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Saudi Orthopedic Association

Journal of Musculoskeletal Surgery and Research

Article in Press

Original Article

The effect of core stabilization exercises on balance and functional performance in individuals with functional ankle instability: An open-label randomized controlled trial

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Received: 15 March 2024
Accepted: 01 July 2024
Epub ahead of print: 31 July 2024
Published:

DOI
10.25259/JMSR_87_2024

Quick Response Code:

ABSTRACT

Objectives: The objective of the study was to evaluate the effect of core stabilization exercises on balance and functional performance in functional ankle instability (FAI).

Methods: An open-label randomized control pilot study was conducted with 30 FAI participants allocated to two groups. Inclusion criteria were the presence of frequent ankle sprains, sense of give-away of the ankle, and identification of FAI score >11. The experimental group (n = 15) received core stabilization exercises along with conventional exercises, whereas the control group (n = 15) received only conventional exercises. The intervention period was six weeks. The outcome measures for static balance, dynamic balance, and functional performance were the single-leg stance test, modified star excursion balance test (mSEBT), and side hop test, respectively. The assessment was done at baseline and six weeks post-intervention.

Results: Within-group analysis showed improvement in the single-leg stance test and all direction reach distances of mSEBT in both groups using the Wilcoxon signed-rank test. Meanwhile, the side hop test revealed no difference between the two groups. A significant improvement was seen in mSEBT and single-leg stance scores ($P \leq 0.05$) between the groups using the Mann–Whitney U-test. However, the side hop test showed no significant difference ($P > 0.05$).

Conclusion: The present study concludes that core stabilization exercises improved balance compared to mobility and strengthening exercises. Hence, it is highly recommended that core stability training be implemented as a holistic approach to managing FAI.

Keywords: Balance, Core stability, Functional ankle instability, Physical function, Performance

INTRODUCTION

Ankle sprains are a commonly reported musculoskeletal disorder.[1] It has been observed that lateral ankle sprain recurs more frequently, leading to chronic ankle instability (CAI).[2] The common features seen in CAI include frequent sprains, a sense of giveaway, pain, reduced range of motion (ROM), muscle weakness, sensorimotor control deficits, and low self-reported function.[3,4] Based on causal factors, there are two types of CAI – mechanical instability (due to damage to the ankle ligamentous structure) and functional ankle instability (FAI) (due to neuromuscular and proprioceptive deficits).[5,6]

How to cite this article: Panhale VP, Walankar PP, Chheda DV. The effect of core stabilization exercises on balance and functional performance in individuals with functional ankle instability: An open-label randomized controlled trial. J Musculoskelet Surg Res. doi: 10.25259/JMSR_87_2024

Repetitive ankle sprains commonly lead to FAI, with a reported prevalence rate of 32–47%.[3] The common clinical features are impaired proprioception, delayed reflexes, muscle weakness, reduced postural stability, and impaired balance.[7,8] It has been reported that FAI contributes to altered day-to-day function and quality of life with increased fear of falls.[9,10]

Varied rehabilitation strategies focus on mobility, muscle strength, balance, and proprioception in FAI.[11,12] Balance training and conventional exercises also improve postural control in patients with ankle instability.[13] The biomechanics of the ankle complex and its injuries are linked to proximal control and core stability.[14]

The lumbar spine, pelvis, and hip musculature form the core. This assists the function of the kinetic chain throughout the body.[15] Core ensures maintenance of the spine's stability within the neutral during the performance of movements. It creates a stable proximal control to ensure proper muscle recruitment and motor control during the distal upper and lower limb movements.[16] Dastmanesh *et al.* reported improved postural control after eight weeks of core stability training in patients with CAI.[17] Alizamani *et al.* showed that 8 weeks of core stabilization training improved ankle muscle strength, dorsiflexion range, and proprioception in athletes with CAI.[18] This study aimed to investigate the effect of core stabilization exercises on balance and functional performance in FAI.

MATERIALS AND METHODS

Study design

It was an open-label, randomized, and controlled pilot study that lasted from November 2020 to May 2021.

Study population

The study population was patients with FAI.

Sampling

A simple random sampling method was used.

Sample size

OpenEpi Software, Version 3, was used to calculate the sample size. Considering power as 80 with a confidence interval of 95%, the sample size accounted for 30 participants [Table 1].

Table 1: Sample size calculation using OpenEpi Software, Version 3.

