

The Comparison of Anatomic Alignment of the Shin, Ankle and Foot in Elite Runners with and without Medial Tibial Stress Syndrome

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Abstract

Introduction: The aim of this study was to examine the anatomic alignment of shin, ankle and feet in elite runners with and without medial tibial stress syndrome (MTSS). **Materials and methods:** The number of subjects employed in this study was 70 male elite runners who were divided into two groups: those with MTSS and a mean age of 25.9 ± 3.21 and the control group with a mean age of 25.3 ± 3.3 . They were investigated for plantar arch index (Staheli), navicular drop, ankle dorsi flexion, plantar ankle flexion, tibia vara and tibial torsion. Data were analyzed employing SPSS software, version 18 and independent samples t-test. **Results:** The results of data analysis revealed that there was a significant difference between the two groups in the mean navicular drop, dorsi flexion and tibial torsion, such that the rate of navicular drop in the affected group was higher than that of the control group ($P=0.011$). In addition, the affected group had limited dorsi flexion of the ankle ($P=0.048$) and low tibial torsion angle ($P=0.002$). However, there was no significant difference between the two groups in the mean plantar arch index (Staheli) ($P=0.428$), plantar flexion ($P=0.448$) and tibia vara ($P=0.672$) ($P>0.05$). **Conclusion:** According to the results of this study, abnormal plantar arch, dorsi flexion limitation and tibial torsion are imperative risk factors in the occurrence of MTSS, which can be forestalled with timely diagnosis of abnormalities and early intervention.

Keywords: Medial tibial stress syndrome, anatomic alignment, elite runner

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Introduction

Medial tibial stress syndrome (MTSS) is one of several injuries caused by excessive use of the lower extremity, which is commonly known as "shank pain" or "shin splints" (1). The medial tibial stress syndrome involves an increase in pain in two-thirds of the distal and posterior tibia (2-4). The highest prevalence rate of shin splint was reported among military forces (1). According to reports, the prevalence of this injury among runners is between 13.2 and 17.3 percent (1, 5). In a study, milgrom *et al.*, reported the prevalence of MTSS among 295 infantrymen to be 41% (6). Various studies have attempted to find the exact pathophysiology of the MTSS, but this has not been elucidated precisely (1). Until recently, tibial periostitis was considered to be the most likely cause of MTSS owing to

excessive traction (1). According to Yagi *et al.*, imaging studies have shown that bone marrow, bone periosteum and adjacent muscles may be injured in MTSS (7). Soleus and posterior tibia produce forces that can apply stress on fascia and tibial periosteum in the proximal bone during running (8, 9). Researchers have identified numerous risk factors for MTSS, including exercises on hard or non-uniform surfaces, incorrect practice techniques, increase in exercise intensity in the short term, shoe shifts, muscle imbalance, non-flexibility and biomechanical abnormalities (1). In addition, previous studies have investigated several other risk factors for MTSS such as increased foot pronation in standing position (1, 10, 11), high body mass index (BMI) (12, 13), female sex (1, 11, 14), increase in the range of motion of the plantar ankle flexion (12, 14) and decrease in the range of motion of the femoral anteversion (12).



Figure 1. Measurement of Foot Arches Index (Static)

The above-mentioned risk factors have not been consistent in all the studies conducted on MTSS, and most of the results are contradictory. Raeisi *et al.*, reported that there was a significant correlation between navicular drop and MTSS, but there was no significant correlation between MTSS and Q angle, the Achilles angle, the tibial angle, the distance of the inner condyles and medial tibial ankles, and lower extremity length. Neal *et al.* (15) and Chuter and Jonge (16) presented strong evidence to show that foot pronation is a risk factor for MTSS. Moen *et al.*, reported that body mass index, decrease in the range of motion of the femoral anteversion, positive navicular drop and an increase in plantar ankle flexion had a significant correlation with shin splint (12).

