Research Paper

Investigating the Effects of Closed Kinetic Chain Exercises on Proprioception and Inversion/Eversion Strength Imbalance of the Ankle Joint in Track and Field Athletes With Medial Tibial Stress Syndrome

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ABSTRACT

Purpose: Correct proprioceptive information and muscle balance of the ankle joint muscles are essential in preventing sports injuries. This study aims to investigate the effect of closed kinetic chain exercises on proprioception and inversion/eversion strength imbalance of the ankle joint in track and field athletes with medial tibial stress syndrome.

Methods: This was a randomized controlled trial study. In the present study, 22 male track and field athletes with a history of medial tibial stress syndrome and 11 male track and field athletes without medial tibial stress syndrome were purposefully selected and divided into 3 groups of 11 people as follows: 1) Closed kinetic chain exercises group, 2) The control group, and 3) The healthy group. The evaluation of absolute error of ankle joint position sense was done using the isokinetic dynamometer device actively on the leg with medial tibial stress syndrome. Isokinetic muscle strength testing was performed at 30°/s and 120°/s to assess the invertor and evertor muscle strength of the ankle. After evaluating the variables in the pre-test, the experimental group received the closed kinetic chain exercises three days each week for 8 weeks. During this period, the control group and the healthy group did not perform any exercises. Finally, after executing the selected protocol, the mentioned variables were measured again in the post-test. The analysis of covariance test was used to check the variables. In addition, the number of changes between groups was checked by the Bonferroni statistical test.

Results: The results of the one-way analysis of variance statistical test showed no significant difference between the mean of the groups in the pre-test ($P\leq0.05$). The results of the analysis of covariance test showed a significant difference between closed the kinetic chain exercises, control, and healthy groups ($P\leq0.05$). The results of the post hoc test regarding the investigation of the intergroup difference. A significant difference was observed between closed kinetic chain exercises and healthy groups with the control group at post-intervention proprioception and inversion/eversion strength imbalance of the ankle joint. In addition, the results showed no significant differences between the closed kinetic chain exercises group and the healthy group ($P\leq0.05$).

Conclusion: It seems that under the influence of a specialized training course of the closed kinetic chain exercises for athletes, because of the significant changes in establishing the muscle balance of the evertor and invertor muscles of the ankle joint and the sense of proprioception in this area, the sports performance of the athletes improves.

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Highlights

- The effect of ckc exercises on Muscle imbalance.
- Muscle imbalance in men with medial tibial stress syndrome.
- Improvement of ckc exercises for proprioception.

Plain Language Summary

Lower shin pain is considered a serious complication in people. This complication mainly occurs among individuals who do too much running and aerobic exercise on flat and uneven surfaces. After a period of running, the pain in the lower part of the leg disappears at night. Its occurrence rate is reported to be very high among runners. Various factors play a role in its occurrence, such as flat soles, muscle weakness, low or high range of motion, shoe type, running surface, and female gender. Accordingly, this study aims to investigate the effect of kinetic chain exercises depending on the sense of proprioception and the imbalance of ankle joint inversion/reversion strength in athletes with medial tibial stress syndrome.

