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Comparing the Onset of Pre-Activity of Leg Muscles between Athletes with Functional Ankle Instability and Healthy Athletes During Landing from a Jump

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ABSTRACT

BACKGROUND AND OBJECTIVE: Functional ankle instability (FAI) is one of the most commonly debilitating complications of acute ankle sprain, which often results in the athlete staying away from exercise for a while. Disorder in the mechanism of feedforward neuromuscular control can be one of the main reasons for this issue. Musculoskeletal pre-activity during landing is an important indicator of this kind of control. The aim of this study was to compare the sequence of pre-activity of leg muscles between athletes with functional ankle instability and healthy athletes during landing from a jump.

METHODS: This cross-sectional study was conducted among 2 groups of athletes including 12 athletes with functional ankle instability and 12 athletes with healthy athletes. The onset of pre-activity of fibularis longus, tibialis anterior and soleus muscles, was recorded and compared using the surface electromyography during landing from a jump.

FINDINGS: The onset of pre-activity of fibularis longus, tibialis anterior and soleus muscles in athletes with functional ankle instability (163.44±24.92, 140.75±13.54 and 169.67±41.13 milliseconds, respectively) was slower than and healthy athletes (242.75±34.15, 208.71±26.44 and 247.11±26.37 milliseconds, respectively) during landing from a jump (p<0.01).

CONCLUSION: Results of the present study indicated that the onset of pre-activity of fibularis longus, tibialis anterior and soleus muscles in athletes with functional ankle instability was slower than healthy athletes during landing from a jump.

KEY WORDS: *Ankle Injury, Joint Instability, Surface Electromyography*.

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Introduction

The ankle joint is one of the most commonly damaged joints in the daily and physical activities (1), such that the sprain of this joint account for about 20% of total sport injuries (2). The recurrent sprained of ankle is considered ankle instability (3). Functional ankle instability (FAI) is a common complication, which occurs in 15 – 60% of cases following initial ankle sprain (3–6).

Deficits in the sensorimotor control system is considered as the main cause of chronic ankle instability (3). However, the mechanism for its creation is still unknown (7). There are two main theories about the mechanism responsible for creating functional ankle instability, which include: articular deafferentation (change in closed-loop neuromuscular control), and altered neuromuscular control of the open loop. In the past, it was assumed that the functional ankle instability was due to the disability in the reflexes of supporting muscles to indicate a rapid and adequate response after applying an inversion force (8). However, this theory is doubtful (9) and is likely to be due to disruption of the ability of the body to avoid situations where the ankle is excessively under inversion force (impairment in open loop control or pre-programmed dynamic stability) (7). Accordingly, one of the possible hypotheses to justify the functional ankle instability is changes in response or the spatio-temporal distribution of muscle activity (10).

The most common mechanism of the ankle sprain is during landing from a jump, and the high sensorimotor function in people with the functional ankle instability is largely evaluated in this jump-landing task (11). The muscle activity in the lower extremity before the leg is in contact with the ground in the jump landing sequence, which is recorded by electromyography is called muscle pre-activity. The sequence control of muscle pre-activity is vital for controlling the stiffness of the lower limb at the instant of leg contact with the ground and hence the ankle stability is vital (2). The earlier the muscle starts to function before the contact, the activity before landing will increase, which will increase the readiness of the system to receive the load; therefore, the proper activation of the muscles before the leg touches the ground is of great importance (12). The pattern of motor control and muscle pre-activity in people with functional ankle instability differs from healthy people when walking (13–18), landing (19), external disturbance (20), and different functional tasks (21–24). Most studies have evaluated the muscle pre-activity rate (21, 23, 24), and only a few studies considered the onset of muscle pre-activity in people with the functional ankle instability (20, 22 and 24). However, in none of these studies, the jump-landing task, which is the most commonly used mechanism for ankle sprain, has not been used to compare the onset of muscle pre-activity and the muscle activation sequence. Undoubtedly, determining changes in the pattern of muscle activation and emotional-motor control of people with the functional ankle instability in the task of landing from a jump can lead to the development of rehab programs in these individuals. Therefore, the aim of this study was to compare the onset of pre-activity of peroneus longus (PL), tibialis anterior (TA) and soleus muscles (SOL) muscles in athletes with the functional ankle instability and healthy athletes during landing from a jump.

