

# Incidence and risk factors of medial tibial stress syndrome: a prospective study in Physical Education Teacher Education students

Sander Blienkendaal,<sup>1</sup> Maarten Moen,<sup>2</sup> Young Fokker,<sup>1</sup> Janine H Stubbe,<sup>3,4,5</sup> Jos Twisk,<sup>6</sup> Evert Verhagen<sup>7,8,9</sup>

**To cite:** Blienkendaal S, Moen M, Fokker Y, *et al*. Incidence and risk factors of medial tibial stress syndrome: a prospective study in Physical Education Teacher Education students. *BMJ Open Sport & Exercise Medicine* 2018;**4**:e000421. doi:10.1136/bmjsem-2018-000421

Accepted 29 August 2018

## ABSTRACT

**Objective** Medial tibial stress syndrome (MTSS) is a common lower extremity overuse injury often causing long-term reduction of sports participation. This study aimed to investigate the incidence and risk factors of MTSS in first-year Dutch Physical Education Teacher Education (PETE) students.

**Methods** This prospective study consisted of physical measures at baseline (height, weight, fat percentage, 3000 m run test, navicular drop test, hip internal and external range of motion, hip adduction and adduction strength, single leg squat and shin palpation), an intake questionnaire at baseline (age, sport participation, presence of MTSS, MTSS history, insole use and use of supportive shoes) and an MTSS registration procedure during the academic year of 2016–2017 (10 months) using a validated questionnaire. In total 221 first-year PETE students were included, of whom 170 (77%) were male and 51 (23%) female. The evaluation of risk factors was conducted with univariable and multivariable logistic generalised estimating equation analyses.

**Results** In total 55 (25%) subjects, 35 (21%) men and 20 (39%) women, developed MTSS during the follow-up period. The associated risk factors were female sex (OR=3.14, 95% CI 1.39 to 7.11), above-average age (OR=0.31, 95% CI 0.13 to 0.76), above-average body mass index (OR=2.29, 95% CI 1.02 to 5.16) and history of MTSS (OR=5.03, 95% CI 1.90 to 13.30).

**Conclusion** The incidence of MTSS is high in PETE students. Several risk factors were identified. These results demonstrate the need for prevention and may provide direction to preventive intervention design.

## INTRODUCTION

Medial tibial stress syndrome (MTSS) is one of the most common lower extremity injuries.<sup>1</sup> It is induced by weight-bearing activities, like running or jumping, and characterised by pain on the posteromedial border of the tibia.<sup>2</sup> Incidence rates of 7%–35% are reported in military personnel,<sup>3–5</sup> 14%–20% in runners<sup>1</sup> and 20% in female Physical Education Teacher Education (PETE) students.<sup>6</sup> Usually, MTSS leads to a prolonged period

## What are the new findings?

- ▶ This is the first study on the incidence and risk factors of medial tibial stress syndrome (MTSS) in male and female Physical Education Teacher Education students.
- ▶ We found a substantially higher incidence of MTSS in women (39%) compared with men (21%).
- ▶ Female sex, below-average age, above-average body mass index and history of MTSS are associated with an increased risk of developing MTSS.

of physical complaints and a reduced ability to participate in sports activities.<sup>7,8</sup> To design preventive measures, a profound insight into, preferably modifiable, factors that are associated with an increased risk of developing MTSS is needed.<sup>9</sup>

Several intrinsic risk factors for MTSS have been identified in review studies. The most significant risk factors are female sex,<sup>2, 10, 11</sup> history of MTSS<sup>11</sup> and higher navicular drop.<sup>2, 10–13</sup> Other significant risk factors are high body mass index (BMI),<sup>2, 11–13</sup> increased weight,<sup>10</sup> high plantar flexion range of motion (ROM),<sup>12, 13</sup> high hip external ROM,<sup>2, 10–13</sup> lower internal rotation ROM,<sup>2</sup> lower calf girth,<sup>2</sup> previous running injury,<sup>10</sup> running experience<sup>11</sup> and orthotic use.<sup>11</sup> Numerous other potentially relevant factors have been investigated for their association with MTSS, including shin pain at palpation, shin oedema, knee varus-valgus, running performance and sports participation.<sup>11</sup> However, the literature is not consistent on the significance of the above risk factors.<sup>10</sup>

For a more indepth exploration of the risk factors, there is a need for more prospective studies.<sup>12</sup> The primary goal of this study was to investigate the incidence of MTSS in PETE students. The secondary goals investigated the significance of factors associated with an increased risk for developing MTSS,



© Author(s) (or their employer(s)) 2018. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

**Correspondence to**  
Sander Blienkendaal; s.  
blienkendaal@hva.nl

including sex, BMI, length, weight, fat percentage, age, MTSS history, shin pain at palpation, shin oedema, navicular drop, hip ROM, hip strength, knee varus-valgus, running performance and sport participation.

