©Journal of Sports Science and Medicine (2011) **10,** 737-742
http://www.jssm.org

Research article

Inversion/eversion strength dysbalance in patients with medial tibial stress syndrome

Oğuz Yüksel [1], Cengizhan Özgürbüz [1]✉, Metin Ergün [1], Çetin İşlegen [1], Emin Taşkıran [2], Nevzad Denerel [1] and Ahmet Ertat [1]

[1] Sports Medicine, and [2] Orthopedics and Traumatology Departments, Ege University School of Medicine, Izmir, Turkey

Abstract

The main purpose of the study is to investigate the inversion/eversion muscle strength balance of the ankle in patients with medial tibial stress syndrome (MTSS). A dysbalance of these muscles may play a role in the pathophysiology of MTSS. Another aim is to measure the medial longitudinal arch and navicular drop in patients with MTSS. A total of 11 patients diagnosed with MTSS in the outpatient clinic of Ege University School of Medicine Sports Medicine Department were enrolled in this study. The control group consisted of 11 regularly exercising individuals. The mean age of the patient group and the control group was 21.0±1.9 years (18-23 years) and 23.2±2.9 years (18-27 years), respectively. A detailed exercise questionnaire was administered to all subjects. Isokinetic muscle strength testing was performed at 30°/sec and 120°/sec to assess invertor and evertor muscle strength of the ankle. Photographs of the weight bearing and non-weight bearing foot were taken to measure the medial longitudinal arch deformation and the navicular drop. At 30°/sec, the average eversion concentric strength was significantly higher in the patient group, and the inversion/eversion strength ratio was significantly higher in the control group ($p < 0.05$). At 120°/sec velocity, average concentric eversion strength was significantly higher in the patient group ($p < 0.05$). The measurements of pronation indicators did not reveal any statistically significant differences between the two groups ($p > 0.05$). MTSS may occur without an increase of pronation indicators like medial longitudinal arch deformation or navicular drop. In such cases, one of the predisposing factors may be the strength dysbalance of the invertor/evertor muscles in favour of the evertor muscles. This observation may be of additional value in the prevention and therapy of MTSS.

Key words: Medial tibial stress syndrome, eversion, inversion, strength dysbalance, pronation, exercise.

Introduction

Medial tibial stress syndrome (MTSS) is one of the most common causes of exercise-induced leg pain. It is characterized with increasing pain in the distal 2/3 of the posteromedial tibia. Two large epidemiological studies reported 13.1% MTSS injuries among 1800 running injuries and 22% MTSS injuries among 385 aerobic dance injuries (Clement et al., 1981; Taunton et al., 1988).

The most common complaint is diffuse pain in the distal posteromedial tibia. Although the anatomic location of MTSS is well known, the pathophysiological mechanism and the specific pathologic lesion remain unclear. The most prominent theories are the "traction induced injury" and the "tibial bone bending" theories (Beck, 1998; Bouche and Johnson, 2007; Couture and Karlson, 2002; Franklyn et al., 2008; Kortebein et al., 2000; Michael and Holder, 1985). Interesting studies about the tibial density in athletes with MTSS are reported by Magnusson et al.; they found a decreased tibial bone density, returning to normal levels after recovery in MTSS suffering athletes (Magnusson et al., 2001; 2003).

During running, while the foot goes from relative supination to pronation, the medial part of the soleus muscle contracts eccentrically. This creates, presumably through the periosteum crossing Sharpey fibers penetrating the tibia, stress at the fascial adhesion site of the soleus muscle. It is believed that long-term excessive exposure to this stress produces MTSS (Kortebein et al., 2000).

Clinical observations revealed that overpronation may be a risk factor for MTSS; and this observation is supported by various biomechanical analyses (Messier and Pittala, 1988; Sharma et al., 2011; Viitasalo and Kvist, 1983; Willems et al., 2006; 2007).

