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The Effect of Intrinsic Foot Muscles Strengthening on the Postural Control Indices in Patients with Chronic Functional Ankle Instability

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ABSTRACT

Background: Foot intrinsic muscles are crucial for supporting the foot on the ground. Their activation can play an important role in postural control in functional ankle instability subjects. This study aimed to determine intrinsic foot muscle strengthening exercises' effect on postural control indices in subjects with chronic functional ankle instability.

Methods: In this randomized clinical trial, 45 subjects with functional ankle instability were included. The subjects were randomly divided into a routine exercise group, an intrinsic muscle-strengthening exercise group, or a control group. Exercises were conducted three times per week for four weeks. Overall, anteroposterior and mediolateral stability indices were measured before and after four weeks with the biodex balance system. Data were analyzed with the paired sample t-test, one-way ANOVA, and Tukey test.

Results: In the intrinsic exercise group, the overall dynamic stability index significantly changed from 1.68±0.8 to 1.24±0.8, the mediolateral dynamic stability index significantly changed from 1.04±0.5 to 0.72±0.3, and the anteroposterior dynamic stability index significantly changed from 1.29±0.5 to 0.84±0.3 ($p<0.05$). They also have significant changes in the mediolateral dynamic stability index for the affected foot from 2.37±1.4 to 1.53±0.7 and the anteroposterior dynamic stability index for the affected foot from1.81±0.6 to 1.23±0.3 ($p<0.05$). There is no significant difference in the dynamic stability index between routine and intrinsic groups ($p>0.05$).

Conclusion: According to the results of the study, the positive effects of foot intrinsic muscle exercise on postural control reactions were shown, so we suggest that in addition to routine exercises, intrinsic exercises should also be considered in subjects with chronic functional ankle instability.

Key words: Functional Ankle Instability, Intrinsic Muscles, Biodex Balance System, Dynamic Balance Index

INTRODUCTION

The ankle joint is very complex in terms of bone structure and function due to the important role of joint mobility and joint stability (1-3). As a result of the complexities of the joint, an ankle sprain is the most common injury to this joint (2). Although ankle sprains are often associated with minor injuries and resolve quickly with minor treatment, feelings of instability in the ankle and recurrence of this injury are reported in 70% of cases (4,5). In fact, mechanical or anatomical instability in the ankle is treated, but functional instability remains after complete repair of the injured ligament (6, 7), which prevents the return to work in 6% of people and disrupts work for at least nine months to six years in 5-15% of people (8). The probability of re-injury is due to reduced sensory inputs to joint receptors and reduced body postural reactions. Reduced sense of position and reduced ability to regenerate angles in the joint cause the foot to be in an appropriate position during the heel strike phase (8,9,10). It finally increases the likelihood of ankle sprain and recurrence even after complete repair of the ankle ligament injury (6,7).

Based on this view, Gross (1987), Wilkerson and Nietz (1994), Mattacola and Dear (2002), and Baltasi and Kohl (2003) emphasize that proprioceptive exercises are necessary for people with functional ankle instability. The results of their research showed an improvement in postural control in these people after proprioceptive exercises (11-14). In addition to postural control, paying attention to foot function and intrinsic muscles of the foot is important in controlling ankle and foot movement in people with ankle instability (15,16,17). The intrinsic muscles have a small cross-section area, are considered tonic and postural muscles, and generally contribute to maintaining the stability of the forefoot and midfoot during walking and standing (18). These muscles act as a functional unit to stabilize the midfoot, navicular bone, and medial longitudinal arch (19). McKeon et al. (2013) consider the foot core a central stabilizing system. In the foot area, stability is provided through an active structure (intrinsic and extrinsic muscles of the foot), a passive structure (ligaments and plantar fascia), and the nervous system (feedback afferents of intrinsic muscles). Intrinsic muscles play a direct and important role in the active and neural subsets and an indirect role in the passive subsets (16). Contraction of these muscles changes the medial longitudinal arch, and stretching these muscles increases nerve impulse transmission. With their connection to passive tissues such as bones, ligaments, and fascia, these muscles increase tension in these structures during contraction. It increases afferent feedback during the medial longitudinal arch deformation and weight bearing. Moreover, the co-activity of intrinsic muscles, extrinsic muscles, and the plantar fascia of the foot protects the foot during adjustment and transmission of forces in activities such as walking and standing (16). In a study conducted by Kelley et al. (2014), results showed that the intrinsic muscles of the foot play a major role in changing and supporting the medial longitudinal arch, energy storage, and energy transmission to the elastic and passive tissues of the medial longitudinal arch. The contraction of these muscles is also important for foot position in different stages of walking (18).

