Research Paper

The Effect of Eight Weeks of Kyokushin Karate Training on leg Muscle Activity and Medial Longitudinal arch Height of Adolescent Girls With Foot Pronation

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ABSTRACT

Purpose: The purpose of this study was to investigate the effects of specialized Kyokushin karate exercises on the activity of leg muscles and the height of the medial longitudinal arch in adolescent girls with foot pronation.

Methods: This study recruited twenty-four adolescent girls with foot pronation who voluntarily agreed to participate and were randomly assigned to either a training group (n=12) or control group (n=12). The training program consisted of eight weeks of specialized Kyokushin karate exercises. The fibularis longus, tibialis anterior, and lateral gastrocnemius muscles activity was measured during single-leg landing using surface electromyography. The medial longitudinal arch height was measured using the navicular drop test. All statistical analyses, including independent and paired t-tests, were conducted using SPSS software, version 26 at a significance level of 0.05.

Results: The results showed that following eight weeks of specialized Kyokushin karate exercises, there was a significant increase in the activity levels of the tibialis anterior (P=0.005) and lateral gastrocnemius (P=0.04) muscles in the training group compared to the control group. However, there was no significant change in the activity of the fibularis longus muscle in the training group compared to the control group (P>0.05). Within the training group, there was a significant increase in the activity of all three measured muscles (fibularis longus, P=0.009; tibialis anterior, P=0.008; and lateral gastrocnemius, P=0.008) from post-test to pre-test (P<0.05). Additionally, the study found that the amount of navicular drop in the training group was significantly reduced compared to the control group (P=0.04) after eight weeks of training

Conclusion: This study demonstrated that eight weeks of specialized Kyokushin karate exercises resulted in a significant increase in the activity levels of the tibialis anterior and lateral gastrocnemius muscles in adolescent girls with foot pronation. These exercises also improved the height of the medial longitudinal arch, indicating a potential solution for correcting flat feet. Therefore, we recommend Kyokushin karate exercises to improve muscle activity and arch height in adolescent girls with foot pronation.

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Highlights

• The activity level of both the tibialis anterior and lateral gastrocnemius muscles in adolescent girls with foot pronation can be increased with Kyokushin karate training.

• There was no significant change in the activity level of the fibularis longus muscle in adolescent girls with foot pronation after eight weeks of Kyokushin karate training.

• Kyokushin karate training can improve the height of the medial longitudinal arch in adolescent girls with foot pronation.

Plain Language Summary

Flat feet is a condition characterized by a reduction in the medial longitudinal arch and is considered an abnormality. It is prevalent in approximately 25% of adults, with a higher incidence in women than men. Kyokushin karate training has been shown to improve the height of the medial longitudinal arch, suggesting it may offer a potential solution for correcting flat feet.

1. Introduction

From a biomechanical perspective, the foot plays a critical role in supporting body weight and generating forward movement during walking and running [1]. The height of the medial longitudinal arch (MLA) during weight bearing is a crucial structural feature of the foot [2]. Flat feet is characterized by a reduction in the medial longitudinal arch and is considered an abnormality [3]. The prevalence of this abnormality in adults is approximately 25%, with a higher incidence in women than men [4] . Janda's theory based on the chain reaction system suggests that individuals with abnormal arches may experience different pathomechanical and physiological complications [5]. The reduction in the medial longitudinal arch of the foot can lead to changes in the alignment of the ankle, resulting in altered plantar muscle activity [6]. Additionally, the reduction in the consistency of the midtarsal and subtalar joints can lead to increased muscle activity and stress on the structures inside the foot to maintain joint stability. This increase in stress can result in changes in joint afferent inputs and a decrease in posture stability [7]. As a result, the activity of the muscles of the lower limbs may be altered in individuals with abnormal arches compared to those with normal arches [6]. Research has shown that foot posture affects the electromyographic activity of lower limb muscles [6] and joint kinematics [8] during walking. Flat feet can alter the activation patterns and amplitude of muscle activity in the lower limbs, leading to compensatory movements at the knee and hip joints, increased joint loading, and potential joint pain [9]. According to some researchers, the tibialis anterior, fibularis longus, internal gastrocnemius, and soleus muscles are clinically susceptible to damage and degenerative changes in flat feet [10]. Biomechanical changes resulting from flat feet can affect joint loads, feedback mechanical efficiency and proprioceptive orientation, and lead to changes in neuromuscular control and muscle imbalance in the lower limbs [11].