## METHODS

### Subjects

All subjects were first-year bachelor's degree PETE students at the Amsterdam University of Applied Sciences. Apart from theoretical courses, the PETE programme consists of six different sports courses (gymnastics, field sports, martial arts, dance, athletics and swimming) with a weekly curricular exposition of approximately 11.5 hours. In total 285 students were invited to participate in the study during the academic year of 2016–2017.

### Study procedure

A prospective study design was used with baseline measures (April–June 2016) and a 10-month follow-up period during the academic year of 2016–2017. Before the baseline measures, subjects were informed about the study procedures and were asked to complete an intake questionnaire and an informed consent. Information was obtained about sex, age, presence of MTSS, MTSS history, insole use, shoe type and participation in sports with high running and jump loads.

Baseline measures consisted of a necessary selection procedure and medical screening and an additional physical screening regarding this study. The selection procedure included a 3000 m running test supervised by teachers of the PETE programme. The medical screening included measurements of length (cm), weight (kg), BMI and fat percentage (%), and was conducted by sports physicians. The additional physical screening on the potential factors associated with MTSS was performed by bachelor's degree Physical Therapy (PT) students who were trained by an experienced physical therapist (YF). This screening consisted of the following tests:

*Navicular drop test* was conducted after marking the navicular prominence in a seated (non-weight-bearing) position with the feet in shoulder width. The distance between the floor and the marked navicular prominence was measured in millimetres. After standing up (weight-bearing), without moving the feet, the measurement of the distance between the navicular prominence and the floor was repeated. The amount of drop for both feet was calculated by subtracting the seated score from the elevated score.<sup>14</sup>

*Hip internal and external ROM measurements* were conducted in a supine position with the hip and knee flexed to 90°. Each hip was internally and externally rotated to a firm feel. Angles were measured using a goniometer.<sup>15</sup> The procedure was executed twice, and the scores were averaged per hip.

*Hip adduction and abduction strength* were measured in a side-lying position using a hand-held dynamometer (HHD) (JTech PowerTrack Commander I) using a 5 s break-test procedure.<sup>16</sup> Before the test, the placing for

the HHD was determined by marking 8 cm above the lateral and medial malleolus. The tested leg was held at a 0° angle, while the other leg was held at a 90° angle. Subjects were instructed to hold on to the side of the examination bed with their hands for stabilisation and to perform the test with maximal effort. The procedure was executed twice, and the scores were averaged per hip. An adduction:abduction ratio was calculated by dividing the average adduction score by the average abduction score.

*Single leg squat test* was conducted to determine varus or valgus angles. White markers (6) were placed at the spina iliaca anterior superior (SIAS), the greater trochanter, the lateral and medial femoral condyle, and the lateral and medial malleoli. Subjects were instructed to execute the single leg squat with their arms crossed in front of their chest with their hands on the shoulder, remain their knees in parallel and their vision forward. To provoke a natural execution of the squat, no technical instructions were given. After a series of practice squats, the squat test was executed twice for both legs and recorded on video (iPad Mini, Apple, California, USA) in the frontal and sagittal planes. Videos were synchronised (Dartfish V.7, Alpharetta, Georgia, USA), and the knee angle (varus-valgus) and the squat angle were determined (Kinovea V.0.8.15) at the lowest squat position or the lowest position that the SIAS marker was visible. The results from the two consecutive squats were averaged per knee. Two-dimensional evaluation of the single leg squat knee angles has good reliability.<sup>17</sup>

*Shin palpation for pain and oedema* was conducted with the subject supine and the knee flexed in 90° and the foot on the examination bed. Place of palpation was determined by marking two-thirds of the distal medial surface of the tibiae. Presence of pain was assessed by palpating the posteromedial border of the tibia, and presence of pitting oedema was assessed by a 5 s hold of the medial tibial surface.<sup>18</sup>