Introduction

Medial tibial stress syndrome (MTSS) is a pain that occurs during activity, especially running, jumping, and continuous training, and it disappears with rest [1]. This pain occurs in the inner part of the tibia (usually the middle third). According to reports, the prevalence of this injury among runners and military soldiers ranges from 13.2% to 17.3%. In other words, MTSS is an exercise-induced, localized pain along the distal two-thirds of the posterior-medial tibia and can be a debilitating injury in runners. In studies of recreational runners, MTSS has been reported as the most or second most frequently diagnosed injury. The incidence of this syndrome among women who perform running 3 to 5 times a week (16.8%) was higher compared to men (10.7%). Problems related to foot kinematics, lower limb angles, navicular bone loss, foot pronation, hard surfaces (asphalt), and shoe material are among the causes of its occurrence among runners [2, 3]. The causes of MTSS are still unclear [4]; however, researchers have considered some factors associated with the possible occurrence of this pain. These factors are described in 2 groups, namely internal and external risk factors. Among the external risk factors is the rapid increase in training intensity or excessive, training on a hard and uneven surface, improper skeletal alignment, type of activity, the surface of the playing field, type of shoes, weather conditions, time of doing the exercise, and so on [5]. The internal risk factors are inappropriate warm-up, repeated and heavy running, history of the previous injury, increased external rotation in the ankle, increased strength of the plantar flexor muscles and ankle evertors, weakness of the anterior and posterior tibial muscles, type of foot posture, gender, poor exercise technique, breakdown of bone minerals, and high body mass index may be effective in the occurrence of MTSS [6]. One of the essential causes of this event is the presence of weakness in the invertor and dorsi flexor muscles and the shortness of the invertor and plantar flexor muscles of the ankle [6, 7]. The weakness of the invertor and dorsi flexor muscles of the lower leg leads to an increase in excessive force on the tibia. This makes the person prone to developing MTSS. Decreased lower limb strength leads to increased pressure on the tibia during action [7]. As a result, patients with MTSS of the tibia tend to reduce the activity of the soleus and tibias anterior muscles, which is probably a protective mechanism against pain [8]. In this regard, Garnock et al. (2018) investigated the causes of medial tibial stress syndrome and reported that the weakness of the invertor muscles and the shortness of the ankle evertor, gender, history of the previous injury, and excessive internal rotation range of the hip are among the causes of this syndrome [5]. Proprioception, one of the most important sensory systems involved in controlling balance and increasing performance is abnormal in people with MTSS because of the pain in the lower limbs, muscle imbalance, and reduced muscle flexibility compared to healthy people [9]. Proprioceptive information obtained through mechanical receptors in muscles, joints, and ligaments is the most critical afferent component of the sensory-motor system. It plays a vital role in joint functional stability and balance control [10]. Factors, such as the lack of neuromuscular coordination, weakness in joint and muscle strength, and limited range of motion of the joint are among the mechanisms that reduce joint proprioception [11]. Theoretically, it is believed that the closed kinetic chain exercises stabilize the postural and dynamic stability and increase muscle strength and joint coordination by creating more compressive force. Finally, they rebuilt the proprioceptors. Therefore, some researchers have suggested these exercises to retrain joint proprioception and increase muscle strength [12]. Increasing muscle strength and improving joint proprioception leads to better functional activities and reduces disability from the results of rehabilitation and sports exercises [13]. However, most studies have used a combination of different exercises. In addition, the differential effects of none of them on joint proprioception and muscle strength have not been evaluated. Therefore, as it is essential to address the issues of muscle imbalance and proprioception in the evaluation and adjustment of treatment programs, the need for further investigations in this field is raised. According to the studies, no research existed that measured the effect of closed kinetic chain exercises on proprioception and inversion/eversion strength imbalance of the ankle joint in track and field athletes with MTSS. As a result, the main problem of the research is whether closed kinetic chain exercises are effective on ankle joint proprioception and the inversion/eversion strength imbalance.

Materials and Methods

Based on the objectives of this study, this was an applied and semi-experimental research. Before the protocol implementation, the steps of obtaining the ethics code were followed in the research and approved by the Ethics Committee of Sport Sciences Research Institute. The statistical population of this research included male track and field athletes in the age range of 18 to 30 years. In the present study, 22 male track and field athletes with a history of MTSS and 11 male track and field athletes without MTSS were divided into 3 groups of 11 people, namely the closed kinetic chain exercises group, the control group, and the healthy group. We used the G*Power software, version 3.1.9.4 to check the size of the statistical sample. In this regard, the list of 250 athlete runners was numbered. Then, based on the numbers placed in the software, the subjects of this study were selected. Even numbers were assigned to the experimental group and odd numbers to the control group. Finally, the numbers were written and the sample size reached 11 people in each group. Additionally, informed consent was obtained from the subjects included in the study. The diagnosis of this syndrome was made by two doctors. Accordingly, people who had pain in the lower two-thirds of the leg, sensitivity to the touch of the leg, and a diameter of the pain was more than 5 cm were considered people subjects with leg pain [2, 3]. On the other hand, the exclusion criteria were knee and ankle ligament tears and a history of fracture and surgery related to muscle or muscle problems. Also, patients with diabetes and vestibular function disorders were excluded from the study. A week before the start of the program during a meeting, the subjects of this study were briefed about the conduction of the research, and a summary of the objectives was explained to the subjects. Then, the informed consent form, based on voluntary participation, was distributed and signed by the participants.