Muscle imbalance occurs when there is an unequal length-tension property between agonist and antagonist muscles, which can interfere with normal muscle function [5]. In individuals with flat feet, researchers have reported that muscle imbalance can lead to changes in the co-contraction ratios of agonist and antagonist muscles. This can be particularly dangerous during sports maneuvers that involve jumping and landing, as repetitive loading can increase the shock experienced during landing [12]. Electromyography studies have shown differences in the activity patterns of leg muscles in individuals with flat feet compared to those with normal feet [9]. In a study by Sajedi et al., which compared the activity of ankle muscles during single-leg landing movements in men with flat and normal feet, significant differences were observed in the activity of the fibularis longus and tibialis anterior muscles between the two groups [13].

Over the years, various therapeutic exercise programs, medical insoles, and different types of shoes have been prescribed for the treatment of flat feet. Studies have shown that exercises such as short foot exercises, which involve contracting the intrinsic muscles of the foot, strengthening exercises with and without elastic bands

[14], and rope jumping exercise [15] can improve flat feet. Recently, it has been suggested that certain physical activities, such as karate, may also be effective in correcting this abnormality [16]. Karate, which means "empty hand," is a form of martial arts that involves fighting without the use of combat equipment. There are different styles of karate, including control styles and semi-control Kyokushin style. Kyokushin karate is the most common style of full-contact karate in the world, founded by Masutatsu Oyama [17]. Kyokushin karate training consists of three main elements: kihon (defenses and basic strikes), kata (formalized sequences of combat techniques), and kumite (the application of the various techniques within a fighting situation.). Kyokushin requires a high level of movement and functional abilities, including speed, strength, and coordination. It is a specialized martial art that demands nerve and muscle coordination [18]. Each technique used in Kyokushin karate is a complex motor skill that requires the neuromuscular control, motor prediction, and a highly developed sense of proprioception [19]. Training in Kyokushin karate requires maintaining correct body posture throughout the exercises, which can be beneficial for individuals with flat feet. In a study conducted by Drzał et al. titled "evaluation of selected postural parameters in children practicing Kyokushin karate," which focused on children aged 7 to 10 who regularly practice Kyokushin karate, it was found that the sport can have a positive effect on postural deformities in children [17].

Given the contents and nature of Kyokushin karate exercises, which have been shown to improve physical fitness and nerve and muscle coordination, particularly in the lower limbs, it is plausible that this form of exercise may enhance neuromuscular control and increase lower limb muscle activity. It seems that this exercise can have a great effect on the correction of flat feet deformity by improving the neuromuscular control and increasing the activity of the lower limb muscles as an auxiliary corrective protocol. Therefore, the aim of this study was to investigate the effect of Kyokushin karate training on the electromyography of leg muscles and correction of foot pronation abnormality in adolescent girls with foot pronation.

2. Materials and Methods

The purpose of this semi-experimental study, comprising a pre-test and post-test with a control group, was to investigate the impact of specialized Kyokushin karate exercises on the activity of calf muscles and the height of the medial longitudinal arch of adolescent girls with foot pronation. The study employed a semi-experimental and practical research design. The statistical population of the study was teenage girls in Karaj city with foot pronation. The sample size was determined using the statistical formula and the results of previous similar studies [20], with a confidence level of 0.95 and a test power of 80%. Based on the Mean±SD of the research variables of Chimera et al. [21], 12 participants were selected for each group. The inclusion criteria required the participants to have a navicular drop of more than 10 (mm) and second degree flat feet, with ages ranging from 13-18 years and a BMI between 20-24. The exclusion criteria included a history of sprained ankles in the past year, a history of fracture or surgery of lower limb joints, observation of postural abnormalities of the knees (genu varum, genu valgum, and genu recurvatum) [6], a history of injury in ligament or meniscus of the knee, pain in the lower limb before and during the tests, the presence of systemic diseases such as rheumatism and diabetes [9], a history of using any type of orthosis or medical insoles before conducting research to correct flat feet, history of neurological disorders or vestibular system, history of rehabilitation program, hearing and vision diseases, and absent in two consecutive training sessions.

