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Predictors of plantar fasciitis in Thai novice conscripts after 10-week military training: A prospective study



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ABSTRACT

Objective: To identify the individual, anatomical, and biomechanical predictors of plantar fasciitis among novice conscripts.

Design: A prospective cohort study.

Setting: Military training camp in Bangkok, Thailand.

Participants: One hundred thirteen novice conscripts without lower extremity pain prior to the commencement of military training.

Main outcome measure(s): Individual, anatomical, and biomechanical variables were assessed in all participants at baseline. The primary criterion variable was the presence or absence of plantar fasciitis. **Results:** After 10 weeks of training, 113 participants were classified as having ($n = 71$) and not having ($n = 42$) plantar fasciitis. The results indicated that the conscripts with poorer quality of movement and lesser femoral anteversion angle tended to exhibit plantar fasciitis (odds ratio = 1.996 and 0.720, respectively). Regarding individual components, the conscripts with higher body mass index and higher stress level had increased risk of plantar fasciitis (odds ratio = 1.238 and 1.110, respectively). Moreover, the conscripts with a higher level of physical exercise before military training had a reduced risk of presenting with plantar fasciitis (odds ratio = 0.242).

Conclusions: Multiple predictors—especially individual characteristics and the abnormalities from the proximal region (other than foot and ankle)—contributed to the development of plantar fasciitis among Thai novice conscripts.

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1. Introduction

Plantar fasciitis (PF) is a common lower-extremity tendinopathy among conscripts who are otherwise healthy (Owens et al., 2013; Taanila et al., 2015). Typical training programs for novice conscripts include running long distances, marching, calisthenics, crawling, jumping, lifting, and carrying loads. Each of these are extrinsic factors that can result in overuse injuries in the lower extremities (Jones, Cowan, & Knapik, 1994). The requirement that trainees be on their feet for long periods is thought to increase the risk of developing PF (Owens et al., 2013).

A combination of extrinsic factors, such as a vigorous training program and inappropriate footwear, and intrinsic individual, anatomical, and biomechanical factors are thought to predispose

trainees to developing PF and other lower-extremity overuse injuries (Krivickas, 1997; Pujalte & Silvis, 2014). Among the intrinsic factors previously shown to predict PF are higher body mass index (BMI) (Irving et al., 2007; Martin et al., 2014; van Leeuwen et al., 2016), a history of musculoskeletal symptoms in the lower extremity (Rome, Howe, & Haslock, 2002), psychological symptoms (e.g., depression, anxiety, and stress) (Cotchett, Munteanu, & Landorf, 2016), limited ankle dorsiflexion (Bolivar, Munuera, & Padillo, 2013; Martin et al., 2014; van Leeuwen et al., 2016), limited first metatarsophalangeal (MTP) joint movement (Martin et al., 2014; van Leeuwen et al., 2016), hamstrings tightness (Bolivar et al., 2013; van Leeuwen et al., 2016), low ankle plantarflexors strength (Martin et al., 2014; van Leeuwen et al., 2016), an abnormal foot arch (Di Caprio et al., 2010; Rome et al., 2002), and excessive foot pronation (Bolivar et al., 2013; Irving et al., 2007; Martin et al., 2014; Rome et al., 2002; van Leeuwen et al., 2016). Such abnormal muscular or structural impairments are thought to change the lower kinetic chain and induce repetitive microtrauma

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at the proximal attachment of the plantar fascia during vigorous activities (Kamonseki et al., 2016; Kibler, Goldberg, & Chandler, 1991; Martin et al., 2014).

The etiology of PF is probably multifactorial (Martin et al., 2014; van Leeuwen et al., 2016). Thus, a physical examination specific to only the ankle and foot regions may not provide enough information for the effective prediction and management of PF (Krivickas, 1997; Nguyen et al., 2013). Clinicians should also perform additional physical examinations of the proximal regions related to the lower kinetic chain. For example, lower-extremity examinations should include the assessment of structural alignment, muscle performance, range of motion, and movement patterns (Nguyen et al., 2013). Although no previous research has indicated the biomechanical link between the foot and the whole extremity as playing a role in PF, a recent systematic review on the relationship between hip muscle performance and the injuries in leg, ankle, and foot found that less muscle strength and delayed onset activation were related to leg, ankle, and foot injuries (Steinberg et al., 2017). Another previous study compared the kinematics and muscle activity of the lower extremity between the runners with Achilles tendinopathy and non-injured control subjects. The study reported that the lower range of knee motion and lower muscle activity of the tibialis anterior, rectus femoris, and gluteus medius during running were observed in the injured group (Azevedo et al., 2009). However, the relationships found in the previous studies may be the result of a compensatory mechanism. Finally, it was not possible to differentiate cause and effect in these studies.