### Follow-up

During the follow-up period, subjects were asked to complete an MTSS registration form every five curricular weeks, in total on seven occasions. MTSS was defined as an exercise-induced pain at the medial side of the tibia.<sup>5</sup> The registration form included the Dutch version of the MTSS score questionnaire, designed and validated by Winters *et al* (2016). The questionnaire contained an entry question regarding the presence of MTSS on the left leg, the right leg or both legs. When MTSS was indicated, the nature of the complaints had to be specified in four questions with four answer options: (1) limitations for participating in sporting activities (no limitations - no participation); (2) pain while performing sporting activities (no pain - unable to exercise); (3) pain during walking (no pain - unable to walk); and (4) pain at rest (no pain - very painful). Based on the answers an MTSS severity score (scale: 0–10, with 0 indicating no complaints and 10 indicating maximal complaints) was calculated.<sup>19</sup>

## Data analysis and statistics

Subjects were included in the study when (1) at least three follow-up questionnaires were completed, and (2) only one or two questionnaires were completed, but with the indication of MTSS in at least one questionnaire. Legs with an MTSS severity score equal or higher than 1 in one or more of the follow-up questionnaires were considered as MTSS legs. Baseline test results were presented in mean and SD for continuous variables and numbers and percentages in dichotomous variables. Continuous data from men and women were combined after dichotomising the data as higher and lower than average for men and women separately. The association between the potential risk factors and MTSS was analysed at the leg level using logistic general estimating equation (GEE) analysis. GEE was used to take into account the dependency of the observations of the two legs within the subject. Both univariable and multivariable logistic GEE analyses were performed. Only variables with a p value lower than 0.20 in the univariable analysis were included in the multivariable analysis. P values smaller than 0.05 were considered significant. All statistical tests were performed with IBM SPSS V.24.

## RESULTS

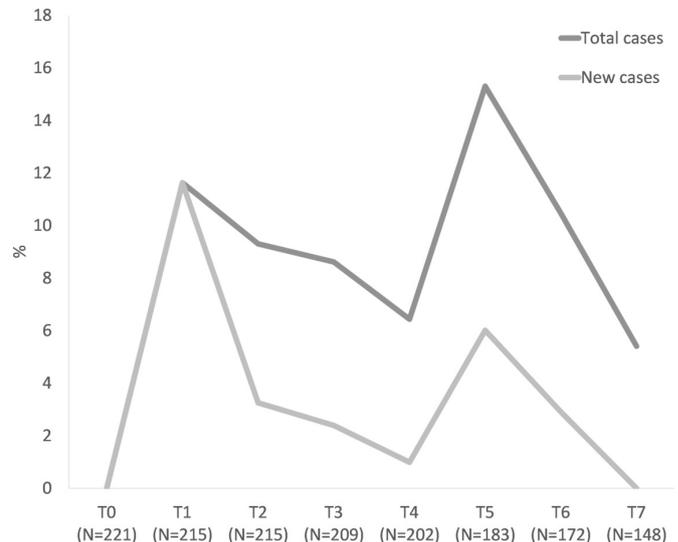
In total 285 subjects enrolled in the study. All of these subjects volunteered to participate in the study. Several subjects had MTSS at the time of administrating the intake questionnaire. This led to the exclusion of 16 subjects. The fact that some subjects completed less than three injury registration questionnaires and did not develop MTSS led to the exclusion of 48 other subjects. Therefore, a total of 221 subjects, 170 (77%) men and 51 (23%) women, were included in the data analysis.

The 221 included subjects returned 1344 filled in questionnaires, indicating a response of 87%. In 130 (10%) questionnaires, an MTSS score equal or higher than 1 was found. These MTSS complaints had a mean severity score of 2.7 (median=2.0, IQR=2). **Table 1** presents the results from the MTSS score questionnaires. These results indicate that in 35% of the cases sports participation was reduced, in 88% pain during sports participation was present, in 51% pain while walking was present, and

**Table 1** Answer distribution of the medial tibial stress syndrome registration form (n=130)

Item number	Item name	Answer option, n (%)			
		1	2	3	4
1	Current sporting activities	84 (65)	36 (28)	6 (5)	4 (3)
2	Pain during sporting activities	16 (12)	95 (73)	15 (12)	4 (3)
3	Pain while walking	64 (49)	58 (45)	8 (6)	0 (0)
4	Pain at rest	57 (44)	67 (52)	4 (3)	2 (2)

Answer option number 1 corresponds to no limitations, and option number 4 corresponds to maximal limitations.