In 60% of the patients, training errors have been reported as the cause of MTSS (Fredericson et al., 1995). Often the symptoms start after a sudden increase in training frequency, duration or intensity (Andrish, 1994; Fredericson et al., 1995; James et al., 1978). Excessive uphill training, changes of the training surface or training footwear were also proposed to be risk factors (Fredericson et al., 1995; James et al., 1978; Krivickas, 1997).

These above-mentioned structural and functional factors may disturb the biomechanics of running. The muscles of the lower leg are important in running biomechanics, and a strength dysbalance may also be a contributing factor in MTSS, especially via promoting pronation and increasing the eccentric soleus contraction force (Michael and Holder, 1985).

Studies about endurance or strength of the muscles in the lower leg in athletes with MTSS revealed different results. Muscle strength endurance of the plantar flexor muscles was found to be decreased in athletes with MTSS (Madeley et al., 2007). Hubbard et al. reported no differences in the peak isometric strength values of the lower leg muscles between the MTSS and the healthy control group (Hubbard et al., 2009).

The purpose of this study is to measure the inversion and eversion strength levels in order to evaluate potential inversion/eversion (I/E) strength dysbalance. A strength dysbalance between the evertor and invertor muscles may promote pronation of the foot which in turn

Received: 19 September 2011 / Accepted: 24 October 2011 / Published (online): 01 December 2011

is an intrinsic risk factor in MTSS. This may provide us additional insight in the prevention and therapy of MTSS. This may be the first study assessing the isokinetic invertor and evertor muscle strengths and ratios of the ankle joint in patients with MTSS. Another aim of the study is to investigate the relationship between MTSS and the pronation indicators such as medial longitudinal arch deformation and navicular drop.

Methods

A total of 11 athletes (7 males, 4 females) with MTSS, who referred to the outpatient clinic of the Ege University School of Medicine, Sports Medicine Department participated in this singled blinded, controlled and cross-sectional study. The control group consisted of 11 (7 males, 4 females) regularly exercising subjects. Physical characteristics of the two groups are given in Table 1.

Table 1. Anthropometric data of the subjects. Data are means (±SD).

	Patient group (n=11)	Control group (n=11)
Age (year)	21.0 (1.9)	23.2 (2.9)
Height (m)	1.79 (.12)	1.73 (.087
Body weight (kg)	72.4 (14.8)	65.8 (13.2)
BMI ($kg·m^{-2}$)	22.4 (2.6)	22.0 (3.1)

BMI: body mass index

Patients between 18-23 years free of systemic diseases, diagnosed with MTSS by two different physicians were included in the study. Patients with anterior- or posterior cruciate ligament injury, with previous lower extremity surgery or fracture, with neurological or vascular pathologies in the lower extremities were excluded from the study. The diagnosis was made according to injury history, including complaints of pain in the distal 2/3 tibia, tenderness with palpation in a diffuse area for at least 5 centimeters in the distal 2/3 of the posteromedial tibia, a positive one leg hop test and by detecting no additional pathologies (Moen et al., 2009; Yates and White, 2004).

The control group consisted of regularly exercising (at least 3 days a week, 1.5 hours) subjects without any history of previously diagnosed MTSS injury, free of any previous surgery, ligament injury or fracture in the lower extremities.

The subjects were informed about testing procedures, possible risks and discomfort that might ensue, and gave their written informed consent to participate in accordance with the Helsinki Declaration (WMADH, 2000).

Exercise questionnaire

The participants were questioned about their starting time of performing sports under the supervision of a coach; and this time was recorded as the age of beginning sports activities. To evaluate their training program, the participants were also questioned about the weekly training frequency and duration, and about how many months they followed this program.

The weekly training day frequency was multiplied with the duration of one training session to calculate the weekly training duration. The weekly training duration multiplied with number of months since the beginning of the training reflected the training level of the subject.

Subjects were also questioned about each sports activity they performed prior to supervision by a coach, to calculate their lifetime cumulative sports activity. For each sports activity, weekly training duration was multiplied with the number of years performing that activity. The scores for the different sport activities were then added to evaluate total training level.

