REVIEW ARTICLE

Update on the biomechanical aspects of the medial tibial stress syndrome

Junya SAEKI

Faculty of Rehabilitation, Osaka Kawasaki Rehabilitation University
Correspondence: Junya Saeki, PhD, RPT, Faculty of Rehabilitation, Osaka Kawasaki Rehabilitation University, 158 Mizuma, Kaizuka, Osaka 597-0104. E-mail: saekij@kawasakigakuen.ac.jp
Disclosure: The authors have no potential conflicts of interest to disclose.

Abstract
Medial tibial stress syndrome (MTSS) causes pain at the posteromedial edge of the tibia during running. As a prevalent running disorder, and it is important to take measures to prevent its onset and recurrence. The effectiveness of preventive interventions for MTSS has been widely studied, but evidence regarding the effectiveness of interventions is said to be very weak. It is therefore necessary to better understand the pathology of running disorders and the load on muscles caused by training, and to develop more accurate preventive measures. Focusing on MTSS as a representative running disorder, we reviewed the relationship between running disorders of the lower legs and the mechanical characteristics of the posterior muscles of the lower legs. The flexor digitorum longus muscle and the adjacent tibialis posterior muscle are stiff in runners with a history of MTSS. Additionally, the tibialis posterior muscle, which may be involved in the development of MTSS, is susceptible to injury regardless of whether shoes are worn.

Key words: *exercise-induced leg pain, shear wave elastography, tibialis posterior, flexor digitorum longus, muscle stiffness*

INTRODUCTION

The prevalence of running injuries in the lower legs is reported to be 20.1% (Kakouris, 2021), and after the knee joint, it is the second most common site of injury (Francis, 2019). Among these injuries, exercise-induced leg pain, including medial tibial stress syndrome (MTSS), is a prevalent running disorder (Kakouris, 2021). A prospective study on track and field athletes reported that it takes 44 to 78 days to return to competition after the onset of MTSS (Moen, 2014), suggesting the necessity of preventive measures. To date, many studies have investigated the effectiveness of interventions to prevent soft tissue injuries when running, such as wearing orthopedic insoles and properly stretching before training. However, evidence of the effectiveness of such intervention is said to be very weak (Yeung, 2011). It is therefore necessary to deepen understanding of the pathology of running disorders and the load on muscles caused by training, and to develop more accurate preventive measures. This article summarizes research on running disorders of the lower leg and the mechanical properties of the posterior muscles of the lower leg.

PATHOLOGY AND RISK FACTORS OF MEDIAL TIBIAL STRESS SYNDROME

MTSS, a typical disease of exercise-induced lower limb pain, is thought to be a microscopic injury at the junction between the medial tibia periosteum and fascia (Reshef, 2012). The T2 value of the medial tibia periosteum on MRI is reportedly increased in patients with MTSS (Moen, 2009). In addition, the elongational stress on the flexor digitorum longus, tibialis posterior and soleus tendon increase the stress on the medial periosteum of the tibia (Bouche, 2007). This stress is thought to be caused by repeatedly stretching the muscles of the lower leg. The onset of MTSS may therefore be related to mechanical characteristics, such as stiffness of the posterior crural muscles.

In a meta-analysis, reported risk factors for the development of MTSS were female sex, a history of MTSS, comparatively little running experience, high body mass index (BMI), large naval drop, and large hip external rotation range of motion (Newman, 2013). History of MTSS is cited as a risk factor for MTSS, so people with a past history are thought to have physical factors that make them more likely to have recurrence. Meanwhile, people with exercise-induced lower limb pain may have muscle spasms or muscle weakness due to pain. To examine the relationship between muscle mechanical properties and exercise-induced leg pain, it may be useful to conduct research on patients with a history of exercise.

TOE FLEXOR MUSCLES AND RUNNING DISORDERS

The fascia of the soleus muscle is attached to the posteromedial area of the tibia, so MTSS has been described as a soleus syndrome (Michael, 1985). The flexor digitorum longus muscle is reportedly attached to the middle or distal third of the tibia, a common site of MTSS, at a higher rate than the soleus muscle (Edama, 2017). Mechanical stress due to tension in the plantar flexor muscles of the toes may therefore be related to the onset of MTSS. The positional relationship between the anatomical attachment site of the posterior crural muscles and the common site of the medial tibial stress syndrome is shown in Figure 1. The relationship between ankle injury muscle strength and the development of MTSS has not reached consensus. A cross-sectional study reported that in people with MTSS, inversion muscle strength is relatively weaker than expulsion muscle strength (Yuksel, 2011). Conversely, a longitudinal study that prospectively examined risk factors for the development of MTSS reported no association between ankle joint muscle strength before MTSS and its actual onset (Hubbard, 2009). A suggested reason for this is that the ankle joint muscle strength is a combination of the actions of these three muscles; the ankle inversion muscles include the tibialis posterior, flexor hallucis longus, and flexor digitorum longus muscles.

