

Research Article

The Comparison of Muscle Timing between Athletes with and without Chronic Ankle Instability during Lateral Jump Landing

Shiravi Z*, Shadmehr A, Moghadam ST and Moghadam BA

Physical Therapy Department, School of Rehabilitation, Tehran University of Medical Sciences, Iran

*Corresponding author: Shiravi Z, Physical Therapy Department, School of Rehabilitation, Tehran University of Medical Sciences, Iran

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Abstract

Most studies have investigated peroneal reaction time in relevant conditions of unexpected inversion perturbation occurring. The need to conduct more functional and dynamic testing that closely mimics athletic performances has been emerged.

The aim of present study was to compare premotor time and motor time of leg muscles between athletes with and without chronic ankle instability during landing phase of a lateral jump condition.

Twelve athletes with self-reported unilateral chronic ankle instability and 12 matched controls participated in the study. Participants performed lateral jump landing test during a relatively simple dynamic choice reaction task.

An electromyography device synchronized with a force plate collected data during the landing phase of lateral jump. Premotor time, motor time and reaction time of leg muscles were recorded and group differences were assessed.

Mean premotor time values for peroneus longus and tibialis anterior muscles were significantly ($P=0.000$, $P=0.035$ respectively) greater in chronic ankle instability patients compared to controls. There was a statistically significant ($p=0.001$, $P=0.014$ respectively) decrease in motor time measures for peroneus longus and brevis muscles in chronic ankle instability group compared to control group. There was no statistically significant difference in reaction time between the 2 groups.

This study found muscle timing deficits in injured ankles of athletes with chronic ankle instability compared to healthy ones. The greater premotor time delay of peroneus longus and tibialis anterior muscles demonstrated in subjects with ankle instability in compared to healthy athletes should be taken in to consideration during assessment and rehabilitation programs.

Keywords: Ankle sprain; Reaction time; Premotor time; Motor time; Neuromuscular control; Choice reaction task; Force plate

Introduction

Ankle sprains are one of the most common injuries affecting athletes [1]. Many ankle injuries are found in sports that require jumping and landing such as basketball, volleyball and soccer [2]. Ankle sprains account for up to 25% of all lost time from participation in sport competitions [1]. People who experience an ankle sprain are at risk of developing Chronic Ankle Instability (CAI) which is characterized by subjective, repeated episodes of giving way after an initial ankle sprain [3]. It has been estimated that up to 80% of athletes experience a recurrent sprain [4]. Symptoms of residual instability represent in 20-40% of patients and this can lead to osteoarthritis in long term [1]. Proprioception, muscle strength, muscle reaction time, and postural control are the factors contributing to impaired neuromuscular control that is believed to be the main cause of ankle instability development [5].

Most recent studies have investigated peroneal reaction time

in CAI in conditions with unexpected inversion perturbations and inconsistent results were reported [6-11]. The external validity of this type of testing is questioned since it is a controlled static position that puts the ankle in a closed-packed configuration [5]. On the other hand, there is a noticeable lack of information about muscle timing of the unstable joint in dynamic conditions such as landing movements.

The casual and dynamic nature of sports is often required for rapid and unanticipated movement responses. As a result, the need to conduct more functional and dynamic testing that most closely mimics athletic performances has been emerged.

For a given sporting task, the success of movement strategy is initially determined by an ability to react or respond to the external stimuli. This reaction time includes Pre-Motor Time (PMT) and Motor Time (MT) [12]. Reaction time can be measured by using simple dynamic Choice Reaction Task (CRT) that create conditions similar to sports.

Table 1: Demographic data of Chronic Ankle Instability (CAI) and Healthy groups.

	CAI (n = 12) Mean (SD)	Healthy (n = 12) Mean (SD)	P value
Age (year)	22.50 (3.26)	24.08 (4.37)	0.32
Height (cm)	174.5 (9.31)	174.8 (9.68)	0.94
Weight (kg)	69.66 (11.78)	72.75 (13.82)	0.56
Body mass index (kg/cm ²)	22.72 (2.47)	23.62 (3.03)	0.43

Table 2: Reliability analysis (average ICC) of premotor time, motor time, and reaction time of the leg muscles in athletes with chronic ankle instability (CAI) (n = 12) and healthy athletes (n = 12).

