Research Paper

The Effect of Comprehensive Corrective Exercise on the Function of Lower Limb and Joint Position Sense in Female Karatekas With Flatfoot

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ABSTRACT

Purpose: Karate is one of the most popular martial arts around the world, and flatfoot deformity is one of the most common disorders in people participating in this sport. This disorder can negatively affect the function and joint position sense (JPS). This study aimed to investigate the effect of 6 weeks of comprehensive corrective exercise training on the function of the lower limb and JPS in female karatekas with flatfoot.

Methods: In this field trial study, 40 female karatekas with flexible flatfoot postures were recruited and randomly divided into two groups of exercise and control. The Staheli index test was performed for all subjects to assess the condition of the foot posture, as one of the inclusion criteria also, single leg 6-m timed hop test, single leg triple hop for distance test, and ankle joint JPS were used to evaluate the function of the lower limb. Then, the exercise group performed 6 weeks of corrective exercises, but the control group did not perform any specific exercises during this period. After 6 weeks, the tests were repeated. A covariance analysis test was used to evaluate the between-groups differences, and paired sample t-test was used to evaluate the within-group changes.

Results: Corrective exercise group in the post-test had a better performance than the pre-test in the Staheli index test, JPS, the single leg 6-m timed hop test, and single leg triple hop for distance test (P=0.0001). However, in the control group, no significant difference was observed between the two stages of the test (P>0.05). Also, by comparing groups in the post-test via the Staheli index test, JPS, single leg 6-m timed hop test, and single leg triple hop for distance test. It was found that the experimental group achieved better results than the control group (P>0.05).

Conclusion: Six weeks of comprehensive corrective training has significantly improved foot posture, JPS, and function of the lower limb in female karatekas with flatfoot. Thus, comprehensive corrective exercises can be used in this group to improve foot posture, JPS, and function of the lower limb.

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Highlights

- Corrective exercises improved posture in female karatekas with flat foot.
- Corrective exercises improved the function of lower limb of female karatekas with flat foot.
- Corrective exercises led to the improvement of joint position sense of female karatekas with flat foot.

Plain Language Summary

Flat foot are one of the most common musculoskeletal disorders in the human body, which can have many negative consequences. This problem is also very common in Karteka people. Among the negative consequences of this abnormality, we can mention the weakness in function as well as the reduction in identifying the position of the ankle joint, which can lead to injury. Corrective exercises are one of the solutions that can help improve this problem and reduce its negative consequences. In this research, the effect of corrective exercises on foot posture, lower limb function, and a person's understanding of the position of the foot joint in female karatekas with flat foot was investigated. The results of this research showed that performing corrective exercises in addition to improving posture has been able to improve function and also understanding of joint position in female karatekas with flat foot. Therefore, according to the results obtained from this research, it is suggested to pay special attention to the function and understanding of the joint position in people with flat foot, Also, corrective exercises should be used in order to improve the posture of the soles of the foot, as well as the function and understanding of the joint position in these people.

1. Introduction

Karate exercises and competitions are mostly carried out in gyms with tatami mats. According to Zvonar et al. (2012), mobility on a flexible pad can strengthen the muscles acting on the foot, and on the other hand, repeated contact between the tatami and the sole can probably affect the foot's supporting arches. Perhaps it is the reason for the prevalence of abnormal foot arches among professional karatekas. In athletes, the imbalance between flexibility and strength in the calf muscles and the muscles acting on the foot can result in flatfoot disorder and change the musculoskeletal structure of the athletes [1]. The proper musculoskeletal structure is one of the most important and influential factors in the quality of life. This structure, especially in the lower limb of each individual, is one of the effective factors in optimal functioning that can influence the biomechanics of human movements and bodies, even in daily and frequent motions such as running, walking, and in general, the motions of humans [2]. In the lower limb of the human, the foot and the sole have a complex and multi-articulated structure that plays a vital role in the function of the lower limb [3]. In activities such as walking, which is the most frequently used action in human life after breathing, the foot plays a critical role as a weight-bearing organ, and meanwhile, it has other roles such as absorbing forces, maintaining balance, and transmitting forward forces [4, 5]. To this end, in this cycle, the foot must optimally distribute the twisting, bending, and shearing forces in a balanced and coordinated way [5]. Improper distribution of these forces can result in injuries to the lower limbs and lead to consequences such as muscle fatigue, joint deformities, disturbance of the body's biomechanical balance, and musculoskeletal pain. Dysfunction and weakness in proprioception are the consequences of musculoskeletal disorders such as flatfoot disorder [6].

