Randomized Controlled Trial of Laser Therapy Versus Conventional Therapy in the Treatment of Medial Tibial Stress Syndrome

Chen-Ling Chen[1], Hua-Ying Chuang[2], Cheng-Chiang Chang[3,4,5], Chih-Hung Ku[6,7,#] and Shin-Tsu Chang[1,3,4,*]

[1]*Department of Rehabilitation, Taichung Veterans General Hospital, Taichung, Taiwan*

[2]*Department of Internal Medicine, Chiali Hospital, Chi Mei Medical Center, Tainan, Taiwan*

[3]*Graduate Institute of Medical Sciences, National Defense Medical Center, Taipei, Taiwan*

[4]*Department of Physical Medicine and Rehabilitation, School of Medicine, National Defense Medical Center, Taipei, Taiwan*

[5]*Department of Physical Medicine and Rehabilitation, Tri-Service General Hospital, Taipei, Taiwan*

[6]*School of Public Health, National Defense Medical Center, Taipei, Taiwan*

[7]*Center for General Education, Kainain University, Taoyuan, Taiwan*

Abstract: *Introduction:* Medial tibial stress syndrome (MTSS) can induce defective biomechanics and cause sacroiliac (SI) joint stress. The purpose of this study was to investigate whether successful therapy of MTSS normalizes SI joint stress.

Methods: Fifty-three patients with MTSS and SI joint stress confirmed by nuclear scintigraphy were enrolled in this prospective trial. Patients were randomly assigned to receive laser therapy or conventional therapy. Patients in the laser therapy group underwent 15 laser sessions over a 5-day period (60 seconds in duration, three times per day). The SI ratio was measured using quantitative sacroiliac scintigraphy (QSS) before and after therapy. Outcome measures included Lower Extremity Functional Scale (LEFS). Generalized estimating equation models were used to evaluate the associations of LEFS. We adjusted for the correlations between QSS and different parts of the SI joint, and adjusted for potential confounders as well.

Results: Age, body weight, and duration did not correlate with QSS or lateralization. There was no significant difference in QSS and laterality of MTSS. However, the LEFS measured after therapy were significantly increased 38.45 ($P < 0.0001$) from LEFS measured before therapy. The QSS was significantly lower after therapy ($P < 0.0001$), indicating that successful therapy of MTSS has a buttom-up effect on SI joint stress ($P < 0.0001$). There was also a significant association between the middle part and the lower part of the SI joint. The QSS for the middle part on both sides was significantly higher than that for the lower part ($P = 0.0250$).

Conclusion: SI joint stress due to bottom-up processing of MTSS can be normalized after successful therapy of MTSS by either laser therapy or conventional therapy.

Keywords: Sacroiliac joint stress, laser, scintigraphy, kinematic chain, medial tibial stress syndrome, medial tibial traction periostitis, dynamic knee valgus.

1. INTRODUCTION

Medial tibial stress syndrome (MTSS), commonly known as 'shin splints', tibial periostitis [1], or medial tibial traction periostitis [2], is a common lower limb overuse injury among athletes, runners, dancers, and military recruits. The incidence of MTSS is reported as being between 4% and 35% in military personnel and athletes [3], and prevalence of MTSS is 16.6% in military recruits [4].

Most bones are lined with a dense layer of connective tissue called periosteum, which provides protection and connects muscle fibers to bone. Periostitis can develop as the result of infectious diseases, malignancy, or other rheumatology-related disorders. Direct traumatic injury to a bone or overuse injuries of a certain limb part are common causes of periostitis [5]. Athletes and casual runners, either male or female, are at risk of developing mechanical periosteum disorder in their lower legs because of the excess pressure they put on the shins during exercise [6]. MTSS can be treated by rest [3, 7], kinesio taping [8], fascial distortion technique [9], lower level laser therapy [10, 11], foot orthoses [12], biomechanical

*Address correspondence to this author at the Graduate institute of Medical Sciences and School of Medicine, National Defense Medical Center, Taiwan. Address: No.161, Section 6, Min-Chuan East Road, Neihu District, Taipei, Taiwan; Tel: (886) 2-87923100; Fax: (886) 2-26337531;
E-mail: stchang@ms87.url.com.tw;

#Co-correspondence to this author at School of Public Health, National Defense, Medical Center, Taipei, Center for General Education, Kainain University, Taoyuan, Taiwan

E-ISSN: 2313-0954/16

shock-absorbing insoles [13, 14], massage [15], and extracorporeal shockwave therapy [16-18].

To our knowledge, there was few article to discuss the consequence of SI joint after pain from MTSS, except one study of Eshed *et al.* (2012), who investigated exertional leg pain in 11 patients with familial Mediterranean fever, and found 10 patients (91%) had signs compatible with enthesitis of the Achilles tendon, long plantar ligament, or the plantar fascia (including enthesophytes, erosions, and bone marrow edema). Interestingly, 9 patients (80%) had radiographic signs of sacroiliitis on the pelvic radiograph [19]. We wonder if there was any possibility of SI joint stress occurring after symptoms of MTSS, and furthermore, if normalization of the SI stress occurs bottom-up after impairment reduction of MTSS.