Apparently, there is a lack of high-quality longitudinal studies that have sought to identify the predictors of the development of PF prospectively (van Leeuwen et al., 2016). Although numerous studies using cross-sectional or matched case-control designs have been conducted, such research is not able to identify causal factors. We were only able to identify one prospective cohort study investigating the risk factors of PF in runners. These investigators found that both varus knee alignment and cavus arch posture were significantly associated with a higher risk of the development of PF in their sample of 166 runners (Di Caprio et al., 2010). However, although these investigators used an appropriate design, the predictors evaluated were limited to just the extrinsic variables and structural alignment of the knee and foot. Additional research is needed not only to replicate these findings, but extend them to include additional intrinsic predictors, to develop a more comprehensive model of the development of PF. For this study, intrinsic predictors included individual predictors such as BMI, physical exercise index, and psychological symptoms; anatomical predictors such as pelvic angle, femoral anteversion angle, tibial torsion angle, and quadriceps angle; and biomechanical predictors such as quality of lower-extremity movement.

Given these considerations, the aim of this prospective cohort study was to identify the intrinsic risk predictors of PF among Thai novice conscripts. This population is ideal for addressing the study aim because the subjects were under the same extrinsic condition. We hypothesized that various intrinsic predictors among individual, anatomical, and biomechanical predictors, especially the abnormalities from the proximal region, other than foot and ankle, would contribute to the presence of PF during the 10-week military training.

2. Materials and methods

2.1. Study design

A prospective cohort study with 10-week follow-up was conducted among male Thai conscripts who attended basic military training from May to July 2016 at the Infantry Battalion of 11th

Military Circle, the central camp for military training in Bangkok, Thailand. Baseline measurement regarding the various predictors of PF were collected within the 1-week period before military training. After 10 weeks of military training, all participants were classified into two groups: (1) a group that developed PF (PF group) and (2) a group that had not developed PF, lower back pain, and lower-extremity pain (healthy group).

2.2. Study population

The study was described to 502 Thai men who were military conscripts and 18 years or older, and they were invited to participate. Of these, 457 agreed to participate, signed the informed consent form, and completed a screening questionnaire. The exclusion criteria were (1) having current or history of lower back or lower extremity pain in the last 3 months rated as 3 cm or more on a 10-cm Visual Analog Scale (VAS), (2) having history of lower-extremity fracture/surgery, or (3) having a medical diagnosis of gout, rheumatoid arthritis, systemic lupus erythematosus (SLE), cancer, or infection disease. In addition, individuals with true leg length differences greater than 1 cm and a positive sign from the straight leg raise (SLR) test as indicated by numbness, paresthesia, or referred pain at the posterior leg were also excluded (Coppieters et al., 2006). One hundred and eighty-seven potential participants met at least one of these criteria, and thus were excluded from the study. The remaining 270 conscripts were re-assessed after they completed 10 weeks of military training. The study procedures were approved by the Internal Review Board of Chulalongkorn University (approval No. 077/2016).

2.3. Questionnaire

Two different sets of self-reported questionnaires were used to assess the study variables. The first set was designed to collect individual predictors at baseline, consisting of age, BMI, psychological symptoms, and baseline activity. The Depression, Anxiety, and Stress Scale short version (DASS-21) was used to assess psychological symptoms, including depression, anxiety, and stress (Brown et al., 1997). Baseline activity was assessed using the physical exercises in leisure (PEL) part of the Baecke physical activity questionnaire (Baecke, Burema, & Frijters, 1982). Both the DASS-21 and PEL have demonstrated validity and reliability in the research setting (Baecke et al., 1982; Brown et al., 1997). The second set of questionnaires was administered every 2 weeks during the 10-week military training. These questionnaires assessed pain intensity in the lower back, hip/thigh, knee, lower leg, and foot/ankle regions (Kuorinka et al., 1987).