One of the musculoskeletal disorders that can cause problems in function and postural control [7, 8], problems in foot pressure [9], various injuries to the lower extremities [9], and alterations in the foot and ankle joint mobility when in contact with the ground is the flatfoot [10]. Thus, as the foot forms the lower part of this chain and provides a small range of surface support to maintain balance, biomechanical changes in the surface support range can affect function. Evidence suggests that when musculoskeletal abnormalities occur, the muscles and ligaments of the concave side show less activity, but the muscles and ligaments of the convex side show more activity [10]. Additionally, skeletal part deformation may lead to greater energy use and mechanical pressure [8].

Poor function in individuals with flatfoot is due to a change in the torque of the muscles around the ankle and disturbed muscle balance. Such biomechanical changes increase the tension on the soft tissues around the foot and further result in increased load on the medial part of the foot instead of the lateral part of the foot, which can affect motor function [8]. Moreover, it is known that many functional activities, such as jumping, hopping, and other explosive motions, require the transfer of ground reaction force to achieve the best result. However, in individuals with flatfoot, this transfer of force does not occur properly due to biomechanical disturbance in this area, leading to a decline in function [6]. Additionally, in postural disorders, the function of the proprioceptors is impaired and affected, which in turn can negatively affect the postural alignment of the body and exacerbate the disorders [11]. In this regard, it has been reported that the ankle proprioception following the foot pronation distortion syndrome and the resulting biomechanical changes, leads to changes in neuromuscular control of the lower limb and alters the feedback and the ankle proprioception [12, 13].

Several studies have investigated the effects of foot posture on balance, function, and joint position sense (JPS) and have reported different results. Based on Sandrey et al. study, there was no significant difference between balance and function between people with normal foot posture and flatfoot. However, in many studies, weakness has been reported in the function and postural control of people with flatfoot compared to people with normal foot posture [6, 14-16].

Regarding the effect of corrective exercises on the JPS, Park et al. [17] reported the positive effects of exercises in both plantar flexion and dorsiflexion. But Rahnama et al. [18] reported that doing exercises did not improve the JPS in the direction of plantar flexion. Furthermore, previous findings on the effect of exercise on function are contradictory [8, 17, 19, 20].

According to previous studies, flatfoot disorder responds positively to corrective exercises, and this disorder can be controlled and improved by appropriate exercises. However, it has also been reported that some exercises are superior to others [21]. To this end, a large number of studies have only performed exercises locally in the area of the disorders. Since the body acts as an interconnected chain and adverse changes in one area also affect other areas of the body, it is better that exercises designed to improve musculoskeletal disorders also emphasize the relationship between joints and muscles and attempt to enhance the individual's function. Thus, given the prevalence of this disorder in karate and its effect on the athlete's performance, and the research gap in this group, it seems necessary to conduct this research. Therefore, the present study aims to investigate the effect of 6 weeks of comprehensive corrective exercise on foot posture, lower limb function, and JPS in female karatekas with flatfoot disorder.