2. METHODS

2.1. Patient Selection

In this prospective trial, male patients with a 3- to 18-week history of lower extremity pain due to mechanic injury after sports or exercise were enrolled from the outpatient clinic of the rehabilitation department of the Tri-Service General Hospital if they met the following inclusion criteria: patients had to be aged 20 to 40 years and have a history of conservative treatment or administration of topical non-steroid anti-inflammatory drugs. Nuclear skeletal scintigraphy was used in all patients to diagnose periostitis in lower limbs. Diagnosis of tibial periostitis can be confirmed by bone scintigraphy [20-23], which fulfilled the modified diagnostic criteria for MTSS as described by Yüksel *et al.* [24]. The site of periostitis showed no sign of fracture or displacement on X-ray images.

Exclusion criteria included periostitis caused by, or chronic disease noted during physical examination or on the medical records, including internal organic diseases, infectious disease, rheumatology-related diseases, immunology-related vascular diseases, hematopathological disorders, chronic exertional compartment syndrome, popliteal artery entrapment syndrome, stress fracture, nerve entrapment, complex regional pain syndrome, and deep vein thrombosis. Patients who had undergone surgery on the lower limbs within the previous six months or who had any history of epilepsy or allergic reactions after any prior laser therapy were excluded. Patients with stress fractures in the area of periostitis were also excluded. Musculoskeletal sonography was performed to exclude the presence of local effusion and hematoma. Patients were also excluded if they had leg length discrepancy known since childhood.

Patients were evaluated by using Lower Extremity Functional Scale [25] before therapy, which was performed again 1-2 weeks later after finishing the interventional therapy. Patients were assigned randomly to receive either laser therapy or conventional therapy. A flow chart outlining the assessment and therapy of patients is shown in Figure **1**.

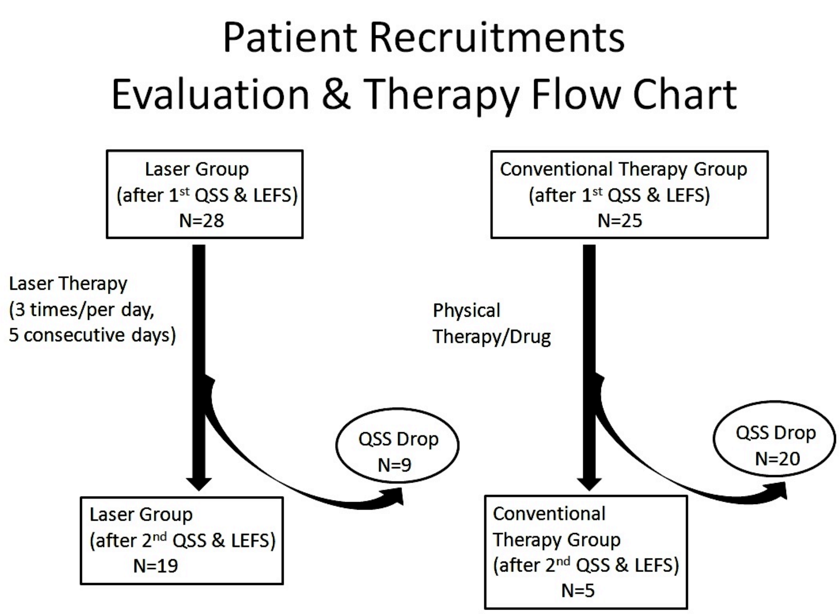

Figure 1: Flow chart outlining the assessment and therapy of patients in the two study groups.

2.2. Intervention with Low-Power Laser

We used a gallium-aluminum-arsenide (GaAlAs) diode laser device (Chattanooga Group, Windham, New Hampshire, USA) in this study, which device probe possesses five 850nm, 200mW diode lasers in the center surrounded by 28 light-emitting diodes (LEDs) and superluminescent diodes (SLDs) with clusters of different wavelengths (twelve 670nm [10mW] LEDs, eight 880nm [25mW] SLDs, and eight 950nm [15mW] SLDs). The total power is 1440mW of light energy comprising 1000mW from lasers and 440mW from LEDs. The laser beam irradiated an area of 31.2cm^2 with 43.2J of energy per point and an energy density per time of 1.4J/cm^2. Each tender area of the tendon-bone interface was divided into 4cm^2 squares. During each session, the total amount of irradiation time per area was 60 seconds. Each patient in the laser group underwent 15 laser sessions during the 5-day trial, 3 times per day for 5 days.

Conventional therapy comprised physical modalities such as infrared and transcutaneous electrical nerve stimulation.