The patient group was asked whether an increase in training duration or intensity occurred in the period one month before the onset of the MTSS symptoms. The answer to this question was noted as yes or no.

Medial longitudinal arch and navicular drop measurements

The medial longitudinal arch (MLA) angle, the MLA deformation and the navicular drop were measured on both sides by marking three points according to Bandholm. Bandholm reported the intra-tester interday reproducibility of all applied measurements to be high ($ICC_{2.1}$ above 0.86) with no systematic test-retest bias (Bandholm et al., 2008)

After shooting (Canon Ixus 85 IS) the photographs of the weight-bearing and non weight-bearing foot's angle between the three marked points under non weight-bearing conditions (MLA angle), the change in this angle on the weight bearing foot (MLA deformation), and the drop of the navicular process under weight bearing conditions (navicular drop) were measured through a computer.

Isokinetic strength measurements

Isokinetic concentric strength of the foot in inversion and eversion were measured on both sides. All participants underwent a standardized 10 minute warm-up phase on stationary bicycles, followed by stretching the lower extremities. After the warm-up, the test was started on an isokinetic dynamometer (Humac Norm Testing & Rehabilitation System 502 140).

The back of the test chair was inclined (0° position). The slope of the dynamometer was adjusted to 55°, and the dynamometer height to zero. For the measurements of the right foot, chair and dynamometer rotations were adjusted to -85° and +5°, respectively; for the left foot to +85° and -5°, respectively. Waist and knee of the participants were fixed in the supine position.

Maximum isokinetic concentric muscle strength of the inversion and eversion muscles of the foot were measured at 30°/sec and 120°/sec angular velocities. Before each test, four submaximal trials were done. The test consisted of five repetitions at 30°/sec and 10 repetitions at 120°/sec. The participants rested 10 seconds after each trial and 120 seconds after switching to a different angular velocity. The dynamometer was calibrated before each test.

Statistical analysis

Statistical analyses were made using the "SPSS v13.0 software package program". For descriptive data, mean and standard deviation (SD) and for relative data, frequency figures were calculated. Data not meeting the intra-group homogeneity precondition were classified as nonparametric, and their inter-group comparison was made by using the Mann-Whitney U test. Remaining data were compared using independent samples T test.

Results

The anthropometric data (Table 1) of the two groups were similar ($p > 0.05$). Mean injury duration of the patient group was 5.0 ± 2.1 weeks (3 to 10 weeks). All patients had bilateral complaints. Symptoms were more severe on the right side in three patients, and on the left side in three.

No statistically significant differences were found between the groups' weekly training days, durations of a single training, total weekly training durations, training periods (in months) and the last training level (training period in months multiplied with weekly training duration). Nevertheless, the total training level difference was statistically significant ($p < 0.001$), (Table 2, 3).

Table 2. Exercise questionnaire. Data are means (±SD).

	Patient group (n=11)	Control group (n=11)
Weekly training (day)	4.1 (1.8)	4.4 (1.3)
Training session duration (hrs)	3.4 (2.5)	3.2 (2.4)
Weekly training duration (hrs)	16.9 (17.8)	15.9 (16.1)
Training period (month)	6.3 (3.4)	7.6 (2.3)
Last training level (months x hrs)	87.3 (83.2)	96.9 (57.1)

Table 3. Total training level and training starting age. Data are means (±SD).

	Patient group (n=11)	Control group (n=11)
Total training level (years x hrs)	34.8 (24.4)	86.3 (50.5)***
Training starting age (yrs)	13.6 (3.8)	10.5 (2.5)*

* $p < 0.056$, *** $p < 0.001$

Of the 11 patients, 9 (81.8%) answered with "yes" to the question whether there was an increase in training duration or intensity in the period one month before the onset of the MTSS symptoms.

At the 30°/sec angular velocity, the average eversion concentric strength was significantly higher in the patient group ($p < 0.05$). I/E strength ratio was significantly higher in the control group at the same angular velocity ($p < 0.05$). At the 120°/sec angular velocity, the average eversion concentric strength was significantly higher in the patient group ($p < 0.05$), (Table 4).