In this study, prior to initiating the protocol, eligible participants were provided with adequate information about the deformity of flat feet, improvement training, the purpose of the research, and how to conduct the study. The forms were given to their parents, and after signing the consent form, they were enrolled as study subjects. After selection, each participant was assigned a number and randomly allocated to either the training or control group using SPSS software, version 26 (select cases/ random sample). To determine the quantitative measure of flat feet, the navicular drop index test was used to measure the pronation degree of the subtalar joint. The navicular drop measurement was performed three times, and the average of calculations was used. This test has adequate validity to measure the amount of foot pronation, with reliability coefficients reported as 0.85 by Ladha et al. [22]. The dominant leg of the subjects was determined using the ball-hitting test [23]. The measurements were conducted at the Biomechanics Laboratory of the Faculty of Physical Education of Kharazmi University, Karaj. The training group underwent the training phase up to one week after the measurement, with the training programs consisting of Kyokushin karate exercises designed by experts in this field. The training group completed their program for eight weeks, with three sessions every week. Each subject underwent a secondary measurement (post-test) up to one week after finishing the exercises. The conditions of each secondary measurement session were exactly the same as the primary measurement session, and each session lasted approximately 15 minutes. Subjects in the control group underwent a secondary measurement after the initial measurement without exercise after eight weeks.

The method to measure of navicular drop

The measurement of navicular drop was conducted following the description by Brody [24]. The participants were seated with their feet flat on a firm surface, with their knees flexed at a 90° angle and their ankle joints in a neutral position. The most prominent point of the navicular tubercle was identified and marked while maintaining subtalar neutral position, which was established when medial and lateral talar depressions were equal. An index card was then placed on the inner aspect of the hindfoot, and the height of the navicular bone was marked on the card. The participants were then asked to stand without changing the position of their feet and while distributing equal weight on both feet. In the standing position, the position of the navicular bone relative to the floor was again identified and marked on the card. Finally, the difference between the original height of the navicular bone in the sitting position and the weight-bearing positions was measured using a tape measure, yielding the navicular drop amount (in mm). The navicular drop test was performed three times for each subject and for the dominant leg. The amount of navicular bone loss of the subject between 5 and 9 mm was considered normal and more than 10 mm as increased ankle pronation and flat feet [24].

Electrode placement

The electrical activity of the fibularis longus, tibialis anterior, and lateral gastrocnemius muscles was recorded using surface electrodes and a Biometrics model electromyography device manufactured in England (Figure 1). To minimize electrical impedance at the sensor junction, any excess hair was first shaved from the skin and cleaned with a cotton swab soaked in alcohol. Next, the biometrics device sensors were connected to the leg muscles. The European SENIAM protocol was followed to identify the location for electrode placement and to determine maximal isometric muscle contractions using bony landmarks [25].

Training protocol

The training sessions took place at the Azadi gym in Karaj city. Research has shown that supervised exercises lead to better results compared to unsupervised exercises [26]. Therefore, an instructor with a first-class national coaching degree in this field led the training sessions and was present to supervise all exercises. The attendance time for the training sessions was based on a schedule that was adjusted in coordination with the researcher to accommodate the participants' preferences. The training group attended three sessions per week, and each participant was required to attend at least 22 of the 24 training sessions. The Kyokushin karate special exercises in this study were designed using the help of Mitt Pa, boxing bags, and other necessary equipment for physical preparation exercises in this field. The movements were based on published books and articles in the field, as well as the opinions of high-level technical professors of the Federation. The researcher, with a first-class national coaching degree and 14 years of coaching experience, compiled the Kyokushin karate exercises for beginners in the study. Each training session began with a standard warm-up program consisting of five minutes of jogging, 15 minutes of general warm-up, and lower extremity stretching exercises (Table 1 and 2). The participants then performed the exercise program that was taught by the instructor. Participants were encouraged to progress in performing the next training techniques and methods

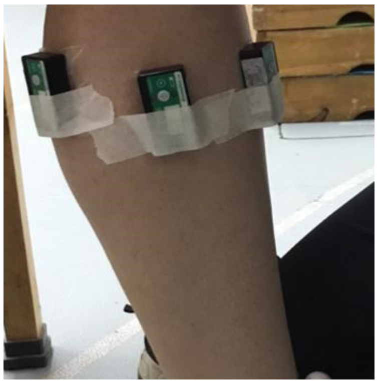

Figure 1. EMG electrode placement locations

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Table 1. Exercises and movements of the training program along with how to perform them.

