Forefoot flexibility and medial tibial stress syndrome

Shintarou Kudo,1,2 Yasuhiko Hatanaka3
1 Graduate School of Health Science, Suzuka University of Medical Science, Japan
2 Department of Physical Therapy, Morinomiya University of Medical Sciences, Japan
3 Department of Physiotherapy, Suzuka University of Medical Science, Japan

Address correspondence and reprint requests to: Shintarou Kudo, Department of Physical Therapy, Morinomiya University of Medical Sciences, Japan. Email: kudo@morinomiya-u.ac.jp

INTRODUCTION

Medial tibial stress syndrome (MTSS) is caused by repetitive loading stress during running and jumping, and occurs in 4% to 35% of athletic and military populations.1–3 MTSS is associated with underlying periostitis of the tibia secondary to tibial strain as well as a spectrum of tibial stress injuries, including tendinopathy, periostitis, periosteal remodelling, and stress reaction of the tibia.4–7

The time to complete a running programme

ABSTRACT

Purpose. To investigate the association between medial tibial stress syndrome (MTSS) and morphology and flexibility of the foot arches.

Methods. 131 feet from 74 healthy subjects and 31 feet from 27 patients with MTSS were classified as normal feet (n=78 in 40 subjects), flat feet (n=53 in 34 subjects), or MTSS feet (n=31 in 27 patients). The medial longitudinal arch (MLA) ratio and the transverse arch length (TAL) were measured in both rearfoot and forefoot loading positions. The difference between the 2 positions indicated the flexibility of the MLA (diff–MLA ratio) and the transverse arch (diff-TAL).

Results. The MLA ratio was higher in normal feet than MTSS feet or flat feet (15.1% vs. 12.8% vs. 12.3%, p<0.001). The diff-TAL was lower in MTSS feet than normal feet or flat feet (0.4% vs. 0.8% vs. 0.9%, p<0.001). The 3 groups were comparable in terms of the diff–MLA ratio and the TAL. Respectively for the MLA ratio and the diff-TAL, the cut-off value was 11.9% and 0.61% based on the Youden index. The sensitivity, specificity, and odds ratio of the cut-off value were 0.4, 0.9, and 4.8 for the MLA ratio, and 0.6, 0.7, and 9.8 for the diff-TAL, respectively.

Conclusion. Decreased flexibility of the transverse arch and decreased MLA ratio are risk factors for MTSS. In contrast, the flexibility of the MLA and the height of the transverse arch were not risk factors for MTSS.

Key words: foot; medial tibial stress syndrome
in athletes with or without physiotherapy or compression stockings is similar.\(^8\) Physiotherapy should be based on the pathophysiology of each athlete.\(^9\) Individuals with MTSS are highly susceptible to re-injury, especially those with training errors, alignment abnormalities, or poor technique.\(^4\) Injury prevention should be taught to athletes, and rehabilitation should be customised.\(^9\)

Risk factors of MTSS may be extrinsic (training volume, training surface, shoes)\(^10\) or intrinsic (foot strike pattern). Rearfoot strike runners have a higher rate of repetitive stress injuries than forefoot strike runners.\(^11\) However, the forefoot strike pattern involves increased contact force of the knee and ankle, and greater plantar flexor muscle force and ankle movement.\(^12\) Thus, forefoot strike runners have better forefoot function to buffer the loading stress. Flat foot deformity is also an intrinsic factor of MTSS,\(^13-16\) but the association between flat foot and MTSS remains controversial,\(^17-22\) as is the association between atypical foot mechanics and running injury mechanics.\(^21\)

The foot consists of 3 arches: the medial longitudinal arch (MLA), the lateral longitudinal arch, and the transverse arch. The arch of the foot is flexible during loading and unloading to buffer the loading stress. Inadequate flexibility of the foot may result in foot and lower-extremity injuries.\(^23-25\) This study investigated the association between MTSS and morphology and flexibility of the foot arches.