2. Materials and Methods

Research design

This study was a field trial study with the corrective exercise as an intervening variable. Also, based on inclusion and exclusion criteria, the females were recruited by the convenience sampling method and conducted a pre-test and post-test in the control and corrective exercise groups. In a pilot study, 80 female karatekas living in Qom City, Iran, with at least four years of karate history suspected of flexible flatfoot disorder were identified by the research examiner. Then, the researcher selected individuals with flexible flatfoot using the Staheli index method. The inclusion criteria were as follows: age between 18 and 30 years; the Staheli index higher than 0.89 [22]; normal body mass index between 18.5 to 24.9 kg/m^2; no neurological diseases; no history of ankle sprain, fracture, or surgery in the lower limb, spine, and pelvis in the last year; no use of medical insoles; and no participation in other corrective training programs, Finally, after obtaining informed consent and based on the inclusion criteria, 44 female karatekas with flatfoot disorder were selected and randomly divided into two groups of 22 as training and control groups. This sample size was estimated based on G-Power software (95% power, alpha error of 0.05, and effect size of 0.61) as 38 for the two groups, which was increased to 44 considering the dropout possibility. It should be noted that in the end, two individuals from the corrective exercise group were excluded from the research process due to their absence in training, and two individuals from the control group due to missing the tests of the post-test stage. In the 1st step after dividing the subjects into two groups, demographic information was obtained from both groups. Then, in addition to the Staheli index, the JPS test was performed in dorsiflexion and plantar flexion motions. Also, the single leg 6-m timed hop test and the single leg triple hop for distance test was conducted, and the results were recorded as the pre-test data for each subject. Next, the corrective exercise group performed 6 weeks of corrective exercise intervention, while the control group did not receive any specific corrective intervention. At the end of 6 weeks, all tests were repeated, and the results were recorded at this stage as the post-test data.

Figure 1. Measurement of the Staheli index

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Before starting the tests, a summary of how they were going to be administered to the subjects was described to all participants who provided informed written consent before participation in the experimental tasks. Also, all procedures were approved by the Local Research Ethics Committee of Physical Education and Sports Sciences. Ethical approval was obtained for the research (IR.SSRC.REC.1400.031).

The Staheli index measurement method

The Staheli index has been used in many studies. In this method, two reference points are placed on each foot track and the lines are drawn from these two points. 1st, the narrow part of the arch of the foot, and in the next step, the widest part of the heel was marked, and the length of both lines was measured and recorded. Then, using the formula for dividing the least wide part of the middle of the foot to the widest part of the heel, the results related to this index were obtained (Figure 1). The normal range of the Staheli index in childhood is between 0.7 and 1.35, and after mid-childhood and throughout adulthood, it is between 0.44 and 0.89. A value greater than this range is considered the flatfoot, and a smaller value than this range is considered the high arch. In this study, having a Staheli index above 0.89 was defined as one of the inclusion criteria. To obtain this index, a black plate and talc powder were used [22].

Single-leg 6-m timed hop test

This test aims to evaluate the ability to generate power, speed, balance, and control by a lower limb in a specific direction with an emphasis on time. To perform this test, a 6-m distance was determined by specifying the start and end points on the ground. The subject was asked to stand behind the start point (to avoid the impact of the upper limb, the subject was asked to keep her hands back) and pass this 6-m distance with the maximum speed with successive jumps and cross the endpoint. The subject was encouraged to move with force, explosively, and quickly. The subject's record at the time of motion

Figure 2. Measurement of single-leg 6-m timed hop test

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Figure 3. Measurement of single leg triple hop for distance test

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before the start line and after the end line was calculated (Figure 2). This motion was performed three times with the dominant foot and the best record was recorded [23]. The reliability coefficient of this test has been reported by different researchers from 0.82 to 0.92 [24].

Single leg triple hop for distance test:

This test aims to evaluate the ability to generate power, speed, balance, and control by one of the lower limbs at a certain distance. In this test, the subject stood behind the starting line with her dominant foot (the identification of the dominant foot was described in section 6-10-3 and performed 3 maximum jumps consecutively with her dominant foot in a straight line. The score of each subject was calculated from the starting line to the point where the subject's heel hit the ground in the 3rd jump, while the hands were kept on the thighs without any moves. This test was carried out 3 times with the dominant foot and its average was considered as the subject's score (Figure 3) [23]. Its reliability coefficient has been reported as 0.98 by Hamilton [25].