Regarding the sporting goals and the need for physical health among athletes as well as the consequences and costs of injury, identification of the factors associated with this injury is important in order to design preventive blueprints for the prevention of injury and application of corrective techniques. According to previous researches, different and limited anatomical, biomechanical, physiological factors and training variables have been employed in this type of study and only two to three variables have been used to compare the two study groups; but, the present study has attempted to eliminate the limitation of previous researches by taking into account the anatomical factor and the simultaneous measurement of the studied variables. On the other hand, in previous researches, a limited number of studies have been conducted on elite athletes, and most researches were carried out on military forces. For this reason, the present study is aimed at providing information on this risk factor for injury by comparing the anatomic alignment of lower extremities in runners with and without MTSS.

Materials and Methods

According to the goals and research content of the study, this was a descriptive and post-event comparative research. For this purpose, according to inclusion and exclusion criteria that included sampling only in the male group who fall within age

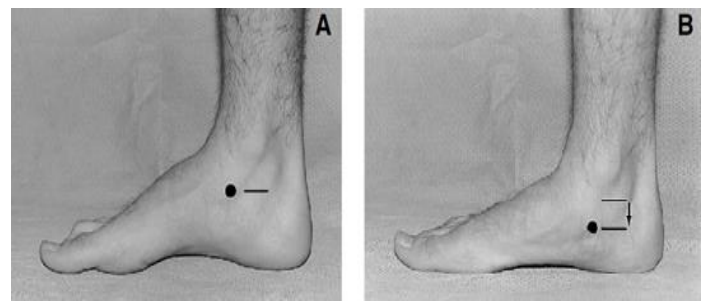


Figure 2. Navi Bone Drop Measurement

bracket of 20 to 30 years, being active in running, not being affected by injuries other than that induced by MTSS, and having at least three years' experience of regular physical activity (exercise). A total of 70 elite runners from the Premier League of Athletics were selected to participate in this study through targeted sampling. Then, 35 runners with MTSS were assigned to the case group and 35 runners without MTSS (healthy) to the control group. All participants in the study used a track and field court for practice and competition. Participants with MTSS were identified based on the pain history that persists from several hours to several days after exercise, the pain location, which is on the tibial posterior extending at least 5 centimeters and palpation that induces pain extension and non-uniform surface of the bone (1).

Depending on the diagnosis, people with pains for reasons other than those induced by MTSS were excluded from the study, such as compartment syndrome, stress fracture, as well as those with a history of surgery and fracture in the lower extremity. In addition, the presence of MTSS was confirmed by an orthopedist.

Measurement process

All measurements were performed by a researcher. Each of these measurements was performed three times by the researcher, and the average of the three measurements was recorded as the person's score. The variables investigated in this study included plantar arch index (Staheli), navicular drop, dorsi flexion, plantar flexion, tibia vara and tibial torsion.

The Staheli index was employed to measure the plantar arch of the subjects. First, talcum powder was sprinkled on a pre-prepared plate, and the subject was asked to walk as normal as possible from a few meters farther, and put his feet on it normally without paying attention to the plate. Thereafter, based on the footprint on the plate, the thinnest point of the plantar arch and the widest point of the heel of each foot were recorded and Staheli index was computed by dividing the thinnest point of the plantar arch by the widest point of the heel (Figure 1). The



Figure 3. Measuring tibia vara

natural range for this age group is between 0.44 and 0.89, and numbers higher than 0.89 were identified as flat foot and those lower than 0.44 as pes cavus. This index was presented by Staheli in 1987 and he has computed the criteria for different ages and genders (17, 18).

Navicular drop test was employed to determine the amount of foot pronation. First, the subject sat on the chair with his thigh and knees in a 90° flexion, his sole of foot on the ground and the subtalar joint in a neutral and relaxed position. The examiner palpated the navicular tuberosity and estimated the distance to the ground using a ruler. The subject was then asked to stand and open the legs to the width of the shoulder and place the body weight evenly on the two legs (weight bearing). Then, with re-palpation of the navicular tuberosity and its marking, the distance between the navicular bone and the ground was estimated. The difference between these two points was recorded in millimeters as the navicular drop level in the two positions (19) (Figure 2). The amount of navicular drop between 9 and 5 mm was considered as a normal foot, more than 10 mm as the foot pronation and less than 4 mm as the foot supination (20). The validity of this test was also reported at 0.94 (21).

