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● *Original Contribution*

SHEAR MODULUS OF THE LOWER LEG MUSCLES IN PATIENTS WITH MEDIAL TIBIAL STRESS SYNDROME

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Abstract—This study aimed to investigate the in vivo kinematics of shear modulus of the lower leg muscles in patients with medial tibial stress syndrome (MTSS). The study population included 46 limbs with MTSS and 40 healthy limbs. The shear modulus of the medial head of the gastrocnemius, lateral head of the gastrocnemius, soleus, peroneus longus and tibialis anterior muscles were measured using shear wave ultrasound elastography. As a result, the shear modulus of the lower leg muscles was significantly greater in patients with MTSS than in healthy patients ($p < 0.01$). Based on the differences in shear modulus of lower leg muscles between the patients with MTSS and healthy patients, the measurements obtained via shear wave ultrasound elastography could be used to evaluate risk factors of MTSS. (E-mail: kei.akiyama@jpnsport.go.jp) © 2016 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Medial tibial stress syndrome, Athletes, Shear wave ultrasound elastography, Injury, Ankle dorsiflexion.**

INTRODUCTION

Medial tibial stress syndrome (MTSS) is a generic term for lower leg pain (Davey et al. 1984; Mubarak et al. 1982; Puranen 1974), including tibial periostitis (Detmer 1986) and shin splint (Clement 1974; Mubarak et al. 1982). In athletes, MTSS reportedly accounts for 9.5% of injuries and 60% of lower limb injuries (Orava and Puranen 1979). With MTSS, athletes should stop participating in competition for up to 16 wk, which could decrease their competitiveness (Beck 1998). Moreover, MTSS is known to have a high recurrence rate (Yates and White 2004). Thus, constructing an injury prevention procedure is warranted. Based on an injury prevention model proposed by Van Mechelen (1997), injury prevention relies on knowledge of risk factors and mechanisms. However, the mechanisms and risk factors for MTSS are not fully understood. Notably, objective evaluations of factors for recurrence could provide important information for prevention programs for MTSS.

Lower limb muscle tightness associated with impaired ankle range of motion has been extensively investigated as a risk factor for MTSS (Tweed et al. 2008; Yates and White 2004; Yüksel et al., 2011), and lower limb muscle tightness is common in patients with MTSS (Newman et al. 2012). Increased tightness of the triceps surae muscle (medial head of the gastrocnemius [MG] lateral head of the gastrocnemius [LG], soleus [SOL]) is thought to result from a failure to absorb impact loads owing to decreased range of motion in ankle dorsiflexion. The ankle dorsiflexion angle during knee joint extension and knee joint flexion has been used to evaluate gastrocnemius muscle tigtness and SOL tightness, respectively (Yates and White 2004). However, no correlation between ankle dorsiflexion and MTSS has been reported (Burne et al. 2004). Therefore, consensus regarding the triceps surae muscle characteristics that represent risk factors for MTSS is lacking.

Furthermore, muscle tightness as a risk factor for MTSS remains controversial because of the typical subjective evaluation using palpation and the use of a push-in type muscle hardness meter—a precise, reliable measurement method is lacking. Therefore, a more reliable, objective technique to determine muscle tightness characteristics is needed to identify the condition for MTSS onset. In this context, shear modulus determined by shear wave ultrasound elastography has recently emerged to evaluate muscle tightness for an index, and its usefulness for objective

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muscle evaluation has been demonstrated (Akagi and Takahashi 2013; Akagi and Takahashi 2014). This technology might help understand the risk factor of MTSS. We hypothesized that triceps surae (MG, LG, SOL) shear moduli are greater in patients with a history of MTSS. Shear modulus of peroneus longus (PL) and tibialis anterior (TA) muscles were not significantly different between the healthy patients and patients with MTSS. The present study aimed to determine a shear modulus to quantify the tightness of lower limb muscles in MTSS using ultrasound elastography.