**MATERIALS AND METHODS**

This study was approved by the ethics committee of our university. 131 feet from 74 healthy subjects and 31 feet from 27 patients with MTSS were classified by a physiotherapist or an orthopaedic surgeon as normal feet (n=78 in 40 subjects), flat feet (n=53 in 34 subjects), or MTSS feet (n=31 in 27 patients). According to the Foot Posture Index,\(^25\) normal foot was defined as 2.4±2.3,\(^26\) and flat foot as >4.7 with no lower-extremity pain. The diagnosis of MTSS was based on (1) continuous or intermittent pain in the medial tibial region, (2) exacerbated by repetitive weight-bearing activity, with localised soreness along the distal two-thirds of the posteromedial tibial crest, (3) no history of paraesthesia or other neurovascular symptoms indicative of other causes of leg pain, or stress fracture of the tibia, and (4) symptoms lasting for at least 2 weeks.

The foot posture was assessed while standing. The MLA ratio was the percentage of the height of the inferior border of the navicular from the floor divided by the foot length. The transverse arch length (TAL) was the percentage of the length from the first metatarsal head to the fifth metatarsal head divided by the foot length. The MLA ratio and TAL were measured in both rearfoot and forefoot loading positions.\(^27-29\) In the latter position, the foot extended forward one foot length, with the lower leg maximally inclined forward and both the hip and knee flexed without raising the heel; 70% to 80% of the body weight was loaded onto the forefoot.\(^28\) The difference between the rearfoot and forefoot loading positions indicated the flexibility of the MLA (diff–MLA ratio) and the transverse arch (diff–TAL).

Variables of the 3 groups were compared using the Kruskal-Wallis test with post hoc Bonferroni test. The cut-off value of significant variables were calculated. A p value of <0.05 was considered statistically significant.

|                        | Normal feet | Flat feet | MTSS feet | p Value |
|------------------------|-------------|-----------|-----------|---------|
| No. of left:right feet | 37:41       | 29:24     | 15:16     | 0.84    |
| No. of male:female     | 13:27       | 14:20     | 13:14     | 0.02    |
| Mean (range) age (years) | 20.0 (19.0-21.3) | 20.0 (19.0-22) | 16.0 (15.0-18.0) | <0.001 |
| Mean (range) height (cm) | 160.4 (157.5-170) | 160 (153.2-170) | 165.0 (155.6-170.0) | 0.09   |
| Mean (range) weight (kg) | 52 (47.4-62.7) | 55.0 (45.4-65.0) | 52.5 (48.0-57.5) | 0.69   |
| Mean (range) MLA ratio (%) | 15.1 (14.2-16.9) | 12.3 (11.8-13.0) | 12.8 (11.2-15.1) | <0.001 |
| Mean (range) diff-MLA ratio* (%) | 0.9 (0.5-2.1) | 0.9 (0.5-1.3) | 0.8 (0.4-1.3) | 0.09   |
| Mean (range) TAL (%) | 40.5 (39.5-41.6) | 40.6 (38.5-41.7) | 40.2 (38.5-40.9) | 0.44   |
| Mean (range) diff-TAL* (%) | 0.8 (0.6-1.1) | 0.9 (0.5-1.3) | 0.4 (0.1-0.6) | <0.001 |

* Difference between the rearfoot and forefoot loading positions
RESULTS

Baseline characteristics of the 3 groups were comparable, except that the MTSS group was younger than the other 2 groups (16 vs. 20 vs. 20 years, p<0.001, Table). The MLA ratio was higher in normal feet than MTSS feet or flat feet (15.1% vs. 12.8% vs. 12.3%, p<0.001). The diff-TAL was lower in MTSS feet than normal feet or flat feet (0.4% vs. 0.8% vs. 0.9%, p<0.001). The 3 groups were comparable in terms of the diff–MLA ratio and the TAL.

Respectively for the MLA ratio and the diff-TAL, the cut-off value was 11.9% and 0.61% based on the Youden index. The sensitivity, specificity, and odds ratio of the cut-off value were 0.4, 0.9, and 4.8 for the MLA ratio, and 0.6, 0.7, and 9.8 for the diff-TAL, respectively.