In this study, the range of motion of the ankle dorsi flexion was estimated employing goniometer. For this purpose, the subject was asked to prostrate with the knees in the extension position and the ankle in a 90° position hanging from the edge of the examination table. The fibula tip, the fifth bone of the sole



Figure 4. Measuring Coarse Twist

of the foot and the ankle were marked as reference points. The goniometer center on the ankle was the fixed arm along the fibula tip, and the movable arm was along the fifth bone of the sole of the foot. The subject was then asked to actively perform the dorsi flexion motion (22). The validity of this technique has been reported at 0.80 (21). The range of motion of plantar ankle flexion was also estimated by the goniometer. To this end, the subject was asked to stand in a supine position, while the knees were in the extension position and the ankle in a 90° position hanging from the edge of the examination desk. The fibula tip, the fifth bone of the foot and the ankle were marked as the reference points. The goniometer center on the ankle was the fixed arm along the fibula tip, and the movable arm was along the fifth bone of the sole of the foot. The subject was then asked to actively perform a plantar flexion (23). The validity of this technique is 0.89 (21).

To measure the tibia vara, the subject was asked to stand on one leg and keep the fingers in contact with the ground, and look forward. Then, the examiner identified the line which divides the shin posterior part into two equal halves, and plotted the line from two-third of the upper shin to above the ankles. The angle between the line perpendicular to the measured surface and the plotted line was recorded as the tibia vara value (Figure 3) (24).

In this study, the thigh foot angle technique was employed to measure tibial torsion. The subject was placed in the prone position on the testing table and the knee joint was at 90° flexion, the center of the heel was marked at the plantar surface, and a line was drawn from this point to the middle of the foot and a line dividing the thigh into two halves was drawn. The intersection angle of these two lines was recorded as the tibial torsion angle (Figure 4) (25, 26).

Statistical analysis

The K-S statistical test was employed to determine the normality of the data. In order to compare the lower extremity variables in the

Table 1. Demographic specifications of the subjects (N=70)

Variable	Affected group	Control group	T	Df	P-value
Age (year)	25.9±3.21	25.3±3.23	0.69	68	0.48
Weight (kg)	70.5±7.62	69.7±7.51	0.48	68	0.62
Height (cm)	181.5±6.7	178.2±7.14	2.003	68	0.49
BMI	21.4±2.09	21.9±1.49	- 1.11	68	0.26

Table 2. Results of independent t-test, mean and standard deviation (M ± SD) of variables (N=70)

Variable	Affected group	Control group	T	Df	P-value
Plantar arch index (mm)	0.58±0.14	0.60±0.14	- 0.79	68	0.42
Navicular drop (mm)	13.4±4.16	10.8±4.30	2.60	68	0.01
Dorsi flexion (degree)	15.78±3.51	17.28±3.24	- 1.85	68	0.04
Plantar flexion (degree)	47.91±8.46	46.51±8.34	0.69	68	0.48
Tibia vara (degree)	9.56±2.95	9.30±2.02	0.42	68	0.67
Tibial torsion (degree)	6.98±3.02	9.35±3.17	- 3.20	68	0.002

group with MTSS and the control group, independent samples t-test was used. SPSS software, version 18 was employed to compute all statistical data. The 95% significance level with an alpha value less than or equal to 0.05 was considered throughout the study.

Results

Demographic information of the subjects is presented in Table 1. T-test results showed no significant difference between the affected and control groups in height, weight, age and body mass index ($P>0.05$). However, this difference was significant in height ($P<0.05$).

Table 2 shows comparison of the measured variables and independent samples t-test results between the two groups. As shown in the results, there was a significant difference between the two groups in the variables of navicular drop, dorsi flexion and tibial torsion ($P<0.05$) such that the subjects with MTSS had higher level of navicular drop, less tibial torsion angle and limitations on the range of motion of ankle dorsi flexion range. However, this difference was not significant in the plantar arch index, the range of motion of plantar flexion and tibia vara level ($P<0.05$).