Power	80
Confidence interval	95%
Sample size	30

Participants

Inclusion criteria

The study included patients having frequent ankle sprains, a sense of give-away of the ankle, and an identification of FAI score of >11.[19]

Exclusion criteria

Subjects having an injury to the lower extremity or spine in the past six months, degenerative conditions, congenital deformities of the lower extremity or spine, surgical history in the previous six months, history of cardiovascular or neurological conditions, and pregnant females were excluded from the study.

Outcomes variables

A single-leg stance test was used to measure static balance. The participant was instructed to stand on one leg while maintaining balance on the other leg. First, with eyes open and then with eyes closed. The time in seconds was recorded. The test was terminated when the participant's foot touched the ground. Usually, normal individuals maintain a single-leg stance for approximately 30–45 s. The number of seconds an individual can maintain in this position, which was recorded. Three trials were conducted, and the average was recorded.[20]

Dynamic balance was measured using the modified star excursion balance test (mSEBT). Three reach distances – Anterior, posteromedial,and posterolateral were recorded. One practice trial for familiarization with the test was given (this practice trial was not included in the test). After a rest pause of 1 min, three trials were conducted. The normalized scores were calculated for each direction. The mean of the normalized distance of three trials in each direction was considered.[21]

Functional performance was measured using a side hop test. Participants were asked to hop in the lateral direction for about 30 cm, side to side, and return to the original position for ten repetitions as quickly as possible. The total time required to perform this test was recorded.[22]

Intervention

Both groups received treatment for six weeks, comprising three supervised weekly sessions, each lasting 40 min. The experimental group received core stabilization exercises along with conventional exercises, whereas the control group received only conventional exercises. A qualified physiotherapist administered the intervention.

The conventional exercises included stretching the gastrocnemius and soleus muscle (30 s) of three repetitions, three sets of ROM exercises of ankle dorsiflexion, plantar flexion, inversion, and eversion (three repetitions in each set), three sets of strengthening exercises of ankle musculature, using TheraBand resistance and bipedal calf raise (ten repetitions in each set), and neuromuscular control exercises. The progression of strengthening exercises was based on increasing the resistance and repetitions. Neuromuscular control exercises comprised balance and proprioceptive training. First, standing on one leg with eyes open, later progressed to eyes closed with 60 s hold for two repetitions was given. Two sets (five repetitions in each set) of step-up and step-down exercises were conducted in all four directions, along with balance board exercises and double-leg and single-leg stances. The total duration of treatment was 40 min.[23]

The experimental group received core stabilization exercises in addition to conventional exercises. The first phase (1–2 weeks) consists of core stabilization exercises, including abdominal drawing-in maneuvers leading to activation of transverses abdominis (TrA) and lumbar multifidus (LM) muscle. Participants were asked to palpate and feel the muscles' contraction to provide feedback. In the second phase (3–4 weeks), coordinated cocontraction of both TrA and LM muscles was integrated, accompanied by upper and lower limb movements performed in different functional positions such as supine lying, sitting, standing, and quadruped. In the third phase (5–6 weeks), integration of core activation during the functional dynamic activities such as sit-to-stand, wall squats, lunges, step up, and step down was incorporated. Proper breathing control and maintenance of the neutral spine during all exercises were emphasized. Three sets of ten repetitions with the maintenance of the final position for 10 s were incorporated into all exercises. The total duration of treatment was 40 min.[24]

Study procedure

After receiving approval from the Ethical Committee, the study was conducted on 30 patients with FAI. The purpose of the study was explained in detail to the participants.

A total of 158 participants were assessed for eligibility, of which 111 were excluded based on the selection criteria, 17 denied participation in the study, and 30 were recruited [Figure 1]. Randomization was done using computer-generated software. Allocation of participants into experimental and control groups was done using sequentially numbered opaque sealed envelopes with a ratio of 1:1. The experimental group (*n* = 15) received core stabilization exercises along with conventional exercises. In contrast, the control group (*n* = 15) received only conventional exercises. The intervention period was six weeks, three sessions per week. Pre- and post-assessment were performed before and after the intervention.