**Figure 1** Incidence (new cases) and prevalence (total cases) of the medial tibial stress syndrome before the start of the year (T0) and during the follow-up period (T1–T7).

in 56% pain at rest was present. Unilateral and bilateral complaints were found in, respectively, 27% (12% only left and 15% only right) and 73% of the cases.

During the follow-up period, 55 (25%) subjects, 35 (21%) men and 20 (39%) women, suffered from MTSS. **Figure 1** shows the development of MTSS during the follow-up period, indicating a substantial increase of MTSS after the first weeks of the PE programme and a fluctuating incidence (range: 0%–12%) and prevalence (range: 5%–15%) during the follow-up period. The subjects indicated MTSS on one to seven occasions in, respectively, 40%, 26%, 13%, 9%, 7%, 4% and 1% of the cases.

The baseline characteristics of legs with and without MTSS are shown in **table 2** for men and women separately. In univariable analysis, the following factors were significantly associated with the development of MTSS: female sex, history of MTSS, above-average hip exorotation ROM, use of supportive shoes and shin oedema (**table 3**). In multivariable regression analysis, the following variables were found to be associated with the development of MTSS: female sex, below-average age, above-average BMI and history of MTSS (**table 3**).

## DISCUSSION

The main findings of this study are first that we found a high incidence of MTSS in our PETE students, in particular in female students. Second, female sex, below-average age, above-average BMI and history of MTSS are associated with an increased risk for the development of MTSS.

### Comparisons with the literature

With an MTSS incidence of 25%, specifically 21% in men and 39% in women, we found relatively high results compared with other studies. Verrelst *et al*<sup>6</sup> found an MTSS incidence of 20% in female PETE students (n=81) during a follow-up period of 29 weeks.<sup>6</sup> Sharma

**Table 2** Descriptives for baseline measures for control legs and MTSS legs

Variables	Male legs (n=340)		Female legs (n=102)	
	Control (n=280)	MTSS (n=60)	Control (n=62)	MTSS (n=40)
<b>Continuous variables</b>				
Age (years, SD)	19.8 (2.4)	19.1 (1.8)	18.8 (1.3)	18.4 (1.5)
Height (cm, SD)	183.7 (6.8)	183.0 (6.1)	171.8 (6.4)	170.9 (7.1)
Weight (kg, SD)	74.6 (9.9)	73.5 (7.7)	63.5 (9.1)	64.3 (6.1)
BMI (kg/height <sup>2</sup> , SD)	22.1 (4.5)	21.9 (1.9)	21.4 (2.7)	22.6 (2.2)
Fat (% , SD)	13.6 (4.4)	12.9 (3.8)	25.2 (3.5)	26.4 (4.7)
3000 m run (min:s, SD)	13:20 (1:22)	13:47 (1:44)	16:24 (1:40)	16:42 (1:44)
Hip exorotation ROM (°, SD)	61.6 (9.7)	62.9 (12.1)	64.4 (8.6)	65.5 (10.3)
Hip endorotation ROM (°, SD)	25.7 (9.2)	26.1 (9.1)	32.5 (9.9)	30.7 (8.5)
Hip strength adduction (n, SD)	182.9 (37.7)	184.6 (36.9)	134.3 (29.0)	136.5 (26.9)
Hip strength abduction (n, SD)	188.0 (41.8)	182.1 (36.9)	144.6 (25.1)	152.4 (28.3)
Hip adduction:abduction ratio (SD)	0.99 (0.16)	1.03 (0.20)	0.93 (0.12)	0.91 (0.14)
Navicular drop (mm, SD)	6.6 (3.1)	7.0 (3.1)	6.4 (2.8)	7.8 (3.5)
Squat knee angle (°, SD)	167.1 (10.1)	167.2 (9.7)	164.0 (8.4)	165.5 (11.3)
<b>Dichotomous variables</b>				
High jump/run sport (no, %)	37 (13)	13 (22)	8 (13)	8 (20)
MTSS history (yes, %)	20 (7)	14 (23)	6 (10)	10 (25)
Insole use (yes, %)	27 (10)	9 (15)	18 (29)	6 (15)
Supportive shoes (yes, %)	17 (6)	7 (12)	2 (3)	8 (20)
Shin pain (yes, %)	83 (33)	21 (38)	25 (43)	19 (48)
Shin oedema (yes, %)	42 (17)	14 (26)	15 (26)	11 (28)

BMI, body mass index; MTSS, medial tibial stress syndrome; ROM, range of motion.