There were no statistically significant differences between the weight-bearing and non-weight-bearing MLA angles, the MLA deformation, and the navicular drop measurements among the two groups (Table 5).

Discussion

MTSS is one of the most common running injuries. Concerning etiology, a wide range of potential biomechanical factors including excessive pronation was investigated (Thacker et al., 2002). It should be kept in mind that different biomechanical factors can cause the same problem. A strength dysbalance in the prime movers of the foot, which are also important contributing factors to running biomechanics may disturb ankle mechanics.

Table 4. Isokinetic strength measurements of the patient and control groups. Data are means (±SD).

	Patient group (n=22)	Control group (n=22)
Inversion AT (30°/sec) (Nm)	21.9(6.6)	20.3 (6.3)
Eversion AT (30°/sec) (Nm)	23.4 (6.7)	18.4 (4.6)**
Inversion/Eversion AT ratio(30°/sec)	.95 (.20)	1.1 (.3)*
Inversion AT (120°/sec) (Nm)	15.2 (4.6)	13.0 (3.8)
Eversion AT (120°/sec) (Nm)	14.4 (4.0)	12.1 (3.4)*
Inversion/Eversion AT ratio(120°/sec)	1.08 (.25)	1.11 (.29)
Inversion AT (30°/sec) (Nm)	21.9 (6.6)	20.3 (6.3)

AT: average torque, * $p < 0.05$, ** $p < 0.01$

Different etiologies for MTSS have been proposed in the past. "Tibial bending" and "traction of the soleus muscle" have been implicated as the cause of MTSS (Beck, 1998; Bouche and Johnson, 2007; Kortebein et al., 2000; Michael and Holder, 1985). Eccentrically fatigue of the soleus as a consequence of repetitive stress, leading to repeated tibial bending and overloading of the bone remodeling capability of the tibia is suggested as a cause of MTSS (Couture and Karlson, 2002; Beck, 1998). On the other side Magnusson et al. found a significant decrease in the tibial bone mineral density in male athletes with MTSS compared to controls and to athletes without MTSS (Magnusson et al., 2001). In a follow-up study, after recovery the tibial bone density returned to nomal levels (Magnusson et al., 2003).

Table 5. Medial longitudinal arch (MLA) measurements. Data are means (±SD).

	Patient group (n=22)	Control group (n=22)
Non-weight bearing MLA angle (°)	131.5 (6.6)	136.2 (9.0)
Weight bearing MLA angle (°)	134.4 (7.2)	138.9 (8.4)
MLA deformation (°)	2.8 (1.6)	2.8 (2.0)
Navicular drop (mm)	3.14 (2.01)	4.50 (2.96)

MLA: medial longitudinal arch

Michael and Holder suggest that during running the foot contacts the ground during the heel strike phase, in supination. While progressing to the mid-stance phase, the foot turns to pronation. In this phase, the soleus muscle contracts eccentrically. The fascia of medial soleus adheres to the posteromedial corner of the distal 1/3 tibia. Repetitive eccentric contractions of the soleus muscle can cause fasciitis or periostitis along the insertion site (Michael and Holder, 1985).

Studies investigating the I/E isokinetic strength ratio measurements mostly focus on ankle sprain injuries. Lin and colleagues investigated inversion and eversion strength of the dominant and non-dominant foot in healthy subjects, and found no statistically significant differences between them. I/E strength ratios at 30°/sec and 120°/sec angular velocities were 1.10 and 1.22, respectively (Lin et al., 2009). Another study reported I/E strength ratios at 30°/sec and 120°/sec angular velocities between 1.14-1.33 and 1.20-1.59, respectively, in healthy subjects (Wilkerson et al., 1997). Likewise, other studies reported that the inversion strength is higher than the eversion strength, and that the I/E ratio is always higher than 1.0 (Amaral De Noronha and Borges, 2004; Kaminski et al., 2003).