Discussion

Regarding navicular drop rate, the results showed that the average of navicular drop in the affected group was higher than that of the control group, indicating a significant increase in foot pronation in the affected group ($P=0.011$). The results of this study are in consonance with the results of Moen *et al.*, (12). In a study conducted on 35 military forces, Moen *et al.*, (12) reported that BMI, reduced femoral anteversion, positive

navicular drop and increase in plantar ankle flexion had a significant correlation with MTSS. On the other hand, the results of the present study are not in consonance with the results of Rinking *et al.* (27). The inconsistent results can be attributed to the different research samples used. This is because in the study of Rinking *et al.*, high school athletes were used but the present study was conducted on elite runners (27). Excessive pronation has been identified as a risk factor for MTSS, as it may influence the distribution of loads in the lower extremities (28). Excessive foot pronation is the mechanism responsible for the loss of forces in the lower extremity by increasing the impact (28). Since the plantar arch is an important component for absorbing the reaction force of the ground during the stepping cycle, excessive pronation induced the intrinsic and extrinsic muscles to stay in eccentric contraction for a longer time. As a result, there is early onset of muscle fatigue, which can further increase the amount of absorbed proximal force on the periosteum and bone, and this can be a factor in the development of MTSS (29). In addition, according to the fascial stretch theory, since the increase in deformation of the inner longitudinal arch requires larger eccentric contractions by the plantar flexor muscles, it can increase the stress at the fascial joint site on the tibia leading to MTSS (30).

Regarding dorsi flexion, the results indicated that the mean dorsi flexion in the affected group was lower than that of the control group, indicating the limitation of dorsi flexion in the affected group ($P=0.048$). The stiffness of soleus and gastrocnemius muscles induced a decrease in the dorsi flexion range of motion (31). The dorsi flexion limitation produced more pressure and ultimately extended to the anterior part of the tibia, the site of muscle attachment on the bone. It is believed

that in individuals with dorsi flexion limitation, these fibers are impaired and have been established to be the primary cause of pain in MTSS (32). According to Thacker *et al.*, most physicians believe that the weakness of soleus muscle is in some way responsible for this injury; also, the body cannot quickly reconstruct bone among training sessions (33). This role of soleus muscle and lack of bone regeneration among training sessions may enervate the muscle and bone and reduce the ability of these two tissues to absorb the applied forces; this force is applied to the bone periosteum, which can lead to MTSS. It has also been reported that the reduction of the ankle dorsi flexion in people with leg and ankle injuries shows that the stiffness of soleus and gastrocnemius muscles disrupts the foot and ankle mechanical performance. In addition, the results of this study showed that non-flexible gastrocnemius muscle induced the restriction of dorsi flexion, which can lead to subtalar joint pronation, stressed tissue and eventually, MTSS (34).

Regarding tibial torsion angle, the results showed that the mean tibial torsion in the affected group was lower than that of the control group ($P=0.002$). The results of this study are inconsistent with the results of Baluchi *et al.* (29). The inconsistent results of this research can be attributed to the technique used for determination of the tibial torsion, because in the study of Baluchi *et al.*, the CT scan technique was used to estimate the tibial torsion (29). Based on the kinematic chain theory, the change of the anatomical state of each part of the body affects its adjacent sections and joints. Tibial torsion is usually associated with bony structures and since tibial torsion is associated with the torsion of the knee and ankle joints, the activity of the muscles changes as well (35). According to the results of this study, individuals with MTSS who had lower tibial torsion than the control group had higher toe-in during running (21). When running and walking with natural toe-out, the axial pressure driven by the movement is directed toward the desired direction but this axial pressure is inclined in toe-in and there may be other problems such as muscle imbalance. The muscle imbalance and frailty, and shortness of a group of other muscles lead to inordinate pressure on the bone periosteum, which can predispose a person to MTSS (34). Based on the kinematic chain system, the orthopedic disorder or anomaly developed in one part of the body is transferred to other parts and affect those parts (35). Consequently, people with excessive pronated foot undergo a change in positions such as tibial anteversion and increase in Q angle, and many of them have increased thigh anteversion (35). People with pronation syndrome have predictable patterns of injury including plantar fasciitis, shin splint, patellar tendonitis and back pain (35).

Regarding plantar arch index, plantar flexion and tibia vara level, the results of the study did not show any difference between the two groups ($P>0.05$). These results are possibly due to the lack of effect of these factors on the prevalence of MTSS.