*et al*<sup>4</sup> found an incidence of 8% in male recruits (n=468) during a 26-week training period.<sup>4</sup> Rauh *et al*<sup>3</sup> found an incidence of 7% in female Marine Corps recruits during a 13-week training period.<sup>3</sup> Yates and White<sup>20</sup> found an incidence of 35% in 124 naval recruits, 26% for men (n=84) and 45% for women (n=40), during a 10-week basis training programme. In runners incidence rates between 14% and 20% are reported during follow-up periods of 12 months.<sup>21–24</sup> Bennett *et al*<sup>22</sup> included 125 high school cross-country runners and found an incidence of 12% during an 8-week training programme. All the above-mentioned studies used a clinical diagnosis of MTSS. Except for the study of Yates and White<sup>20</sup>, all studies found a lower incidence compared with our study.

There are three major differences between these studies and our study. First, our study used self-evaluation of MTSS complaints, which may also be sensitive to several other injuries in the lower extremities (eg, tibial stress fracture, chronic exertional compartment syndrome, and muscle and tendon injuries).<sup>6</sup> Most studies in MTSS used clinical diagnosis of the MTSS, and this methodological difference helps to explain the lower incidence of MTSS in the literature compared with our study. We attempted to minimise self-evaluation errors by using a validated questionnaire<sup>19</sup> and a clear definition.<sup>5</sup> Nevertheless, the

self-evaluation procedure of MTSS complaints may be the primary explanation for the higher MTSS incidence in our study. Second, our study consists of a 10-month follow-up period, which is substantially longer than most of the previous studies. A longer follow-up period may be associated with higher incidence of MTSS. Third, most studies involve a different population (runners or militaries) compared with our study. The training regimens of these populations may be very different regarding training frequency, volume and type compared with the training regimens of PETE students.

Only one study, in militaries, found a higher incidence compared with our study.<sup>20</sup> The authors report a weekly physical activity of 16 hours and explain that this is relatively high for militaries. Also, that study is unique in the confidentiality of the diagnosis of MTSS, meaning that the subjects were probably more comfortable in coming forward with any complaints because there were no consequences of reporting this injury. The high weekly physical activity and the confidentiality may explain the higher incidence found in that study compared with other studies in militaries and our study.

Winters *et al*<sup>19</sup> is the single study in the literature that reports responses per item of the MTSS score questionnaire.<sup>19</sup> Their study shows that in MTSS-diagnosed patients

**Table 3** Results from univariable and multivariable GEE analyses

Variable	Univariate		Multivariate	
	OR (95% CI)	P values	OR (95% CI)	P values
<b>Subject variables</b>				
Sex (female)	3.01 (1.53 to 5.91)	<0.01**	3.14 (1.39 to 7.11)	<0.01**
Age (>mean)	0.54 (0.27 to 1.04)	0.07	0.31 (0.13 to 0.76)	0.01*
Height (>mean)	0.93 (0.49 to 1.79)	0.83		
Weight (>mean)	0.96 (0.51 to 1.83)	0.91		
BMI (>mean)	1.68 (0.89 to 3.23)	0.12	2.29 (1.02 to 5.16)	0.05*
Fat (>mean)	1.21 (0.63 to 2.35)	0.57		
3000 m run (>mean)	1.58 (0.79 to 3.18)	0.20		
High jump/run sport (no)	0.57 (0.26 to 1.26)	0.17	0.47 (0.17 to 1.29)	0.14
MTSS history (yes)	3.72 (1.63 to 8.50)	<0.01**	5.03 (1.90 to 13.30)	<0.01**
Insole use (yes)	1.15 (0.48 to 2.75)	0.76		
Supportive shoes (yes)	2.98 (1.11 to 7.98)	0.03*	2.65 (0.62 to 11.24)	0.19
<b>Leg variables</b>				
Hip exorotation ROM (>mean)	2.01 (1.06 to 3.81)	0.03*	1.89 (0.86 to 4.14)	0.11
Hip endorotation ROM (>mean)	1.22 (0.65 to 2.29)	0.54		
Hip strength adduction (>mean)	1.34 (0.71 to 2.52)	0.37		
Hip strength abduction (>mean)	1.06 (0.56 to 1.99)	0.86		
Hip adduction:abduction ratio (>mean)	0.96 (0.72 to 1.28)	0.79		
Navicular drop (>mean)	0.99 (0.65 to 1.50)	0.95		
Squat knee angle (>mean)	1.22 (0.93 to 1.59)	0.15	1.33 (0.93 to 1.91)	0.12
Shin pain (yes)	1.24 (0.66 to 2.33)	0.51		
Shin oedema (yes)	2.08 (1.08 to 4.01)	0.03*	1.92 (0.87 to 4.23)	0.11

\*P&lt;0.05, \*\*p&lt;0.01.