Proprioceptive sensation evaluation

The evaluation of absolute error of ankle joint position sense was done actively on the dominant leg using isokinetic dynamometer model 4 pro, made in the USA. This instrument is valid and reliable in prior publications [14]. First, the person was placed on a chair in a vaulted position and rested his leg on a platform with 40 cm height. Then, the participant put the bare part of his foot on a plate in line with the dynamometer's axis. The examiner identified the Talocrural joint in 15 degrees of plantar flexion and tied the lower part of the leg with a strap. Test positions included 15 degrees of inversion and maximum active inversion minus 5 degrees in the subtalar joint. During the feedback test, the vision was removed by a blindfold. First, the tester took the person's leg passively until maximum eversion. Then, the examiner moved the foot randomly in the direction of one of the two test positions. In this case, the person maintained the current position for 10 s to focus on the foot position and remember it. Then, the tester passively took the leg with a speed of 5 deg/sec until maximum eversion and asked the person to actively return to inversion, and the patient was taught to press the stop key when the leg reached the test position. Each test condition was performed three times, and at the end, the average value of the angle error from the reference angle of the test was recorded for analysis [15].

Isokinetic strength measurements

Isokinetic concentric strength of the leg was measured in inversion and deviation on both sides. Before doing the exercises, the subjects performed warm-up and stretching exercises for 10 min. Subsequently, the data collection process started on the isokinetic dynamometer. The examiner placed the back of the chair in an inclined position at 0 degrees. The tilt of the dynamometer was set to 55 degrees and its height was set to 0 degrees.

Table 1. Corrective exercises of the closed kinetic chain

Exercise No.	Exercise Type	Description	Set and Repetition
1	Preparation	Preparation of mental, psychological, social, and family conditions; providing explanations about medial tibial stress syndrome and the working methods of corrective exercises	20 min (1st week)
2	Release (putting the soles of the feet on the tennis ball and jelly roll)	Forward and backward on the ball and roll and moving the feet inward and outward on the ball and roll	3 rounds of 60 s (1st and 2nd week)
3	Release (external biceps, soleus, iliotibial Band)	Putting the muscle on the foam roller and moving the muscle forward and back	The 1st and the 2nd week • A 30-s double round (external part) • A 30-s round of biceps • One 30-s round of the iliotibial band
4	Releasing pain points and severe cramping	Gentle massage on the front-inner part of the leg	3 rounds of 60 s (1st and 2nd week)
5	Lengthening (biceps and external hamstring stretching)	Active stretching, static stretching, isometric stretching, proprioceptive neuromuscular facilitation stretching	The 2nd and 3rd week • A 30-s round of biceps stretching (external rotation of the rear leg) • A 30-s round of plantar muscle stretching • One round of 30-s stretch of the biceps femoris in the open arch position • One 30-s round of latissimus dorsi stretching in a standing position
6	General warm-up	Walking, doing general stretching exercises, strengthening exercises, and general balance	10 min (every week)
7	Specialized warm-up	Walking on the outer edge of the foot and doing specialized stretching exercises	15 min (every week)
8	Activation in the closed movement chain	A) Gathering the fabric in a sitting position B) Weight transfer to the tip of the toe and heel C) Walking on the outer edge of the foot while the toes are together D) External rotation of the thigh while the sole is on the floor E) Placing the ball between the knees and walking F) Sitting on the Bosu ball and the heel on the ground and the toe up and down G) Walking in the form of boxing feet on the outer edge of the foot	1 to 3 rounds-10 repetitions (3rd week), 15 repetitions (4th week), 5 repetitions (5th week)
9	Activation in closed kinetic chain exercises in Advanced mode	A) Gathering the cloth with claws in a standing position B) Gathering the cloth with the foot if a weight is placed on that side of the cloth C) Doing the inversion movement while standing with a band tied to the soles of the feet D) Performing dynamic movements (running, jumping, squatting, climbing stairs; in all cases, the subject should move his knees to the varus position) E) Sitting on the Bosu ball, the heel is on the ground and raise, and lower the toe; in this case, the subject should use the other leg as an extra load so that the subject puts the sole of the other foot on the toe and performs the movement (in this case, the alignment of standing is essential) F) Dorsi flexion of the leg in the standing position against the resistance of the band Plantar flexion with ankle inversion in a standing position against the resistance of the band	1 to 3 rounds-10 repetitions (4th week), 15 repetitions (5th and 6th week), 10 repetitions (8th week)