2.3. Quantitative Sacroiliac Scintigraphy for the Diagnosis of SI Stress

Musculoskeletal bone scan and quantitative sacroiliac scintigraphy (QSS) were performed after intravenous injection of 750 MBq Tc-99m methylene diphosphonate. The enrolled patients underwent QSS measurement before and after therapy. The planar imaging of the SI joints was performed with image acquisition around the SI joints using a single-head rotating gamma camera (IGE Starcam; GE Medical Systems, Milwaukee, WI). Data were acquired in a 128 X 128 matrix. Rectangular regions-of-interests (ROIs) were drawn from the right and left SI joints as well as the sacrum, which represented the background activity (Figure **2a**). All ROIs were drawn and semi quantitative analysis was done by the nuclear medicine physician.

Skeletal scintigraphy shows osteoblastic activity in periosteum of bones by way of degree of activity uptake, thereby confirming the presence of periosteal reaction that may not be apparent radiographically [23]. QSS is now widely used as a practical tool to detect and quantify SI disease [26, 27]. Through QSS the SI/S ratio can be obtained, which is the ratio between the total number of counts from the right and left SI joints divided by total counts from the sacrum (S) [28, 29]. The equation for calculating the ratio is: SI/S ratio = (mean SI counts/pixel) / (mean sacral counts/pixel). The ratio for the upper, middle, and lower parts of left- and right-sided (lateralization) SI joints was measured separately. The SI/S ratio acted as an objective measure of SI joint disorder in our study. A part of data and images were processed in Department of Nuclear Medicine, Taichung Veterans General Hospital. Figure **2b** was a representative image of the changes in QSS after therapy for MTSS.

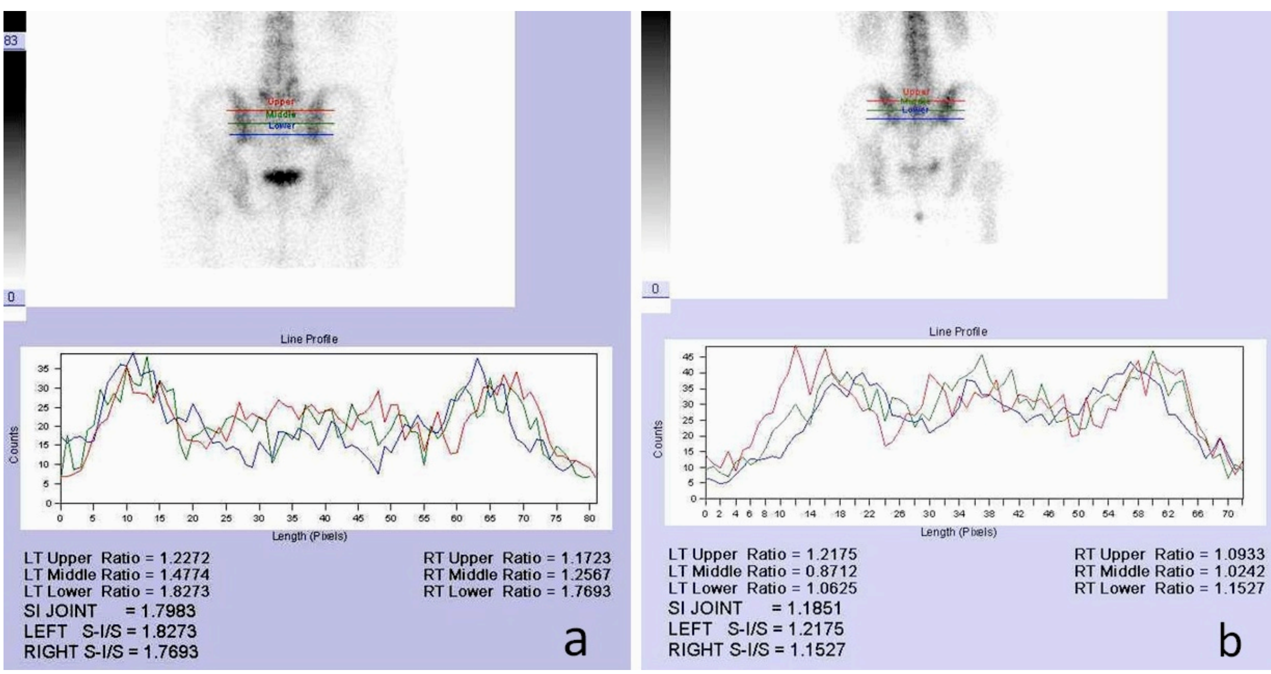

Figure 2: Representative images of measurements of the SI/S ratio obtained from QSS before (**a**) and after (**b**) therapy of case 17 (O.-F.B) with MTSS. QSS: quantitative sacroiliac scintigraphy, which is derived from the counting number of the sacroiliac (SI) joint divided by that of sacrum (S).