2.4. Lower-extremity physical examination

All participants were also given a lower-extremity physical examination at baseline. This examination was adapted from clinical measures assessing anatomical and biomechanical characteristics (Nguyen et al., 2013; Piva et al., 2006) of the lower extremity, as well as from clinical practice guidelines (Martin et al., 2014; McPoil et al., 2008). The goal was to assess physical impairments thought to be related to the development of PF. Each of the assessments used in the present study had been shown to be reliable in the context of lower extremity examination (Nguyen et al., 2013; Piva et al., 2006; Shultz et al., 2006). With respect to biomechanical assessment, the lateral step down test has been reported as an appropriate tool for determining lower-extremity movement patterns instead of using the three-dimensional (3D) motion analysis system, the gold standard for biomechanical assessment (Piva et al., 2006; Rabin, Kozol, & Finestone, 2014). Before collecting data for

the current study, we performed a pilot study to compute the intrarater reliability of all physical examinations among 10 male conscripts. The results showed intraclass correlation coefficient [ICC (3,1)] ranging from 0.58 to 0.95, which indicates moderate to good reliability (Portney & Watkins, 2009); reliability data were reported in the brackets of each of the following assessments.

The pelvic angle (ICC, 0.78) was assessed in a standing position from anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) landmarks. The Image J program was used to measure the angle from digital photographs (Fig. 1A). (Abramoff, Magalhaes, & Ram, 2004) The femoral anteversion angle (ICC, 0.67) was measured using the Craig test in a prone position with 90° knee flexion of the tested leg (Fig. 1B). (Magee, 1992) And, the tibial torsion angle (ICC, 0.58) was determined as the angle between a transmalleolar line and a mid-parallel line to the long axis of the femur (Fig. 1C) (Kwon et al., 2009).

The assessment of knee alignment from photographic analysis included quadriceps angle and knee extension angle. The quadriceps angle (ICC, 0.94) at the middle patella was determined as the angle between the ASIS and the tibial tuberosity landmarks (Fig. 1D). (Magee, 1992) To determine the genu recurvatum angle (ICC, 0.91), we measured the knee extension angle at the lateral femoral condyle between the greater trochanter and the lateral malleolus landmarks (Fig. 1E). Participants were classified as having an abnormal angle when the angle was greater than 10° (Devan et al., 2004).

The hamstring length (ICC, 0.85) was assessed with a passive SLR test (Fig. 1F). (Bolivar et al., 2013) Ankle plantarflexor strength (ICC, 0.88) was assessed using the single-leg heel rise task (Fig. 1G). Normal strength was defined as individual repetition at least 25 times and, with each repeat, the range of movement (ROM) was more than 50% of individual full ROM at the first time (Lunsford & Perry, 1995). The active ankle dorsiflexion angle was assessed with both knee extension (ICC, 0.95) and knee flexion of 90° (ICC, 0.89) (Fig. 1H and I, respectively). (Riddle et al., 2003) The ROM of the first MTP joint extension (ICC, 0.65) was determined as the angle between a line parallel to the bisection of the proximal phalange and a

line parallel to the bisection of the metatarsal bone (Fig. 1J). (Otter et al., 2015) Foot alignment (ICC, 0.74) was assessed in the standing position. The rearfoot angle was determined as the angle between a line connecting the calcaneal points and the other connecting the leg points (Fig. 1K) (Buchanan & Davis, 2005).

