Research Paper

Effects of Combined Exercises and Short Foot Exercise With and Without Isometric Hip Abduction In Women With Flatfoot

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ABSTRACT

Purpose: This study aims to examine the effect of 6 weeks of combined exercises (CE), short foot exercise (SFE), and SFE with isometric hip abduction (IHA) on dynamic balance (DB), joint position sense (JPS), and strength in women with flexible flatfoot (FF).

Methods: A total of 40 women with flexible flatfoot (FF) participated in this semi-experimental study and were randomly assigned to three groups as follows: CE (n=14), SFE (n=13), and IHA (n=13). Six weeks of exercise were split into 3 sessions under supervision and 3 sessions at home were completed by the participants. The Y balance test, goniometer, and dynamometer were used to assess DB, JPS, and strength before and after the exercises, respectively. The mixed-model repeated-measures multivariate analysis of variance statistical test was used to analyze the data with a significance level of 0.05.

Results: The results revealed that after performing the exercises, there was a significant difference in the DB in the SFE group in two posteromedial and posterolateral directions; meanwhile, in the IHA group this difference was in three directions, while in the CE group, it was in the posterolateral direction ($P<0.05$). After the exercises, no significant difference was observed in either group's JPS or plantar flexors and dorsal flexors strength ($P>0.05$). Between the groups, there was no difference in any of the other variables ($P>0.05$).

Conclusion: Considering that the DB changes in the IHA group were more than in the other two groups, these exercises are suggested to improve the DB in women with FF.

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Highlights

• The combined exercises, short foot exercise, and SFE with isometric hip abduction (IHA) exercises improved navicular drop in women with flexible flatfoot.

• Dynamic balance in the IHA group improved more than the other two groups.

• The six weeks of the exercise program were not sufficient to increase joint position sense and strength.

Plain Language Summary

With a 20% prevalence in adults, flexible flatfoot (FF) is one of the common orthopedic problems. This study aims to examine the effects of 6 weeks of combined exercises (CE), short foot exercise (SFE), and SFE with isometric hip abduction (IHA) exercise on the dynamic balance (DB), joint position sense (JPS), and strength of women with FF. A total of 40 women with FF participated in this semi-experimental study and were randomly assigned to three groups as follows: CE (n=14), SFE (n=13), and IHA (n=13). Six weeks of exercise were completed by the participants. It was split into 3 sessions under supervision and 3 sessions at home. The Y balance test, goniometer, and dynamometer were used to assess DB, JPS, and strength before and after the exercises, respectively. According to the results, the IHA group's DB considerably improved in all 3 directions of the test following the intervention. This difference was seen in the posterolateral and posteromedial directions in the SFE group, but only in the posteromedial direction in the CE group. The results regarding the variables of strength and JPS in the study groups did not show any significant difference. The results confirmed that all three training methods were successful in enhancing DB; however, because IHA exercises were more successful, it is advised that women with FF utilize these exercises to enhance DB. Also, it is advised to assess how long-term training programs affected the elements of strength and JPS.

Introduction

The foot is a multi-jointed, exclusive mechanism that is crucial to the lower limb's ability to move. Any alteration to the soles of the foot may affect the body's lower limbs and other joints [1]. As a result of body weight distribution during various movements, the foot includes shock-absorbing features, such as transverse, lateral, and medial longitudinal arches (MLA) [2]. The reduction of the MLA, which contains two rigid and flexible varieties, is referred to as flatfoot, also known as pes planus, planovalgus foot, or fallen arch. While the flexible type occurs when the MLA forms without carrying weight, the rigid flatfoot is characterized by a reduction of the MLA regardless of weight bearing [3, 4].