Considering the importance and characteristics of the foot's intrinsic muscles, it is necessary to consider these muscles in the rehabilitation program. There is no available research to refer directly to the rehabilitation program for these muscles. Tendulkar et al. (2017) showed that strengthening the intrinsic foot muscles was more effective than electrical stimulation in improving the foot position index and foot function index in people with flat feet (19). Furchet and Gojanovic (2016) stated that dysfunction and weakness in the active supporters of the medial longitudinal arch cause injuries such as inflammation of the plantar fascia, Achilles tendonitis, posterior tibialis muscle, metatarsalgia, and finally, medial tibial stress syndrome. Thus, strengthening the foot core muscles can be important in reducing the stiffness of the foot system and controlling the arch changes (20). A pilot study revealed that foot intrinsic muscle exercises improve the control of the foot position while running (21). Another study has emphasized the importance of strengthening the intrinsic muscles of the foot to control foot pronation (22). In addition, to increase the support of the foot on the ground and increase foot stiffness during walking, it is necessary to pay attention to the intrinsic muscles of the foot (21, 22). Finally, since there is no available clinical trial research on the effect of strengthening the intrinsic muscles of the foot in people with functional ankle instability, the present study was conducted to investigate the effect of intrinsic foot muscle strengthening on the postural control reaction in patients with functional ankle instability.

Methods

This study was a randomized controlled trial. Forty-five subjects with functional ankle instability participated in this study and were divided into three groups by simple non-probability sampling. All protocols were approved by the ethical committee of the Zahedan University of Medical Science (IRCT20180714040466N2), and all participants signed written informed consents.

Inclusion criteria of the study (23-24)

Inclusion criteria included men and women aged between 18 and 45 years with unilateral functional ankle instability without pain, at least one ankle sprain in a recent year, lack of mechanical functional instability in the affected ankle by anterior drawer test, no history of fracture, dislocation, structural abnormalities, numbness, and tingling in the lower limb, and no history of dizziness or head trauma.

Exclusion criteria of the study (23, 25-27)

Exclusion criteria included pain or inflammation in the ankle, receiving other treatment during the research, unwillingness to continue treatment, not completing the course of treatment, and taking painkillers, sedatives, and alcohol 48 hours before the test.

Sample Size

The sample size was determined based on a pilot study. Ten subjects were divided randomly into two equal groups, and the main part of the study was conducted on them. The means and SDs for the parameters from this pilot study, with α= 0.05 and 90% power, were used to calculate the sample size. According to the results of the pilot study, the sample size in each group was 15 patients.

Procedure

The initial clinical examination study was performed by measuring demographic information and performing ankle clinical tests. Then, the main research information, including overall stability index (OSI), anteroposterior stability index (APSI), and mediolateral stability index (MLSI), was recorded by the Biodex Balance System (SD 950-340, Biodex Medical Systems, Inc., Shirly, NY, USA). It has reliability and validity for measuring balance indices (28, 29).