Measurement of ankle JPS:

The subject sat in a chair with the trunk at 90 degrees to the thigh and the thigh at 90 degrees to the knee. The chair height was such that the soles of the subject's feet did not touch the ground during the test. After calibrating the goniometer, the fixed arm of the goniometer was aligned with the tibia and the moving arm of the goniometer with the fifth metatarsal of the dominant foot, and the anatomical axis of rotation was aligned with the goniometer's mechanical axis of rotation. The angle for investigating the JPS is 10 degrees of dorsiflexion and 20 degrees of plantar flexion. The test was performed 3 times with the eyes open at the desired angle to increase the subject knowledge about the method of performing

Figure 4. Measurement of ankle JPS

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the test. To eliminate the visual intervention, the subject's eyes were closed using a blindfold, and after 5 s, she was asked to actively move the ankle and reconstruct the desired angle and announce it with the term "reach." This act was repeated 3 times, with each repetition recording the made angle and the error rate calculated and recorded. The mean error of these 3 attempts was recorded as the angle of joint reconstruction at the target angles of 10 degrees of dorsiflexion and 20 degrees of plantar flexion. The average of the 3 angles obtained was recorded as the main value for each motion, and the difference between the angle drawn by the sample and the angle drawn by the subject was statistically examined as an error (Figure 4) [26].

Corrective exercise protocol

The training program of the present study was conducted for 6 weeks with three 45 to 60 min sessions per week under the direct supervision of a corrective exercise instructor. The corrective exercise program in this study, with emphasis on improving intermuscular relationships, consists of Thera-Band hip abduction exercises, hip external rotation with Thera-Band, rolling of the sole, rotating both ankles towards each other, gathering the mat with the sole, lifting the heel with the help of a chair, walking on a heel with a straight knee, slow walking (with foot pronation control), feet together squat (with foot pronation control), standing on one foot, brisk walking (with foot pronation control), single-leg squat (with foot pronation control), rotating both ankles towards each other (by placing the ball between two ankles), taking small rings and placing them around a bar with the tips of the toes, lifting the heel with weights in both hands, standing on one leg (with weights in both hands), and walking on sand (with foot pronation control). These 15 exercises were performed in a 6-week program, so 10 exercises per week were included in the program and performed by the subjects. The control group performed their daily activities during this period and did not participate in the training program [11]. The principle of overload in the present exercises was applied according to the needs of the subject by increasing the load by changing the Thera-Band resistance, increasing the training time, and also changing the type of training. In all training sessions, the principle of warming up and cooling down was performed at the beginning and end of the exercises.

Statistical analysis

The information obtained and recorded from the evaluations was analyzed by descriptive and inferential statistics using SPSS software, version 26. The normality of the data distribution was examined by the Shapiro-Wilk test, and then, considering the condition of normal distribution, the analysis of covariance was used to examine the differences between the two groups. Then, a paired t-test was used for a more accurate examination of the intergroup changes. The significance level in this study was 95%, and an alpha less than or equal to 0.05 was considered.

3. Results

Information related to the age, height, weight, and body mass index of the subjects is presented for two study groups in Table 1. In addition, the comparison of the two groups was performed using the independent t-test. The test results showed that the two groups were identical in terms of their characteristics.

The comparison of the two groups in the post-test phase was performed using the analysis of covariance, with controlling for the pre-test effect as a covariate. The results of this analysis are presented in Table 2.