Exercise No.	Exercise Type	Description	Set and Repetition
10	Performance consistency	A) Ankle balance movements (standing on the Bosu ball) B) Standing with one foot on the ground C) Bending on the ground and picking up the object with the other foot from the ground D) Performing squat movements with the knees facing outward and on the outer edge of the foot in a standing position E) Placing the Physioball between the arch of the back and the wall; in this position, by contracting the abdomen, lower the thigh about 6 inches and return to the previous position (legs are shoulder-width apart) F) Placing all fours on the ground, in this position, open the thigh and shoulder opposite each other G) Balance on one leg, 10 to 15 repetitions H) Squat on the kiss J) Squat by keeping the ball between the knees K) Squat with a band around the knee L) Squat with one foot on the Bosu ball M) One-leg squat N) Ball squat, rise, lunge, squat on one leg	1 to 3 rounds-10 repetitions (6th and 7th week), 15 repetitions (8th week)

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In this regard, to evaluate the right leg, the rotation of the chair and the dynamometer were set to -85 and +5 degrees, respectively (+85 and -5 degrees respectively for the left leg). The maximal isokinetic concentric muscle strength of the leg inversion and inversion muscles was measured at angular speeds of 30 degrees/s and 120 degrees/s. Before each assessment, 4 submaximal trials were performed. The test performed in this study included 5 repetitions at a speed of 30 degrees/s and 10 repetitions at a speed of 120 degrees/s. The subjects rested for 10 s after each test and 120 s after changing to a different angular speed. Also, the dynamometer was calibrated before each test [7].

Exercise program

The basis of the exercises used in this protocol are specific exercises to stabilize the ankle joint, strengthen

Table 2. Demographic information of research variables

Index	Groups	Mean±SD	Analysis of Variance	P
Age (y)	Control	24.32±1.35	0.702	0.531
	Training	24.78±1.63		
	Healthy	25.21±1.10		
Height (m)	Control	177.00±1.12	0.385	0.745
	Training	176.93±1.80		
	Healthy	174.85±1.02		
Weight (kg)	Control	72.65±1.65	0.660	0.514
	Training	73.33±2.01		
	Healthy	72.95±1.80		
Sports history (y)	Control	12.60±0.50	0.420	0.759
	Training	13.10±0.60		
	Healthy	12.40±0.65		

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Table 3. Results of the analysis of covariance for proprioception of the ankle joint

Variables	Groups	Mean±SD	F	P	Partial Eta²
Pre-test 15 degrees of inversion	Training	8.60±2.04	42.65	0.001	0.73
	Control	8.85±1.15			
	Healthy	6.59±1.10			
Post-test 15 degrees of inversion	Training	6.62±1.20			
	Control	8.90±1.86			
	Healthy	6.60±1.12			
Pre-test maximum active inversion minus 5 degrees	Training	4.20±1.32	29.45	0.001	0.63
	Control	4.27±1.45			
	Healthy	2.65±1.15			
Post-test maximum active inversion minus 5 degrees	Training	2.80±1.48			
	Control	4.30±1.74			
	Healthy	2.66±1.13			