2.4. Data and Statistical Analyses

We used the Excel software package (Microsoft Corp, Redmond, WA, USA) to record the data and PROC GENMOD (SAS software, version 9.2, SAS Institute, Carry, NC, USA) for statistical analysis. Generalized estimating equations (GEEs) were applied to evaluate the associations of LEFS. We adjusted for the correlations between QSS and different parts of the SI joint, and adjusted for potential confounders as well. The analysis was also adjusted for age. A *p* value ≤ 0.05 was deemed to indicate a statistically significant difference.

The research protocol (TSGHIRB, No. 098-05-153) was approved by the Institutional Review Board of Tri-Service General Hospital. The study conformed to the principles of the Declaration of Helsinki and all patients provided written informed consent.

3. RESULTS

A total of 53 patients (mean age, 23 years; range, 18.0-36) were recruited in our study, and the majority of these injuries confirmed as periostitis involve the tibia (20), followed in decreasing frequency by the tarsal/metatarsal bones (17), knee (14), femur (1), and hip (1). Patients were randomly sorted into laser group and conventional therapy group after they finished the QSS and LEFS. There were 28 patients receiving laser therapy, but nine did not undergo QSS after therapy. Twenty five underwent conventional therapy, and only five patients underwent post-therapy QSS (Figure **1**). Of 20 patients, the pain was present on palpation of the distal two-thirds of the lateral and medial tibial border over the length of 9cm and on muscle manual testing of foot flexors.

The GEE model was adjusted for age using PROC GENMOD within SAS (version 9.2). After we adjusted for age and therapy effect, the group differences of the LEFS before and after therapy was 38.45, e.g. the LEFS after therapy was 38.45 units (P < 0.0001) higher than LEFS before therapy (Table **1**).

As shown in Table, while building the model we considered the following potential confounders: subject characteristics, lateralization (left, right) and part of the foot (upper, middle, lower). After adjusting for those confounders, we found that QSS after therapy was significantly higher in both groups, indicating that successful therapy of MTSS had a therapeutic effect on SI joint disorder (P < 0.0001). However, there was no significant difference in QSS between the right and left sides (*P* > 0.05, data not shown). The QSS for the middle part on both sides was significantly higher than that for the lower part (*P* = 0.0250). The results indicate that only the QSS for the middle part of the joint is associated with the QSS for the lower part of the joint.

4. DISCUSSION

MTSS is a recognized complication of the chronic, intensive, weight-bearing training commonly practiced by athletic and military populations and is one of the most common causes of exertional leg pain in athletes. MTSS is a common overuse injury characterized by pain located on the medial side of the lower leg during weight bearing activities such as gait. MTSS is not just a soft-tissue injury but also a bony injury, because MTSS subjects have smaller tibial cross-sectional dimensions than do their uninjured exercising counterparts [30]. A work using magnetic resonance imaging to study pathophysiology of MTSS from shin splint syndrome to a stress fracture suggested that a

Table 1: Generalized Estimating Equations Analysis for Functional Scale and SI/S Ratio at Different Site, Part and Therapy Effect

Parameter		Estimate ± SE	95% CL	Z	Pr > |Z|
LEFS					
	After vs. Before	38.45 ± 6.90	34.17 - 27.33	18.74	< 0.0001
Intercept for QSS		1.25 ± 0.03	1.21 - 1.34	39.12	< 0.0001
Part	Upper vs. Lower	-0.06 ± 0.04	-0.14 - 0.00	-1.8	0.0571
	Middle vs. Lower	-0.05 ± 0.03	-0.10 - 0.01	-2.21	0.0247

QSS: quantitative sacroiliac scintigraphy, which is derived from the counting number of the sacroiliac (SI) joint divided by that of sacrum (S).

Statistical model was assessed by using GEEs and was adjusted for LEFS, site (left vs. right), part (upper, middle and lower), time and therapy by using PROC GENMOD (SAS, 9.2v).

GEE, Generalized estimating equations; SE, Standard error; CL, Confidence limits.

LEFS: Lower Extremity Functional Scale.

P < 0.05 = statistically significant.

progression of injury can be identified, starting with periosteal edema, then progressive marrow involvement, and ultimately frank cortical stress fracture [31]. Early treatment of MTSS not only can prohibit ensuing stress fracture, but also, we presumed, buttom-up normalize the stress of SI joint. Risk factors contributing this injury include pronated foot posture [32], sport (cross-country/track), and decreased left calcaneal bone mineral density [33].

In this prospective study, we found that SI joint stress resulting from processing of MTSS could be normalized bottom-up after successful therapy of MTSS by either laser or conventional therapy. Our study responded to a work regarding leg disorder in individuals with familial Mediterranean fever, which data claimed that exertional leg pain is frequently associated with sacroiliitis [34]. In view of our patient selection, however, we did not consider it as an underlying ankle enthesopathy, nor a new feature of spondyloarthritis.