Order of Training	Explanation of Exercise/ Movement	Order of Training	Explanation of Exercise/ Movement	Order of Training	Explanation of Exercise/ Movement
A	Hiza Giri (knee strike)	G	Zenkotsudachi or standing leaning forward	M, N	Kata number four and five
B	Mai Ke Aghe Geri (rising kick from the front)	H	Kokutsu dachi or standing leaning back	O	Strength training
C	Yokoke Aghegiri (rising leg kick from the side)	I	Sanchin Dachi or standing in the hourglass pose	P	Flexible training
D	Maigiri (front kick)	J	Kata number one	Q	Sprint training
E	Mashi-Gari (rotational foot kick)	K	Kata number two	R	Agility training
F	Yokogiri (striking with the outer blade of the foot to the side)	L	Kata number three	S	Cardiovascular training
	1	2	3	4	5
Performing the trainings	Performing the technique in the air	Implementation of the technique in Dachi	Performing the technique by hitting the paunch pad	Performing the technique by hitting the punching bag	Implementing the technique to the opponent's body

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to fully learn each training session, which was designed in a chain-like manner. The instructor controlled the time of the exercises using a stopwatch, and each session lasted between 75 and 90 minutes.To comply with the principles of exercise science and to reduce the effect of training intensity gradient on post-test results, the training program included a gradient, constant, and maintenance phase in the last two weeks, aimed at achieving the best training performance.

Extraction and calculation of electromyography variables

A force plate device called Bretex, manufactured in the United States, was utilized in conjunction with an electromyography device to determine the contact duration of the foot with the ground. The electromyography signals recorded during a single leg landing task were employed to compute the electrical activity of the leg muscles. The single-wave signals were filtered and smoothed, and the `RMS algorithm was employed for processing the signals in the time domain with a time constant of 20 milliseconds, using the Megawin software, version 3. The resulting number from the RMS processing indicated the average power of the signal, which reflected the level of muscle activity. In line with previous studies on leg muscle activity in individuals with foot pronation during landing, the time interval of 250 milliseconds after landing was considered to calculate the activity level of the leg muscles [20]. A MATLAB program, version R2021a was developed by an electronics expert to evaluate the activity level of the leg muscles. The raw electromyography signals recorded during the single-leg landing task (Figure 2)

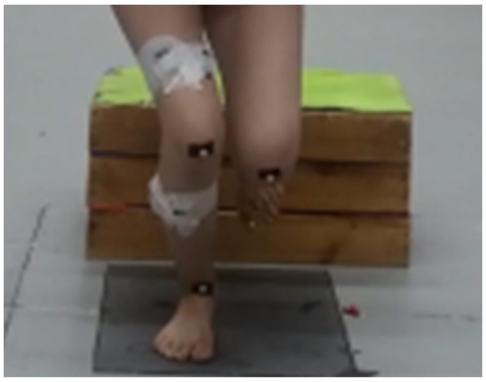

Figure 2. Subject performing a single-leg drop landing from a height of 40 cm

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Table 2. Training program in 24 sessions.