According to estimates, research evidence indicated that 20% of adults have flexible flatfoot (FF) [5]. In this circumstance, muscular strength declines first, followed by loosening and loss of flexibility in the ligaments, and lastly, changes in the structure of the foot take place [6]. To maintain stability and control posture in this circumstance, there is an excessive amount of foot movement in the middle [3]. A closed kinetic chain that ends with the foot is crucial in preserving both static and dynamic balance (DB). Because of this, if one of the chains is impaired, frail, aberrant, or broken, it has an impact on other parts of the chain. According to research, changes in environmental inputs, which are a secondary cause of joint injury, have an impact on static and DB [7]. The individual's proprioceptive awareness of their body and how it interacts with the environment is one of the variables that can prevent and warn about joint damage. The movement sensor, known as proprioception, which determines the position and motion of joints as well as the direction, intensity, and speed of joint movement, receives sensory inputs from receptors found in the muscle spindle, tendons, and joints [8]. The proprioceptive function may be impaired by several conditions, including osteoarthritis, musculoskeletal abnormalities that raise the likelihood of further damage, aging, ligament damage in the joint, traumas, and edema of the joint [8]. It has been determined that postural stability and altered or reduced joint proprioception are risk factors for lower limb injuries [9].

It has been demonstrated that MLA height is connected to the strength and control of the knee and ankle muscles, which are crucial for carrying out functional activities and maintaining DB. The decrease or loss of MLA height during walking degrades balance parameters, reduces muscle strength endurance, and decreases the absorption of ground reaction forces [9]. Since both static and dynamic systems (such as bones, ligaments, aponeuroses, and muscles) support the foot arch, FF rehabilitation entails both static support, such as an orthosis, and dynamic support, in the form of muscle strengthening [10]. Studies conducted in the past on a variety of training techniques have included proprioceptive neuromuscular facilitation strengthening exercises, intrinsic foot muscle exercises, toe curl exercises, and investigations on the effects of foot and ankle interventions. Flexible flat soles have been treated clinically with a towel curl, SFE to strengthen the internal foot muscles, a combination of iliopsoas stretching exercises, and strengthening of the tibialis posterior and central region [5, 11–14].

One approach that therapists and researchers are interested in using to treat flatfoot is a mixture of strengthening and stretching exercises. This is because, according to research by Farhan Alam et al. (2018) titled “effects of selective strengthening of tibialis posterior and stretching of iliopsoas on the navicular drop, dynamic balance, and lower limb muscle activity in the pronated foot”, performing tibialis posterior strengthening exercises and stretching of iliopsoas in addition to exercises such as towel curl can improve significant clinical outcomes, such as ND, muscle activation, and DB [13]. Another exercise method that might work the foot’s inner muscles, known as the core, is SFE. Exercises known as SFE entail attempting to move the first metatarsal head toward the calcaneus without flexing the toes [14]. In earlier research, patients with pes planus who performed SFE for 6 weeks experienced improvements in foot arch height, decreased foot pain, and increased foot function [11]. In a recent study, Choi et al. (2020) examined the effects of hip joint stability on knee and rearfoot mechanics while using isometric hip abduction (IHA) for hip stability during SFE. The findings of this study demonstrated that isometric hip abduction can be a useful technique to lessen compensatory tibialis anterior activity and increase the activity of abductor hallucis muscles during SFE for individuals with pes planus, considering the weakness of abduction in people with pes planus and the compensatory activity of tibialis anterior to compensate [15]. Researchers are still looking for the best treatment method to help pes planus patients, after performing numerous studies. This study examined the effects of a 6-week of CE, SFE, and SFE with IHA exercises on joint position sense (JPS), strength, and DB in women with FF.

Materials and Methods

The participants in this randomized, single-blind clinical trial were 45 women with FF. Following an initial description of the research methodology by the researcher, the participants were chosen following the inclusion criteria. If the participants wished to take part in the research, they signed an informed consent form to enroll. For the family F test, three groups, and two times of measurement, the sample size was estimated using the G*Power software, version 3.1 with 42 participants along with the following parameters: Effect size=0.5, test power=0.8, and significance level=0.05 [16]. As a result, we considered 15 participants for each group. Using the Randlist software, the participants were divided into 3 groups. The current study was carried out in compliance with the ethical principles of Helsinki and was approved by the Ethics Committee of Arak University and was registered in the Iranian Registry Clinical Trials. The inclusion criteria were being of the female gender, having 18 to 28 years of age, having a body mass index of 18 to 25, having an ND higher than 10 mm, and having the absence of a lower limb or back injuries in 6 months preceding the study. Also, individuals who did not finish the training sessions were not included in the study. All participants’ right feet were dominant and the evaluations were focused on this foot. Baseline evaluations were done before starting the exercises. Thereafter, for 6 weeks, the participants in each group received the necessary interventions. The grouping of the participants was hidden from the assessors and data analysts.