With respect to mechanism, the role of biomechanical kinematic chain of the lower extremities should be accentuated. Abnormal gait pattern interferes with crucial spinal segmental movements, and can result in serial postural distortions, muscular imbalances, spinal joint dysfunction, and low back disorders [35]. A previous review article identifying the functional biomechanical deficits in the kinetic chain that contribute to this repetitive microtrauma, for instance, inadequate internal rotation of the tibia and femur, and result in inhibition or decreased recruitment of the gluteal muscles, or further SI joint stress [36]. The results of our study responded to the fact that the existence of a kinematic chain, where changes in leg position led to significant alterations of the pelvic position [37].

The pattern of radioactive uptake in shin splints reflects the actual underlying physiology. The calf muscles (gastrocnemius and soleus) provide additional power for running when the runner spends longer times to extend the foot. The extra power involved places greater stress on the soleus, which attaches directly to the posteromedial tibial cortex. This increased stress results in enhancing tension and pulling of the muscle on the tibial periosteum, leading to stress along the diaphysis [3, 17]. The linear pattern (on the delayed phase of the bone scan only) thus represents periostitis along the insertion of these muscles [38]. We believe that if overload in activity, the kinetic chain goes upward to femur, hip and SI joint. When the SI joint becomes injured or stress, pain can develop, a condition called SI joint stress. Mechanical changes in the pelvic girdle can lead to alterations of the SI joint, so a pelvic tilt may increase the incidence of SI joint stress [39]. It is possible that the kinematic chain linking the lower extremities and the pelvis compensates, at least in part, for the mechanical changes in the pelvic girdle [40]. After MTSS had been successfully treated, all the compensation for abnormal stress reversed. Therefore, it appears that individual SI joints react to different leg positions. However, further observation is needed to identify the amount of pelvic tilt that affects spinal posture.

The dynamic knee valgus (DKV) plays a crucial role in the kinematic chain. DKV is a neuromuscular driver of foot pronation through torque conversion at the sub-talar joint [41]. DKV likely potentiates MTSS through excessive tibial rotation resulting from excessive pronation and torque conversion at the sub-talar joint, providing partial explanation for similarities in higher MTSS incidence in females. Moen *et al.* (2012) found that decreased hip internal range of motion was associated with MTSS [42], and Pietrzak (2014) pointed out that a few of specified exercises could attenuate DKV *via* improving kinetic chain biomechanics [43]. A recent study demonstrated that after instruction individuals can decrease hip adduction and correct DKV affecting pelvis, femur, tibia and trunk segment kinematics, and that pain reduction in the corrected condition is associated with improved segment kinematics [44]. We believe that restoring proper biomechanics to the entire kinetic chain and rehabilitation of the injured area should be the primary aim of treatment to optimize shock absorption, and that the recovery of leg pain normalizes the SI joint stress [45]. A previous review article confirmed that a long-term successful outcome and prevention of rein jury are more likely if the focus of rehabilitation is on the restoration of the functional kinetic chain of muscles and joints, rather than on a specific injured tissue [36].

The relationship between dysfunction of the lower third part of the SI joint and MTSS is unclear. The pelvic girdle is connected by a strong fibrous tissue to the lumbar spine at the SI joint [46]. Accompanying with disorders of SI joints, the caudal part of the SI joint is often involved first, and the disease progresses cranially [47]. Similarly, increased uptake of isotope in the lower part of the SI joint on scintigraphic images was found in late-stage SI joint disorder [48]. In an investigation of the anatomic structures involved in early- and late-stage SI joint disorder, Muche *et al.*

(2003) found that the iliac side of the SI joints was more frequently involved in early stage than the sacral side (58% versus 48%). They also found that the dorsocaudal part (lower third) of the synovial joint and the bone marrow were the most frequently stress structures in early stage [49].

Observation of SI joint from anatomical view, it can be divided as the upper third, middle third and lower third parts with distinct histological structures in each part [26, 27]. Mechanical shearing injury due to malposture might contribute to the pathogenesis of SI joint stress. We speculate that the lower third part of the SI joint might exert a kind of reaction in response to alteration of kinematic chain. The SI joint acts as a "self-bracing mechanism" because of its corkscrew shape created by the different wedge angles in transverse cross-sections at the cranial and caudal ends of the joint, which provide resistance to sliding [50, 51]. The self-bracing mechanism can be damaged by abnormal shearing forces resulting from malposture. Abnormal shearing force always physically concentrates at the lower third of the SI joint [52]. That is the reason why disorders occurring in the lower third of the joint are more obvious than in other parts, as measured numerals shown on Figure **2a** and **b**.

5. STUDY LIMITATIONS

There are a number of limitations in our study. First, the small sample size deemed our main limitation. The small sample size of patients with MTSS confirmed by bone scintigraphy is not a representative distribution of the population. Second, we did not measure three-dimensional angular movements with a computer-based video analysis system to measure pelvis tilt or list in our patients. Third, whole body kinematic chain dysfunction is still a relatively unstudied field and further studies are necessary. In our study, the therapy results were merely estimates based on SI/S ratio obtained from QSS images.