Methods

After being approved by the Ethics Committee of the University of Tehran (IR.ut.Rec.1396036) and obtaining written consent from the participants, this cross-sectional study was carried out among 24 18 – 30 – year – old male student – athletes who had been members of sports teams in volleyball, basketball and soccer fields with a minimum of five – year experience in training and participation in club and university competitions. The sample size was calculated using the results of previous studies and the statistical formula for determining the sample size for each group of at least 12 subjects (25).

Samples were categorized in two groups in terms of age, height, weight, BMI, history and type of exercise activity. Healthy athletes without a history of ankle sprain over the past two years, obtaining a score of more than 26 in the Ankle Joint Functional Assessment Tool Questionnaire (26) and full ankle range of motion were included in the study. Athletes with functional ankle instability also have at least one inversion damage to the ankle during the past two years who require some protection as intolerance of weight and inactivity; lack of signs of acute ankle sprain (such as inflammation and sensitivity) in the last six weeks; having a sense of ankle instability or a feeling of joint being loose during daily or sport activities for at least two times within the past two years; achieving a score of less than or equal to 26 in the Ankle Joint Functional Assessment Tool

Questionnaire (26) were included in the study. The ability of the subject to bear weight completely, normal walking and complete motion range of the ankle joint, and lack of mechanical instability of the ankle joint were specified through the negative anterior drawer test result and negative talar tilt test result in the orthopedic specialist's examination.

Athletes with history of lower extremity injuries, history of lower extremity surgery, balance disorders such as systemic diseases, diabetes, lower extremity problems, disorders of leg and spine, their unwillingness to continued collaboration, and pain during the tests so that the subject was unable to cooperate were excluded.

The recording of electrical activity of the muscles was done using surface electrodes by the surface electromyography Model 6000 ME (Megawin– Finland). Electromyographic data were collected at a frequency of 1000 Hz per second. These signals were first amplified 10 times and filtered in the range of 20 to 500 Hz. The electrodes used were silver / silver chloride and one-time use F-RG model (Skintact Company). For each muscle, two electrodes were attached with a distance of 2 cm from center to center after preparing the skin. The location of muscle electrode was determined using previous authoritative sources (7,27). The earth electrode was also attached at the right distance from the muscles and on a bone sign. The electrical activity of the leg muscles was recorded during the jump-landing task (24).

The subjects of the functional ankle instability group were tested with injured leg and the control group with were tested with the dominant leg. In the present study, functional ankle instability was observed in the dominant legs of the subjects, therefore, in order to be consistent, an electromyographic assessment of the healthy group was performed on the dominant leg. However, in both groups, ten subjects had right – leg dominance and two subjects had left – leg dominance. Recently, Raina et al. (2008) suggested that there is still insufficient evidence of association between dominant leg and injury (28).

It has been shown that the repeatability of jump height in the landing task is very high (ICC = 0.84) (29). In this study, the height of jump was determined on the stadiometer based on five percent of each subjects' height, which was controlled by the researcher. Each subject performed a landing – jump task ten times and with a one – minute interval between each of the repetitions. If the landing was carried out with a non-test leg and a touch of it with a foot switch or landing was not in the center of the foot switch, or landing with an extra small jump, or there was a lot of fluctuations in the hands, body and the opposite leg, which lead to test leg rising from the foot switch, or the jump height was more or less than the 5% criterion, the test was repeated again (14).

The onset of muscle pre-activity was calculated using MATLAB software and processed in the time zone with a time constant of 20 milliseconds. The threshold for the onset of muscle activity was where muscle activity exceeded the mean plus three standard deviations of the baseline, and up to 25 milliseconds after that, activity continued above this threshold (30). At the end of the time, the activity of each muscle was calculated in ten different repetitions, and with the averaging between these ten times, the start time of the final muscle activity was obtained for each individual. In – group reliability (ICC) of the time of measuring PL, TA and SOL muscle pre-activity in the performance of the jump-landing task was reported to be 0.91, 0.84, and 0.87, respectively (31).