Variable	Muscle	CAI		Healthy	
		ICC (95% CI)	Sig. (2- tailed)	ICC (95% CI)	Sig. (2- tailed)
Premotor time (ms)	Peroneus Longus	0.68	0.041	0.66	0.019
	Peroneus Brevis	0.63	0.043	0.76	0.004
	Gastroc-soleus	0.84	0.000	0.85	0.000
	Tibialis anterior	0.73	0.024	0.70	0.036
Motor time (ms)	Peroneus Longus	0.93	0.000	0.70	0.012
	Peroneus Brevis	0.92	0.000	0.98	0.000
	Gastroc-soleus	0.75	0.003	0.71	0.006
	Tibialis anterior	0.78	0.002	0.72	0.005
Reaction time (ms)		0.87	0.000	0.76	0.002

(ms: millisecond)

In the past, sole use of forward jump-landing protocols probably masked the important aspects of neuromuscular control. During the lateral jump landings, the COM will oscillate primarily in the frontal plane [13]. As lateral ankle sprains occur in the frontal plane, we evaluated reaction times of leg muscles during the landing after a lateral jump.

With these facts in mind the current study aimed to Compare Premotor Time (PMT) and Motor Time (MT) of leg muscles between CAI athletes and healthy ones in landing phase of a lateral jump condition during a simple Choice Reaction Task (CRT).

Materials and Methods

Subjects

Twelve control subjects without CAI (3 females and 9 males) and 12 subjects with CAI (4 females and 8 males) voluntarily participated in the study. They were matched according to age, body mass, height, type and duration of physical activity, and lower-limb dominance. The subjects with CAI had a mean (SD) age, weight, height, and body mass index of 22.5 (3.2) years, 69.6 (11.7) kg, 1.74 (0.93) m, and 22.7 (2.4) kg/m², respectively. Additionally, individuals in the control group had a mean (SD) age, body mass, height, and body mass index of 24.0 (4.37) years, 72.7 (13.80) kg, 1.74 (0.96) m, and 23.6 (3.0) kg/m², respectively (Table 1). Participants were physical education students of Tehran University exercising regularly three times a week for at least 2 h each time. All subjects were college basketball, volleyball or football players. The side tested for those in the control group was matched to the involved side of those in the CAI group, taking in to account lower-limb dominance. Limb dominance was

determined by the preferred limb used to kick a ball. In each group 10 subjects were tested on their nondominant limb and 2 subjects were tested on dominant limb.

Subjects with CAI were included in the study if they had at least 1 significant unilateral inversion sprain of either ankle that resulted in pain, swelling, and loss of function within the last year followed by more than 1 repeated injury or the perception of ankle instability or “giving-way”, no reported history of ankle injury within the 3 months prior to participation and an age between 18 and 30 years. Subjects in the CAI group had a range of 1 to 3 ankle sprains within the previous 12 months and did not undergo rehabilitation. The information was gathered by a trained physical therapist using self-report questionnaire and clinical examination. Individuals in the control group were excluded if they reported a history of ankle sprain or perception of giving-way in the ankle. Subjects in both groups were excluded if they had cardiovascular disease, vestibular or respiratory disorder, auditory or cognitive deficit, diabetes or recent lower-limb or low back pathology, or were using any medicine that could affect their balance.

The study was approved by the Ethics Committee of Tehran University of Medical Sciences and subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study.

Procedures

Subjects' leg muscles and force plate data were initially recorded during a relatively simple dynamic Choice Reaction Task (CRT). Before the initiation of testing, routine warm-up exercises were performed by participants. They were asked to perform lateral jump landing task on either the dominant or the nondominant limb and then 75 percent of the maximum jump distance was used for the test. Subjects were allowed as many practice trials as needed to feel comfortable with the jump protocol and a 2-minute rest period before completing the testing protocol to prevent fatigue.

We recorded surface EMG data from gastro-soleus, peroneus longus, peroneus brevis and tibialis anterior muscles in each group. An eight-channel EMG machine (Data Link) manufactured by Biometric Ltd (UK) with a sampling frequency of 1000 Hz, 20-470 frequency range and sensitivity of 100 mV/D was used. Electrode placement was carried out in accordance with the SENIAM research group recommendations. Before electrodes placement, the skin was shaved and cleansed with alcohol. Data collection of gastro-soleus was carried out with the electrode placed on the junction of the medial and lateral head of the muscle in plantar flexion position. Peroneus longus and peroneus brevis electrodes were placed on upper and lower quarter of the line which connects fibula head to lateral malleolus, respectively (Seniam.org). Data for tibialis anterior were collected by an electrode placed on the upper third of the line which connects fibula head to medial malleolus. A reference electrode was placed on the right hand of the participants. Electrodes for each muscle were placed longitudinally over the muscle belly. The test leg was wrapped with elastic bandage to prevent electrode movement and noise. To determine foot contact with the ground, a foot switch was attached to the heels of both feet. This indicator was synchronized with EMG recording.