The lower-extremity movement pattern was measured using the lateral step down test (ICC, 0.87) with the contralateral leg hanging down off the 15-cm step height (Fig. 1L). To complete the test, each participant bent his hip and knee of the tested leg until his contralateral leg smoothly touched the floor. Afterward, he returned to the starting position by slowly extending the tested hip and knee. During this test, the examiner searched for any participant's abnormal movements with respect to five criteria including arm strategy, trunk movement, pelvic plane, knee position, and steady stance. Abnormal movement of each criterion would be scored according to the following details. Arm strategy: the participant would receive 1 point if he removed a hand from the waist to recover balance. Trunk movement: he would receive 1 point if he leaned his trunk to any side. Pelvic plane: he would receive 1 point if his pelvis rotated or was elevated on one side compared with the other. Knee position: he would receive 1 point if his tibial tuberosity deviated medially to the second toe, and would receive 2 points if his tibial tuberosity deviated medially to the medial border of the foot. Steady stance: he would receive 1 point if he stepped down on the contralateral side. The sum score could range from 0 to 6 points, with higher scores indicating poorer quality of movement. The lower-extremity movement pattern was then classified into three quality of movement levels labeling good (0–1 point), moderate (2–3 points), or poor (4–6 points) quality (Piva et al., 2006).

2.5. Study procedures

A total of 270 participants completed the first set of self-report questionnaires and received the physical examination before the beginning of military training from three physical therapists (PTs) who conducted the specific assessments in a standardized manner. At 2-week intervals during the 10-week military training, all participants were asked to complete the second set of self-reported questionnaires. The participants who reported foot or heel pain were required to see a physical therapist (P.H.) with 9 years of clinical experience in the assessment and treatment of foot and ankle problems to diagnose the presence or absence of PF. The PF diagnostic criteria included the tenderness of the medial calcaneal tubercle, heel pain from ordinary weight-bearing activities, and heel pain during the first few steps of walking after a prolonged period of inactivity that gradually decreased after walking for a while (Martin et al., 2014; McPoil et al., 2008).

At the end of the military training program, a total of 247 participants completed the self-reported questionnaire every 2 weeks. Only 23 participants dropped out of the study. The remaining participants were divided into three groups consisting of individuals (1) with a diagnosis of PF (n = 71), (2) without a diagnosis of PF and without lower back and lower-extremity pain (n = 42), and (3) without a diagnosis of PF but with lower back and lower extremity pain (n = 134). As this study emphasized the prediction of PF, the participants who reported having lower back or lower extremity separately from PF during the military training were excluded from further analysis, leaving 113 participants for the planned analyses.

2.6. Statistical analysis

We first performed a series of univariate analyses to identify any univariate differences between the participants with and without

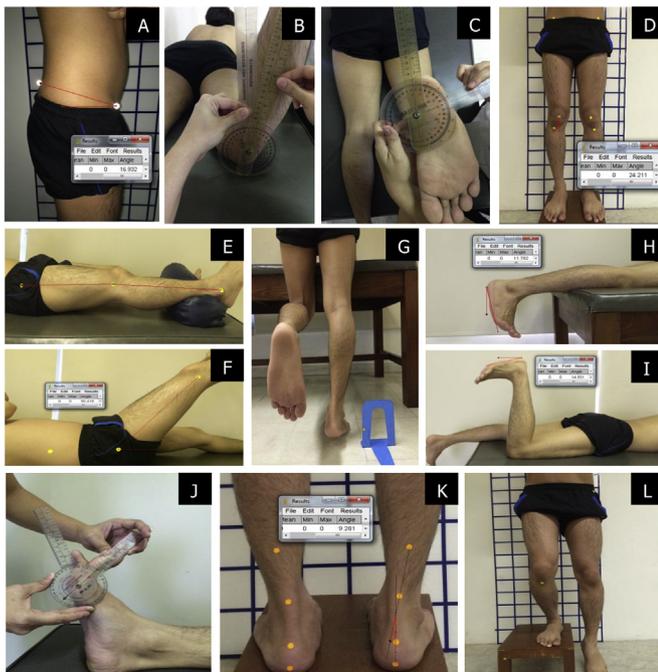


Fig. 1. Physical assessment in the present study.