According to the analysis of covariance, after controlling the effect of the pre-test (covariate variable), there was a significant difference between the control and corrective exercise groups in the variables of foot posture, single leg triple hop, single-leg 6-m timed hop, and JPS of the ankle joint in the post-test (P=0.0001), so that the

Table 1. Mean±SD related to the individual characteristics of the subjects

Variables / Group	Mean±SD		P
	Corrective Exercise	Control	
Age (y)	20.00±1.81	21.02±2.19	0.11
Height (cm)	161.40±6.49	160.40±4.23	0.69
Weight (kg)	55.27±6.56	55.75±3.90	0.78
BMI (kg/m²)	21.27±2.66	21.61±1.57	0.63

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Table 2. Results of analysis of covariance related to research variables

Variables	Time	Group	Mean	F	*df*	P	η^2
The Staheli index	Post-test	Corrective exercise	0.769	253.996	1	0.0001**	0.873
		Control	1.069				
Single leg triple hop for distance test (cm)	Post-test	Corrective exercise	367.199	51.425	1	0.0001**	0.582
		Control	335.201				
Single leg 6-m timed hop test (s)	Post-test	Corrective exercise	2.498	31.485	1	0.0001**	0.460
		Control	2.760				
Dorsiflexion JPS (degree)	Post-test	Corrective exercise	3.848	73.131	1	0.0001**	0.664
		Control	5.201				
Plantarflexion JPS (degree)	Post-test	Corrective exercise	3.280	48.874	1	0.0001**	0.569
		Control	4.535				

+Adjusted based on pre-test values; * Significance at the level of P<0.05.

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Table 3. Paired sample t-test results to evaluate within-group changes

Variables	Group	Mean±SD		t	P
		Pre-test	Post-test		
The Staheli index	Corrective exercise	1.06±0.13	0.77±0.10	15.897	0.0001*
	Control	1.04±0.11	1.06±0.11	-1.385	0.182
Single leg triple hop for distance test (cm)	Corrective exercise	336.15±16.84	368.00±20.57	-9.273	0.0001*
	Control	333.75±19.86	334.40±16.27	-0.194	0.848
Single leg 6-m timed hop test (s)	Corrective exercise	2.76±0.27	2.49±0.026	8.020	0.0001*
	Control	2.77±0.33	2.76±0.26	0.146	0.885
Dorsiflexion JPS (degree)	Corrective exercise	4.99±1.24	3.77±1.19	9.840	0.0001*
	Control	5.31±1.47	5.33±1.30	-0.250	0.805
Plantarflexion JPS (degree)	Corrective exercise	1.45±4.25	1.43±3.06	8.994	0.0001*
	Control	1.01±4.71	1.25±4.76	-0.450	0.658

* Significance at the level of P<0.05.

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Staheli index, the error rate of the JPS, and time of the single-leg 6-m timed hop test and the distance passed in the triple hop were higher in the post-test in the corrective exercise group compared to the control group.

For examining the changes from the pre-test to the post-test in the two groups separately, the paired t-test was used, the information of which is presented in Table 3.

The results of the paired t-test indicated that in the corrective exercise group, a significant reduction occurred in the results related to the foot posture, the single-leg 6-m timed hop, and the error rate of the JPS, and there was a significant increase in the results of the single leg triple hop test in pre-test compared to the post-test (P=0.0001). However, no significant change was observed between different stages of the research in any of the variables in the control group.

4. Discussion

The results of this study indicate that 6 weeks of comprehensive corrective exercise significantly improves posture, lower limb function, and JPS of the ankle joint in female karatekas with flexible flat foot disorder, in both dorsiflexion and plantar flexion motions.

