0.176		0.128		0.528			
F6 (N/kg)	-7.22 (-8.69 – -	-7.19 (-8.19 – -	-6.23 (-8.49	-5.72 (-8.49	-6.00 (-7.13	-6.02 (-6.93 – -	0.639	0.677
	5.87)	6.35)	4.89)	4.42)	5.13)	5.74)		
<i>P</i> -value ^b	0.735		0.345		0.753			
F7 (N/kg)	-7.40 (-8.74	-6.93 (-7.61 – -	-6.58 (-7.70 – -	-6.52 (-7.78 – -	-6.44 (-7.68 – -	-6.63 (-7.31 – -	0.459	0.671
	6.37)	6.34)	6.49)	4.83)	5.54)	4.90)		
<i>P</i> -value ^b	0.499		0.398		0.753			
TF6 (%)	20.33 (18.00 -	17.40 (16.00 -	19.80 (18.20 -	17.80 (17.20 -	19.00 (16.75 –	18.25 (17.10 -	0.422	0.176
	22.40)	20.00)	20.60)	18.40)	21.10)	23.55)		
<i>P</i> -value ^b	0.018		0.176		0.600			

Table 4 Comparison of the shear ground reaction force (GRF)-time variables between three subgroups and within-group comparison.

Variables	Plantar fasciitis	antar fasciitis severity, median (IQR)								
	Mild (n = 7)		Moderate (n = 7)		Severe (n = 6)		group (B)	group (A)		
	Before (B)	After (A)	Before (B)	After (A)	Before (B)	After (A)	P-value ^a	<i>P</i> -value ^a		
TF7 (%)	55.50 (55.33 -	54.80 (51.60 -	55.60 (52.00 -	54.20 (50.80 -	51.90 (50.63 -	55.08 (51.93 -	0.748	0.662		
	57.60)	57.20)	59.20)	58.33)	58.06)	56.75)				
<i>P</i> -value ^b	0.043		0.150		0.598					

P-value^a tested by the Kruskall Wallis test; *P*-value^b tested by the Wilcoxon signed ranks test; N/kg: newton per kilogram; %: percent

of stance phase; B: Before exercise; A: After exercise