Assessment of lumbar proprioception in participants with functional ankle instability: a cross-sectional study

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Background
Functional ankle instability (FAI) represents 40–75% of residual disability after acute lateral ankle sprain. FAI has been associated with impaired muscle strength and postural and neuromuscular control.
Purpose
The aim of this study was to investigate the association between FAI and lumbar proprioception.
Patients and methods
Thirty individuals of both sexes (17 female and 13 male) were selected. The FAI group included 15 participants (nine female and six male) and the control group included 15 normal individuals (eight female and seven male). Lumbar proprioception was assessed using the Biodex system 3 pro isokinetic dynamometer.
Results
There was a significant increase in repositioning error in the FAI group compared with the control group ($P<0.001$).
Conclusion
There was an association between FAI and an increase in lumbar reposition error compared with healthy individuals. This effect should be considered in the rehabilitation protocol of patients with FAI.

Keywords:
functional ankle instability, lumbar proprioception, repositioning error

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Introduction

Proprioception is thought to have a key role in maintaining normal spinal movement and stability. Proprioception deficits are thought to cause a change in the neuromotor system and could alter dynamic spine stabilization and cause back posture instability [1,2]. Impaired proprioception may be a major risk factor for recurrent injuries even after the restoration of injured muscles and ligaments [3]. Deficits of proprioceptive are thought to be both a consequence and a cause of injury [4].

Lateral ankle sprains are one of the most prevalent injuries in high school, collegiate, and recreational sports [5]. It was reported that up to 40–75% of sufferers continue to report residual disability, which might persist for several years after the inversion trauma [6]. As the joint becomes unstable over time and continues to 'roll' past its physiological limits, the risk of damaging the articular surface within the joint and developing osteoarthritis increases [7,8].

The term functional ankle instability (FAI) describes the subjective sensation of giving way or feeling joint instability after repeated ankle sprain episodes. The causes of FAI have been suggested to include deficit in ankle proprioception, prolonged peroneal reaction time, muscle weakness, sensory motor dysfunctions and impaired balance control, or a combination of them [6,9].

Researchers have suggested that participants with FAI had poor postural control and postural stability as a consequence of sensory motor system impairments (poor sensory integration of afferent and efferent signals) [10–12].

Terada *et al.* [13] reported that, after lateral ankle sprain, altered afferent inputs from the somatosensory system around the ankle and central changes in sensorimotor control may result in proximal joint adaptations to compensate for residual symptoms and functional impairments.

A lateral ankle sprain not only affects local musculature around ankle joint but may also lead to proximal muscle weakness of the bilateral gluteus maximus, biceps femoris, and lumbar erector spinae [14].

Hertel [15] stated that ankle instability can have a long-term biomechanical alteration in the musculoskeletal system. Understanding the pathomechanical and pathophysiological effects of ankle instabilities is an integral part in treating patients with these dysfunctions and preventing further injuries.

Local effect of FAI on ankle proprioception and muscle strength around the ankle and proximal muscles had been reported. The association between FAI and lumbar proprioception was not clearly established. Thus, this study was carried out to investigate whether there was an association between FAI and lumbar proprioception.

Patients and methods

This study was conducted in the isokinetic laboratory of the Faculty of Physical Therapy, Cairo University, during the duration from September 2015 to November 2015 to investigate the association between FAI and lumbar proprioception.

Design of the study

The study design was an observational cross-sectional one.

Selection of patients

A total of 30 participants of both sexes (17 female and 13 male) were selected from students of Faculty of Physical Therapy, Cairo University. Their ages ranged from 18 to 25 years. The FAI group included 15 participants (nine female and six male) having FAI and the control group included 15 normal individuals (eight female and seven male). Before participating in the study, all participants were signed an institutionally approved informed consent form prior to starting the study, which was approved by the ethics committee of the Faculty of Physical Therapy, Cairo University. All participants were chosen by their willingness to participate. Participants in both groups were assessed by an orthopedist.