In most previous studies, the Staheli index has been used for the evaluation of the condition of the sole. Their results were consistent with the present study [19, 27-31]. As reported by Park et al., by increasing the strength of the muscles acting on the foot during exercise and reducing the tension in the plantar fascia, the foot posture is corrected [17]. Posa et al. stated that maintaining the arch of the foot is highly dependent on the extensor muscles of the foot, especially the tibialis posterior muscle and the triceps surae, and corrective exercises can effectively improve the position of the sole by strengthening these muscles [32]. Also, Najafi et al. (2017) reported that corrective exercises can change the activity of the muscles, such as the tibialis anterior muscle responsible for controlling the arch of the foot, and correct the pronated foot posture [33]. According to the related literature and the emphasis on strengthening the muscles affecting the flat foot disorder, especially the tibialis posterior muscle, strengthening these muscles can be one of the possible reasons for the improvement of this disorder. Also, corrective exercises by observing the FITT principle (frequency, intensity, time, type) can probably increase the strength and ability of the muscles that control the arch of the foot, actively stabilize the central area of the foot, reduce tension on inactive tissues, such as the plantar fascia, and correct the leg posture by controlling the navicular bone, especially through strengthening the tibialis anterior muscle. Decreased muscle mass in the foot area results in erroneous mechanical responses, and the muscles in this area, especially the tibialis posterior, lose the mechanisms of stabilization and arch maintenance, which will lead to flat foot disorder [34]. Therefore, corrective exercises during 6 weeks have recovered this stabilization mechanism by developing neuromuscular adaptations, especially in motor chains, and thus creating new neural pathways to send peripheral messages to the central nervous system. Also, by increasing motor impulses from the brain to the muscles, it helps active control of the arch of the feet, correcting the deformity of the sole. Lazuta et al. reviewed and investigated the effect of exercise interventions on the posture of flatfoot, and stated that corrective interventions train the muscles to provide the right arch. Also, by providing permanent sensory feedback and data to the central nervous system, they send the message on the posture of the sole of the foot, and this information is sent to the brain even when the muscles are not under training. Therefore, the central nervous system also sends the message to the muscles that they maintain the correct position of the foot even in non-training conditions, which can also be another possible reason for the improvement of flatfoot disorder in this study [35].

In the present research, the single leg 6-m timed hop test and the single leg triple hop for distance test were used to evaluate the performance of karatekas with flatfoot disorder. The research results suggested a significant improvement in both functional tests after 6 weeks of comprehensive corrective exercise training. Park et al., Nikkhuamiri et al., and Sulowska et al. reported consistent results with our study [8, 17, 19].

Nikkhuamiri et al. investigated the effect of corrective exercises on balance and function in adolescent girls with flatfoot disorder and reported that corrective exercises significantly improved the scores of motor function tests [8]. Six weeks of corrective exercises appear to improve muscle balance by correcting the flatfoot posture of the karatekas, restoring proper biomechanics to the foot area by creating equal torque around the ankle joint axis, leading to enhanced performance in single leg 6-m timed hop test and the single leg triple hop for distance test. On the other hand, factors such as strength and muscle volume play a critical role in promoting motor function [36]. Research has also indicated that leg muscle strength is reduced in individuals with flatfoot, and early fatigue will lead to reduced performance in these people due to muscle weakness [6]. It seems that the training protocol of the present study, by creating awareness of the motions and muscles used during training, could increase the level of neurological, muscular, and metabolic adaptations, and by calling more motor units as well as muscle hypertrophy, lead to increased strength, and consequently, the improvement of the motor function of karatekas. Based on Janda's theory on pronation distortion syndrome, special attention should be paid to other regions, including the proximal parts of the lower limb, in correcting the deformity of the flatfoot. In designing an effective corrective program, exercises should be used in which the proximal leg muscles, such as the abductor and external rotators of the hip muscle, are strengthened and the adductor muscles are stretched [11]. These muscles contribute to controlling the motions of all lower limbs in different planes of motion [37]. Possibly, as the strength of the abductor's muscles and external rotators increase, as well as the length of the adductor muscles, the motion of the internal rotation and the proximity of the hip and lower limb to the midline of the body is reduced, and controlled. Such reduction is transferred to the distal region of the lower limb (ankle), which corrects and reduces the eversion of the ankle joint, and ultimately improves postural stability indexes [11]. Consequently, these muscles play a crucial role in the alignment of the lower limb, because when the distal region of the lower limb is fixed somewhere, motion in one region affects other regions of the motion chain [37]. In general, it leads to a decrease in pronation, which is supported by the results obtained in the field of pressure in different regions of the sole of the foot. Therefore, in the present study, it was attempted to use also exercises related to upper chains, such as the central area of the body.