When the MLA ratio was <11.9%, the risk of MTSS increased 4.8 times. When the diff-TAL was <0.61%, the risk of MTSS increased 9.8 times. Both decreased flexibility of the transverse arch and decreased MLA ratio are risk factors for MTSS.

DISCUSSION

Greater navicular drop is associated with higher risk of MTSS.13,14,16,21 Subjects with a navicular drop >10 mm were 1.99 times more likely to develop MTSS.22 In our study, the MLA ratio did not differ significantly between MTSS feet and flat feet. Rather, the flexibility of the transverse arch was significantly lower in MTSS feet than normal feet and flat feet. Nonetheless, both the MLA and the transverse arch can affect MTSS.30 Forefoot strike runners have a decreased risk of running injuries because the muscles of the lower leg play a protective role,11,31 despite the increased contact force of the ankle and ankle movement during first half of the stance phase.12,32 We hypothesised that decreased forefoot flexibility increases ankle plantar flexion movement and mechanical stress of the leg. The TAL and diff-TAL reflect the structure and function of the transverse arch.27,28 The transverse arch involves the metatarsals and is maintained by static (deep transverse metatarsal ligaments) and dynamic (peroneus longus and adductor hallucis oblique head) stabilisers.23 Stiffness in these muscles and ligaments is caused by repetitive loading stress. A foot with decreased flexibility of the transverse arch cannot buffer loading stress, resulting in increased loading stress to the tibia. Moreover, decreased forefoot flexibility increases the mechanical stress to the tibial periosteal and the deep flexor fascia increases by increasing the activity of the tibialis posterior muscles, the flexor digitorum longus, and the soleus. Thus, decreased flexibility of the transverse arch (rather than the height of the arch) is a risk factor for MTSS.

There were limitations to this study. It was a cross-sectional design; subjects without MTSS at the time of testing could still have developed MTSS later. A prospective cohort design would increase the validity. This study focused on foot structure and function, although other intrinsic and extrinsic factors such as training volume and gender are also associated with development of MTSS. A prospective cohort study using multiple regression analysis is needed to investigate the risk factors of MTSS.

CONCLUSION

Decreased flexibility of the transverse arch and decreased MLA ratio are risk factors for MTSS. In contrast, the flexibility of the MLA and the height of the transverse arch were not risk factors for MTSS.

DISCLOSURE

No conflicts of interest were declared by the authors.

REFERENCES

1. Andrish JT, Bergfeld JA, Walheim J. A prospective study on the management of shin splints. J Bone Joint Surg Am 1974;56:1697–700.
2. Bennett JE, Reinking MF, Pluemer B, Pentel A, Seaton M, Killian C. Factors contributing to the development of medial tibial stress syndrome in high school runners. J Orthop Sports Phys Ther 2001;31:504–10.
3. Clanton TO, Solcher BW. Chronic leg pain in the athlete. Clin Sports Med 1994;13:743–59.
4. Beck BR. Tibial stress injuries. An aetiological review for the purposes of guiding management. Sports Med 1998;26:265–79.
5. Anderson MW, Ugalde V, Batt M, Gacayan J. Shin splints: MR appearance in a preliminary study. Radiology 1997;204:177–80.
6. Detmer DE. Chronic shin splints. Classification and management of medial tibial stress syndrome. Sports Med 1986;3:436–46.
7. 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. Am J Sports Med 1995;23:472–81.

8. Moen MH, Holtslag L, Bakker E, Barten C, Weir A, Tol JL, Backx F. The treatment of medial tibial stress syndrome in athletes: a randomized clinical trial. Sports Med Arthrosc Rehabil Ther Technol 2012;4:12.

9. Galbraith RM, Lavallee ME. Medial tibial stress syndrome: conservative treatment options. Curr Rev Musculoskelet Med 2009;2:127–33.

10. Thacker SB, Gilchrist J, Stroup DF, Kimsey CD. The prevention of shin splints in sports: a systematic review of literature. Med Sci Sports Exerc 2002;34:32–40.