BMI, body mass index; GEE, general estimating equation; MTSS, medial tibial stress syndrome; ROM, range of motion.

(N=133), in 78% sports participation was reduced due to MTSS-related pain. Furthermore, the study shows that 97% of the patients reported pain during sporting activities, 69% reported pain while walking and 64% reported pain at rest. Our results are, respectively, 35%, 78%, 51% and 56%. This indicates that Winters *et al*<sup>19</sup> found a substantially higher severity of MTSS compared with our study. This can be explained by the fact that we used the MTSS score questionnaire to monitor complaints in a non-patient group. This logically leads to the inclusion of cases with mild MTSS. This principle is well documented in the literature.<sup>25</sup>

No studies regarding the risk factors of MTSS specifically in PETE students were found. A history of MTSS, with an OR of 5.03 (95% CI 1.90 to 13.30), is the most relevant risk factor in our study. Injury history is, in general, a robust risk factor for injuries in the literature.<sup>26-27</sup> This is also the case for MTSS.<sup>10-11</sup> Based on five prospective studies, Newman *et al*<sup>11</sup> report an overall OR of 3.74 (95% CI 1.17 to 11.91) for subjects with a history of MTSS to repeat occurrence of MTSS. Compared with this review study, our study found a relatively strong association between MTSS history and the reoccurrence of MTSS. However, ORs up to 18.3,<sup>28</sup> 20.0<sup>29</sup> and 30.0<sup>30</sup> can

be found in the literature. Therefore, our results are still in agreement with the literature.

Review studies report that women (athletes, runners and militaries) are more likely to develop MTSS compared with men by 2.35 (95% CI 1.58 to 3.50)<sup>10</sup> and 1.71 (95% CI 1.15 to 2.54)<sup>11</sup> times. Our study found a relative risk of 3.14 (95% CI 1.39 to 7.11) for the female sex, which is slightly higher but in agreement with the literature. It is unknown why women are more predisposed to develop MTSS. Newman *et al*<sup>11</sup> suggest that differences in running kinematics between men and women may be attributed to the increased risk for women.

Most review studies on the risk factors of MTSS report a significant relationship between a higher BMI and MTSS risk.<sup>10-13</sup> Our study found an OR of 2.29 (95% CI 1.02 to 5.16) for the group with an above-average BMI, which is consistent with the literature. An explanation for this finding is that a higher body weight relative to body height causes a relatively high mechanical loading to the tibia during weight-bearing activities.<sup>12</sup> When this frequently occurs during a prolonged period, the body is unable to recover appropriately, producing bony overload and adhering complications.<sup>12</sup>

Our study found conflicting results with the literature regarding age as a risk factor for developing MTSS. The literature consistently reports that age is not associated with an increased risk.<sup>10</sup> Our study found an OR of 0.31 (95% CI 0.13 to 0.76) for the above-average age group. Observations from practice are in line with this result. Therefore, this might be a specific risk factor in our PETE population. A rationale for this finding is that older students are more likely to sustain an acute lower extremity injury compared with younger students.<sup>31</sup> Older and injured students may be less actively involved in the sports programme and therefore less susceptible to developing MTSS. However, we lack data to support this rationale.

All the other risk factors in our study did not have a significant relationship with the development of MTSS in our PETE students. These include height, weight, fat percentage, running performance, sports participation, insole use, use of supportive shoes, hip exorotation ROM, hip endorotation ROM, hip adduction and abduction strength, hip adduction-abduction strength ratio, navicular drop, squat knee angle, shin pain at palpation, and shin oedema.

