Original Article

Effect of Ankle Sprain on Postural Control and Electrical Activity of Selected Muscles after Single-Leg Jump Landing Task

Behnaz Maleki[1*], Zahed Mantashloo[2], Shahin Salehi[3], Amirhosein Abedi Yekta[3]

[1] Department of Sport Injury and Corrective Exercise, Bu-ali Sina University, Hamedan, Iran
[2] Department of Sport Biomechanics, Kharazmi University, Tehran, Iran
[3] Department of Sports Medicine, School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Received: 12 April, 2019; Accepted: 28 June, 2019

Abstract

Background: Ankle joint plays an important role in restoring the balance of individuals. Ankle sprain injury effects on balance of affected individuals. The changes in the postural control and activity of the ankle muscle, because of ankle sprain, can put the patients at reinjure risk and lower extremity injuries, especially during dynamic activities. The aim of this study was to investigate the electrical activity of ankle joint stabilizer muscles and postural stability after single-leg jump landing in individuals with ankle sprain.

Materials and Methods: In this cross-sectional study, 30 non-athletic students were participated. They were divided in two groups of 15 people, in the form of accessible and purposeful. Subjects was asked to land on a force plate with Single-leg, by at least 80% of their maximum jump. The com-cop changes assessment was used as an indicator for postural control evaluation. After jump landing, muscles activity was recorded on the ankle joint by surface electromyography (EMG) device. MATLAB software was used to analyze data, and MANOVA test was performed to compare two groups.

Results: The results showed a significant reduction in EMG of soleus, gastrocnemius, and peroneus longus muscles (p=0.03, p=0.01 and p=0.006 respectively). Tibialis anterior activity significantly increased (p=0.001) in patient group than to healthy group. Postural control was significantly lower in patient group than healthy group, in all directions (p=0.00 and p=0.00 respectively).

Conclusion: Decreased postural control indicates changes in EMG of the stabilizer muscles of this joint in people with ankle sprain injury.

Keywords: Ankle sprain, Electromyography, Postural balance

***Corresponding Author:** Behnaz Maleki, MSc in Sport Injury and Corrective Exercise, Department of Sports Science, Bu-ali Sina University, Hamedan, Iran. Orcid Code: 0000-0001-6209-8398 , Email: b.maleki@phe.basu.ac.ir

Please cite this article as: Hashemi M, Taheri M, Adlkhoo H, Dadkhah P, Abbasian MR. Comparison of the Effect of Intra-Articular Injection of Autologous (Orthokine) Interleukin-1 Receptor Antagonist (IL-1Ra) and Hyaluronic Acid in Pain Control of Knee Osteoarthritis. Novel Biomed. 2019;7(4):218-24.

Introduction

Ankle joint is a vulnerable joint in active individuals[1]. The ability in maintaining stability is essential in static and dynamic situations of daily activities such as standing, walking and moving[1]. This is while human activities do not end there. There are many movements among daily activities, including running, dropping and jumping[2]. Ankle joint is responsible for body stability during such activities[1]. Because of the ankle joint position in compared to other lower extremity joints, this joint suffers maximum body weight, loads and forces[3]. Ankle sprain injury is the most common injury in this joint[4]. The injury is a common ligament injury among different people, especially athletes[4] that accounts about 15-23% among all sports injuries in schools and universities[5]. A total of 74% of the people with ankle sprain also subsequently experience ankle joint instability[6]. The instability of ankle sprain refers to a reduction in strength, the changes in proprioception, neuromuscular and postural control[7]. Postural control is divided in two parts: static and dynamic[8]. Jump landing is a kind of dynamic postural control[8]. Ankle sprain is common injury in dynamic sports such as handball, volleyball, basketball and soccer, which are associated with jump landing movements[9]. These movements impose heavy loads and impulses on the ankle structures[10]. The keys to preventing ankle damages due dynamic activities are the appropriate absorption of ground reaction forces (GRF), proper motion control, high muscular strength, timely activation of the muscles and receptors in the lower extremity joints, especially the ankle joint[11]. The mechanical receptors located on the joints are responsible to provide the proprioception for proper position during jump landing[12]. If the afferent information be correct from the capsule, ligament and muscle-tandem receptors, then the efferent response will lead to coordinated and controlled movements of the muscles and organs. Otherwise, it may lead changes in length-tension of the muscles, their electrical activity, and motor control[12].