Table 3: Comparison of timing variables of leg muscles between athletes with chronic ankle instability (CAI) (N=12) and healthy athletes (N= 12).

Variables	Muscles	Mean (SD)		Sig. (2-tailed)	F
		CAI	Healthy		
Premotor time (ms)	Peroneus Longus	357 (67)	178 (49)	0.00	2.70
	Peroneus Brevis	244 (36)	212 (62)	0.14	1.83
	Gastroc-soleus	370 (214)	417 (230)	0.61	0.96
	Tibialis Anterior	419 (287)	224 (81)	0.03	7.67
Motor time (ms)	Peroneus Longus	606 (246)	1168 (433)	0.00	0.23
	Peroneus Brevis	718 (156)	1112 (488)	0.01	3.36
	Gastroc-soleus	861 (285)	1056 (316)	0.12	0.006
	Tibialis Anterior	998 (580)	1061 (299)	0.73	2.57
Reaction time (ms)		1082 (224)	1272 (314)	0.10	0.37

(ms: millisecond)

Participants started the test by standing barefoot on both feet at a determined distance (75% maximum jump) from the center of the force plate. A box, set according to the height of individuals, located 1 m away in front of their eyes. Red and green lamps which turn on randomly by the tester were sat in the box. Participants were required to jump as quickly as possible from this position to the force plate if the green lamp turn on and keep their balance for 5 seconds after landing; conversely, participants were instructed to stand still when the red lamp turned on. Each subject was to land on the test leg, stabilize as quickly as possible, and balance for 5 seconds with hands on the hips looking straight ahead. Jumping was repeated three times and the mean values were used for final analysis. In sum, Data Link software was used to analyze the EMG data. Force plate was synchronized with foot switch and EMG recordings.

Data analysis

Root Mean Square (RMS) of raw EMG signals was obtained and the time window of 50 ms was used for smoothing signals, so that, frequencies below 20 Hz, mostly related to movement noises, were excluded. Landing premotor time of the target muscles was defined as the time interval between foot contact with the force plate (identified by foot switch when test heel was contacted with the force plate) and onset of the first EMG signal activity (3× EMG activity of muscles at rest). Motor time was defined as the time span between onset of the EMG activity and Time Tost Abilization (TTS) (identified by data collected from force plate) Stabilization times in the medial/lateral direction were determined using the technique of sequential estimation using the Colby et al. method; as the time when the sequential average diminished to within one-quarter of the overall signal's standard deviation [14]. Reaction time was also defined as the time interval between foot contact and TTS.

Statistical analysis

All data were analyzed using SPSS software version 20. A one-sample Kolmogorov Smirnov test was performed to determine normal distribution of all variables ($P > 0.05$). Reliability analysis for all data was performed by ICC in each group consisting of all subjects. The mean of the three trials of data gathering was used for statistical analysis to obtain the highest possible reliable value. Independent t

-tests were used to determine any difference between two groups.

Results

There were no statistically significant differences in age, height, weight and body mass index between the two groups (Table 1). Values of Kolmogorov-Smirnov showed that the distribution of all variables in both groups were normal. The results of reliability analysis (using ICC) are available in Table 2. ICC values were interpreted according to Munro's classification of reliability: 0.26 to 0.49 reflects a low correlation, 0.50 to 0.69 reflects a moderate correlation, 0.70 to 0.89 reflects a high correlation and 0.90 to 1.00 indicates a very high correlation [15]. Except for premotor time of peroneus longus and brevis of the patients and premotor time of peroneus longus of the healthy controls, which indicated a moderate correlation, all parameters had high or very high correlations.

Findings showed that mean PMT (Pre-Motor Time) values for peroneus longus and tibialis anterior muscles were significantly ($P=0.000$, $P= 0.035$ respectively) greater in CAI patients compared to controls. There was a statistically significant ($p=0.001$, $P= 0.014$ respectively) decrease in MT (Motor Time) measures for Peroneus longus and brevis muscles in CAI group compared to control group. PMT and MT measures for gastroc- soleus were not significant. There was no statistically significant difference in RT between the two groups (Table 3).