Regarding the measurement of toe plantar flexor muscle strength, we reported the use of a newly-developed first and second to fifth metatarsophalangeal (MTP) joint plantar flexor muscle strength measuring device. The first MTP joint and the second to fifth MTP joints were found to have different force exertion characteristics of the plantar flexion, which are the actions of the flexor hallucis longus and flexor digitorum longus muscles (Saeki, 2021). Furthermore, regarding the relationship between toe plantarflexion strength and MTSS, we showed MTP joint plantarflexion strength to be higher in people with a history of MTSS (Saeki, 2017b). The flexor hallucis longus muscle, the main action muscle for plantar flexion of the first MTP joint, has the same action as the flexor hallucis longus and tibialis posterior muscles in the ankle joint, but it does not attach to the tibia. The flexor hallucis longus muscle is therefore unlikely to be the cause of pain on the medial side of the tibia. In patients with a history of MTSS, activity of the flexor hallucis longus muscle may be increased to avoid contraction of the flexor hallucis longus muscle, which attaches to the medial side of the tibia and can cause pain. Additionally, the center of foot pressure during walking in patients with MTSS shifts inward and follows a more linear trajectory than that of healthy individuals (Kinoshita, 2019). Furthermore, the maximum abduction moment during the stance phase of running in people with a history of MTSS is reportedly larger than in people without a history of MTSS (Ohmi, 2023). These biomechanical features led to an increase in the plantar flexor strength of the first toe.

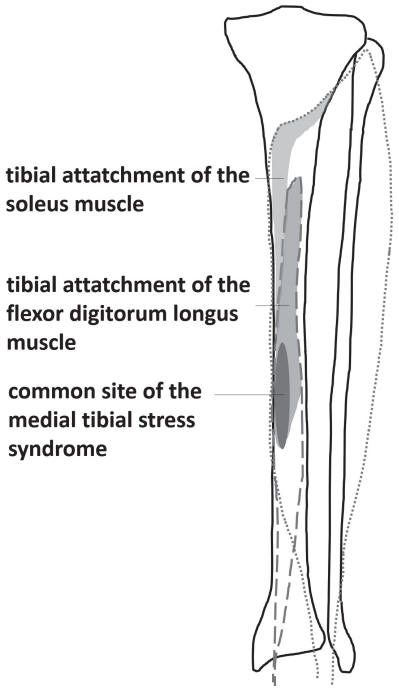

Figure 1. Positional relationship between the anatomical attachment site of the posterior crural muscles and the site where medial tibial stress syndrome frequently occurs.

MUSCLE STIFFNESS OF THE POSTERIOR MUSCLES OF THE LOWER LEG AND RUNNING DISORDERS

Elongational stress on the flexor digitorum longus, tibialis posterior, and soleus tendons increases periosteal stress on the medial side of the tibia (Bouche, 2007). Stiffness of these muscles may therefore be associated with the development of MTSS. Shear wave elastography has recently been used as an index to evaluate muscle stiffness (Hug, 2015). The elastic modulus of the posterior crural muscles can be measured with high reproducibility (Saeki, 2017a).

Regarding the relationship between muscle elasticity and MTSS using shear wave elastography, people with MTSS tend to have stiff muscles (high

shear elastic modulus) in their lower legs (Akiyama, 2016), but when there is pain, there is a possibility that the elastic modulus of the material is evaluated to be high because of the influence of muscle spasms. Elsewhere, a study examined the characteristics of the elastic modulus of muscles including the ankle incisor muscles in people with a history of MTSS who did not have pain at the time of measurement. The elastic modulus of the flexor digitorum longus and tibialis posterior muscles were found to be higher in people with a history of MTSS (Saeki, 2018). The flexor digitorum longus anatomically attaches to the common site of the MTSS, while the posterior tibialis muscle does not attach to the common site of the MTSS (Edama, 2017). However, tension is transmitted between adjacent muscles via the fascia (Yanas, 2021), so the stiffness of the flexor digitorum longus and tibialis posterior muscles may influence each other and be related to the development of MTSS. In addition, no significant difference was found in the elastic modulus of the soleus muscle, irrespective of whether or not a person had a history of MTSS (Saeki, 2019). However, there are gender differences in the stiffness and attachment sites of the soleus muscle, with soleus muscles in women tending to be stiffer than those of men (Saeki, 2019), and the attachment rate to MTSS-prone sites is higher (Nakamura, 2019). The relationship between gender differences in muscle stiffness and the development of MTSS still therefore requires attention.