Individuals with unilateral FAI who met the following criteria were included in the study: complains of repeated episodes of giving way or feeling of joint instability after the initial lateral ankle sprain and full weight-bearing. They were not undergoing formal or informal rehabilitation at the time of the study.

Both groups' BMIs were less than 25 kg/m^2. Participants in both groups were excluded if they had one of the following criteria: ankle joint swelling or any rheumatological disorders, ankle surgery in either leg, flat foot, marked limitation in ankle range of motion, any joint disease or bone fracture in the lower extremity or trunk, history of neurological disorder affecting the lower extremities, vestibular dysfunction, balance disorder, or low back pain.

Instrumentations

Foot and ankle disability index

The foot and ankle disability index (FADI) contains four pain-related items and 22 activity-related items, and each question can be scored on a five-point Likert scale (from 0 to 4). The FADI has a total score of 104 and then transformed into percentage [16].

Biodex system 3 pro isokinetic dynamometer

The Biodex system 3 pro isokinetic dynamometer (Biodex Medical Inc., Shirley, New York, USA), equipped with a special reclined back attachment, was used to measure the repositioning accuracy of the lumbar region in this study [17].

Moreover, it was provided with a computer system with a menu of programs and a special testing chair for the testing of the lumbar region.

The Biodex isokinetic dynamometer had been found to be a valid and reliable device for position measurements [18].

Weight and height scale

Weight and height scale was used for measuring the participants' weight and height.

Procedures

All participants agreed to participate in the study by completing an informed consent form. Their ages, heights, and weight were recorded. Participants were given verbal instructions concerning the purpose and procedure of the study.

As regards answering questions on their ankle functional abilities, the participants were instructed to answer every question with one response that most closely described the condition within the past week, and to mark as NA if the activity in question was limited by something other than the foot or ankle. Participants were instructed to rate the activity as follows: no difficulty at all, 4 points; slight difficulty, 3 points; moderate difficulty, 2 points; extreme difficulty, 1 point; unable to perform the activity, 0 point; or NA, not applicable [16].

For pain related to the foot and ankle, participants rated pain as follows: no pain, 4 points; mild pain, 3 points; moderate pain, 2 points; severe pain, 1 point; or unbearable pain, 0 point. The FADI scores were recorded and then transformed into percentage [16].

(1) The Biodex system 3 was started, and then system calibration and stabilization were performed before each testing session.
(2) The participants were positioned on the chair of the Biodex system in seated compressed position. Knee block positions were individually adjusted with two curved anterior leg pads, and the feet were held in a position with no contact with the floor. Both thighs were stabilized with two straps. The pelvic brace was then applied and positioned as far down as possible to press firmly but comfortably against the superior aspect of the proximal thighs. In addition, a lumbar pad was located against the lower lumbar spine.
(3) The seat was adjusted so that the axis of the actuator arm was aligned with the L5/S1 disc space. This was clinically identified by means of palpation of the posterior superior iliac spine, which is at the level of S2, and then moving one inch superiorly.
(4) The upper part of the trunk was strapped to the back attachment with a belt.
(5) With the participant sitting erect, the force application straps were adjusted vertically with the second intercostal cartilage on the anterior chest wall. The head was stabilized neutrally on an adjustable head rest.

Each participant was positioned into an upright neutral starting position. This position will be such that the anterior superior iliac spine and the posterior superior iliac spine were aligned in the horizontal plane [19].

The predetermined spinal range of motion, which was chosen to be the ‘target position’ for the participants during the testing, was from neutral spinal posture to 30° lumbar flexion. This position was adopted because it was of a magnitude that could be attained by all participants [20].

Each participant was asked to move into flexion as much as he or she could, to determine the maximum available lumbar Range of motion (ROM) and to determine whether he or she was able to perform the experimental task. The dynamometer was locked in the 0° position to ensure the same starting position in the three testing trials for each participant. This was followed by a practice trial in which each participant was allowed to perform three repetitions of the test.

Once each participant had completed the practice trial, the standard test session started, which consisted of the following: each participant was positioned in 30° of lumbar flexion for 10 s and was instructed to remember the position because he or she would be asked to reproduce this position with eyes blindfolded. Afterward, the participant returned to the neutral position and then was given the verbal instruction of reproducing the target position as accurately as he or she could.