In this study, I/E strength ratios in the patient group at 30°/sec and 120°/sec angular velocities were 0.95 ± 0.20 and 1.08 ± 0.25, respectively. In the healthy control group, I/E strength ratios at 30°/sec and 120°/sec angular velocities were 1.1 ± 0.3 and 1.11 ± 0.29, respectively.

The I/E strength ratio at 30°/sec angular velocity was significantly lower in the patient group ($p < 0.05$). There was no statistically significant difference in the average inversion forces between the two groups. Average eversion strength figures at 30°/sec and 120°/sec angular velocity were significantly higher in the patient group ($p < 0.05$).

Eversion strength was higher in the patient group, whereas inversion strength scores were similar in the two groups. While the foot is contacting the ground, the greater eversion strength moment will pronate the foot and excessive pronation may result in overloading of the soleus muscle.

During running, plantar flexor activity increases rapidly at heel strike, and remains dominant during the whole stance phase. In the midstance phase, plantar flexor muscles do not affect the ankle joint, but they contract eccentrically and slow down the vertical downward movement of the body. They continue this support until the propulsive phase. In the propulsive phase, a switch to concentric contraction provides the propulsion (Mann et al., 1986). During walking the soleus muscle displays an EMG activity of 25% MMT (manual muscle test) in the midstance phase, and 75% MMT in the toe off phase (Perry, 1992). It is plausible to consider a higher increase in soleus activity during running.

The activity of the prime evertor muscles begins with the forefoot loading at the end of the midstance phase and shows peak activity at the toe-off phase (Perry, 1992). Michael and Holder suggested that the traction force generated on the soleus fascia from the heel strike phase to the midstance phase precipitates MTSS (Michael and Holder, 1985). After eccentrically contracting until the middle of the midstance phase, the soleus switches to contract concentrically, at this moment the peroneal muscles start to display activity. Soleus is an invertor and plantar flexor of the foot, peroneus longus acts as an evertor and plantar flexor. The action of the propulsive phase depends on a balanced contraction between the evertor and invertor muscles. In the case of stronger evertor muscles, the foot may remain longer in pronated position. Prolonged pronation will lead to longer lasting traction stress on the soleus fascia, which in turn can facilitate the development of MTSS.

I/E strength ratio imbalance can result from improper walking or running pattern, or from a disalignment of the lower extremities. The effects of I/E strength dysbalance on the soleus muscle during walking, running or jumping are not investigated in this study. However, it seems possible that an increased pronation resulting from evertor muscle dominance can produce changes in the soleus loading.

Training periods of the subjects were similar. There were no significant differences between the groups regarding weekly training days and training duration. However, the lifetime training level was significantly higher in the control group ($p < 0.001$). Functional adaptation seems to be more distinct in athletes with higher lifetime training level. Adequate functional adaptation to sports activity provides a very high prevention from overuse injuries (Andrish et al., 1974; Heir, 1998; Watson and Dimartino, 1987).

Pronation is related to the prolongation of the MLA (Hunt et al., 2001). The flattening deformation of the MLA serves as an important shock absorber (Nack and Phillips, 1990; Ogon et al., 1999). MLA deformation and navicular drop are important criteria of foot pronation (Hunt et al., 2001). However, in this study there was no significant difference between the two groups, regarding MLA deformation and navicular drop. Studies with contrary (Bandholm et al., 2008; Viitasalo and Kvist, 1983; Yates and White, 2004) and similar results (Plisky et al., 2007; Reinking and Hayes, 2006) are given in the literature.

The correlation in the standing position and during walking regarding MLA deformation and navicular drop is highly questionable (Bandholm et al., 2008; Nielsen et al., 2009; Rathleff et al., 2010). Therefore, MLA deformation and navicular drop measurements in standing subjects will not necessarily reflect the conditions in walking or running subjects.

The increases in training intensity, duration and content were numerous times associated with MTSS (Clement et al., 1981; Marti et al., 1988; Rudzki, 1997). Indeed, 81.8% of the patient group described the beginning of their symptoms after such an increase in their training program. The supervising coach has to be aware of the difference between the performance profile of the athlete and the required performance profile for the training program. An appropriately designed training program will provide important prevention from overuse injuries.