Statistical analysis

The Statistical Package for the Social Sciences version 24: IBM Corp was used to analyze the data. The normality of

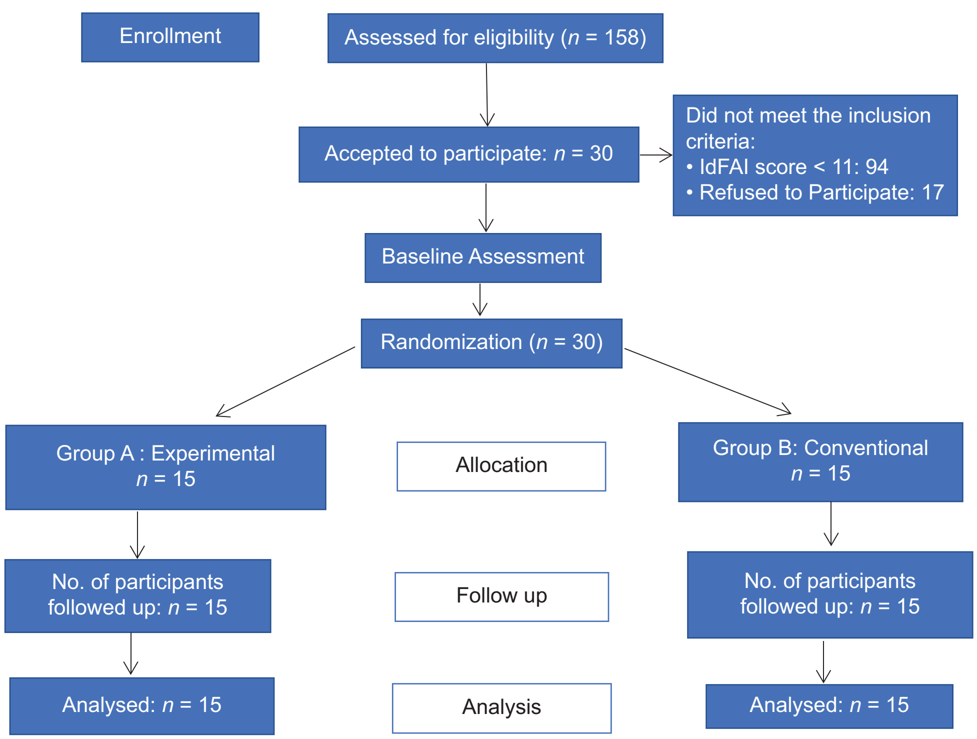

Figure 1: Consort flow diagram.

the data was evaluated using the Shapiro–Wilk test. Since the data was not normally distributed, non-parametric tests were used for data analysis. Demographic data was represented using descriptive analysis. Comparison within the group was done using the Wilcoxon signed-rank test. The scores were compared between the groups using the Mann–Whitney U-test. Statistical significance was set at $P < 0.05$.

RESULTS

Most participants were female (n = 26, 86.7%), compared to males (n = 4, 13.3%). The median and interquartile range values of demographic characteristics such as age, height, weight, and body mass index are shown in Table 2.

Within-group analysis showed an improvement in the experimental and control groups for the single-leg stance test and all direction reach distances of mSEBT. However, no improvement was seen in the pre- and post-scores of the side hop test [Tables 3 and 4].

Between-group analysis revealed significant improvement in mSEBT and single-leg stance scores in the experimental group compared to the control group. However, no significant difference was seen in side hop test scores [Table 5].

Table 2: Demographic characteristics of participants.

Variables	Experimental group (n=15)	Control group (n=15)
	Median (IQR)	**Median (IQR)**
Age (years)	23 (22–25)	22 (21–24)
Height (cm)	161 (158–164)	158 (156–160)
Weight (kg)	63 (56–77)	58 (47–60)
Body mass index (kg/m^2)	24.7 (21.2–29)	22.8 (18.8–24.3)
Sex (n [%])		
Male	2 (13.3)	2 (13.3)
Female	13 (86.7)	13 (86.7)

IQR: Interquartile range

DISCUSSION

The present study revealed that core stabilization exercises improved static and dynamic balance compared to mobility and strengthening exercises. However, there was no effect on the functional performance test or sidehop.

Core muscles act as a corset to provide stability while performing motion. It builds up inertia in response to any perturbation given to the body. It comprises abdominal muscles in front, vertebrae and gluteal muscles behind, diaphragm at the roof, and pelvic floor muscles from the floor. Intra-abdominal pressure increases on activation of the transverse abdominis muscle, which leads to an increase in the intra-abdominal pressure, which, further, causes tightening of the thoracolumbar fascia.[15]

These contractions occur before initiating limb movement, allowing a stable base for lower limb movement.[15] The rectus abdominis and oblique muscles provide postural stability as they are activated in a direction-specific pattern concerning limb movement. A precise cocontraction of the transversus abdominis and multifidus leads to an increase in muscle stiffness due to the feedforward nature of activation, thus utilizing primary muscles more efficiently and providing segmental stabilization.[25]

Table 3: Comparison of pre- and post-scores of outcome variables in the experimental group using the Wilcoxon signed-rank test.