The participant reported to the tester on reaching the target position as perceived by him or her. The participant was required to hold the final position for 3 s and then a hold button was pressed so that the reproduced position was recorded. The test was repeated three times with a rest period of 10 s between each trial. No verbal or visual feedback on accuracy was provided to the participants [21].

The absolute error values about the 30° target position were recorded for the three trials performed by each participant and then the mean deviation for each participant was calculated [22].

Sample size estimation and statistical analysis

The current study was conducted on 15 FAI patients and 15 controls based on sample size calculation to be able to reject the null hypothesis that the population means of the FAI and control groups are equal with power (95%) and type I probability of 0.05. The mean and SD difference of the pilot study between both groups was 2.2±2.08 with power (95%) and type I probability of 0.05 using G*power 3.1 software (Universities, Dusseldorf, Germany).

Numerical data were explored for normality by checking the distribution of data, calculating the mean, median, and mode values, drawing histogram and box plot, and using the tests of normality (Kolmogorov–Smirnov test). Lumbar proprioception of participants with FAI showed a parametric distribution, whereas lumbar proprioception of control participants showed nonparametric distribution.

For parametric data (demographic data of the participants), the independent *t*-test was used.

For nonparametric data, the Mann–Whitney test was used to compare between lumbar proprioception of FAI and control participant.

Numerical data were presented as mean and SD. Qualitative data were presented as frequencies (*n*) and percentages (%). The χ^2-test was used for comparisons between male and female patients.

The significance level was set at *P* value of 0.05 or less. Statistical analysis was performed with IBM SPSS Statistics version 20 (SPSS Inc., Chicago, Illinois, USA).

Results

Demographic data of the participants

There was no significant difference between the two groups as regards age, weight, height, BMI, and sex ($P>0.05$) (Table 1).

Comparison of lumbar proprioception between functional ankle instability and control participants

There was a significant increase in lumbar repositioning error in FAI compared with healthy participants as the mean value in the FAI group was 3.44±1.38 and it was 1.7±0.76 in the control group ($P<0.001$) (Table 2).

Discussion

This study was conducted to investigate the association between effect of FAI and lumbar proprioception. The FAI of participants was assessed using the FADI. The Biodex system 3 pro was used for assessment of repositioning error of the lumbar spine for all participants in both groups.

The study findings revealed that there was a significant increase in lumbar repositioning error in the FAI group compared with the control group. This finding might be due to damage of the articular mechanoreceptors in the lateral ankle ligaments, which resulted in proprioceptive deficits [14]. Damaged joint mechanoreceptors during an ankle sprain trigger a whole chain of adaptation reactions [14]. Thus, interruption of the flow of impulses from the mechanoreceptors in an ankle joint capsule into the central nervous system would result in clinically evident disturbances of perception of joint position and movement and of the reflexes concerned with posture and gait [23].

Moreover, this finding might be attributed to impairment in neuromuscular control, which occurs after lateral ankle sprain [24]. In addition, researchers Hubbard *et al.* [12] and Mckeon *et al.* [25] had suggested that participants with FAI have sensory motor system impairments, which lead to poor sensory integration of afferent and efferent signals.

An increase in lumbar repositioning error could be attributed to malalignment of the pelvis, as ankle sprain induces subtaler joint supination leading to compensatory tibial, femoral, and pelvis external rotation [26].

Moreover, the increase in lumbar repositioning error in the FAI group may be attributed to the finding of Terada *et al.* [13], who reported that, after lateral ankle sprain, altered afferent inputs from the somatosensory system around the ankle and central changes in sensorimotor control may result in proximal joint adaptations to compensate for residual symptoms and functional impairments. In addition, postural control and motor control deficits may play an important role in lumbar proprioception alteration in cases of the FAI group, as reported by Homle *et al.* [10], Docherty *et al.* [11], Hubbard *et al.* [12] and Beckman and Buchanan [27].