METHODS

Patients

The experiment was performed in 40 limbs of 20 healthy male athletes and 46 limbs of 24 of male athletes (22 athletes had MTSS on both sides, 2 athletes had MTSS on one side) diagnosed with MTSS by a physician based on the definition given by Yates and White (2004). The characteristics of the healthy patients were as follows age, 19.4 y ± 2.9 y; height, 165.8 cm ± 7.3 cm; and weight, 65.2 kg ± 14.1 kg. The characteristics of the patients with MTSS were as follows age, 21.9 y ± 6.4 y; height, 172.1 cm ± 4.7 cm; and weight, 68.3 kg ± 10.7 kg. The patients in both groups participated in a variety of sports (Table 1). All healthy patients were without serious injury, disorders or past surgical history in the lower limbs; they also had no symptoms that could impair gait and had been active in sports within 6 mo before the experiment.

The ethics committee of Japan Institute of Sports Sciences provided approval for the study design. Before participation, all of the patients provided their consent, after they were informed in writing and verbally of the study purpose, requirements, risks and ability to decline participation at any time.

Range of motion of ankle dorsiflexion

The ankle dorsiflexion angles in knee flexion and knee extension were measured using a standard clinical goniometer. The ankle dorsiflexion angles in knee flexion position were measured in a standing position with knees fully flexed and hip flexed to 180°. The ankle dorsiflexion angles in knee extension were measured in a standing position with knees and hips flexed to 180°. To measure ankle dorsiflexion, the fulcrum of the goniometer was centered with the lateral aspect of the lateral malleolus (Norkin and White 2003). The proximal arm was in line with the lateral midline of the fibula, using the fibular head as a reference point while the distal arm was aligned with the fifth metatarsal (Norkin and White 2003). The subject was then instructed to actively move the foot into dorsiflexion. Caution was taken to avoid medial or lateral hip rotation as well as ankle inversion or eversion. The ankle range of motion was measured three times in 5° intervals, and the mean of the three measurements was used for analyses.

Table 1. Athletic events by patient type, by group

Athletic event	MTSS	Healthy
Lacrosse	1	1
Badminton	3	1
American football	10	6
Track and field	3	7
Basketball	3	1
Soccer	3	3
Volleyball	1	1
Total	24	20

MTSS = medial tibial stress syndrome.

Shear modulus of the lower leg muscles

Following the measurement of ankle dorsiflexion, MG, LG, SOL, PL and TA muscles were measured using shear wave ultrasound elastography (Aixplorer; SuperSonic Imagine, Aix-en-Provence, France). To standardize the impact of elapsed time after exercise on the muscle, this measurement was conducted 12–24 h after exercise, after a 10-min rest at room temperature (23°C).

Images of the affected limbs in the athletes with MTSS and both limbs in the healthy athletes were obtained at 30% of the length of the lower leg (from the center of the lateral malleolus to the popliteal line) for MG, LG (Akagi and Takahashi 2013), PL and TA, as well as at the site at 70% of the length of the lower leg for SOL (Fig. 1). To prevent pressure on the lower leg muscles, the posterior leg muscles (MG, LG and SOL) were

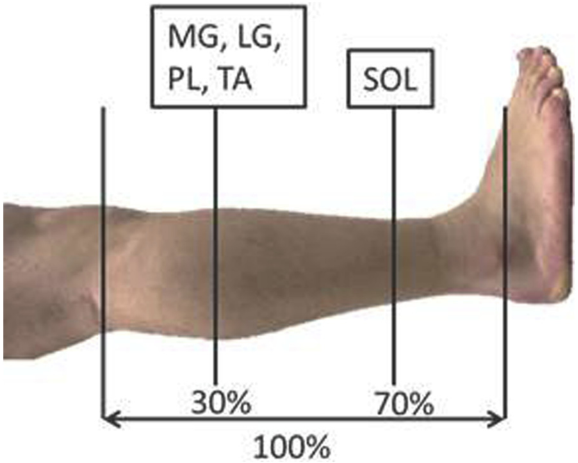

Fig. 1. Shear wave ultrasound elastography measurement sites for the medial gastrocnemius, lateral gastrocnemius, tibialis anterior and peroneus longus at a site 30% along the lower leg, and for the soleus at 70% along the lower leg (from the popliteal crease to the lateral malleolus). LG = lateral head of the gastrocnemius; MG = medial head of the gastrocnemius; PL = peroneus longus; TA = tibialis anterior; SOL = soleus.