Movement (Rep, Duration×Set)			Session	Movement (Rep, Duration×Set)			Session	Movement (Rep, Duration×Set)			Session
L, K, J 3 set	O	F (3, 4, 5), D (3, 4, 5), E (3, 4, 5) 3×15	17	K 2 set	P	A3, B3, C3, E3, D3, F1 3×12	9	G 20×3 (sec)	S	A1, B1 3×12	1
L, N, K, J 3 set	P	A1, B1, C1, F (3, 4, 5), D (3, 4, 5), E (3, 4, 5) 3×15	18	L 2 set	S	A2, B2, C2, E2, F2, D2, E3 3×12	10	G 20×3 (sec)	O	A1, B1, C1 3×12	2
N, M, L 2 set	S	A2, B2, C2, E4, F4, D4 3×12	19	J, L 2 set	O	B2, C2, E3, D3, F3 3×12	11	G,H 20×3 (sec)	P	A1, B1, C1, D1 3×12	3
K,N 2 set	Q	D5, F5, D5, A2, B2, C2 3×12	20	K, L 2 set	P	B2, C2, E2, F2, D2, F3, E3 3×12	12	H,G 25× 3 (sec)	S	A1, B1, C1, D1, A2 3×12	4
L,J 2 set	P	A (1, 2), B (1, 2), C (1, 2), D2, E2, F2 3×12	21	L, K 3 set	P	A1, B1, F2, E2, D2, F4, E4, D4 15×3	13	H,G 25× 3 (sec)	O	A2, B2, C1, D1, E1 3×12	5
J, N 1 set	O	F (3, 5), E (3, 5), D (3, 5) 3×12	22	K, J 3 set	O	B1, C1, F2, E2, D2 15×3	14	I,H,G 25× 3 (sec)	P	A1, B1, C1, D1, A2, B2, E1 3×12	6
L,K 1 set	S	A (2, 3), B (2, 3), F (2, 3), D (2, 3) 3×12	23	L, K 3 set	Q	A1, C1, F2, E2, D2, F5, E5, D5 15×3	15	J 1set	Q	A2, B2, C2, E2, D1 3×12	7
K, M 1 set	R	A1, B1, C1, D1, E1, F1 3×12	24	K, J 3 set	S	A1, B1, C1, F (2, 4, 5), E (2, 4, 5), D (2, 4, 5) 15×3	16	J 2 set	R	A3, B3, C3, E3, E2, D2 3×12	8

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were converted to ASCII format using Megawin software, version 3, and passed through a low-pass filter with a frequency of 50 Hz (6th-order butterworth filter) in the program. For the normalization of muscle activity, the maximum voluntary isometric contraction of each muscle was used as the reference value, and the amount of muscle activity was determined as a percentage of the maximum voluntary contraction [25]. The reference value was obtained by repeating each state of maximum voluntary contraction twice for five seconds, and then the average of the middle three seconds of maximum voluntary contraction was used to normalize the data, as per the sources [9].

Paired t-tests were used for between-group comparisons with pre-test and post-test variables and independent t-tests were used for within-group comparisons of post-test variables. The effect size of the training program for each of the significant differences between the variables between groups was measured by Cohen's D method. An effect size of 0.2 to 0.5 was considered small, an effect size of 0.5 to 0.8 was considered medium, and an effect size of 0.8 or higher was considered large [27]. Data analysis was done using SPSS software, version 26 under Windows and at a smaller alpha level equal to 0.05.

3. Results

Table 3 presents the average and standard deviation of age, height, weight, and body mass index of the samples tested in the relevant groups. The independent t-test revealed no significant difference between the two groups in terms of age, weight, height, and body mass index (P<0.05), indicating homogeneity of the groups in these characteristics. Tables 4 report the variable values of the activity level of the fibularis longus, anterior tibialis, and lateral gastrocnemius muscles, as well as navicular drop, in the different groups and stages of the research. The Shapiro-Wilk test indicated a normal distribution of data in the research variables (P>0.05). Given the non-assumption of homogeneity of variances between the two groups (Levene test results), the paired t-test was utilized to analyze the pre-test and post-test data of the aforementioned variables, while the independent t-test was utilized for comparing between groups.

The within-group paired t-test results indicated no significant difference in the activity level of the fibularis longus, anterior tibialis, and lateral gastrocnemius muscles, as well as the amount of navicular drop, in the pre-test and post-test of the control group (P>0.05). On the other hand, in the training group, a significant difference was observed in the activity level of the fibularis longus (P=0.009), anterior tibialis (P=0.008), and lateral gastrocnemius (P=0.008) muscles, as well as navicular drop (P=0.003).

The independent t-test results comparing the post-test data between the two study groups demonstrated no significant difference in the activity level of the fibularis longus muscle (P>0.05). However, a significant difference was observed in the changes in the activity level of the tibialis anterior muscles (P=0.005, effect size=1.52) and lateral gastrocnemius (P=0.04, effect size=0.83), as well as navicular drop (P=0.4, effect size=0.75), between the control and training groups.