Based on the results of this research, it is suggested that before exercises, heel alignments of the lower extremities be investigated in athletes. In the case of an abnormality, it should be corrected as much as possible. Since injury itself may induce an anatomic limb alignment, it is recommended that team physicians should design and execute appropriate rehabilitation programs so that the secondary abnormalities in the individual caused by muscle frailty and shortness can be prevented.

Conclusion

Since the results of this study showed that increased foot pronation, limited dorsi flexion range of motion and reduction of tibial torsion angle in runners with MTSS were higher than those in the control group, soft tissue around the joints is enervated due to heel anatomic alignment and biomechanical changes in the lower extremity joints. This could lead to a decrease in load absorption by the muscles and tissues, which is the primary cause of periostitis, eventually culminating in MTSS. Based on these results, a preventive approach should be adopted to deal with the MTSS before exercises and MTSS should be prevented by examining and controlling the knee joint, tight anteversion and range of motion in the runners as well as correcting heel alignments and disorders.

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Authors' contributions:

All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

References

1. Yates B, White S. The incidence and risk factors in the development of medial tibial stress syndrome among naval recruits. *The American journal of sports medicine*. 2004;32(3):772-80.
2. Fredericson M, Bergman AG, Hoffman KL, Dillingham MS. Tibial stress reaction in runners: correlation of clinical symptoms and scintigraphy with a new magnetic resonance imaging grading system. *The American journal of sports medicine*. 1995;23(4):472-81.