The Biodex system consists of a circular moving desk with a diameter of 55 cm, which is placed at a height of 20 cm above the ground inside the body of the equipment. This desk can tilt in different directions up to 20 degrees relative to the horizon plane. The overall stability index shows the variance in plate deviation from the horizontal plane. The anteroposterior and mediolateral indices show the deviation of the plate from the horizontal position in the sagittal and frontal planes, respectively. The indices' scores show the deviation from the horizontal position, so the lower scores indicate better balance (28, 29). The difficulty level is also adjustable, meaning the system can change the stiffness from 1 (least stable) to 12 (most stable).

The subjects stood on the balance board without shoes or stockings. The right heel was placed at the intersection of lines E and 9. The left heel was placed on the intersection of lines F and 12. The feet were 20 degrees out of alignment. The hands were laid one across the other on the thorax. To measure dynamic stability indices in the two-leg position, subjects at a stability level of 8 were tested with open eyes. To measure dynamic balance indices in the one-leg position, subjects at a stability level of 4 were tested with open eyes on the affected leg. Each test lasted 20 seconds and was repeated three times, and the rest time was selected to be 10 seconds. The parameters of the overall balance index, anteroposterior stability index, and mediolateral stability index were recorded.

Then, subjects were randomly divided into three groups: the control group, routine exercises group, and foot intrinsic exercises group. The subjects in the control group did not receive any intervention or exercise for four weeks.

Subjects in the routine group performed the following exercises (30): theraband strengthening exercises for dorsiflexor and plantar flexor muscles; plantar flexor muscle stretching; alternatively, weight bearing on the heel and toe; maintaining balance on the tilt board; leg reaches exercises; jumping on the ground; and foam.

Subjects in the intrinsic muscle exercises group performed the following exercises (16, 29–31): rolling up the towel with fingers, short foot exercise, abduction and adduction of toes, piano key exercise, thumb extension, and thumb stretching. Passive exercises included mobilizing the subtalar joint, midfoot, and forefoot. The techniques were performed based on the Maitland method.

The subjects performed exercises three times a week for four weeks under the supervision of a physiotherapist at the physiotherapy clinic (6).

Statistical Analysis

Results were presented as mean values and standard deviation (SD). The criterion of significance was set at $p<0.05$. Data analysis was performed with SPSS version 21. The assumption of a normal distribution was assessed using the K-S test. The assumption of equality of variances was tested using Levene's test. A paired t-test was used to compare stability variables before and after the intervention. ANOVA and Tukey tests were used to compare differences between the three groups after the intervention.

Results

Using a pilot study, the sample size was estimated to be 45 people for three groups, and 45 eligible people completed the study. The demographic characteristics of the subjects were compared between the three groups. There was no significant difference among the three groups in these variables ($p> 0.05$) (Table 1).

Table 1. Demographic and baseline characteristics of subjects

	Intrinsic Group (n=15)	Routine Group (n=15)	Control Group (n=15)	p-value
Age (year)	35.8±12.1	31.2±7.8	34.0±6.6	0.4*
Weight (kg)	65.6±13.4	68.2±10.5	70.1±8.5	0.5
Height (m)	1.68±8.3	1.73±7.0	1.72±7.4	0.1
Gender(male/female)	12/3	8/7	4/11	0.6

*Significant P<0.05.

The Kolmogorov-Smirnov test was performed to check the normal distribution of data, and the results confirmed the normal distribution of the studied variables ($p> 0.05$).

A paired t-test was used to compare stability index variables before and after the intervention. The results of Table 2 show that in the intrinsic group, there were significant differences in all of the dynamic stability indices before and after training ($p <0.05$), except for the overall dynamic stability index of the affected foot, which did not change significantly (p> 0.05). In the routine group, all of the variables of dynamic stability indices showed significant changes (p <0.05). In the control group, significant changes were observed only in the overall and mediolateral dynamic stability indices (p <0.05).