Table 3. Characteristics of subjects

Variables	Groups	Mean±SD	t	P
Age (y)	Control	16.10±1.80	0.34	0. 74
	Training	15.80±2.15		
Height (m)	Control	1.64±0.04	0.75	0.46
	Training	1.63±0.02		
Weight (kg)	Control	60±12.83	1.07	0.30
	Training	54.00±12.14		
BMI (kg/m^{-2})	Control	22.11±4.51	0.97	0.34
	Training	20.15±4.48		

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Table 4. Means and standard deviations for the two groups of research variables.

Groups	Research Variables	Mean±SD	
		Pre-test	Post-test
Control	Fibularis longus	0.106±0.050	0.110±0.048
	Anterior tibia	0.087±0.040	0.086±0.037
	Lateral gastrocnemius	0.061±0.070	0.062±0.082
	Navicular drop	13.40±1.429	13.30±1.54
Training	Fibularis longus	0.081±0.032	0.150±0.670*
	Tibialis anterior	0.059±0.025	0.161±0.059*+
	Lateral gastrocnemius	0.045±0.017	0.115±0.036*+
	Navicular drop	13.80±1.135	12.30±1.059*+

+Independent samples t-test, P<0.05, *Paired samples t-test, P<0.05.

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4. Discussion

The objective of this study was to examine the impact of Kyokushin karate training on the activity level of leg muscles and the height of the medial longitudinal arch among adolescent girls with foot pronation. The findings revealed that after eight weeks of Kyokushin karate training, the exercise group experienced a significant increase in the activity level of the tibialis anterior and lateral gastrocnemius muscles compared to the control group. However, no significant increase was observed in the activity level of the fibularis longus muscle.

The current study's findings were consistent with Najafi et al. [28], Jafarnezhadgero [29], Hovanlou et al. [30], and Mostaghni et al. [16]. This similarity could be due to the nature of the exercises performed or the participants' similar characteristics. Electromyography studies have demonstrated differences in the activity pattern of leg muscles in individuals with flat feet compared to those with normal feet [9]. The tibialis anterior muscle is an eversion controller and functions as a foot pronation controller [31]. Its involvement in active inversion indicates its ability to provide and support the dynamic medial longitudinal arch of the foot. The fibularis longus muscle is the most important evertor of the ankle complex [32]. Its stabilizing role in preventing sudden and severe inversion in the foot-ankle group is significant, especially during landing [20]. The long tendon of the tibialis posterior muscle along with the flattened medial arch in the foot reduces the efficiency of the plantar flexors due to the length-tension relationship. Also, by increasing the internal rotation of the leg and thigh, which is the result of having foot pronation, it directly affects the plantar flexors and reduces muscle strength. To compensate for this inefficiency and to control the body and prevent falling during the middle-stance and pushing phases of gait, the lateral gastrocnemius muscle becomes overactive [33].The appropriate pattern of muscle activity and the simultaneous action of agonist and antagonist muscles around the joint are crucial from a biomechanical perspective, as it is considered a factor in maintaining joint stability [34]. The current study's findings were not consistent with those of Murley et al. [9] and Chang et al. [12]. The inconsistency could be due to the investigation of leg muscle activity in individuals with foot pronation in a static state, differences in participant characteristics such as age, gender, and different populations, as well as variations in evaluation tools or methods. Differences in study designs could also be one of the reasons for the non-consistency among these studies.

Upon reviewing past studies, it was found that no previous research has investigated the effect of Kyokushin karate exercises on the activity level of the calf muscles of girls with foot pronation during single-leg landing. Therefore, the researcher was unable to make direct comparisons with previous research. Kyokushin karate is a mixed sport that involves frequent changes in the state of sports performance. Both halves of the athlete's body continuously and repeatedly experience symmetric and asymmetric pressures during training. Additionally, the trunk, core, arms, and legs muscles develop uniformly.

