

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

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

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

in athletes with or without physiotherapy or compression stockings is similar.⁸ Physiotherapy should be based on the pathophysiology of each athlete.⁸ 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.

Table
Comparison of normal feet, flat feet, and medial tibial stress syndrome (MTSS) feet

	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 (19-21.3)	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) medial longitudinal arch (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) transverse arch length (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.³³ 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.

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