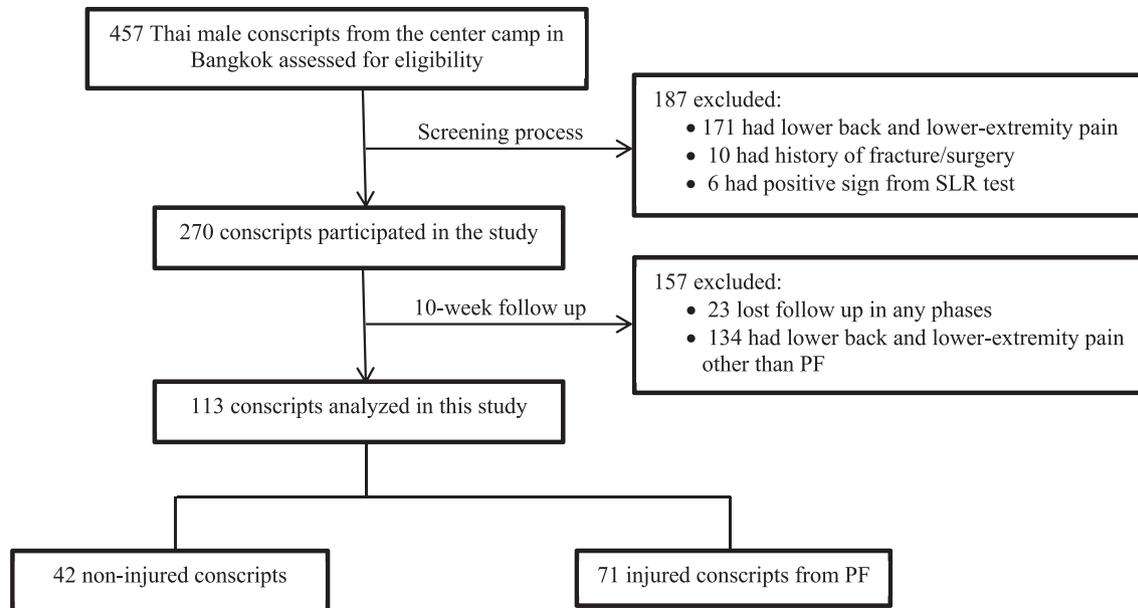


Fig. 2. A flow diagram of the participations in this study.

PF, using either the independent *t*-test or the Mann-Whitney *U* test. The effect sizes for the between-group comparisons were additionally calculated to assess the magnitude of mean difference effect (Cohen, 1988). We then entered any predictors that evidenced significant univariate difference in a multiple logistic regression analysis, using the forward stepwise method. We also calculated adjusted odds ratios (Hosmer & Lemeshow, 2000). The more painful side was selected for the analysis. In case of bilaterally non-injured legs of the healthy group or having equal foot pain intensity of the PF group, the leg side was randomly selected using random numbers generated from a computer program. All statistical analyses were performed using SPSS software version 22.0 (IBM statistics), with a significance level of $P < 0.05$.

3. Results

Seventy-one (26%) of 270 conscripts had PF symptoms after 10 weeks of military training. The 71 participants with PF had an average age of 21.54 ± 1.14 years (mean \pm standard deviation) and a mean BMI of 23.37 ± 3.81 . The average age of the 42 participants without PF was 21.24 ± 1.03 years, and they had a mean BMI of 20.80 ± 2.69 . Sixty participants with PF (85%) reported unilateral foot pain; whereas 11 (16%) reported bilateral foot pain. The average pain intensity score of the 71 participants with PF was 4.76 ± 2.46 cm on the VAS. There were no significant differences of the whole physical examination between both leg sides. Table 1 presents the baseline values of the participants' intrinsic predictors with means, standard deviations, *P*-values, and effect sizes (ES). On comparison between the healthy and PF groups, significant differences were found in eight intrinsic predictors, including five individual predictors, two anatomical predictors, and one biomechanical predictor. The results showed that the PF group had a 12.36% increase in BMI (ES = 0.78), a 10.54% decrease in PEL score (ES = 0.53), a 39.72% increase in depression score (ES = 0.48), a 66.44% increase in anxiety score (ES = 0.74), a 57.69% increase in stress score (ES = 0.91), a 14.08% decrease in femoral anteversion angle (ES = 0.75), a 9.91% decrease in ankle plantarflexor strength (ES = 0.42), and a 13.71% increase in the score of the lateral step down test (ES = 0.54).