### Strengths and limitations

Our study has some limitations that need to be addressed. First, our study used a self-evaluation injury registration. This method may overestimate the actual incidence of MTSS. We attempted to minimise this effect by using a validated questionnaire and a precise definition. Second, our study managed to reach a response of 87%. The 13% missing may bias the results, underestimating the incidence of MTSS and the significance of the risk factors. Third, we did not control for sports exposition. Fourth, the physical screening test results may have limited reliability. Most of the conducted tests are well documented in the literature and have good reliability. However, we did not analyse inter-rater reliability during the training sessions. Thus, the results should be treated with care.

This study also had some strengths. First, we used a relatively large population compared with previous prospective studies, and we included both men and women. Second, we used a relatively extended follow-up period in comparison with most previous studies on MTSS.

### CONCLUSION

We conclude that MTSS is a substantial problem in our PETE population. The most relevant risk factors are female sex, below-average age, above-average BMI and history of MTSS. These results can be used for targeting preventive measures. Future studies should aim to investigate the validity of the MTSS score questionnaire regarding the detection of MTSS or incorporate clinical diagnosis of MTSS in the study. Furthermore, we suggest investigating the relation between sport exposition changes and the development of MTSS.

### Author affiliations

<sup>1</sup>Amsterdam University of Applied Sciences, Centre for Applied Research in Sports and Nutrition, Amsterdam, The Netherlands

<sup>2</sup>Onze Lieve Vrouwe Gasthuis (OLVG), Amsterdam, The Netherlands

<sup>3</sup>Codarts University of the Arts, Rotterdam, The Netherlands

<sup>4</sup>Performing Artist and Athlete Research Lab (PEARL), Rotterdam, The Netherlands

<sup>5</sup>Rotterdam Arts and Science Lab (RASL), Rotterdam, The Netherlands

<sup>6</sup>Department of Epidemiology and Biostatistics, VU University Medical Center, Amsterdam, The Netherlands

<sup>7</sup>Amsterdam Collaboration on Health and Safety in Sports & Department of Public and Occupational Health, Amsterdam Movement Science, VU University Medical Center, Amsterdam, The Netherlands

<sup>8</sup>UCT/MRC Research Unit for Exercise Science and Sports Medicine (ESSM) Department of Human Biology, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa

<sup>9</sup>School of Physical Education, Faculty of Physical Therapy & Occupational Therapy, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

**Acknowledgements** The authors would like to thank the PETE students for participating in this study. Furthermore, the authors thank Sander Plomp and the study counsellors of the first-year PETE programme for their contributions to the study.

**Contributors** SB, MM, YF and JS designed the study. SB and YF conducted the study. JT advised on statistical analysis. SB and EV drafted the manuscript. All authors edited and approved the final manuscript.

**Funding** The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

**Competing interests** None declared.

**Patient consent** Not required.

**Ethics approval** The study procedures were approved previously by the ethical committee of the Academic Medical Centre in Amsterdam (reference number: W14\_222# 14.17.0285) [31].

**Provenance and peer review** Not commissioned; internally peer reviewed.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

### REFERENCES

- Lopes AD, Hespanhol Júnior LC, Yeung SS, *et al.* What are the main running-related musculoskeletal injuries? A Systematic Review. *Sports Med* 2012;42:891–905.
- Moen MH, Tol JL, Weir A, *et al.* Medial tibial stress syndrome: a critical review. *Sports Med* 2009;39:523–46.
- Rauh MJ, Macera CA, Trone DW, *et al.* Selected static anatomic measures predict overuse injuries in female recruits. *Mil Med* 2010;175:329–35.
- Sharma J, Golby J, Greeves J, *et al.* Biomechanical and lifestyle risk factors for medial tibia stress syndrome in army recruits: a prospective study. *Gait Posture* 2011;33:361–5.
- Yates B, White S, Ben Yates SW. The incidence and risk factors in the development of medial tibial stress syndrome among naval recruits. *Am J Sports Med* 2004;32:772–80.
- Verrelst R, De Clercq D, Willems TM, *et al.* Contralateral risk factors associated with exertional medial tibial pain in women. *Med Sci Sports Exerc* 2014;46:1546–53.
- Moen MH, Bongers T, Bakker EW, *et al.* Risk factors and prognostic indicators for medial tibial stress syndrome. *Scand J Med Sci Sports* 2012;22:34–9.
- Moen MH, Holtslag L, Bakker E, *et al.* The treatment of medial tibial stress syndrome in athletes; a randomized clinical trial. *Sports Med Arthrosc Rehabil Ther Technol* 2012;4:12.
- van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med* 1992;14:82–99.
- Reinking MF, Austin TM, Richter RR, *et al.* Medial Tibial Stress Syndrome in Active Individuals: A Systematic Review and Meta-analysis of Risk Factors. *Sports Health* 2017;9:252–61.