Table 2. Means and standard deviations of overall, mediolateral, and anteroposterior stability indices, and p-values for within-group comparisons

	Intrinsic Group (n=15)			Routine Group (n=15)			Control Group (n=15)		
	Before *	After	P-value	Before	After	P-value	Before	After	P-value**
Overall Dynamic Stability Index	1.68±0. 8	1.24±0. 8	0.000	1.87±0. 4	1.28±0. 5	0.000	1.82±0.5	1.61±0. 3	0.008
Mediolateral Dynamic Stability Index	1.04±0. 5	0.84±0. 3	0.000	1.42±0. 4	1.01±0. 3	0.000	1.12±0.3	1.06±0. 1	0.32
Anteroposterior Dynamic Stability Index	1.29±0. 5	0.84±0. 3	0.000	1.42±0. 4	1.01±0. 3	0.000	1.12±0.3	1.06±0. 1	0.31
Overall Dynamic Stability Index Affected Foot	4.36±5. 1	2.18±0. 9	0.12	3.39±1. 9	2.42±0. 9	0.03	3.7±1.07	3.58±1. 2	0.44
Mediolateral Dynamic Stability Index Affected Foot	2.37±1. 4	1.53±0. 7	0.01	2.64±1. 2	1.40±1. 2	0.000	2.59±1.1	2.50±1. 4	0.71
Anteroposterior Dynamic Stability Index Affected Foot	1.81±0. 6	1.23±0. 3	0.007	2.39±3. 1	1.58±0. 4	0.01	2.42±0.7 6	2.17±0. 6	0.15

* Values are means ± SD

** Significant P<0.05.

The ANOVA test was used to compare the three groups, and the Tukey test was used to compare the two groups (Table 3).

To ensure the accuracy of the randomization process, we compared the pre-study data of the three groups. The results showed no difference between the three groups in variables before intervention (p>

0.05).

The results of the ANOVA test showed that the difference between groups in the variables of mediolateral dynamic stability index and overall mediolateral and anteroposterior dynamic stability indices of the affected foot was significant (p <0.05).

The results of the Tukey test showed that the comparison of intrinsic and routine groups does not show a significant difference in dynamic stability indices (p> 0.05). The comparison between intrinsic and control groups shows a significant difference in the affected foot's overall mediolateral and anteroposterior dynamic stability indices (p <0.05). A comparison of routine and control groups also shows a significant difference in the affected foot's overall, mediolateral, and anteroposterior dynamic stability indices (p <0.05).

Table 3. Means and standard deviations of overall, mediolateral, and anteroposterior stability indices and p-values for between-group comparisons

	Intrinsi Group*	Routir Grouj	Contrc Grouj	p-value between three Groups*	p-value Intrinsic an Routine Groups	p-value Intrinsic an Control Groups	p-value Routine anc Control Groups
Overall Dynamic Stability Index	1.24±0.ξ	1.28±(5	1.61±(3	0.08	0.96	0.10	0.17
Mediolateral Dynamic Stability Index	0.72±0.(	0.77±(2	1.01±(3	0.03	0.91	0.4	0.10
Anteroposterior Dynamic Stability Index	0.84±0.:	1.01±(3	1.06±(1	0.13	0.31	0.13	0.88
Overall Dynamic Stability Index Affected Foot	2.18±0.ξ	2.41±(9	3.58±1 2	0.01	0.94	0.03	0.01
Mediolateral Dynamic Stability Index Affected Foc	1.53±0.7	1.40±(8	2.50±1 4	0.01	0.94	0.03	0.01
Anteroposterior Dynamic Stability Index Affected Foc	1.23±0.:	1.58±(4	2.17±(6	0.000	0.12	0.000	0.004

* Values are means ± SD

** Significant P<0.05.

Discussion

The result of this study supports the beneficial effects of the foot muscle's intrinsic exercises on the dynamic stability indices, especially on the affected foot. But there were no differences between routine and intrinsic groups. Therefore, rehabilitation interventions are needed to improve postural dynamic reactions in subjects with functional ankle instability without pain. Also, in all variables, the score of stability indices in the intrinsic group was lower than that of the other two groups, indicating a greater improvement of the balance indices in the intrinsic group compared to the other two groups.