CONCLUSION

Nuclear scintigraphic imaging revealed a marked improvement in QSS, especially in the lower third part of the joint, after therapy for MTSS. Examination of the kinematic chain from the leg to the back while simultaneously measuring the quantitative SI ratio provides valuable information for exploring the relationship between SI joint disorders and MTSS.

CONFLICTS INTEREST

The first three authors authors (Chen CL, Chuang HY, and Chang CC) contributed equally to this study.

ACKNOWLEDGEMENTS

This research project was supported by Scientific Research Grant No. C-11-010 (2011) and No. MAB-102-56 (2013) provided by the Ministry of National Defense-Medical Affairs Bureau, Taiwan.

REFERENCES

[1] Fournier PE. [Tibial periostitis ("medial tibial stress syndrome")]. Rev Med Suisse Romande 2003; 123(6): 369-70.

[2] Brukner P and Khan K. Clinical Sports Medicine, third ed. ed. McGraw Hill, North Ryde, Australia 2007.

[3] Moen MH, Tol JL, Weir A, Steunebrink M and De Winter TC. Medial tibial stress syndrome: a critical review. Sports Med 2009; 39(7): 523-46. http://dx.doi.org/10.2165/00007256-200939070-00002

[4] Sobhani V, Shakibaee A, Khatibi Aghda A, Emami Meybodi MK, Delavari A and Jahandideh D. Studying the relation between medial tibial stress syndrome and anatomic and anthropometric characteristics of military male personnel. Asian J Sports Med 2015; 6(2): e23811. http://dx.doi.org/10.5812/asjsm.23811

[5] Williams C, O'Brien B and Duffy G. Asymptomatic periostitis of the navicular and fifth metatarsal bones in a high jumper. Clin Nucl Med 1998; 23(9): 613-4. http://dx.doi.org/10.1097/00003072-199809000-00011

[6] Hod N, Ashkenazi I, Levi Y, Fire G, Drori M, Cohen I, *et al.* Characteristics of skeletal stress fractures in female military recruits of the Israel defense forces on bone scintigraphy. Clin Nucl Med 2006; 31(12): 742-9. http://dx.doi.org/10.1097/01.rlu.0000246632.11440.70

[7] Craig DI. Current developments concerning medial tibial stress syndrome. Phys Sportsmed 2009; 37(4): 39-44. http://dx.doi.org/10.3810/psm.2009.12.1740

[8] Griebert MC, Needle AR, McConnell J and Kaminski TW. Lower-leg Kinesio tape reduces rate of loading in participants with medial tibial stress syndrome. Phys Ther Sport 2016; 18: 62-7. http://dx.doi.org/10.1016/j.ptsp.2014.01.001

[9] Schulze C, Finze S, Bader R and Lison A. Treatment of medial tibial stress syndrome according to the fascial distortion model: a prospective case control study. Scientific World J 2014; 790626.

[10] Nissen LR, Astvad K and Madsen L. [Low-energy laser therapy in medial tibial stress syndrome]. [Article in Danish] Ugeskr Laeger 1994; 5; 156(49): 7329-31.

[11] Chang CC, Ku CH, Hsu WC, Hu YA, Shyu JF and Chang ST. Five-day, low-level laser therapy for sports-related lower extremity periostitis in adult men: a randomized, controlled trial. Lasers Med Sci 2014; 29(4): 1485-94. http://dx.doi.org/10.1007/s10103-014-1554-z

[12] Loudon JK and Dolphino MR. Use of foot orthoses and calf stretching for individuals with medial tibial stress syndrome. Foot Ankle Spec 2010; 3(1): 15-20. http://dx.doi.org/10.1177/1938640009355659

[13] Craig DI. Medial tibial stress syndrome: evidence-based prevention. J Athl Train 2008; 43(3): 316-8. http://dx.doi.org/10.4085/1062-6050-43.3.316

[14] Yeung SS, Yeung EW and Gillespie LD. Interventions for preventing lower limb soft-tissue running injuries. Cochrane Database Syst Rev 2011; 6(7): CD001256. http://dx.doi.org/10.1002/14651858.cd001256.pub2

[15] Fogarty S. Massage treatment and medial tibial stress syndrome; A commentary to provoke thought about the way massage therapy is used in the treatment of MTSS. J Bodyw Mov Ther 2015; 19(3): 447-52. http://dx.doi.org/10.1016/j.jbmt.2014.11.003

[16] Rompe JD, Cacchio A, Furia JP and Maffulli N. Low-energy extracorporeal shock wave therapy as a treatment for medial tibial stress syndrome. Am J Sports Med 2010; 38(1): 125-32. http://dx.doi.org/10.1177/0363546509343804

[17] Reshef N and Guelich DR. Medial tibial stress syndrome. Clin Sports Med 2012; 31(2): 273-90. http://dx.doi.org/10.1016/j.csm.2011.09.008