Long-term stretching is a way to reduce muscle stiffness (Ichihashi, 2016). Stretching reportedly has no effect on MTSS (Pope, 2000), but previous studies have targeted the gastrocnemius and soleus muscles, and it is unclear whether stretching interventions for the flexor digitorum longus muscle can prevent MTSS. Future prospective studies should examine how the stiffness of the flexor digitorum longus and posterior tibialis muscles influences the development of MTSS.

WEARING SHOES AND RUNNING DISORDERS

Running disorders in the lower legs and feet are reported to be more common in barefoot runners who run without shoes compared with runners wearing normal running shoes (Altman, 2016). However, habitual barefoot running training can reportedly improve running performance (Altman, 2012), suggesting the effectiveness of incorporating barefoot running into training.

The elastic modulus calculated by shear wave elastography is also useful as an indicator of muscle damage (Lacourpaille, 2014). In an investigation of the effect of wearing shoes on the load on lower limb muscle groups caused by running, the vastus lateralis muscle was shown to be easily injured in shoe running, the peroneal muscle group was prone to injury in barefoot running, and the tibialis posterior muscle can become injured regardless of whether shoes are worn or not (Saeki, 2022). Another study at different running speeds reported that the elastic modulus of the flexor digitorum longus muscle, in addition to the tibialis posterior muscle, was increased after running with shoes (Ohya, 2017). The ease with which the load is applied to the flexor digitorum longus muscle is therefore thought to differ depending on the running speed.

Interestingly, running while wearing shoes has been suggested to increase the load on the vastus lateralis muscle, which is a knee joint extensor muscle (Saeki, 2022). The plantar contact pattern during running is different between barefoot running and shoe running (Sinclair, 2013), and rearfoot running places a greater mechanical load on the knee joint than forefoot running (Kulmala, 2013). The measures that should be taken to prevent running injuries (e.g. selective stretching) may therefore differ depending on the ground contact pattern.

CONCLUSION

In this article, we reviewed the relationship between running disorders of the lower legs and the mechanical characteristics of the posterior muscles of the lower legs. The flexor digitorum longus muscle is attached at a higher rate than the soleus muscle to the site where MTSS, a typical running injury, occurs in the lower leg. Additionally, the flexor digitorum longus muscle (which is attached to the most common site) and the adjacent tibialis posterior muscle are stiff in runners with a history of MTSS. Attention has often been focused on the soleus muscle as a preventive measure against the onset of running disorders in the lower legs, but it is necessary to focus on the stiffness of the flexor digitorum longus and posterior tibialis muscles. Additionally, the tibialis posterior muscle, which may be involved in the development of MTSS, is susceptible to injury regardless of whether shoes are worn, but there is change to the load placed on the muscle owing to changes in the plantar contact pattern caused by wearing shoes.

REFERENCES

Akiyama K, Akagi R, et al. Shear modulus of the lower leg muscles in patients with medial tibial stress syndrome. Ultrasound Med Biol 42 (8), 1779-1783, 2016

Altman AR, Davis IS. A kinematic method for footstrike pattern detection in barefoot and shod runners. Gait Posture 35 (2), 298-300, 2012

Altman AR, Davis IS. Prospective comparison of running injuries between shod and barefoot runners. Br J Sports Med 50 (8), 476-480, 2016

Bouche RT, Johnson CH. Medial tibial stress syndrome (tibial fasciitis): a proposed pathomechanical model involving fascial traction. J Am Podiatr Med Assoc 97 (1), 31-36, 2007

Edama M, Onishi H, et al. Gender differences of muscle and crural fascia origins in relation to the occurrence of medial tibial stress syndrome. Scand J Med Sci Sports 27 (2), 203-208, 2017

Francis P, Whatman C, et al. The proportion of lower limb running injuries by gender, anatomical location and specific pathology: a systematic review. J Sports Sci Med 18 (1), 21-31, 2019

Hubbard TJ, Carpenter EM, et al. Contributing factors to medial tibial stress syndrome: a prospective investigation. Med Sci Sports Exerc 41 (3), 490-496, 2009