The role of the intrinsic muscles of the foot in supporting the structural support of the foot and the arch of the foot is obvious. In terms of neurophysiology and physiologic and metabolic structure, they are considered a part of the tonic and postural muscles and can produce tension for a long time. They also regularly transmit information about the soles of the feet, the base of support, and contact with the central nervous system. In addition, the intrinsic and extrinsic muscles contribute in the form of muscular synergy during walking, especially during the transition from the double leg stance phase to the single leg stance phase, for supporting and rigidizing the arches, pushing the body forward, and adjusting the forces (16-21). Kelly et al. (2012) showed that the activity of the intrinsic muscles of the leg increases with increasing postural fluctuations. Therefore, these muscles are clearly involved in postural control (32).

In another study, Koyama and Yamauchi (2017) showed that intrinsic muscle fatigue reduces the rate of change in COP. This article emphasizes the importance and specific characteristics of intrinsic muscles in controlling postural reactions (33). The results of the mentioned study also support the results of our study. Tendulkar et al. (2018) showed that foot intrinsic muscle exercises are more effective in improving postural index and leg function index than faradic stimulation (19). Although it showed clear differences with our study in the methodology and the instruments used, it indicated the importance of intrinsic muscles. Lee and Choi (2019) investigated the effect of six weeks of foot intrinsic muscle exercise and its relationship with balance in patients with chronic ankle instability and showed that intrinsic muscle strengthening exercises improved the ability to maintain balance (34). In a clinical study, Lee et al. (2019) investigated the function of the somatosensory sensation of the leg using Biodex and vibration equipment in people with ankle instability. This study showed that in subjects with chronic ankle instability, short-foot exercise significantly improved dynamic stability, balance, and proprioception (35). The results of all of the studies show the role of intrinsic muscles in controlling postural fluctuations, which is consistent with the result of our study.

In general, the results of the present study suggest that rehabilitation interventions are necessary for people with functional ankle instability even if they are asymptomatic. Like extrinsic muscles, intrinsic muscles are effective in controlling body fluctuation. Also, it is recommended that foot muscle intrinsic exercises be prescribed for people with functional and anatomical instability. However, these exercises are not considered routine in rehabilitation programs for people with ankle functional and anatomical instability.

An important point in our study was the significant differences in the dynamic stability indices of the affected foot between intrinsic and control groups. The subjects of our study did not have any specific symptoms, and they did not have noticeable problems controlling the body's stability and double leg posture. But they have difficulty controlling postural fluctuations in certain functions, such as standing on single leg and changing the phase of walking from a double-leg to a single-leg position. As stated above, the role of controlling foot position on the ground and controlling postural fluctuations in the transitional phase increases and is noticeable (16-21). The results of the study are in line with those of our study. We showed that using an intrinsic exercise program in people with functional ankle instability reduced postural fluctuations, especially during standing on the affected leg. In general, results showed the importance of the intrinsic muscles during single-leg standing and controlling postural fluctuations. Changes in postural fluctuations while standing on the affected leg in both of our treatment groups were significant, indicating the special involvement of both intrinsic and extrinsic muscles in controlling the foot position and adapting to the support level while standing on one leg.

Conclusion

Based on the results of the present study, foot intrinsic exercise improved postural stability in subjects with chronic functional ankle instability. The present study indicated the importance of intrinsic muscles in controlling posture fluctuations in individuals with functional ankle instability, especially in specific stages of function such as single-leg standing or transitional phases of walking. Therefore, we suggest that intrinsic exercises should also be considered in rehabilitation programs for subjects with chronic functional ankle instability in addition to routine exercises.

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Authors' contributions:

All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

Conflict of interest

The authors declared no conflict of interest.

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