Effect of FAI on proximal muscles may give another explanation for alteration of lumbar proprioception, as Martin *et al.* [14]. Friel *et al.* [28], Van Deun *et al.* [29] and Bullock-Saxton *et al.* [30] concluded that a lateral ankle sprain not only affects local musculature but may also lead to proximal muscle weakness of the bilateral gluteus maximus, biceps femoris, lumbar erector

Table 1 Demographic data of the participants

Variables	FAI group (*n*=15) (mean±SD)	Control group (*n*=15) (mean±SD)	*P* value
Age (years)	21.2±2.4	21.13±2.1	0.937
Sex (*n*/%)			
Male	6/40%	7/53.3%	0. 713
Female	9/60%	8/46.7%	
Weight (kg)	68.46±13.5	62.8±14	0.270
Height (cm)	166.46±10.1	167.13±9.68	0.855
BMI (kg/m^2)	24.42±2.9	22.3±3.3	0.07
Duration of FAI onset (years)	1.67±0.62		
Scale	77.6±8.7		

FAI, functional ankle instability. *P* value=significance level.

Table 2 Mean±SD values and results of comparison of lumbar proprioception between functional ankle instability and controls

Variables Repositioning error (deg.)	FAI group (n=15) Mean±SD	95% confidence interval		Control group (n=15) Mean±SD	95% confidence interval		*P* value
		Lower limit	Upper limit		Lower limit	Upper limit	
	3.44±1.38	2.6	4.21	1.7±0.76	1.2	2.1	<0.001*

FAI, functional ankle instability. *P* value=significance level. *Significant.

spinae, and hip abductors. This reduction in muscle strength may be associated with poor proprioception [31]. Moreover, hip abductors have an important role in the stability of hip joint and controlling trunk position in the frontal plane; this effect may clarify the current finding [32].

The current study is in agreement with the findings of Lentell *et al.* [33] and Willems *et al.* [7], who reported that there was an evidence that ankle proprioception and evertor muscle strength are impaired in people with FAI.

Moreover, the finding of this study is supported by Marshall *et al.* [34], who investigated the relation between FAI and trunk instability by assessing the time to stabilization (TTS) response to sudden balance disturbance. TTS is an assessment measure of lower limb function and FAI. Trunk instability has also been associated with low back pain. Investigators screened 24 individuals, 12 with FAI and 12 without FAI. Individuals with FAI had a more delayed TTS and are more likely to develop low back pain compared with individuals without FAI.

In addition, Gribble and Robinson [35] reported that individuals with chronic ankle instability had deficits in ankle plantar flexion and in knee flexor and extensor torque, suggesting that distal joint instability may lead to knee joint neuromuscular impairment.

In addition, Gribble and Robinson [36] found greater knee extension before and at the point of ground impact. However, Caulfield and Garrett [37] observed greater knee flexion before and after landing during a drop-jump task.

In line with the current study, Delahunt *et al.* [38] observed a difference between the FAI group and the control group in the ankle joint kinematics and electromyographic activities of the tibialis anterior, soleus, and rectus femoris muscle activation during a lateral-hop task in individuals with FAI, ankle joint movement, and neuromuscular control that could predispose to further injury.

However, the current work is in disagreement with that of Noronha *et al.* [39], who concluded that ankle proprioception was not impaired after an ankle sprain.

Moreover, the current study is in disagreement with that by Friel *et al.* [28], who investigated the effect of ankle instability on hip extensor strength and concluded that there is no statistically significant difference in hip extensor strength between the involved and uninvolved limbs of patients with unilateral ankle instability.

The main limitations of this study were using the FADI scale, which did not reveal the severity of FAI, number/frequency of episodes of giving way, and nature of previous treatment during ankle sprain was not documented.

Conclusion

FAI may be associated with lumbar proprioception deficit. On the basis of the current study finding, back proprioception should be considered in rehabilitation program of ankle instability. Further studies should be conducted in different age groups and take sex as a factor. Further studies should be conducted to assess cervical and hip joint proprioception in FAI participants.

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Conflicts of interest

There are no conflicts of interest.

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