The improvement observed in the results of the functional tests in our study may be partly because of the correction of the sole posture and the improvement of muscle balance in the muscles of the proximal joints of the foot. In this study, special attention was paid to the joints adjacent to the deformed region, which may suggest that somehow this coherence created by the exercises can be a factor in retraining the locomotor system to return to a helpful functional and synergistic motor pattern. The use of multiple joint actions helps regain neuromuscular control and can improve the coordinated motion among the muscles involved [38]. In general, one of the reasons for the improved function following the implementation of this program is the improvement of the muscle balance of the subjects after participating in the training course, as well as reducing the compensatory pronation of the subtalar joint and increasing the stability of the plantar structures. In addition to these mechanisms, exercise may have helped improve proprioception, which was also noted in this study. In this regard, motor function is improved by preparing motor neurons and increasing coordination and integration of motor units, co-contraction of partner muscles, and ultimately improving neuromuscular responses.

In postural disorders, the sensory function of proprioception is impaired and affected by the abnormality, which in turn can adversely affect the postural position of the body, exacerbating the abnormality [11]. In this study, the JPS of the ankle was measured in dorsiflexion and plantar flexion motions, and the results indicated the improvement of the JPS in both motions. The results of the present study are in line with the reports of Park et al. and Golchini et al. [17, 39]. Golchini et al., in their work entitled "The effect of systematic corrective exercises on ankle proprioception in individuals with flexible pronation distortion syndrome," reported that the JPS of the joint in the four motions of plantar flexion, dorsiflexion, eversion, and inversion significantly improved.

JPS is particularly influenced by receptors in the muscles called muscle spindles. Muscle spindles have a primary ending that responds to changes in the length and speed of muscle stretch, as well as a secondary ending that responds only to changes in muscle length [40]. Muscle spindles receive static and dynamic stimuli from gamma afferent neurons, and it is possible that corrective exercise increases the activity of gamma afferents and, as a result, improves the JPS. In general, flatfoot leads to changes in the lengths of the ankle muscles. In this regard, the results of the present study imply that changes in the lengths of muscles, as a result of flatfoot, have an adverse influence on the activity of the muscle spindles, and this is the reason why poor JPS is induced by flatfoot. Further, changes in muscle balance and posture following corrective exercises can be one of the possible reasons for a significant improvement in the JPS. Overall, the reason for this improvement was the increase in the function of muscles, joint receptors, muscle spindles, and the Golgi tendon organ [39]. Park et al. stated that performing corrective exercises can be effective in restoring proprioception by improving the motion sense and the JPS. Also, short foot exercises in the standing position can increase the activity of the intrinsic muscle spindles and stimulate proprioception [17]. Rahnama et al. also studied the JPS of the ankle in karateka girls after 8 weeks of exercise training with a balance board [18]. However, their findings were consistent with the present study only in improving the JPS of the ankle during dorsiflexion motion, and they did not find a significant improvement in the JPS of the ankle in a plantar flexion motion. This discrepancy can be justified by the different training protocols applied in these studies. Since in the present study all the muscles of the lower limb were trained, increasing the efficiency and activity of all muscles, especially the extensor muscles of the ankle, could cause a significant improvement in the JPS in both plantar flexion and dorsiflexion motions. Additionally, since the sense of status in the subjects in the control group did not change significantly, the changes in the JPS in the subjects of the control group did not change significantly, and these changes in JPS in the case group can be attributed to the effectiveness of corrective exercises [18].

Research limitation

One of the limitations of this study was using the female gender, so we suggest addressing males in future research. Other limitations of this study were the inability to control the level of motivation and psychological factors of the subjects and the lack of control over the sleep and nutrition of the subjects.

5 .Conclusion

The results of the present study indicate that 6 weeks of comprehensive corrective exercise training significantly improves the JPS and function of the lower limbs in female karatekas with flexible flatfoot disorder.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles have been considered in this article. The participants were informed about the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information; they were free to leave the study whenever they wished, and if desired, the research results would be available to them. Ethical approval was obtained for the research (Code:IR.SSRC.REC.1400.031)

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Authors' contributions

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Conflict of interest

The authors declared no conflict of interest.

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