To analyze the data, SPSS Ver. 18 software was used. Independent t-test was used to determine the difference between the two groups at the onset of muscle pre-activity, and to test the difference between demographic characteristics in the two groups. Shapiro-Wilk test was used to investigate the normal distribution of data in each variable. Paired t-test was used to determine the difference in the sequence of the onset of muscle pre-activity in each group, while $p<0.05$ was considered significant.

Results

The results showed that the distribution of data in all study variables is normal. In addition, there was no significant difference in term of age, height, weight and BMI between the two groups (Table 1). The results showed that there was a significant difference in onset of PL, TA, and SOL muscle pre-activity during the landing from a jump task between the two groups (Table 2); the onset of the pre-activity of the three muscles in the athletes with functional ankle instability was delayed and slower than the control group ($p<0.01$). The results showed that in the functional ankle instability group, the PL and SOL muscles were activated simultaneously with each other and the TA muscle was activated afterwards, but there was no significant difference between the onset of PL muscle and TA muscle (Table 3). In addition, in the group of healthy athletes, SOL and PL muscles were activated simultaneously, and TA muscle was activated afterwards, and there was a significant difference between the pre-activity onset of TA muscle and PL and SOL muscles ($p<0.05$).

Table 1. Demographic characteristics of healthy subjects and subjects with functional ankle instability (mean±SD) (N=12)

Group / Variable	Injured Mean±SD	Healthy Mean±SD	P-value
Age(year)	21.33±1.56	22.6±0.65	0.75
Weight(kg)	68.85±6.06	73.11±8.4	1.3
Height(cm)	177.25±9.7	177.57±4.30	0.71
Body mass index(kg/m^2)	21.91±1.67	22.11±2.61	0.91

Table 2. Comparison of muscle pre-activity onset (millisecond) between healthy subjects and subjects with functional ankle instability and mean±SD deviation (CI-95%)

Group / Muscle	Injured Mean±SD	Healthy Mean±SD
soleus	169.67±41.13 (195.80–143.53)	247.11±26.37 (283.86–230.34)
peroneus longus	163.44±24.92 (179.28–147.61)	242.75±34.15 (264.45–221.05)
tibialis anterior	140.75±13.54 (149.35–132.14)	208.71±26.44 (225.51–191.91)

P=0.001

Table 3. Comparison of the onset of muscle pre-activity in each of the research groups

Group	Muscle	Muscle	P-value
Healthy	tibialis anterior	soleus	0.005
	peroneus longus	soleus	0.74
	tibialis anterior	peroneus longus	0.001
Injured	tibialis anterior	soleus	0.03
	peroneus longus	soleus	0.68
	tibialis anterior	peroneus longus	0.11

Discussion

The results showed that in athletes with functional ankle instability, the onset of leg muscle pre-activity is different from healthy athletes. Furthermore, there was a significant difference between the sequence of leg muscle pre-activity in athletes with functional ankle instability and healthy subjects during landing from a jump. In the group of athletes with functional ankle instability, the PL and SOL muscles were activated simultaneously and then the TA muscle was activated. However, there was no significant difference between the onset of PL and TA muscles pre-activity. In contrast, in healthy athletes, the sequence of the onset of muscle pre-activity was as follows: first the SOL muscle, then the PL muscle, and finally the TA muscle with a significant difference with PL muscle, were activated.

The results of the present study are consistent with the results of Suda et al. (24), and Fu et al. (2) who showed that the sequence of the onset of lower extremity muscles pre-activity in athletes with functional ankle instability is different from healthy ones. Suda et al. showed that although there is no difference in the pre-activity of the muscles between the control group and the functional ankle instability group, in patients with functional ankle instability, TA muscle activates more slowly than the PL and gastrocnemius muscles, which is similar to the results of the present study (24).