For 6six weeks on every day (3 sessions under supervision and 3 sessions at home), the participants in all three groups performed CE (a combination of strengthening, stretching, and balance exercises) (Table 1), SFE (Table 2), and IHA. The IHA performed like SFE whereas an elastic band was placed above the knee to provide resistance to the hip abductor muscles. The workouts changed every 2 weeks and were divided into 3 levels, from easy to difficult. It is important to note that 5 individuals in the second level of exercises were not included in the study since they did not finish the training sessions.

The Y-balance test was used to assess DB. Three graduated PVC pipe rulers in the anterior, posteromedial, and posterolateral orientations were included with the Y-balance test kit. Without shoes or socks, each participant stood on the platform in the center of the Y-balance test kit and pushed forward with the reaching foot of a reach indicator mounted on a graduated ruler of a PVC pipe. The test was run three times in each direction and the average of the three times in each direction was recorded.

Table 1. Combined exercises

1st and 2nd Week	3rd and 4th Week	5th and 6th Week (With Resistance Band)
Toe-spread-out exercise Hallux-extension exercise Lesser-toe-extension exercise	Hip abduction while lying on the side	Leg: Flexion-adduction-external rotation with knee flexion Foot: Dorsiflexion-supination-inversion with toes extension
Picking up small objects with the toes	Picking up small glass stones using toes and depositing the stones elsewhere	Leg: Extension-abduction-internal rotation with knee extension Foot: Plantar flexion-pronation-eversion with toes flexion
Rolling a tennis ball	Curling the towel with the toes	Leg: Flexion-abduction-internal rotation with knee flexion Foot: Dorsiflexion-pronation-eversion with toe extension
Pulling the foot with a towel around the heel	Dorsiflexion and plantarflexion with elastic band	Leg: Extension-adduction-external rotation with knee extension Foot: Plantar flexion-supination-inversion-with toes flexion
Write the alphabet	Heel cord stretch	Resistive inversion and eversion with an elastic band
Leaning on the back of the chair by lifting one foot	Heel cord stretch with bent knee	Maintaining balance in a stable and unstable base

PHYSICAL TREATMENTS

The collected values were divided by the leg length of each participant and the resulting number was multiplied by 100 to normalize individual differences in leg length. The practice was done twice in each direction before the measurement to reduce the impact of learning on the result. The test would be repeated in that direction if the participant maintained their weight on the reaching leg, lifted the supporting foot's heel, had his hands hang below their waist, or had otherwise lost their balance at any time during the test [2, 12].

Muscle strength was measured by a Lafayette handheld dynamometer model 01165. The manual muscle tester dynamometer is a manually operated evaluation tool for measuring a patient's muscle strength. The manual muscle tester device is reliable, valid, and calibrated. the measurement results are available in pounds or kilograms. The supine posture, with the heel out of the bed, the ankle in a neutral position, and the distal end of the foot fastened by a strap were used to test the strength of the ankle plantar flexor muscles. The maximal force was measured by the dynamometer as the ankle flexed into the plantar flexion position, which was done by positioning it at the end of the metatarsal heads on the sole. While the dynamometer was mounted on the metatarsal head and the participant made a dorsiflexion movement, the strength of the dorsi flexor muscles was measured in the same manner. Each situation's measurement was carried out 3 times, with the mean being the person's score [9]. The results were adjusted by dividing by each person's weight.

To assess the JPS and reestablish the 15-degree plantarflexion angle, a universal goniometer from Iran was employed. The participant was seated with the thigh and knee at a 90-degree angle to calculate the absolute error of the reconstruction of the ankle joint angle. To quantify the sense of ankle joint position, the target angle was 15 degrees of plantar flexion [17]. The participant was first asked to recall the target angle after the examiner moved the ankle 3 times to the angle and held it for 5 s while the participant's eyes remained open. The participant was then instructed to actively reconstruct the target angle while their eyes were blindfolded to eliminate visual interference. He was also instructed to signal the examiner by saying "good" when they reached the target angle. No matter whether the direction was positive or negative, the amount of deviation between the angle formed in the reconstruction of the ankle joint angle and the goal angle was deemed the error angle as a JPS. This action was carried out 3 times, and the final record for each participant was determined by taking the mean of the 3 angle errors.