Conclusion

Our knowledge about MTSS is still very limited. Further studies with isokinetic strength measurements in MTSS patients are needed to verify our findings. However, in athletes displaying I/E dysbalance, a proper strengthening program can serve as an additional tool in preventing MTSS. Likewise, in MTSS patients with I/E dysbalance, well-designed rehabilitation programs to improve strength balance may have positive effects on therapy outcomes.

References

Amaral De Noronha, M. and Borges Jr, N.G. (2004) Lateral ankle sprain: isokinetic test reliability and comparison between invertors and evertors. *Clinical Biomechanics* **19,** 868-871.

Andrish, J.T., Bergfeld, J.A. and Walheim, J. (1974) A prospective study on the management of shin splints. *Journal of Bone and Joint Surgery-American Volume* **56**A, 1697-1700.

Andrish, J.T. (1994) Leg pain. In: *Orthopedic Sports Medicine*. Ed:

DeLee, J.C., Drez, D. Philadelphia: W.B. Saunders. 1603-1607.

Bandholm, T., Boysen, L., Haugaard, S., Zebis, M.K. and Bencke, J. (2008) Foot medial longitudinal-arch deformation during quiet standing and gait in subjects with medial tibial stress syndrome. *The Journal of Foot and Ankle Surgery* **47**(2), 89-95.

Beck, B.R. (1998) Tibial stress injuries. An aetiological review for the purposes of guiding management. *Sports Medicine* **26(4),** 265-279.

Bouche, R.T. and Johnson, C.H. (2007) Medial tibial stress syndrome (tibial fasciitis): a proposed pathomechanical model involving fascial traction. *Journal of the American Podiatric Medical Association* **97** (1), 31-36.

Clement, D.B., Taunton, J.E., Smart, G.W. and McNicol, K.L. (1981) A survey of overuse running injuries. *Physician and Sportsmedicine* **9,** 47-58.

Couture, C.J. and Karlson, K.A. (2002) Tibial stress injuries: decisive diagnosis and treatment of 'shin splints'. *The Physician and Sportsmedicine* **30(6),** 29-36.

Franklyn, M., Oakes, B., Field, B., Wells, P. and Morgan, D. (2008) Section modulus is the optimum geometric predictor for stress fractures and medial tibial stress syndrome in both male and female athletes. *American Journal of Sports Medicine* **36**, 1179-1189.

Fredericson, M.A., Bergman, A.G., Hoffman, K.L. and Dillingham, M.S. (1995) Tibial stress reaction in runners. *American Journal of Sports Medicine* **23,** 472-481.

Hubbard, T.J., Carpenter, E.M. and Cordova, M.L. (2009) Contributing factors to medial tibial stress syndrome: a prospective investigation. *Medicine and Science in Sports and Exercise* **41**, 490-496.

Hunt, A.E., Smith, R.M., Torode, M. and Keenan, A.M. (2001) Intersegment foot motion and ground reaction forces over the stance phase of walking. *Clinical Biomechanics* **16**, 592- 600.

Heir, T. (1998) Musculoskeletal injuries in officer training: one-year follow-up. *Military Medicine* **163,** 229-233.

James, S.L., Bates, B.T. and Osternig, L.R. (1978) Injuries to runners. *American Journal of Sports Medicine* **6,** 40-50.

Kaminski, T.W., Buckley, B.D., Powers, M.E., Hubbard, T.J. and Ortiz, C. (2003) Effect of strength and proprioception training on eversion to inversion strength ratios in subjects with unilateral functional ankle instability. *British Journal of Sports Medicine* **37,** 410-415.

Kortebein, P.M., Kaufman, K.R., Basford, J.R. and Stuart, M.J. (2000) Medial tibial stress syndrome. *Medicine and Science in Sports and Exercise* **32**(3 Suppl), S27-33.

Krivickas, L.S. (1997) Anatomical factors associated with overuse sport injuries. *Sports Medicine* **24,** 140-141.