Fu et al. reported that in a voluntary fall, the pre-activity of TA muscle in injured people was faster than healthy people. Probably the difference between the results of this study and the study of Fu et al. is due to the non-functional jump-landing task employed in their study and the predicted time of contact with the ground (2). Kazemi et al. also found that there was a significant difference between the pattern and onset of the leg muscle pre-activity between healthy subjects and subjects with functional ankle instability following external disturbances, which is in line with the results of the present study (20).

In the justification of the research results, it was stated that the delay in the onset of leg muscle pre-activity before landing in athletes with functional ankle instability is related to changes in motor program in the central nervous system and a change in the feedforward neuromuscular control pattern (7).

It can be caused by a change in the afferent activity of ligamentous and joint mechanoreceptors at the onset of acute ankle sprain (7) and, consequently, an inappropriate adaptation and a change in motor patterns in athletes with functional ankle instability (24). In the ankle joint, damage to the sensorimotor control system of the joint is one of the main causes of repeated instability (32). In addition, it has been argued that the timing of feedforward responses depends on the integrity of the sensory inputs (33). Therefore, the other possible cause of the difference between the two groups in the present study could be the impairment of the sensorimotor control system in athletes with functional ankle instability. Similar to the results of studies by Suda et al. (24) and Ebig et al. (34), there was no significant difference in the onset of PL and TA activity in the group of athletes with functional ankle instability, which represents a pattern in which PL muscle is faced with lack of performance (24).

However, in healthy athletes, the sequence of the onset of muscle pre-activity during landing was initially verified by the SOL muscle, then the PL muscle and, finally, the TA muscle (24), which could indicate a programmed arrangement in which the plantar-flexion torque is developed by the SOL, followed by a torque of the overture by the PL to prepare the leg and ankle for the contact (24). The delay in the onset of activity of the muscles of the TA muscle compared to the PL muscle represents an eversion torque in the ankle that tends to stop the ankle inversion during landing (ankle sprain) (35).

In the present study, the onset of SOL muscle pre-activity was faster than PL in both groups, but no significant difference was observed at the onset of the pre-activity of these two muscles. However, the onset of the pre-activity of these two muscles in athletes with functional ankle instability was slower than healthy athletes. This indicates the contraction delay of the two muscles when landing (36).

The contraction of the antagonistic muscles of the ankle before landing increases the stiffness of the joint and can increase the stability of the ankle joint and prepare it for controlling the rapid and severe change in the muscle – tendon complex and rapid movements during the landing (12). The results of this study showed that the onset of SOL muscle pre-activity during the jump-landing task is delayed in patients with functional ankle instability. The SOL muscle plays an important protective role in the ankle and legs before and after the foot contacts the ground during landing. Before landing, the activity of the muscle increases the stiffness of the joint before the mechanical loading (contact with the ground) (37) and by improving the response to the landing level, it allows the person to confront with the collapse of the lower extremity correctly (38). Delay at the onset of SOL muscle pre-activity during landing decreases the pre-activity of this muscle, and consequently decreases the production of plantar-flexion torque in the leg and ankle complex when contacting the ground (10). Although in both groups, TA was activated after the other two muscles, its pre-activity was delayed in athletes with functional ankle instability compared to healthy athletes. It was specified that during landing, in which the interior arc is straight, the eccentric action of the intervertebral muscles controls the eversion and extension of leg and ankle complex (39).

In the present study, the delay in TA muscle pre-activity in the functional ankle instability group is probably due to delay in the eccentric action of the muscle in the lack of proper control of the severity of the eversion and extension of the ankle and the instability of the ankle (40). The results of this study showed that there is a significant difference in athletes with functional ankle instability in comparison with healthy subjects at the onset of leg muscle pre-activity during jump-landing.

In these individuals, the PL and TA muscles are activated simultaneously and after the plantarflexion muscles (gastrocnemius and SOL), while in healthy people, the TA muscle activates after the PL muscle. Therefore, it is recommended that in the rehabilitation of athletes with functional ankle instability, more attention should be given to neuromuscular training programs aimed at improving motor patterns and feedforward strategies.

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