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the weakened muscles, and stretch shortened muscles in MTSS, retrain the proprioception of the ankle joint, balance in the ankle joint, and subsequently balance for the whole body were considered [16]. Accordingly, the participants of the experimental group took part in the closed kinetic chain exercises program taken from the American National Academy of Sports Medicine training program [16]. They participated in 24 training sessions under the supervision of a researcher 3 times a week. Because muscle adaptations occur in the first 4 weeks, the duration of the exercises was considered 8 weeks. Each training session lasted about 45 min and included a standard warm-up, stretching, and strength exercises for lower limb muscles. In the implementation process, the number of practices gradually increased during the 8 weeks of the training program and based on the individual characteristics of each subject (Table 1).

Statistical analyses

Data analysis was done by the SPSS software, version 24. The Shapiro-Wilk test was used to check the normal distribution of the data and the analysis of covariance test was used to check the variables. In addition, the number of changes between groups was checked by the Bonferroni statistical test.

Results

The result of the analysis of variance test in the pre-test did not show a significant difference ($P \geq 0.05$), which indicated the homogeneity of the subjects in the values of individual characteristics (Table 2). All the presumptions for analysis of covariance were observed for proprioceptive and invertor to evertor muscle strength of the ankle joint, such as normal distribution, equality of variations, and correlation coefficient for all proprioception muscle strength of the ankle joint variables. The results of the one-way analysis of variance test indicated no significant difference between mean groups in the pre-test. The results of the analysis of covariance test showed a significant difference between the closed kinetic chain exercises group, the control group, and the healthy group (Table 3 and Table 4). Table 5 presents the results of the post hoc test regarding the investigation of intergroup differences. A significant difference was observed between closed kinetic chain exercises and healthy with the control group at post-intervention proprioception and inversion/eversion strength imbalance of the ankle joint. In addition, the results showed no significant difference between the closed kinetic chain exercises group and the healthy group.

Table 4. Results of the analysis of covariance for inversion/eversion strength imbalance of the ankle joint

Variables	Groups	Mean±SD	F	P	Partial Eta²
Pre-test inversion at 30°/s (nm)	Training	18.40±4.25	45.60	0.001	0.75
	Control	19.80±3.92			
	Healthy	24.90±3.25			
Post-test inversion at 30°/s (nm)	Training	25.90±4.12			
	Control	19.60±4.10			
	Healthy	24.95±3.10			
Pre-test eversion at 30°/s (nm)	Training	24.20±3.40	43.40	0.001	0.72
	Control	23.20±3.40			
	Healthy	20.50±3.30			
Post-test eversion at 30°/s (nm)	Training	20.80±3.70			
	Control	23.45±3.45			
	Healthy	20.45±3.12			
Pre-test inversion/eversion at a ratio of 30°/s	Training	0.85±0.96	34.45	0.001	0.65
	Control	0.88±0.65			
	Healthy	1.23±1.02			
Post-test inversion/eversion at a ratio of 30°/s	Training	1.20±1.12			
	Control	0.87±0.78			
	Healthy	1.22 ± 1.10			
Pre-test inversion at 120°/s (nm)	Training	13.40±3.20	4.52	0.021	0.23
	Control	14.62±3.25			
	Healthy	17.05±3.20			
Post-test inversion/eversion at a ratio of 30°/s	Training	16.70±3.40			
	Control	14.60±3.40			
	Healthy	17.10±3.15			
Pre-test eversion at 120°/s (nm)	Training	12.25±2.01	1.31	0.12	0.02
	Control	13.54±2.80			
	Healthy	14.10±2.10			
Post-test eversion at 120°/s (nm)	Training	13.95±3.10			
	Control	13.70±2.96			
	Healthy	14.10±3.10			
Pre-test inversion/eversion at a ratio of 120°/s	Training	1.20±0.90	25.85	0.001	0.52
	Control	1.10±0.60			
	Healthy	2.02±0.75			
Post-test inversion/eversion at a ratio of 120°/s	Training	1.98±0.85			
	Control	1.09±0.75			
	Healthy	2.04±0.72			