Furthermore, during the training and learning processes, the activation of agonists and antagonists is crucial, as well as during the control of movement accuracy [35]. The effectiveness of the Mae-Geri technique requires a dynamic sequence of movement from the trunk, pelvis, knee, ankle, and foot, resulting in the activation of neuromuscular support in the lower limb and enabling synergy from the pelvis to the foot [36]. A study titled "Kinematic analysis of mae-geri kicks in beginner and advanced kyokushin karate athletes" demonstrated that Kyokushin karate training can change the neuromuscular control strategy and be effective in improving movement patterns [18]. In this regard, Jemili et al.'s study, which investigated the effect of three months of Kyokushin karate training on the electromyography of the biceps and triceps muscles in the gyaku-zuki-punch technique and the biceps femoris in the kiza-mawashi-guiri-kick technique, showed an increase in the activity level of these muscles after Kyokushin karate training [37]. This finding is consistent with Cesari and Bertucco's research, which demonstrated higher neuromuscular activity during punching in elite karate athletes compared to beginners [38]. The activity level of the fibularis longus muscle increased significantly in the training group, but there was no significant difference between the training and control groups. It is possible that the duration of training and the type of Kyokushin karate exercises performed in this study, which focused less on this muscle, might have resulted in this outcome.

The results of the current study demonstrate that eight weeks of Kyokushin karate training can effectively reduce the decrease in the height of the medial longitudinal arch in the training group. As previously mentioned, flat feet is a condition characterized by the loss or reduction of the height of the medial longitudinal arch of the foot [39]. Several factors can contribute to this deformation, including the shortness of the fibularis longus muscle, tibialis anterior and tibialis posterior muscles, as well as the soleus-lateral gastrocnemius muscle complex (Achilles tendon) and fibularis brevis and longus [11]. Interestingly, the involvement of the tibialis anterior muscle in active inversion suggests its potential to provide dynamic support to the medial longitudinal arch of the foot [32]. Notably, the present study is the first to investigate the effect of Kyokushin karate exercises on the correction of flat feet.

Correct body posture is a crucial aspect of Kyokushin karate training [17]. The ability to change direction quickly and perform techniques with speed requires a high degree of coordination and balance [36] To achieve proper technique execution, stretching exercises are typically included at the beginning of training to ensure flexibility of the muscular and ligament systems and prevent postural abnormalities [40]. Research has shown that Kyokushin athletes have superior performance stability, as well as significant changes in posture characteristics, which can have a positive impact on competitive activities and physical condition during adolescence [41]. Additionally, a study conducted by Jurkiewicz et al. on Kyokushin karate athletes demonstrated that the longer an athlete has been involved in this sport, the greater their level of stability and stability in both lower limbs [42] explaining the positive effects of Kyokushin karate training on foot arch deformities. Building on previous research and the nature of Kyokushin karate exercises, the findings of the current study indicate that the activity of tibialis anterior and lateral gastrocnemius muscles increased, with a higher percentage of increase observed in the tibialis muscle. This change in muscle activity may contribute to improving flat feet, potentially explaining the positive effects of Kyokushin karate training on foot arch deformities. Furthermore, Kyokushin karate training is an activity that engages and strengthens the muscles surrounding the ankle, particularly the posterior leg muscles and intrinsic muscles of the foot. Weakness in the extrinsic muscles, such as the supinator, invertor, posterior compartment, and intrinsic foot muscles, as well as decrease in dynamic stability is a crucial factor in creating flexible flat feet [42]. Strengthening the plantar flexors, which also function as invertors and supinators, and the intrinsic muscles, which can be enhanced by performing Kyokushin karate training, may increase dynamic stability and reduce excessive pronation of the subtalar joint in individuals with flexible flat feet. This strengthening could also contribute to an increase and improvement in the height of the medial longitudinal arch.

5. Conclusion

The results of the current study indicate that eight weeks of Kyokushin karate training significantly increased the activity level of both the tibialis anterior and lateral gastrocnemius muscles. However, the activity level of the Fibularis longus muscle did not show a significant change. Furthermore, these exercises also improved the height of the medial longitudinal arch, indicating a potential solution for correcting flat feet. Therefore, we recommend Kyokushin karate exercises to improve muscle activity and arch height in individuals with flat feet.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Sport Sciences Research Institute (No.: IR/SSRI.REC.2022.12432.1550).

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Authors' contributions

All authors equally contributed to the preparation of this article.

Conflict of interest

The authors declared no conflict of interests.

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