Variable	Experimental group		
	Pre-median (IQR)	**Post-median (IQR)**	***P*-value**
Single-leg stance test (sec)			
Eyes Open (Rt)	33.00 (22.58–60.00)	57.72 (49.33–60.00)	0.003*
Eyes Open (Lt)	32.60 (24.65–57.67)	57.73 (49.40–60.00)	0.001*
Eyes Closed (Rt)	7.91 (5.87–16.54)	22.53 (16.15–40.47)	0.001*
Eyes Closed (Lt)	8.16 (6.36–12.84)	20.98 (16.11–40.19)	0.001*
mSEBT (cm)			
Ant (Rt)	94.99 (87.27–97.25)	106.58 (99.77–108.82)	0.001*
Ant (Lt)	95.04 (86.52–99.41)	104.68 (98.35–110.02)	0.001*
PM (Rt)	83.37 (74.13–93.54)	90.47 (84.93–101.24)	0.003*
PM (Lt)	84.91 (71.36-89.29)	89.11 (79.09–104.11)	0.006*
PL (Rt)	68.57 (60.30–78.43)	80.60 (73.60–85.96)	0.003*
PL (Lt)	65.12 (58.04–77.72)	73.57 (67.60–82.54)	0.002*
Side hop test (sec)			
Rt	21.08 (0.00–28.02)	22.55 (18.41–30.48)	0.638
Lt	27.99 (0.00–38.20)	24.35 (18.90–29.35)	0.975

*P<0.05 is statistically significant. Ant: Anterior, PM: Posteromedial, PL: Posterolateral, mSEBT: Modified star excursion balance test, Rt: Right, Lt: Left, cm: Centimeters, sec: Seconds, IQR: Interquartile range

Table 4: Comparison of pre- and post-scores of outcome variables in the control group using Wilcoxon signed-rank test.

Variable	Control group		
	Pre-median (IQR)	Post-median (IQR)	*P*-value
Single-leg stance test (sec)			
Eyes Open (Rt)	53.49 (43.15–60.00)	60.00 (47.56–60.00)	0.022*
Eyes Open (Lt)	42.51 (27.41–58.67)	57.24 (42.72–60.00)	0.005*
Eyes Closed (Rt)	17.45 (10.33–21.27)	25.71 (16.18–34.14)	0.011*
Eyes Closed (Lt)	15.33 (8.67–22.87)	26.23 (17.37–33.65)	0.001*
mSEBT (cm)			
Ant (Rt)	96.74 (89.68–112.26)	97.80 (95.22–111.60)	0.017*
Ant (Lt)	96.63 (90.40–111.00)	101.69 (93.60–115.38)	0.003*
PM (Rt)	95.77 (81.78–102.39)	97.06 (88.88–109.98)	0.017*
PM (Lt)	90.94 (79.10–101.08)	100.65 (88.96–108.88)	0.001*
PL (Rt)	70.14 (66.63–83.73)	68.03 (63.43–87.87)	0.047*
PL (Lt)	77.67 (67.46–92.68)	83.24 (75.96–93.37)	0.012*
Side hop test (sec)			
Rt	24.78 (16.90–30.01)	22.91 (17.50–36.02)	0.910
Lt	17.47 (0.00–31.08)	21.40 (16.98–50.05)	0.300

*$P<0.05$ is statistically significant. Ant: Anterior, PM: Posteromedial, PL: Posterolateral, mSEBT: Modified star excursion balance test, Rt: Right, Lt: Left, cm: Centimeters, sec: Seconds, IQR: Interquartile range

Table 5: Comparison of outcome variables between experimental and control groups using Mann–Whitney U-test.