Magnusson, H.I., Westlin, N.E., Nyqvist, F., Gärdsell, P., Seeman, E. and Karlsson, M.K. (2001) Abnormally decreased regional bone density in athletes with medial tibial stress syndrome. *American Journal of Sports Medicine* **29**(6), 712-715.

Magnusson, H.I., Ahlborg, H.G., Karlsson, C., Nyquist, F. and Karlsson, M.K. (2003) Low regional tibial bone density in athletes with medial tibial stress syndrome normalizes after recovery from symptoms. *American Journal of Sports Medicine* **31**(4), 596-600.

Mann, R.A., Moran, G.T. and Dougherty, S.E. (1986) Comparative electromyography of the lower extremity in jogging, running, and sprinting. *American Journal of Sports Medicine* **14**, 501-510.

Lin, W.H., Liu, Y.F., Hsieh, C.C. and Lee, A.J. (2009) Ankle eversion to inversion strength ratio and static balance control in the dominant and non-dominant limbs of young adults. *Journal of Science and Medicine in Sport* **12**(1), 42-49.

Madeley, L.T., Munteanu, S.E. and Bonanno, D.R. (2007) Endurance of the ankle joint plantar flexor muscles in athletes with medial tibial stress syndrome: a case-control study. *Journal of Science and Medicine in Sport* **10**, 356-362.

Marti, B., Vader, J.P., Minder, C.E. and Abelin, T. (1988) On the epidemiology of running injuries: the 1984 Bern Grand-Prix study. *American Journal of Sports Medicine* **16,** 285-294.

Messier, S.P. and Pittala, K.A. (1988) Etiologic factors associated with selected running injuries. *Medicine and Science in Sports and Exercise* **20,** 501-505.

Michael, R.H. and Holder, L.E. (1985) The soleus syndrome. A cause of medial tibial stress (shin splints). *American Journal of Sports Medicine* **13**(2), 87-94.

Moen, M.H., Tol, J.L., Weir, A., Steunebrink, M. and de Winter, T.C. (2009) Medial tibial stress syndrome. A critical review. *Sports medicine* **39**, 523-546.

Nack, J.D. and Phillips, R.D. (1990) Shock absorption. *Clinics in Podiatric Medicine and Surgery* **7,** 391-397.

Nielsen, R.G., Rathleff, M.S., Simonsen, O.H. and Langberg, H. (2009) Determination of normal values for navicular drop during walking: a new model correcting for foot length and gender. *Journal of Foot and Ankle Research* **2,** 12.

Ogon, M., Aleksiev, A.R., Pope, M.H., Wimmer, C. and Saltzman, C.L. (1999) Does arch height affect impact loading at the lower back level in running? *Foot and Ankle International* **20,** 263-266.

Perry, J. (1992) Normal gait. In: *Gait analysis: Normal and pathological function*. Thorofare, New Jersey, SLACK Incorporated, USA, 49-167.

Plisky, M.S., Rauh, M.J., Heiderscheit, B., Underwood, F.B. and Tank, R.T. (2007) Medial tibial stress syndrome in high school cross-country runners: incidence and risk factors. *Journal of Orthopaedic and Sports Physical Therapy* **37**(2), 40-47.

Rathleff, M.S., Nielsen, R.G., Simonsen, O., Olesen, C.G. and Kersting, U.G. (2010) Perspectives for clinical measures of dynamic foot function-reference data and methodological considerations. *Gait and Posture* **31**, 191-196

Reinking, M.F. and Hayes, A.M. (2006) Intrinsic factors associated with exercise related leg pain in collegiate cross-country runners. *Clinical Journal of Sport Medicine* **16**(1), 10-14.

Rudzki, S.J. (1997) Injuries in Australian Army recruits. Part I: decreased incidence and severity of injury seen with reduced running distance. *Military Medicine* **162,** 472-476.

Sharma, J., Golby, J., Greeves, J. and Spears, I.R. (2011) Biomechanical and lifestyle risk factors for medial tibial stress syndrome in army recruits: A prospective study. *Gait and Posture* **33**, 361-365.