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Table 5. The results of the post hoc test as compared to inter-group

Variables	Groups		Mean±SD	P
15 degrees of inversion	Training	Control	3.10±0.90	0.001
		Healthy	-1.85±1.20	0.24
	Control	Training	-3.10±0.90	0.001
		Healthy	3.40±0.96	0.001
Maximum active inversion minus 5 degrees	Training	Control	4.10±1.05	0.001
		Healthy	-1.20±0.84	0.26
	Control	Training	-4.10±1.05	0.001
		Healthy	4.15±1.20	0.001
Inversion at 30°/s (nm)	Training	Control	5.8±1.25	0.001
		Healthy	-1.05±0.90	0.28
	Control	Training	-5.8±1.25	0.001
		Healthy	5.85±1.25	0.001
Eversion at 30°/s (nm)	Training	Control	5.10±1.30	0.001
		Healthy	-0.95±0.54	0.30
	Control	Training	-5.10±1.30	0.001
		Healthy	6.10±1.41	0.001
Inversion/eversion at a ratio of 30°/s	Training	Control	4.10±1.10	0.001
		Healthy	1.02±1.15	0.28
	Control	Training	-4.10 ± 1.10	0.001
		Healthy	4.65±1.20	0.001
Inversion at 120°/s (nm)	Training	Control	3.05±1.12	0.001
		Healthy	0.80 ± 0.98	0.32
	Control	Training	-3.05±1.12	0.001
		Healthy	3.50±1.20	0.001
Inversion/eversion at a ratio of 120°/s	Training	Control	3.32±1.42	0.001
		Healthy	-0.90±0.95	0.32
	Control	Training	-3.32±1.42	0.001
		Healthy	4.60±1.25	0.001

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Discussion

The findings indicated the effectiveness of closed kinetic chain exercises on improving ankle joint position sense at 15°C and 5°C inversion angles and the ratio of invertor to evertor muscle strength at 30°C and 120°C angles in athletes with MTSS. Based on the researcher's findings, no study was found in this field that considered the role of closed kinetic chain exercises on the proprioceptive sense of the ankle joint and the ratio of invertor muscle strength to evertor in athletes with MTSS. Therefore, some studies with a different statistical population and exercise protocol are discussed in line with the present study. Naderi et al. (2019) investigated the effect of bilateral orthosis supporting the inner arch of the foot on improving the plantar pressure distribution pattern in people with MTSS. This study showed that the use of arch support orthoses might be an effective tool to equalize pressure distribution patterns in all parts of the soles of the feet [17]. Garcia et al. (2017) studied the effect of shock therapy, stretching, and strengthening exercises on improving the pain and performance of 42 military students with MTSS. The researchers of this study reported that the use of shock therapy, along with stretching and strengthening exercises lead to an improvement in the amount of pain and an increase in running time in these people [18]. Griebert (2016) reported that in people with MTSS, because of excessive pronation of the ankle joint, the amount of force loading on the sole of their foot is faster (higher) than in the control group; on the other hand, the sense of the position of the ankle joint is weaker. He also observed that the loading rate of the forces in the inner part of the sole and the level of feeling of the position of the ankle joint improved immediately after using the Kinesio tape [19].

The possible reasons for the increase in the sense of the ankle joint position following closed kinetic chain exercises can be considered the change in the feedback of the mechanoreceptors which leads to the reorganization of the central nervous system and sensorimotor integration and causes a difference in the motor response [20, 21]. It is also possible to mention the activation of proprioceptive receptors, preparation of motor neurons in a group of muscles and joints to perform a movement, increasing coordination and integration of motor units, co-contraction of cooperating muscles, and increased inhibition of opposing muscles [22]. In addition, these exercises cause simultaneous contraction of the muscles around the joints which improves the control of joint stability and proprioception. For the neuromuscular control of different body parts within the movement chain, the presence of proprioception is necessary; therefore, a weight-bearing activity is needed in the lower limb so that the muscles and joints can work simultaneously and synergistically with each other. Thus, closed kinetic chain exercises using leg, wrist, knee, and thigh muscles apply pressure and natural forces on all the joints inside the chain; meanwhile, it is beneficial for improving proprioceptive efficiency. On the other hand, closed kinetic chain activities can be coordinated using multi-joint and multi-faceted movements, proprioceptive feedback sent from posterior bodies, Raffinic terminals, Golgi bodies, Majoni, and Golgi tendon organs [21].