Discussion

This is the first study to measure premotor time and motor time of the leg muscles of athletes with chronic ankle instability after landing from lateral jumping. Findings showed significant differences in premotor time and motor time of the peroneus longus in athletes with CAI compared to healthy athletes. Also, premotor time of tibialis anterior and motor time of peroneus brevis had significant differences between the two groups. The results for gastroc- soleus were not significant.

Contribution of delayed peroneal reaction time to CAI progression may clear the clinical relevance of impairment and clinical intervention strategies to address these deficits [16].

Previous data describing leg muscle PMT and MT measures for similar landing tasks could not be found in the literature. Most studies have investigated peroneal reaction time in CAI in conditions with unexpected inversion perturbations [6-11]. Results indicated that the subjects with ankle instability had a prolonged reaction time in the Peroneus longus [8,9] and brevis [8] muscles. Thus, they concluded that the increase in the peroneal reaction time indicated a deficit in the peripheral reflex stabilization of the ankle joint consistent with articular deafferentation theory. Despite methodological differences, our findings are consistent with above results, as premotor time of peroneus longus in patients was shown to be longer.

Van Deun et al. (2007) examined the onset of muscle activity of 14 muscles of the lower limb and trunk during a transition from the double leg stance to a single leg stance position in eyes-open and eyes-closed test conditions between control subjects and subjects with chronic ankle instability. They found that subjects with CAI had significantly later onset times for the ankle, hip, and hamstring muscles compared to control subjects [17]. The present study showed

later muscle timing only in peroneus longus and tibialis anterior but no difference was found in gastroc-soleus muscle. Authors suggest more investigations of testing lower limb muscles in a more functional and dynamic situation that closely mimic mechanisms of injury in these patients.

Mitchell et al. (2008) reported muscle reaction time for the FAI group's unstable (UA) and Stable Ankles (SA) and the control group's dominant (DA) and Nondominant Ankles (NDA) to Unilateral Simulated Ankle Sprain (USAS). The reaction time of Peroneus Longus (PL), Peroneus Brevis (PB), and Tibialis Anterior (TA) in the UA were significantly slower ($p < 0.025$) than the SA and control group's DA in the limb experiencing USAS. The reaction time of the support limb PL, TA, and Extensor Digitorum Longus (EDL) muscles of the UA were slower than the DA ($P < 0.025$) [10]. Similar to Mitchell et al, this study found differences in timing of peroneus longus, peroneus brevis and tibialis anterior between CAI patients and healthy controls; but we did not assess neuromuscular control strategy of extensor digitorum longus.

Although, the reaction time of examined muscles in the present study did not differ between the two groups, differences were observed in PMT and MT. Since this study defined reaction time as the time span between foot contact and Time to Stabilization (TTS), this includes all biomechanical and neuromuscular factors; so no difference between groups could be due to the fact that our patients were athletes who involved in sports despite their ankle injury. On the other hand, It should be noted that longer pre-motor time would shorten motor time and *vice versa*.

A recent study by Fereydounnia et al. (2015) investigated the muscle timing on injured and non-injured leg of CAI athletes in response to visual stimulus during forward jumping. Surface EMG of peroneus longus, peroneus brevis, tibialis anterior and gastroc-soleus was recorded on two legs of eight athletes with CAI during forward jumping. They found that PMT of peroneus longus was significantly longer and MT of peroneus longus was significantly shorter in non-injured leg compared to injured leg. No significant difference was noted in the timing of other leg muscles [18]. The methods were the same with the exception that we studied landing phase of lateral jumping and we compared injured ankle with the matched ankle of the healthy athletes. Therefore, difference in results may refer to differences in direction and phase of jumping. Though consistent with the result of this study, muscle timing changes in patients with ankle instability.

Although, in this study we tested landing instead of sudden perturbation, we also found longer premotor time of peroneus longus in accordance with some of previous results that confirm deafferentation theory. However, more studies are required to investigate neuromuscular strategy during landing to support our findings.

Small sample size, lack of investigating muscle timing in jumping phase, lack of checking contralateral ankle, knee, hip and trunk muscles, and using wired EMG are limitations of this study.

Conclusions

This study found neuromuscular control deficits between

injured ankles of athletes with chronic ankle instability and healthy athletes, characterized by a difference in muscle timing. The greater premotor time delay of peroneus longus and tibialis anterior muscles demonstrated in subjects with ankle instability should be taken in to consideration during assessment and rehabilitation programs. The extent to which delayed muscle timing contributes to CAI progression will elucidate the clinical relevance of this impairment and clinical intervention strategies to address these deficits.