11. Newman P, Witchalls J, Waddington G, *et al.* Risk factors associated with medial tibial stress syndrome in runners: a systematic review and meta-analysis. *Open Access J Sports Med* 2013;4:229–41.
12. Hamstra-Wright KL, Bliven KC, Bay C. Risk factors for medial tibial stress syndrome in physically active individuals such as runners and military personnel: a systematic review and meta-analysis. *Br J Sports Med* 2015;49:362–9.
13. Winkelmann ZK, Anderson D, Games KE, *et al.* Risk factors for medial tibial stress syndrome in active individuals: an evidence-based review. *J Athl Train* 2016;51:1049–52.
14. Bennett JE, Reinking MF, Rauh MJ. The relationship between isotonic plantar flexor endurance, navicular drop, and exercise-related leg pain in a cohort of collegiate cross-country runners. *Int J Sports Phys Ther* 2012;7:267–78.
15. Burne SG, Khan KM, Boudville PB, *et al.* Risk factors associated with exertional medial tibial pain: a 12 month prospective clinical study. *Br J Sports Med* 2004;38:441–5.
16. Thorborg K, Couppé C, Petersen J, *et al.* Eccentric hip adduction and abduction strength in elite soccer players and matched controls: a cross-sectional study. *Br J Sports Med* 2011;45:10–13.
17. Munro A, Herrington L, Carolan M. Reliability of 2-dimensional video assessment of frontal-plane dynamic knee valgus during common athletic screening tasks. *J Sport Rehabil* 2012;21:7–11.
18. Newman P, Adams R, Waddington G. Two simple clinical tests for predicting onset of medial tibial stress syndrome: shin palpation test and shin oedema test. *Br J Sports Med* 2012;46:861–4.
19. Winters M, Moen MH, Zimmermann WO, *et al.* The medial tibial stress syndrome score: a new patient-reported outcome measure. *Br J Sports Med* 2016;50:1192–9.
20. Yates B, White S. The incidence and risk factors in the development of medial tibial stress syndrome among naval recruits. *Am J Sports Med* 2004;32:772–80.
21. Lysholm J, Wiklander J. Injuries in runners. *Am J Sports Med* 1987;15:168–71.
22. Bennett JE, Reinking MF, Pluemer B, *et al.* Factors contributing to the development of medial tibial stress syndrome in high school runners. *J Orthop Sports Phys Ther* 2001;31:504–10.
23. Pileggi P, Gualano B, Souza M, *et al.* Incidência e fatores de risco de lesões osteomioarticulares em corredores: um estudo de coorte prospectivo. *Revista Brasileira de Educação Física e Esporte* 2010;24:453–62.
24. Jakobsen BW, Krøner K, Schmidt SA, *et al.* Prevention of injuries in long-distance runners. *Knee Surg Sports Traumatol Arthrosc* 1994;2:245–9.
25. Clarsen B, Bahr R. Matching the choice of injury/illness definition to study setting, purpose and design: one size does not fit all! *Br J Sports Med* 2014;48:510–2.
26. Meeuwisse WH, Tyreman H, Hagel B, *et al.* A dynamic model of etiology in sport injury: the recursive nature of risk and causation. *Clin J Sport Med* 2007;17:215–9.
27. Bahr R, Holme I. Risk factors for sports injuries—a methodological approach. *Br J Sports Med* 2003;37:384–92.
28. Garnock C, Witchalls J, Newman P. Predicting individual risk for medial tibial stress syndrome in navy recruits. *J Sci Med Sport* 2018;21:586–90.
29. Reinking MF, Austin TM, Hayes AM. Risk factors for self-reported exercise-related leg pain in high school cross-country athletes. *J Athl Train* 2010;45:51–7.
30. Hubbard TJ, Carpenter EM, Cordova ML. Contributing factors to medial tibial stress syndrome: a prospective investigation. *Med Sci Sports Exerc* 2009;41:490–6.
31. Blienkendaal S, Goossens L, Stubbe JH. Incidence and risk factors of injuries and their impact on academic success: A prospective study in PETE students. *Scand J Med Sci Sports* 2017;27:1978–85.