We used the SPSS software, version 26 to analyze the data. The Shapiro-Wilk test was initially used to confirm that the data were normally distributed. The mixed-model repeated-measures multivariate analysis of variance statistical test was applied with consideration for the data's normal distribution (P=0.05). Pre-test versus post-test time was the within-subject component, while the group was the between-subject factor (CE, SFE, IHA). The outcomes of the Benferroni post hoc test were examined to compare groups and times and whether there was a significant interaction between time and group as well as a main effect for both variables (time and group). All statistical analyses for the main effect and interactions were found to have a significant level ($P<0.05$). The (pre-test-post-test)/pre-test formula was also used to estimate the difference percentage of variable changes.

Results

The mean and standard deviation of the demographic characteristics of the participants are given in Table 3.

The results of the statistical analysis of the investigated variables are given in Table 4. The results show a substantial main effect of time on the DB variable. Following 6 weeks of CE, the findings of the post hoc test revealed that the dynamic balance was improved with an increase in reach distance in the posteromedial direction (P=0.001). Also, in the SFE group, this variable revealed a significant difference in the posterolateral (P=0.017) and posteromedial ($P<0.001$) directions. An increase in achievement was seen in the IHA group in all 3 directions, namely anterior (P=0.003), posterolateral (P=0.029), and posteromedial (P=0.018).

According to the results, the main effects of time, group, and the interaction impact of time*group on the muscle strength variable were not significant ($P>0.05$). The obtained results also indicated that the primary effects of time, group, and the interaction of time*group on the perception of JPS were not statistically significant ($P>0.05$) (Table 4).

Discussion

This study aimed to examine the effects of 6 weeks of CE, SFE, and IHA exercises on the DB, JPS, and strength of women with FF. According to the results, the IHA group's DB improved considerably in all 3 directions (anterior (DP=6.32), posterolateral (DP=6.43), and posteromedial (DP=9.42)) following the intervention. This difference was observed in the posterolateral (DP=14.37) and posteromedial (DP=9.49) directions in the SFE group, but only in the posteromedial direction in the CE group (DP=14.32). The smallest alterations in the foot should affect balance control and then performance since the foot is the last part in the body's kinetic chain and provide a limited base of support surfaces to maintain balance [9, 18].

In daily physical activities, such as sitting, standing, walking, functional activities, and sports, balance is extremely important and can enhance the quality of life. The dynamics of the body posture to avoid falls are described by the complicated movement skill known as balance. Humans require intricate coordination of the sensory system, central nervous system, and motor system to maintain balance [13]. To maintain good posture, the perception of motion and postural motions can be enhanced by stimulating the soles of the foot. SFE is a sensorimotor training that actively builds the MLA and horizontal arch as well as the internal foot muscle [12]. Our findings indicated that the IHA and SFE groups had improved balance. The abductor hallucis and flexor hallucis brevis muscles, which are IFM to maintain the MLA and help form the arch and maintain body balance, are

Table 2. Short foot exercises

SFE Exercises		
The 1st and 2nd week	3rd and 4th week	5th and 6th week
Exercise while sitting	Exercise standing on two-legs	Exercise standing on one-leg

Notes: Short foot exercises: Lesser toe extension, toe spread, doming, and hallux extension.

PHYSICAL TREATMENTS

Table 3. Demographic characteristics of the participants

Groups	No.	Age (y)	Weight (kg)	Height (cm)	Body Mass Index (kg/m²)
Combined	14	21.92±1.43	60.0±11.01	162.57±7.51	22.71±4.04
SFE	13	21.92±1.49	53.61±8.38	160.61±3.92	20.79±3.25
SFEISO	13	21.23±1.09	57.23±8.04	160.46±5.62	22.34±3.83
P		0.327	0.217	0.588	0.385

SFEISO: Short foot exercises with isometric hip abduction; SFE: Short foot excursive.