[18] Winters M, Eskes M, Weir A, Moen MH, Backx FJ and Bakker EW. Treatment of medial tibial stress syndrome: a systematic review. Sports Med 2013; 43(12): 1315-33. http://dx.doi.org/10.1007/s40279-013-0087-0

[19] Eshed I, Kushnir T, Livneh A, Langevitz P, Ben-Zvi I, Konen E, *et al*. Exertional leg pain as a manifestation of occult spondyloarthropathy in familial Mediterranean fever: an MRI evaluation. Scand J Rheumatol 2012; 41(6): 482-6. http://dx.doi.org/10.3109/03009742.2012.698301

[20] Samuelson DR and Cram RL. The three-phase bone scan and exercise induced lower-leg pain. The tibial stress test Clin Nucl Med 1996; 21(2): 89-93. http://dx.doi.org/10.1097/00003072-199602000-00001

[21] Shikare S, Samsi AB and Tilve GH. Bone imaging in sports medicine. J Postgrad Med 1997; 43(3): 71-2.

[22] Jimenez CE. Advantages of diagnostic nuclear medicine part 1: musculoskeletal disorders. Phys Sportsmed 1999; 27(12): 44-72. http://dx.doi.org/10.3810/psm.1999.11.1103

[23] Flynt L and Balon HR. 17-year-old runner with shin pain. J Nucl Med Technol 2014; 42(3): 238-9. http://dx.doi.org/10.2967/jnmt.113.135897

[24] Yüksel O, Ozgürbüz C, Ergün M, Işlegen C, Taskiran E, Denerel N, *et al*. Inversion/Eversion strength dysbalance in patients with medial tibial stress syndrome. J Sports Sci Med 2011; 10(4): 737-42. eCollection 2011.

[25] Moen MH, Schmikli SL, Weir A, Steeneken V, Stapper G, de Slegte R, *et al*. A prospective study on MRI findings and prognostic factors in athletes with MTSS. Scand J Med Sci Sports 2014; 24(1): 204-10. http://dx.doi.org/10.1111/j.1600-0838.2012.01467.x

[26] Chang ST, Ku CH and Cherng SC. Evidence-based correlation between anti-streptolysin O serum titer and sacroiliac joint disorder. J Rheumatol 2007; 34(8): 1746-52. Epub 2007 Jul 1.

[27] Chang CC, Chu HY, Chiang SL, Li TY and Chang ST. Impairment of static upright posture in subjects with undifferentiated arthritis in sacroiliac joint in conjunction with elevation of streptococcal serology. J Back Musculoskelet Rehabil 2009; 22(1): 33-41. doi: 10.3233/BMR-2009-0217.

[28] Bozkurt MF, Uğur O, Ertenli I and Carner B. Combined use of bone and bone marrow scintigraphies for the diagnosis of active sacroiliitis. Ann Nucl Med 2001; 15(2): 117-21. http://dx.doi.org/10.1007/BF02988601

[29] Huang JY, Tsai MF, Kao PF and Chen YS. Automatic computer- aided sacroiliac joint index analysis for bone scintigraphy. Comput Methods Programs Biomed 2010; 98(1): 15-26. http://dx.doi.org/10.1016/j.cmpb.2009.07.010

[30] Franklyn M, Oakes B, Field B, Wells P and Morgan D. Section modulus is the optimum geometric predictor for stress fractures and medial tibial stress syndrome in both male and female athletes. Am J Sports Med 2008; 36(6): 1179-89. http://dx.doi.org/10.1177/0363546508314408

[31] Fredericson M, Bergman AG, Hoffman KL and 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(4): 472-81. http://dx.doi.org/10.1177/036354659502300418

[32] Neal BS, Griffiths IB, Dowling GJ, Murley GS, Munteanu SE, Franettovich Smith MM, *et al*. Foot posture as a risk factor for lower limb overuse injury: a systematic review and meta-analysis. J Foot Ankle Res 2014; 7(1): 55. http://dx.doi.org/10.1186/s13047-014-0055-4

[33] Reinking MF, Austin TM, Bennett J, Hayes AM and Mitchell WA. Lower extremity overuse bone injury risk factors in collegiate athletes: a pilot study. Int J Sports Phys Ther 2015; 10(2): 155-67.

[34] Eshed I, Rosman Y, Livneh A, Kedem R, Langevitz P, Ben-Zvi I, *et al*. Exertional leg pain in familial Mediterranean fever: a manifestation of an underlying enthesopathy and a marker of more severe disease. Arthritis Rheumatol 2014; 66(11): 3221-6. http://dx.doi.org/10.1002/art.38797

[35] Khamis S and Yizhar Z. Effect of feet hyperpronation on pelvic alignment in a standing position. Gait Posture 2007; 25(1): 127-34. Epub 2006 Apr 18. http://dx.doi.org/10.1016/j.gaitpost.2006.02.005

[36] Geraci MC Jr and Brown W. Evidence-based treatment of hip and pelvic injuries in runners. Phys Med Rehabil Clin N Am 2005; 16(3): 711-47. http://dx.doi.org/10.1016/j.pmr.2005.02.004