All eight intrinsic predictors were included in the multiple logistic regression analysis. Three intrinsic predictors (i.e., depression score, anxiety score, and ankle plantarflexor strength) were excluded from the model. As shown in Table 2, the final logistic regression model was statistically significant with a chi-square value of 50.90 ($P < 0.001$). All of the predictor variables explained 50% (Nagelkerke R^2) of the variance in the incidence of PF and correctly classified 78% of cases. The results indicated that every 1 kg/m^2 increase in the BMI would increase the odds of being in the PF group by 1.238 [95% confidence interval (CI), 1.046–1.466]. With respect to the stress score, every 1 point increase in stress score increased the odds by 1.110 (95% CI, 1.020–1.208). Every 1 point increase in the PEL score decreased the odds by 0.242 (95% CI, 0.091–0.642). Individuals with more than 1 degree of femoral anteversion angle decreased the odds by 0.720 (95% CI, 0.567–0.914), whereas a 1 point higher score for the lateral step down test increased the odds by 1.969 (95% CI, 1.074–3.608).

4. Discussion

The purpose of this prospective longitudinal study was to identify the multivariate risk factors for developing PF in a sample of young men subject to significant physical exercise and activity (i.e., Thai novice conscripts undergoing 10 weeks of military training). Of the 113 participants who developed PF or not, the results identify specific intrinsic predictors for PF among Thai novice conscripts, which include BMI, baseline physical exercise activity, psychological stress, the femoral anteversion angle, and quality of movement from the lateral step down task.

The current findings support a conclusion that multiple predictors contribute to the development of PF. Although there is some overlap between the predictors of PF in the current study and those from other studies (Di Caprio et al., 2010; Werner et al., 2010), not all of the intrinsic predictors from the current study were the same as those identified in two previous studies. Werner et al. (Werner et al., 2010) found that intrinsic predictors among the plant workers included job dissatisfaction, forefoot pronation, and high metatarsal pressure. However, the Werner et al. study was not a prospective longitudinal design, so it is not possible to determine

Table 1
Comparison of each predictor between the healthy (n = 42) and PF (n = 71) groups.

Variables	Mean (S.D.)		P-value	ES
	Healthy (n = 42)	PF (n = 71)		
Individual factors				
Body mass index	20.80 (2.69)	23.37 (3.81)	<0.001*	0.78
Physical exercise index	2.94 (0.61)	2.63 (0.57)	0.005*	0.53
Depression scores	7.10 (5.14)	9.92 (6.16)	0.022*	0.48
Anxiety scores	7.33 (5.20)	12.20 (7.75)	0.001*	0.74
Stress scores	9.95 (4.87)	15.69 (7.45)	<0.001*	0.91
Anatomical factors				
Pelvic angle	9.03 (5.24)	8.78 (5.34)	0.812	0.05
Femoral anteversion angle	11.93 (1.72)	10.25 (2.67)	<0.001*	0.75
Tibial torsion angle	20.26 (4.11)	21.84 (5.19)	0.096	0.34
Quadriceps angle	16.45 (5.88)	16.53 (6.82)	0.949	0.01
Knee extension angle (genu recurvatum)	3.08 (2.26)	3.65 (2.55)	0.311	0.24
Hip flexion angle (hamstring length)	54.17 (5.50)	52.49 (8.74)	0.213	0.23
Ankle plantarflexor strength (heel raising times)	23.31 (4.21)	21.00 (6.51)	0.033*	0.42
Ankle DF angle with knee extension	4.64 (4.88)	5.11 (5.33)	0.815	0.09
Ankle DF angle with knee flexion	19.38 (9.13)	17.66 (7.91)	0.293	0.20
First MTP joint dorsiflexion angle	79.95 (8.55)	77.49 (8.79)	0.149	0.28
Rearfoot angle	8.79 (6.35)	8.94 (4.94)	0.890	0.03
Biomechanical factors				
Quality of movement scores	3.21 (0.78)	3.65 (0.86)	0.005*	0.54

* Significance level at $P < 0.05$.

Table 2
Multivariate logistic regression analysis of factors associated with an incidence of PF^a (n = 113).