Hug F, Tucker K, et al. Elastography for muscle biomechanics: toward the estimation of individual muscle force. Exerc Sport Sci Rev 43 (3), 125-133, 2015

Ichihashi N, Umegaki H, et al. The effects of a 4-week static stretching programme on the individual muscles comprising the hamstrings. J Sports Sci 34 (23), 2155-2159, 2016

Kakouris N, Yener N, et al. A systematic review of running-related musculoskeletal injuries in runners. J Sport Health Sci 10(5), 513-522, 2021

Kinoshita K, Okada K, et al. Alignment of the rearfoot and foot pressure patterns of individuals with medial tibial stress syndrome: a cross-sectional study. Phys Ther Sport 38, 132-138, 2019

Kulmala JP, Avela J, et al. Forefoot strikers exhibit lower running-induced knee loading than rearfoot strikers. Med Sci Sports Exerc 45 (12), 2306-2313, 2013

Lacourpaille L, Nordez A, et al. Time-course effect of exercise-induced muscle damage on localized muscle mechanical properties assessed using elastography. Acta Physiol (Oxf) 211 (1), 135-146, 2014

Michael RH, Holder LE. The soleus syndrome. A cause of medial tibial stress (shin splints). Am J Sports Med 13 (2), 87-94, 1985

Moen MH, Tol JL, et al. Medial tibial stress syndrome: a critical review. Sports Med 39 (7), 523-546, 2009

Moen MH, Schmikli SL, et al. A prospective study on MRI findings and prognostic factors in athletes with MTSS. Scand J Med Sci Sports 24 (1), 204-210, 2014

Nakamura M, Ohya S, et al. Differences in muscle attachment proportion within the most common location of medial tibial stress syndrome in vivo. Orthop Traumatol Surg Res 105 (7), 1419-1422, 2019

Newman P, Witchalls J, et al. Risk factors associated with medial tibial stress syndrome in runners: a systematic review and meta-analysis. Open Access J Sports Med 4, 229-241, 2013

Ohmi T, Aizawa J, et al. Biomechanical characteristics of the lower extremities during running in male long-distance runners with a history of medial tibial stress syndrome: a case control study. BMC Musculoskelet Disord 24 (1), 103, 2023

Ohya S, Nakamura M, et al. The effect of a running task on muscle shear elastic modulus of posterior lower leg. J Foot Ankle Res 10, 56, 2017

Pope RP, Herbert RD, et al. A randomized trial of preexercise stretching for prevention of lower-limb injury. Med Sci Sports Exerc 32 (2), 271-277, 2000

Reshef N, Guelich DR. Medial tibial stress syndrome. Clin Sports Med 31 (2), 273-290, 2012

Saeki J, Nakamura M, et al. Ankle and toe muscle strength characteristics in runners with a history of medial tibial stress syndrome. J Foot Ankle Res 10, 16, 2017

Saeki J, Ikezoe T, et al. The reliability of shear elastic modulus measurement of the ankle plantar flexion muscles is higher at dorsiflexed position of the ankle. J Foot Ankle Res 10, 18, 2017

Saeki J, Nakamura M, et al. Muscle stiffness of posterior lower leg in runners with a history of medial tibial stress syndrome. Scand J Med Sci Sports 28 (1), 246-251, 2018

Saeki J, Ikezoe T, et al. Menstrual cycle variation and gender difference in muscle stiffness of triceps surae. Clin Biomech (Bristol, Avon) 61, 222-226, 2019

Saeki J, Iwanuma S, et al. Force generation on the hallux is more affected by the ankle joint angle than the lesser toes: an in vivo human study. Biology (Basel) 10 (1), 2021

Saeki J, Shiotani H, et al. Effect of shod and barefoot running on muscle mechanical properties. J Sports Med Phys Fitness 62 (7), 883-889, 2022

Sinclair J, Greenhalgh A, et al. The influence of barefoot and barefoot-inspired footwear on the kinetics and kinematics of running in comparison to conventional running shoes. Footwear Sci 5 (1), 45-53, 2013

Yanase K, Yagi M, et al. Epimuscular myofascial force transmission from biarticular rectus femoris elongation increases shear modulus of monoarticular quadriceps muscles. J Biomech 122, 110421, 2021

Yeung SS, Yeung EW, et al. Interventions for preventing lower limb soft-tissue running injuries. Cochrane Database Syst Rev (7), Cd001256, 2011

Yuksel O, Ozgurbuz C, et al. Inversion/eversion strength dysbalance in patients with medial tibial stress syndrome. J Sports Sci Med 10 (4), 737-742, 2011