PHYSICAL TREATMENTS

Table 4. Mixed-model repeated-measures multivariate analysis of variance test results

Variables	Groups	Mean±SD		Effect	F	P	Effect Size	Difference Percentage
		Week 0	Week 6					
Anterior (cm)	Combined	81.10±8.13	80.85±6.78	Time	8.02	0.007*	0.178	0.3
	SFE	81.92±9.77	84.8±7.61	Group	0.317	0.73	0.017	3.51
	SFEISO	79.47±8.77	84.5±8.55	Time×Group	2.94	0.065	0.137	6.32
Posteromedial (cm)	Combined	73.95±13.4	84.54±10.99	Time	23.82	<0.001*	0.392	14.32
	SFE	82.95±14.78	90.83±12.85	Group	2.05	0.143	0.100	9.49
	SFEISO	82.97±12.24	90.79±11.72	Time×Group	0.266	0.768	0.014	9.42
Posterolateral (cm)	Combined	78.2±10.76	82.18±9.78	Time	27.48	<0.001*	0.462	5.08
	SFE	79.52±12.04	91.24±8.79	Group	1.08	0.349	0.055	14.73
	SFEISO	82.7±12.44	88.02±14.05	Time×Group	3.17	0.053	0.147	6.43
Plantar flexion (kg/kg body weight)	Combined	15.49±5.36	16.39±2.52	Time	2.32	0.136	0.059	5.81
	SFE	16.58±3.43	17.77±3.69	Group	0.800	0.475	0.041	7.17
	SFEISO	15.45±2.3	16.27±3.28	Time×Group	0.03	0.970	0.002	5.3
Dorsiflexion (kg/kg body weight)	Combined	9.22±2.74	9.87±2.65	Time	2.47	0.124	0.063	7.04
	SFE	11.66±3.16	11.76±1.92	Group	3.07	0.058	0.142	0.85
	SFEISO	10.93±2.58	11.4±1.57	Time×Group	0.396	0.676	0.021	4.3
Joint position sense (deg.)	Combined	3.67±1.01	3.03±1.27	Time	3.81	0.059	0.093	17.43
	SFE	3.1±1.35	2.42±1.56	Group	0.934	0.402	0.048	21.93
	SFEISO	3.05±1.86	2.65±1.93	Time×Group	0.083	0.921	0.004	13.11

*P<0.05 PHYSICAL TREATMENTS

SFE: Short foot exercise; SFEISO: Short foot exercises with isometric hip abduction.

activated during sensorimotor training using the body's proprioceptive feedback. These exercises strengthen the asymmetric plantar muscle and help the brain's motor area map new and useful movements by sending sensory signals to the sensory cortex area of the brain. As a result, it helps to preserve the body's balance and stability and improves a sense of motion and postural problems [12].

Also, it appears that combining SFE with IHA helps increase hip stability, which aids in enhancing balance in all 3 directions of the Y balance test. The only group to experience an improvement in anterior access was the IHA group. Individuals with pronated feet outperformed those with normal and supinated feet in the anterior direction of the star balance test, according to a previous study by Cote et al. on the impact of pronated and supinated foot posture on static and dynamic stability. These researchers explained this superiority as being due to the pronation group's increased foot mobility as compared to the other two groups [19]. IHA activities are comparable to SFE, with the exception that an elastic band is tied above the knee joint, and hip abduction resistance is used in SFE [7]. It appears that completing IHA exercises with standing on two legs in the second level and on one leg in the third along with IHA can provide additional benefits for enhancing balance. Poor foot position sense makes it more difficult for the sole surface and support surface to adapt to one another, forcing the body to make closer postural adjustments to maintain balance and vertical position [19]. The IHA group's hip approach has likely been reinforced and this has been related to improvement in balance in this group.

Moreover, SFE was superior to CE in that it improved in both posterolateral and posteromedial directions. Vladimir Janda and Maria Vavrova created the sensorimotor stimulation methodology based on the Freeman theory (1965). The purpose of the sensorimotor stimulation method, which emphasizes the relationship between afferent and efferent structures, is to automatically activate the muscle reflex so that there is no need for higher motor control and the movement is only under subcortical control. To engage the foot muscle, SFE can be used. The deep receptors of the foot are stimulated as a result of the foot being shortened in the longitudinal and transverse axes to create the arch during this exercise. As a result, the position of the joints and the distribution of the pressure applied to them alter [20]. The gastrocnemius, soleus, TA, tibialis posterior, dorsi flexor and plantar flexors, ankle invertor, ankle evertor, peroneus longus, peroneus brevis, as well as iliopsoas stretch were the CE utilized in this study [5, 21]. The majority of these activities were performed while sitting or lying down, which is likely one of the reasons why they had little to no impact on balance. According to the findings of Yalfani et al. individuals with flatfoot have much worse balance in the single-legged standing posture because it is more difficult to control body movements due to the smaller surface area needed to maintain balance [7]. Our study's findings on balance enhancement were in line with the studies of Kim and Kim (2016) [12], Hyong et al. (2016) [2], and Alam et al. (2018) [13].