Predictors	Beta	S.E.	Adjusted OR (95% CI)	P-value
Body mass index	0.214	0.086	1.238 (1.046–1.466)	0.013*
Physical exercise index	-1.418	0.498	0.242 (0.091–0.642)	0.004*
Stress score	0.104	0.043	1.110 (1.020–1.208)	0.015*
Femoral anteversion angle	-0.329	0.122	0.720 (0.567–0.914)	0.007*
Quality of movement scores	0.677	0.309	1.969 (1.074–3.608)	0.028*

* Significance level at $P < 0.05$.

^a Model chi-square test, $\chi^2 (5) = 50.897$ ($P < 0.001$). Overall percentage of correctly predicted = 77.9%. Goodness of fit (Hosmer and Lemeshow test) = 0.829. Pseudo- $R^2 = 0.495$.

those predictors as the cause of PF.

In the only prospective study we could identify, Di Caprio et al. (Di Caprio et al., 2010) found that the intrinsic risk factors of PF among runners included having a cavus arch and a varus knee. However, in the current sample, the eversion range of both groups fell within normal range (between 3° and 9°) (Buchanan & Davis, 2005) as seen in Table 1. These results suggest that most participants in both groups did not have a high arch, low arch, or pronated foot. Thus, even if these factors contribute to PF, it would not have been possible to identify them as predictors in the current study due to the lack of variability in these at baseline.

Among all of the anatomical variables, only the femoral anteversion angle was included in the final predictive model. Although the mean angle of both groups were in the normal range (between 8° and 15°) (Sahrmann, 2002), the PF group demonstrated less femoral anteversion than the non-PF group. Such alignment indicates a lateral rotation of the hip during non-weight bearing; however, this might have induced the medial rotation via the subtalar joint articulation during weight acceptance (Chuter & Janse de Jonge, 2012). Thus, while walking, the body weight is transferred to the medial side of the foot earlier, which can result in stress on medial foot structures including the plantar fascia, and also reduces the strength of primary foot and ankle muscles for ambulation, such as the gastrosoleus muscles (Bolgia & Malone, 2004; Sahrmann, 2002). Although our study did not find lower strength of ankle plantarflexors to be a significant predictor, individuals with PF had lower strength than healthy participants.

Theoretically, the ankle plantarflexors functioned during the propulsive phase to raise the medial longitudinal arch and supinate the subtalar joint that could enhance arch stability; the hip and knee were thus flexing and externally rotating to propel the body forward (Neumann, 2010). Weaker plantarflexors may lead to an insufficient concentric force generation for gait propulsion that could induce injuries within the kinetic chain of the lower extremity (Chuter & Janse de Jonge, 2012).

There is growing evidence for proximal and distal factors that might contribute to lower-extremity injury. In this view, each bony segment in the lower limb can be viewed as a rigid link with the connecting joints including the subtalar, ankle, knee, and hip joints (Chuter & Janse de Jonge, 2012). The current findings indicate poorer quality of movement at baseline in the PF group than in the non-PF group. The assessment of movement quality from the lateral step down test included the entire trunk and lower extremity. This suggested the possibility that an alteration of lower-extremity movement pattern, consisting of excessive adduction and medial rotation of the femur as well as the knee valgus, may overload weight-bearing activity and produce excessive medial rotation of the tibia and foot pronation, which could lead to the disruption of plantar fascia (Barwick, Smith, & Chuter, 2012; Chang et al., 2014). Despite there being a strong theoretical basis linking biomechanical dysfunction of the lower limb and foot function, information regarding the proposed mechanism of PF is needed to further determine the causal chain(s) that can lead to PF. Such analysis could potentially come from research using motion analysis.