11. Daoud AI, Geissler GJ, Wang F, Saretsky J, Daoud YA, Lieberman DE. Foot strike and injury rates in endurance runners: a retrospective study. Med Sci Sports Exerc 2012;44:1325–34.

12. Rooney BD, Derrick TR. Joint contact loading in forefoot and rearfoot strike patterns during running. J Biomech 2013;46:2201–6.

13. 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. J Foot Ankle Surg 2008;47:89–95.

14. Raissi GR, Cherati AD, Mansoori KD, Razi MD. The relationship between lower extremity alignment and medial tibial stress syndrome among non-professional athletes. Sports Med Arthrosc Rehabil Ther Technol 2009;1:11.

15. 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.

16. Rathleff MS, Kelly LA, Christensen FB, Simonsen OH, Kaalund S, Laesser U. Dynamic midfoot kinematics in subjects with medial tibial stress syndrome. J Am Podiatr Med Assoc 2012;102:205–12.

17. Busseuil C, Freychat P, Guedj EB, Lacour JR. Rearfoot-forefoot orientation and traumatic risk for runners. Foot Ankle Int 1998;19:12–7.

18. Wen DY, Puffer JC, Schmalzried TP. Lower extremity alignment and risk of overuse injuries in runners. Med Sci Sports Exerc 1997;29:1291–8.

19. Burne SG, Khan KM, Boudville PB, Mallet R, Newman PM, Steinman LJ, et al. Risk factors associated with exertional medial tibial pain: a 12 month prospective clinical study. Br J Sports Med 2004;38:441–5.

20. Lun V, Meeuwisse WH, Stergiou P, Stefanyshyn D. Relation between running injury and static lower limb alignment in recreational runners. Br J Sports Med 2004;38:576–80.

21. Ferber R, Hreljac A, Kendall KD. Suspected mechanisms in the cause of overuse running injuries: a clinical review. Sports Health 2009;1:242–6.

22. Newman P, Witchalls J, Waddington G, Adams R. 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.

23. Greisberg J, Sperber L, Prince DE. Mobility of the first ray in various foot disorders. Foot Ankle Int 2012;33:44–9.

24. McPoil TG, Warren M, Vicenzino B, Cornwall MW. Variations in foot posture and mobility between individuals with patellofemoral pain and those in a control group. J Am Podiatr Med Assoc 2011;101:289–96.

25. Redmond AC, Crosbie J, Ouvrier RA. Development and validation of a novel rating system for scoring standing foot posture: the Foot Posture Index. Clin Biomech (Bristol, Avon) 2006;21:89–98.

26. Redmond AC, Crane YZ, Menz HB. Normative values for the Foot Posture Index. J Foot Ankle Res 2008;1:6.

27. Kudou S, Hamajima K, Kaneiwa J, Hatanaka Y. Reliability of the transverse arch of the foot as an indicator of foot conditions. J Foot Phys Ther Sci 2012;24:335–7.

28. Kudo S, Hatanaka Y, Naka K, Ito K. Flexibility of the transverse arch of the foot. J Orthop Surg (Hong Kong) 2014;22:46–51.

29. Hamajima K, Kaneiwa J, Kudo S. Investigation of the measurement reliability of the medial longitudinal arch of the foot [in Japanese]. Rigakuryoho Kagaku 2012;27:177–80.

30. Willems TM, De Clercq D, Delbaere K, Vanderstraeten G, De Cock A, Witvrouw E. A prospective study of gait related risk factors for exercise-related lower leg pain. Gait Posture 2006;23:91–8.

31. Scott SH, Winter DA. Internal forces at chronic running injury sites. Med Sci Sports Exerc 1990;22:357–69.

32. Williams DS 3rd, Green DH, Wurzinger B. Changes in lower extremity movement and power absorption during forefoot striking and barefoot running. Int J Sports Phys Ther 2012;7:525–32.

33. Kelikian AS. Sarrafian’s anatomy of the foot and ankle descriptive, topographic, functional. Anatomy of the foot and ankle. 3rd ed. Philadelphia: JB Lippincott; 2011:34–9.