3. Sommer HM, Vallentyne SW. Effect of foot posture on the incidence of medial tibial stress syndrome. *Medicine and science in sports and exercise*. 1995;27(6):800-4.
4. Sobhani V, Shakibae A, Aghda AK, Meybodi MKE, Delavari A, Jahandideh D. Studying the relation between medial tibial stress syndrome and anatomic and anthropometric characteristics of military male personnel. *Asian journal of sports medicine*. 2015;6(2).
5. O'Connor FG, Wilder RP, Nirschl R. *Textbook of running medicine*: McGraw-Hill New York City; 2001.
6. Milgrom C, Giladi M, Stein M, Kashtan H, Margulies J, Chisin R, et al. Medial tibial pain. A prospective study of its cause among military recruits. *Clinical orthopaedics and related research*. 1986(213):167-71.
7. Yagi S, Muneta T, Sekiya I. Incidence and risk factors for medial tibial stress syndrome and tibial stress fracture in high school runners. *Knee Surgery, Sports Traumatology, Arthroscopy*. 2013;21(3):556-63.
8. Prentice WE. *Rehabilitation techniques in sports medicine*: WCB/McGraw-Hill Dubuque, IA, USA; 1999.
9. Beck BR, Osternig LR. Medial tibial stress syndrome. The location of muscles in the leg in relation to symptoms. *JBJS*. 1994;76(7):1057-61.
10. Bandholm T, Boysen L, Haugaard S, Zebis MK, Bencke J. Foot medial longitudinal-arch deformation during quiet standing and gait in subjects with medial tibial stress syndrome. *The Journal of foot and ankle surgery*. 2008;47(2):89-95.
11. Raissi GRD, Cherati ADS, Mansoori KD, Razi MD. The relationship between lower extremity alignment and Medial Tibial Stress Syndrome among non-professional athletes. *BMC Sports Science, Medicine and Rehabilitation*. 2009;1(1):11.
12. Moen M, Bongers T, Bakker E, Zimmermann W, Weir A, Tol J, et al. Risk factors and prognostic indicators for medial tibial stress syndrome. *Scandinavian. Journal of medicine & science in sports*. 2012;22(1):34-9.
13. Plisky MS, Rauh MJ, Heiderscheit B, Underwood FB, Tank RT. Medial tibial stress syndrome in high school cross-country runners: incidence and risk factors. *Journal of orthopaedic & sports physical therapy*. 2007;37(2):40-7.
14. Burne S, Khan K, Boudville P, Mallet R, Newman P, Steinman L, et al. Risk factors associated with exertional medial tibial pain: a 12 month prospective clinical study. *British journal of sports medicine*. 2004;38(4):441-5.
15. Neal BS, Griffiths IB, Dowling GJ, Murley GS, Munteanu SE, Smith MMF, et al. Foot posture as a risk factor for lower limb overuse injury: a systematic review and meta-analysis. *Journal of foot and ankle research*. 2014;7(1):55.
16. Chuter VH, de Jonge XAJ. Proximal and distal contributions to lower extremity injury: a review of the literature. *Gait & posture*. 2012;36(1):7-15.
17. Staheli LT, Chew DE, Corbett M. The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. *The Journal of bone and joint surgery American volume*. 1987;69(3):426-8.
18. Onodera AN, Sacco ICN, Morioka EH, Souza PS, de Sá MR, Amadio AC. What is the best method for child longitudinal plantar arch assessment and when does arch maturation occur? *The Foot*. 2008;18(3):142-9.
19. Brody D. Techniques in the evaluation and treatment of the injured runner. *The orthopedic clinics of north America*. 1982;13(3):541-58.
20. Cote KP, Brunet ME, II BMG, Shultz SJ. Effects of pronated and supinated foot postures on static and dynamic postural stability. *Journal of athletic training*. 2005;40(1):41.
21. Magee DJ. *Orthopedic physical assessment-E-Book*: Elsevier Health Sciences; 2014.
22. Venturini C, Ituassu N, Teixeira L, Deus C. Intrarater and interrater reliability of two methods for measuring the active range of motion for ankle dorsiflexion in healthy subjects. *Brazilian Journal of Physical Therapy*. 2006;10(4):407-11.
23. Rajabi R, Samadi H. *Laboratory manual of corrective exercise for post graduated students*. Tehran: University of Tehran. 9-42:(17)3;2008 .
24. Lohmann KN, Rayhel HE, Schneiderwind WP, Danoff JV. Static measurement of tibia vara: reliability and effect of lower extremity position. *Physical therapy*. 1987;67(2):196-9.
25. Uhorchak JM, Scoville CR, Williams GN, Arciero RA, Pierre PS, Taylor DC. Risk factors associated with noncontact injury of the anterior cruciate ligament. *The American journal of sports medicine*. 2003;31(6):831-42.
26. Kwon O, Tuttle L, Commeyan P, Mueller M. Reliability and validity of measures of hammer toe deformity angle and tibial torsion. *The Foot*. 2009;19(3):149-55.
27. Reinking MF, Austin TM, Hayes AM. Risk factors for self-reported exercise-related leg pain in high school cross-country athletes. *Journal of athletic training*. 2010;45(1):51-7.
28. Blackburn MH. A Prospective Design Identifying Etiological Risk Factors Associated with MTSS and Stress Fractures in Female Intercollegiate Athletes. 2002.
29. Balochi R, Naderi E, Ghiasi A. A survey of lower extremity alignment in the athletes affected by shin splint. *Applied Sport Physiology Research*. 2010;6(12):31-40.
30. Bouche RT, Johnson CH. Medial tibial stress syndrome (Tibial fasciitis) A proposed pathomechanical model involving fascial traction. *Journal of the American Podiatric Medical Association*. 2.6-31:(1)97;007
31. Oatis CA. *Kinesiology: the mechanics and pathomechanics of human movement*: Lippincott Williams & Wilkins Philadelphia; 2009.
32. Craig DI. Medial tibial stress syndrome: evidence-based prevention. *Journal of athletic training*. 2008;43.8-316:(3)
33. Thacker SB, Gilchrist J, Stroup DF, Kimsey Jr CD. The impact of stretching on sports injury risk: a systematic review of the literature. *Medicine & Science in Sports & Exercise*. 2004;36(3):371-8.
34. Bartosik KE, Silder M, Hillstrom HJ, Palamarchuk H, Huxel K, Kim E. Anatomical and biomechanical assessments of medial tibial stress syndrome. *Journal of the American Podiatric Medical Association*. 2010;100(2):121-32.
35. Solberg G. *Postural disorders and musculoskeletal dysfunction: diagnosis, prevention and treatment*: Elsevier Health Sciences; 2007.