Thacker, S.B., Gilchrist, J., Stroup, D.F. and Kimsey, C.D. (2002) The prevention of shin splints in sports: a systematic review of literature *Medicine and Science in Sports and Exercise* **34**(1), 32-40.

Taunton, J.E., McKenzie, D.C. and Clement, D.B. (1988) The role of biomechanics in the epidemiology of injuries. *Sports Medicine* **6**, 107-120.

Viitasalo, J.T. and Kvist, M. (1983) Some biomechanical aspects of the foot and ankle in athletes with and without shin splints. *American Journal of Sports Medicine* **11,** 125-130.

Watson, M.D. and Dimartino, P.P. (1987) Incidence of injuries in high school track and field athletes and its relation to performance ability. *American Journal of Sports Medicine* **15,** 251-254.

Wilkerson, G.B., Pinerola, J.J. and Caturano, R.W. (1997) Invertor versus evertor peak torque and power deficiencies associated with lateral ankle ligament injury. *Journal of Orthopaedic and Sports Physical Therapy* **26,** 78-86.

Willems, T.M., De Clercq, D., Delbaerea, K., Vanderstraelena, G., De Cock, A. and Witvrouw, E., (2006) A prospective study of gait related risk factors for exercise-related lower leg pain. *Gait and Posture* **23**, 91-98.

Willems, T.M., Witvrouw, E., De Cock, A. and De Clercq, D. (2007) Gait related risk factors for exercising-related lower-leg pain during shod running. *Medicine and Science in Sports and Exercise* **39**, 330-339.

WMADH (2000) World Medical Association Declaration of Helsinki. *The Journal of the American Medical Association* **20**, 3043-3045.

Yates, B. and White, S. (2004) The incidence and risk factors in the development of medial tibial stress syndrome among naval recruits. *American Journal of Sports Medicine* **32,** 772-780.

Key points

- At 30°/sec, the average eversion concentric strength was significantly higher in the MTSS group, and the inversion/eversion strength ratio was significantly higher in the control group.
- At 120°/sec velocity, average concentric eversion strength was significantly higher in the MTSS group.
- MTSS may occur without an increase of pronation indicators like medial longitudinal arch deformation or navicular drop. In such cases, one of the predisposing factors may be the strength dysbalance of the invertor/evertor muscles in favour of the evertor muscles.

AUTHORS BIOGRAPHY

Oğuz YÜKSEL
Employment
Ege University School of Medicine, Sports Medicine Department, Izmir, Turkey
Degree
MD
Research interests
Sports traumatology

Cengizhan ÖZGÜRBÜZ
Employment
Assoc. Prof., Ege University School of Medicine, Sports Medicine Department, Izmir, Turkey
Degree
MD
Research interests
Sports traumatology, exercise physiology
E-mail: cengizhan.ozgurbuz@ege.edu.tr

Metin ERGÜN
Employment
Assoc. Prof., Ege University School of Medicine, Sports Medicine Department, Izmir, Turkey
Degree
MD
Research interests
Sports traumatology

Çetin İŞLEGEN
Employment
Prof., Ege University School of Medicine, Sports Medicine Department, Izmir, Turkey
Degree
MD
Research interests
Exercise physiology

Emin TAŞKIRAN
Employment
Prof., Ege University School of Medicine, Orthopedics and Traumatology Department, Izmir, Turkey
Degree
MD
Research interests
Knee surgery, sports traumatology, arthroscopy

Nevzad DENEREL
Employment
Ege University School of Medicine, Sports Medicine Department, Izmir, Turkey
Degree
MD
Research interests
Sports traumatology

Ahmet ERTAT
Employment
Prof., Ege University School of Medicine, Sports Medicine Department, Izmir, Turkey
Degree
MD
Research interests
Exercise physiology

🖂 **Dr. Cengizhan Özgürbüz**
Ege University School of Medicine, Sports Medicine Department, Izmir, Turkey