The results regarding the variables of strength and JPS in the study groups did not show any significant difference, despite the differences percentage of JPS (DP=13.11 in IHA; 17.43 in CE; and 21.93 in SFE group). To sustain the arch structure and start a dynamic movement, the foot and ankle muscles must be strong [2]. Zhao et al. examined the connection between arch height, ankle muscle strength, and physical performance in their study [6]. According to the findings, those with higher MLA have weaker ankle muscles, whereas people with lower arches (flatfoot) had stronger ankle muscles. Although the physical performance was not connected with arch height, ankle muscle strength was. Scientists hypothesized that an adaptation to sustain body weight and absorb shock may account for the lower arch and stronger ankle muscles [6]. On the other hand, patients with flatfoot have been found to have muscle weakness in their feet, particularly in the inner muscles [21]. Our findings indicated that following interventions, strength increased but this difference was not statistically significant. These differences might also be noteworthy if the workouts were performed for a longer amount of time. Also, since we only looked at plantar flexion and dorsiflexion muscle strength, the results for other muscles especially the built-in core muscles of the sole could differ.

After 6 weeks, joint position sense did not show any difference in any of the groups. Position sense, kinesthesia, and force sensing are subsets of proprioception. The position sensor is responsible for determining the exact position of a certain part of the body in space. The information associated with these senses is communicated to the central nervous system through position sense receptors, which include muscle spindle receptors, Golgi tendon organ, and joint receptors. To keep the joint stable and ensure that muscle contractions are coordinated and timed correctly, the joint must have a normal sense of position. The findings of the study by Nobakht et al., comparing the perception of ankle joint position in female students with and without increased foot pronation and supination, revealed no statistically significant difference between the study groups in terms of the mean absolute error of the reconstruction of the examined angles [8]. According to these researchers, aberrations of enhanced pronation and supination may not have a significant impact on the accuracy of ankle joint proprioceptive function [19]. We anticipated that JPS, a subset of depth sensing, would increase in light of the study's improvement in balance. The results of Cote et al. also confirmed our findings. According to these researchers, alterations in proprioceptive receptors are not to blame for the difference in stability between various foot types (normal foot, excessive pronation, and supination) but rather the structure and biomechanics of the foot are the reasons [19]. The angle (15 degrees of plantarflexion) used for reconstruction and given that we did not quantify the feeling of JPS during dorsiflexion movement may also have contributed to these results. One of the research's limitations was the possibility that the outcomes would have been different, had this variable been examined. In addition, we employed an open kinetic chain of motion to rebuild the angle of the ankle joint, as opposed to the Y balance test's closed kinetic chain design. As studies have shown that a closed kinetic chain causes the greatest involvement of proprioception receptors, probably that the ankle joint angular reconstruction test's use of an open kinetic chain did not result in the greatest involvement of proprioception receptors. As a result, after finishing the exercises, there was no difference in the accuracy of this feeling across the research groups. It is suggested that future studies investigate JPS in the closed kinetic chain and during weight bearing. It is also suggested to investigate the effect of these exercises over a longer period.

Conclusion

The results showed that all 3 training methods were successful in enhancing DB; however, because IHA exercises were more successful, it is advised that women with FF utilize these exercises to enhance DB. Also, it is advised to assess how long-term training programs affected the elements of strength and JPS.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Local Ethics Committee of Arak University (Code: IR.ARAKU.REC.1401.010) and listed in the Iranian Registry of Clinical Trials (Code: IRCT20220409054456N1). Before experimental procedures began, all the participants reviewed and voluntarily signed an informed written consent form.

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Authors' contributions

Conceptualization, methodology, software, formal analysis investigation, writing–review & editing, supervision and project administration: Zahra Raeisi; Data curation: Aftab Zarali; Writing the original draft: All authors.

Conflict of interest

The authors declared no conflict of interest.

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