Some studies have indicated that peroneal reaction time values could be used to control ankle rehabilitation programs [19]. Since rehabilitation decreases peroneal latency in ankles with CAI, continued prescription of sensorimotor rehabilitation to individuals with CAI specially using dynamic tasks is advised.

The future studies should consider lower limb muscle timing to provide more information regarding muscular activity during the landing test.

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References

1. Richie DH. Functional instability of the ankle and the role of neuromuscular control: a comprehensive review. *The journal of foot and ankle surgery*. 2001; 40: 240-251.
2. Wikstrom EA, Tillman MD, Borsa PA. Detection of dynamic stability deficits in subjects with functional ankle instability. *Med Sci Sports Exerc*. 2005; 37: 169-175.
3. Hertel J. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *Journal of athletic training*. 2002; 37: 364.
4. Rahnama L, Salavati M, Akhbari B, Mazaheri M. Attentional demands and postural control in athletes with and without functional ankle instability. *Journal of Orthopaedic & Sports physical therapy*. 2010; 40: 180-187.
5. Gutierrez GM., Kaminski TW, Douex AT. Neuromuscular control and ankle instability. *PM&R*. 2009; 1: 359-365.
6. Ebig M, Lephart SM, Burdett RG, Miller MC, Pincivero DM. The effect of sudden inversion stress on EMG activity of the peroneal and tibialis anterior muscles in the chronically unstable ankle. *Journal of Orthopaedic & Sports Physical Therapy*. 1997; 26: 73-77.
7. Fernandes N, Allison GT, Hopper D. Peroneal latency in normal and injured ankles at varying angles of perturbation. *Clinical Orthopaedics and related research*. 2000; 375: 193-201.
8. Konradsen L, Ravn JB. Ankle instability caused by prolonged peroneal reaction time. *Acta Orthopaedica*, 1990; 61: 388-390.
9. Lofvenberg R, Karrholm J, Sundelin G, Ahlgren O. Prolonged reaction time in patients with chronic lateral instability of the ankle. *The American Journal of Sports Medicine*. 1995; 23: 414-417.
10. Mitchell A, Dyson R, Hale T, Abraham C. Biomechanics of ankle instability. Part 1: Reaction time to simulated ankle sprain. *Medicine+ Science in Sports+ Exercise*. 2008; 40: 1515-1521.
11. Vaes P, Duquet W, Gheluwe VB. Peroneal reaction times and eversion motor response in healthy and unstable ankles. *Journal of Athletic Training*, 2002. 37: 475-480
12. McLean SG, Borotikar B, Lucey SM. Lower limb muscle pre-motor time measures during a choice reaction task associate with knee abduction loads during dynamic single leg landings. *Clinical Biomechanics*. 2010; 25: 563-569.

13. Wikstrom EA, Tillman MD, Schenker SM, Borsa PA. Jump-landing direction influences dynamic postural stability scores. *Journal of Science and Medicine in Sport*. 2008; 11: 106-111.
14. Liu K, Heise GD. The effect of jump-landing directions on dynamic stability. *Journal of applied biomechanics*. 2013; 29: 634-638.
15. Domholt E. *Rehabilitation research: Principles and applications*. St Louis, MO: Elsevier Saunders. 2005
16. Hoch MC, McKeon PO. Peroneal reaction time after ankle sprain: a systematic review and meta-analysis. *Med Sci Sports Exerc*. 2014; 46: 546-556.
17. Van Deun S, Staes FF, Stappaerts KH, Janssens L, Levin O, Peers KK. Relationship of chronic ankle instability to muscle activation patterns during the transition from double-leg to single-leg stance. *The American journal of sports medicine*. 2007; 35: 274-281.
18. Fereydounnia S, Shadmehr A, Talebian Moghadam S, Olyaei G, Jalaie S, Tahmasebi A. Muscle timing in injured and non-injured leg of athletes with chronic ankle instability in response to a visual stimulus during forward jumping. *Journal of Bodywork and Movement Therapies*. 2016; 20: 3-9.
19. Menacho MO, Pereira HM, Oliveira BI, Chagas LM, Toyohara MT, Cardoso JR. The peroneus reaction time during sudden inversion test: systematic review. *J Electromyogr Kinesiol*. 2010; 20: 559-565.