Variable	Experimental group	Control group	*P*-value
Single-leg stance test (sec)			
Eyes Open (Rt)	57.72 (49.33–60.00)	60.00 (47.56–60.00)	0.04*
Eyes Open (Lt)	57.73 (49.40–60.00)	57.24 (42.72–60.00)	0.35
Eyes Closed (Rt)	22.53 (16.15–40.47)	25.71 (16.18–34.14)	0.04*
Eyes Closed (Lt)	20.98 (16.11–40.19)	26.23 (17.37–33.65)	0.34
mSEBT (cm)			
Ant (Rt)	106.58 (99.77–108.82)	97.80 (95.22-111.60)	0.03*
Ant (Lt)	104.68 (98.35–110.02)	101.69 (93.60–115.38)	0.22
PM (Rt)	90.47 (84.93–101.24)	97.06 (88.88–109.98)	0.000*
PM (Lt)	89.11 (79.09–104.11)	100.65 (88.96–108.88)	0.71
PL (Rt)	80.60 (73.60–85.96)	68.03 (63.43–87.87)	0.02*
PL (Lt)	73.57 (67.60–82.54)	83.24 (75.96–93.37)	0.14
Side hop test (sec)			
Rt	22.55 (18.41–30.48)	22.91 (17.50–36.02)	0.87
Lt	24.35 (18.90–29.35)	21.40 (16.98–50.05)	0.14

*$P<0.05$ is statistically significant. Ant: Anterior, PM: Posteromedial, PL: Posterolateral, mSEBT: Modified star excursion balance test, Rt: Right, Lt: Left, cm: Centimeters, sec: Seconds

The activation of core musculature is necessary to generate rotational torques, which assist in the production of motion in the extremities.[15] During the performance of mSEBT, an individual needs to maintain balance on the stance leg and reach using the opposite leg in a specified direction. This leads to the firing of rectus abdominis and oblique muscles before limb movement. This helps to maintain balance. Furthermore, the multifidi and transverse abdominis muscles would help maintain dynamic balance during lower extremity movement by supporting the lumbar spine.[26]

Kahle and Gribble reported that a six-week core stability program led to an improvement in dynamic balance. This study hypothesized that recruitment of the abdominal muscles provides a stable base of support for postural stability.[27] Dastmanesh *et al.* reported improved postural control after eight weeks of core stability exercise training in patients with CAI. Core stability promoted an increase in the feedforward mechanism and improved neuromuscular control of the lower extremities.[17] This agrees with the findings of our study.

The present study showed no effect of core stabilization on the functional performance – side hop test. Naderi *et al.* divided 36 athletes with FAI into three groups – core stability training group, neuromuscular training group, and control group.

Exercises were administered for six weeks in core stability training and neuromuscular training groups. The control group did not receive any treatment. There was an improvement in dynamic balance and physical function in athletes with FAI in the core stability training and neuromuscular training group compared to the control group. However, the core stability training and neuromuscular training groups were equally effective.[28] Apart from core stability, a major requirement for the hop test was cardiorespiratory endurance, which was not very well trained and, hence, compromised in our study population. Furthermore, our study included the general population, which was not involved in any sports or high level of training and exercise, which could be the reason for the lack of significant improvements in the hop tests.[29]

There are a few limitations in the study. The sample size was small, and the duration of the intervention was six weeks, which is relatively short, the inclusion of the general population who were not involved in sports, and the majority of participants were females.

CONCLUSION

The present study concludes that core stabilization exercises have an additional effect in improving static and dynamic balance compared to conventional exercises in individuals with FAI.

Recommendations

Studies with long-term effects of core stability training with larger cohorts that will help generalize the results can be conducted in the future. Incorporating a core stability program provides a comprehensive and holistic approach toward rehabilitation in individuals with FAI. Hence, it is highly recommended that core stability training be implemented to manage FAI.

ACKNOWLEDGMENTS

We would like to acknowledge all the participants who willingly participated in the study.

AUTHORS' CONTRIBUTIONS

VPP and PPW were involved in the conception, design, data analysis, and manuscript editing. DVC was involved in the data collection. PPW and DVC were involved in compiling the first draft. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

ETHICAL APPROVAL

Ethical approval has been obtained from the Institutional Research Review Committee MGM/DCH/IEC//14/2020 dated March 16, 2020.

DECLARATION OF PARTICIPANT CONSENT

The authors certify that they have obtained all appropriate participant consent forms. In the form, the participants have given their consent for their images and other clinical information to be reported in the journal. The participants understand that their names and initials will not be published, and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY FOR MANUSCRIPT PREPARATION

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

FINANCIAL SUPPORT AND SPONSORSHIP

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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