Other results of this study showed that 8 weeks of a closed range of closed kinetic chain exercises improves the ratio of invertor to evertor muscle strength, which is reduced in athletes with MTSS with muscle weakness due to problems walking or running [23]. Also, the loss of the navicular bone can be caused by the strength of the erator muscles [24]. In this regard, Newsham et al. (2012) and Rompe et al. (2010), proprioceptive neuromuscular facilitation and stretching exercises lead to improvement of muscle balance, reduction of pain, and improvement of performance through improvement of invertor muscle strength and evertor muscle stretch [25, 26]. Selvaraj et al. (2019), in a review study, stated that closed movement chain exercises improve the coordination of the neuromuscular system and change the muscle contraction pattern, such as reducing the contraction time and increasing the contraction amplitude. By creating the simultaneous activity of the gamma nerves, its ascending activity increases the muscle spindle and improves the production force [27]. On the other hand, the results of the present study are not consistent with the study of Henry et al. (2010). Henry et al.'s study (2010) indicated that peroneal muscle activity was not affected after closed kinetic chain exercises [28]. The discrepancy between the results of this study and the current research can be considered the difference in the type of exercises and subjects, which can be the possible reason for the adaptations of physiology in the present study. The strength of the ankle joint muscles depends on various factors that can be changed by training. Factors affecting strength include muscle size, action potential intensity, and nerve impulses, which increase with exercise. Researchers believe that another factor in increasing muscle strength is improving the coordination of motor units. Also, previous studies have shown that when the force exerted on the muscle tendons and connective tissue structures exceeds the tolerance threshold, the Golgi tendon organ causes the motor neurons of the muscle to be deactivated to prevent the application of such forces [29]. Exercise increases the strength produced by the muscle by reducing the inhibitory mechanism of the Golgi tendon organ [29]. It seems that closed kinetic chain exercises can lead to higher levels of strength by creating the mentioned adaptations in the neuromuscular system. The importance of strength in preventing sports injuries has been well demonstrated by researchers. Ankle joint muscle strength creates dynamic stability and functional stability of the ankle joint [28].

Conclusion

According to the results obtained in this research, it is suggested that, if possible, the specialized training protocol of the closed kinetic chain exercises be included as a part of the training programs of track and field athletes suffering from MTSS, in addition to using the benefits of increasing the strength of the limb muscles. It can improve the proprioceptive sense of the ankle joint of the athletes, reduce the prevalence of sports injuries, especially in competitive track and field athletes, and increase their sports performance.

Study limitations

The limitations of the present study included not controlling nutrition, stress, and daily activities that were outside of our physical exercises, and on the other hand, not measuring the motivation of subjects with MTSS to enter the research. In addition, correcting the abnormality of the MTSS could have a significant effect on the improvement of the subjects' function. This had a special place in this study.

Ethical Considerations

Compliance with ethical guidelines

This study approved by Institutional Ethics Committee of Sport Sciences Research Institute (Code: SSRI.REC-2202-1492. The subjects provided informed consent to participate in this research.

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Authors' contributions

Conceptualization and software: Taleb Fadaei Dehcheshmeh; Data analysis: Ali Shamsi Majelan, Mohammad Rahim Amiri Tape Bor and Bayan Heydariyan; Data curation, visualization, investigation and project administration: Taleb Fadaei Dehcheshmeh and Ali Shamsi Majelan; Methodology: Taleb Fadaei Dehcheshmeh, Bayan Heydariyan and Mohammad Rahim Amiri Tape Bor; Writing and validation: All authors.

Conflict of interest

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