[37] Kim W, João F, Tan J, Mota P, Vleck V, Aguiar L, *et al*. The natural shock absorption of the leg spring. J Biomech 2013; 46(1): 129-36. Epub 2012 Nov 28. http://dx.doi.org/10.1016/j.jbiomech.2012.10.041

[38] Love C, Din AS, Tomas MB, Kalapparambath TP and Palestro CJ. Radionuclide bone imaging: an illustrative review. Radiographics 2003; 23(2): 341-58. http://dx.doi.org/10.1148/rg.232025103

[39] Clinton SC, George SE, Mehnert M, Fitzgerald CM and Chimes GP. Pelvic floor pain: physical therapy versus injections. PM and R 2011; 3(8): 762-70. http://dx.doi.org/10.1016/j.pmrj.2011.07.006

[40] Betsch M, Schneppendahl J, Dor L, Jungbluth P, Grassmann JP, Windolf J, *et al*. Influence of foot positions on the spine and pelvis. Arthritis Care Res (Hoboken) 2011; 63(12): 1758-65. http://dx.doi.org/10.1002/acr.20601

[41] Yamaguchi S, Sasho T, Kato H, Kuroyanagi Y and Banks SA. Ankle and subtalar kinematics during dorsiflexion-plantarflexion activities. Foot Ankle Int 2009; 30(4): 361-6. http://dx.doi.org/10.3113/FAI.2009.0361

[42] Moen MH, Bongers T, Bakker EW, Zimmermann WO, Weir A, *et al*. Risk factors and prognostic indicators for medial tibial stress syndrome. Scand J Med Sci Sports 2012; 22(1): 34-9. http://dx.doi.org/10.1111/j.1600-0838.2010.01144.x

[43] Pietrzak M. Diagnosis and management of acute medial tibial stress syndrome in a 15 years old female surf life-saving competitor. Int J Sports Phys Ther 2014; 9(4): 525-39.

[44] Graci V and Salsich GB. Trunk and lower extremity segment kinematics and their relationship to pain following movement instruction during a single-leg squat in females with dynamic knee valgus and patellofemoral pain. J Sci Med Sport 2015; 18(3): 343-7. Epub 2014 Apr 26. http://dx.doi.org/10.1016/j.jsams.2014.04.011

[45] Krenner BJ. Case report: comprehensive management of medial tibial stress syndrome. J Chiropr Med 2002; 1(3): 122-4. http://dx.doi.org/10.1016/S0899-3467(07)60019-6

[46] Duval K, Lam T and Sanderson D. The mechanical relationship between the rear foot, pelvis and low-back. Gait Posture 2010; 32(4): 637-40. http://dx.doi.org/10.1016/j.gaitpost.2010.09.007

[47] Namey TC, McIntyre J, Buse M and LeRoy EC. Nucleographic studies of axial spondarthritides I. Quantitative sacroiliac scintigraphy in early HLA-B27-associated sacroiliitis. Arthritis Rheum 1977; 20(5): 1058-64. http://dx.doi.org/10.1002/art.1780200504

[48] Kaçar G, Kaçar C, Karayalçin B, Güngör F, Tuncer T and Erkiliç M. Quantitative sacroiliac joint scintigraphy in normal subjects and patients with sacroiliitis. Ann Nucl Med 1998; 12(3): 169-73. http://dx.doi.org/10.1007/BF03164785

[49] Muche B, Bollow M, François RJ, Sieper J, Hamm B and Braun J. Anatomic structures involved in early- and late-stage sacroiliitis in spondylarthritis: a detailed analysis by contrast- enhanced magnetic resonance imaging. Arthritis Rheum 2003; 48(5): 1374-84. http://dx.doi.org/10.1002/art.10934

[50] Snijders CJ, Vleeming A and Stoeckart R. Transfer of lumbosacral load to iliac bones and legs Part 1: Biomechanics of self-bracing of the sacroiliac joints and its significance for treatment and exercise. Clin Biomech (Bristol, Avon) 1993; 8(6): 85-94. http://dx.doi.org/10.1016/0268-0033(93)90002-Y

[51] Snijders CJ, Vleeming A and Stoeckart R. Transfer of lumbosacral load to iliac bones and legs Part 2: loading of the sacroiliac joints when lifting in a stooped posture. Clin Biomech (Bristol, Avon) 1993; 8(6): 295-301. http://dx.doi.org/10.1016/0268-0033(93)90003-Z

[52] Li H, Huang W, Xu Y and Lian G. On the squeeze flow of a bingham fluid between two rigid spheres. Particul Sci Technol: An Intern J 2004; 22(1): 1-20. http://dx.doi.org/10.1080/02726350490422383

Received on 25-03-2016 Accepted on 14-04-2016 Published on 16-12-2016

DOI: http://dx.doi.org/10.12974/2313-0954.2016.03.02.1