Furthermore, the present study identified an association between lower baseline exercise activity level and the development of PF. This finding is in line with previous prospective research investigating overuse injuries in young conscripts (Taanila et al., 2015). It confirms physical activity level as a key predictor of the development of various overuse injuries during military training. Exercising on a regular basis can promote health and tissue resilience through changes in adipose tissue content and contracting skeletal muscles. The balance between the amounts of visceral adipose tissue and duration and intensity of contracting skeletal muscle may improve muscular function and lipid metabolism (Silverman & Deuster, 2014). Whereas, physical inactivity is

typically associated with an accumulation of visceral fat mass, which leads to poor musculoskeletal and cardiorespiratory fitness (Bonney, Ferguson, & Smits-Engelsman, 2018; Silverman & Deuster, 2014). In accordance with the present study, the result demonstrated a higher risk of PF among the conscripts with higher BMI at baseline. A systematic review also reported BMI as a significant factor concurrently associated with the presence of PF (Martin et al., 2014). Individuals who are overweight or obese are two to six times more likely to also have PF, respectively (Riddle et al., 2003). Through the use of a prospective longitudinal design, the current findings provide stronger support for the causal influence of BMI on the development of PF. Individuals with higher BMI might continually experience a vicious cycle of reduced lower extremity muscle strength, low cardiorespiratory fitness, and physical inactivity that would have a detrimental impact on musculoskeletal health (Bonney et al., 2018).

Moreover, psychosocial factors appear to play an important role for the development of PF (Cotchett, Whittaker, & Erbas, 2015; Werner et al., 2010). The present study identified baseline stress as a psychological risk factor for the development of PF. Previous cross-sectional research in factory workers similarly found job dissatisfaction to be a social risk factor for the development of PF (Werner et al., 2010). Another cross-sectional study investigating the impact of depression, anxiety, and stress on foot pain scores from the foot health status questionnaire (FHSQ) among the patients with PF found that depression and perceived stress were the significant predictors of foot pain, although anxiety was not associated with foot pain in their model (Cotchett et al., 2015). In general, psychological symptoms have been identified as key causes of detrimental impacts on functional status and physical fitness (Taanila et al., 2015). There are direct interactions between the brain, perceptions, emotional reactions, and the body that influence physical function and symptom expression in each person (Sullivan & Hudson, 2017).

The current study has some limitations that should be considered when interpreting the results. For example, the participants in this study were novice conscripts (i.e., young otherwise healthy men) who underwent a specific course of vigorous physical activity. Thus, the results may or may not generalize to other populations, such as women, older individuals, and more experienced military personnel. Replication of the current findings in other populations would be needed to determine their generalizability. Apart from this, a priori sample size estimation suggested that at least 146 conscripts were needed to achieve medium effect size and 80% power from the regression analysis (Cohen, 1988). However, the current sample size was 113 participants, indicating a quite small sample size; this must be kept in mind while interpreting the results.

Despite these weaknesses, the current study also has important strengths. Primary among them is the use of a longitudinal prospective predictive design, which allows for the ability to draw causal conclusions regarding the predictors that could contribute to the development of PF. Moreover, to our knowledge, it is the first study to evaluate the influence of psychological symptoms, proximal region, and quality of movement from the lateral step down test to the incidence of PF. As a result, we were able to identify a number of predictors that included both anatomical and psychosocial predictors related to the development of PF.

The findings have important implications for both clinical practice and future research. They provide an empirically based guide for screening novice conscripts who may be at the greatest risk for developing PF before beginning of military training. Also, as the level of physical exercise and BMI were both found to be associated with greater risk, novice conscripts could be told to both (1) increase their physical fitness and (2) lower their BMI before

attending the military program. Future research to investigate the quality of neuromuscular function of muscles involved in the lateral step down movement is needed. The results of such studies may possibly provide benefits to reduce the incidence of PF during military training.

5. Conclusion

In conclusion, the results indicated that conscripts with poorer quality of movement from the lateral step down test were twice as likely to exhibit PF. The conscripts with a lower femoral anteversion angle were at increased risk of presenting with PF. In terms of individual components, the conscripts with a higher BMI and higher stress level were at increased risk of PF. In addition, the conscripts with a higher physical exercise level before the military program had a reduced risk of presenting with PF. These findings provided information regarding the risk predictors for PF, which would be useful for preventing overuse injuries of the lower extremities, especially from a military training program. Both prevention and treatment programs should consider the importance of proximal structure and psychological factors to achieve a better outcome.

Authors' contributions

PH, SB, and PP: (1) Substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data. (2) Drafting the article or revising it critically for important intellectual content. (3) Final approval of the version to be published. (4) Taking public responsibility for its content.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ptsp.2018.10.004>.

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