Studies have shown that ankle sprain injury reduces the ability of individuals to adjust the acceleration of the center of mass in relation to the stability range during the landing. It also reduces the balance and postural control by defecting in the proprioception and muscular control[13, 14]. Considering the ability to predicting com-cop changes in terms of stability, this variable provides useful information for assessing the ankle joint function, as an indicator of body postural control[15]. Individuals must successfully reduce the acceleration and absorb ground reaction force (GRF) after jump, landing that occurs by muscle contraction in each joint of the motor chain[16]. Activation of the muscles is accompanied with a delay during jump landing in people with ankle sprain that causes the changes in their electrical activity[17]. The changes in electrical activity of the muscles may be part of the landing pattern differences[18]. Individuals with ankle sprain perform a compensated dorsi flexion after jump landing to reduce grf on ankle joint[18].

Muscular activity assessment and postural control of body can help in exercises designing and rehabilitation programs, to improve the injury in these patients. Researchers in the current study try to understand the relationship between these variables by measuring these cases and electrical activity effects of the muscles on postural control in different directions.

The hypothesis of this study was survey the reduction electrical activity of selected muscles in patients with ankle sprain in compared to control group. It assumed that postural control decreases in all directions in these individuals in compared to healthy subjects during single-leg jump landing task.

Methods

In this cross sectional study, 30 non-athlete men were present (15 subject with normal ankle and 15 subject with ankle sprain). The inclusion criteria in patient group were the occurrence of ankle sprain, maximum 12 months and at least 3 months before entering to study, existence of symptoms such as inflammation, pain in at least one of all sprains and feeling of instability during dynamic and daily activities.

The patients excluded from current study if they suffered from musculoskeletal dysfunction, trauma or lower limb disease, injuries affecting balance such as middle ear and vestibular system injury, as well as patients whose were improved their balance and muscle activity by therapeutic interventions. The control group selected based on the exclusion criteria for the patient group. The group also had no history of pain, injuries and surgery in lower limbs, at least 6 months before entering the study. After referring to the lab and completing the consent form, subjects were asked to complete the sports medicine information questionnaire and personal information form for participation in this study. The demographic characteristics of the subjects presented in Table 1 for both patient and control groups. The stages of tests and how measuring variables were explained for the subjects. Each of the subjects practiced several single-legged jump-landing task for familiarization before start. Subjects were asked to perform initial warm-up before performing test, to prevent damages.

To recording the EMG waves, the skin was electrodeased after hair removal and purification by isopropyl alcohol of 5%. The electrodes were attached to tibialis anterior, gastrocnemius, soleus and peroneus longus muscles by using Seniam method. Surface electromyography signals were recorded by using EMG device (MED model, construction of the UK) in maximum voluntary contraction (MVC) and jump landing motion tests. This device includes transmitter and receiver units. The transmitter unit in the waistband of the subject is 8-channel and each channel's bandwidth is 1000 Hz. The device also has the ability to send waves up to 100 meters far from the receiver unit by antenna and wirelessly, with sensitivity less than 1 microvolt. To filtering EMG data, the band pass better worth filter method was used with a cutoff frequency of 10 to 500 Hz. Normalization of the EMG data was performed by MVC test.

The experimental protocol of the study included the implementation of 5 single-leg jump landings on the subjects' dominant limb (The dominant limb of all subjects was right foot). At first, the subjects tested Sargent vertical jump. Then they landed on a platform with a height of 80% of their maximum jump. The first and fifth tasks values were eliminated, because of familiarity with test process and fatigue of the subjects. The scores mean of three middle execution were recorded for analysis.

To measuring body postural control, we used the force plate (Kistlermodel, made in Switzerland) with a 1000 Hz sampling rate. The signals of this system were filtered with a 20 Hz low-pass filter. The EMG device and force plate systems worked synchronously and simultaneously. The com-cop changes was calculated by using winter inverted pendulum formula in the anterior-posterior and internal-external directions[19]. In this formula "I" is the inertia torque in ankle joint (H is height and M is body weight), COM is acceleration of center of mass (in both anterior-posterior and internal-external directions), W is the person's weight and H is person's height[19]. Since the center of pressure and center of mass are separately measured, the correlation of the equation (COM-COP) with COM is the Criterion for validity of this Simple model[19]. The correlation mean is reported 0.94 in the anterior-posterior and internal-external directions[19]. The length and width of leg were used to normalizing cop-cop changes data. The MATLAB software was used to analyze the data from the force plate and EMG devices.

$$\text{COP-COM} = \text{I} \times \text{COM} / \text{WH}$$ [19]

The Shapirowilk test was used to normalize data distribution. The variance analysis of the variables was done by leven's test. The multivariate analysis of variance (MANOVA) was used to compare the groups. The level of significance was set as $p \leq 0.05$. Statistical analysis was conducted in SPSS (Version 22).

Results

Demographic variables were not significantly different in both groups and they were homogeneous ($p \geq 0.05$) (Table 1). The results indicated that postural control was 82% lower in Anterior-posterior direction ($p < 0.001$) and 269% lower in medio-lateral direction ($p < 0.001$) in patient group in compared to healthy group (Fig. 2). Figure 3 showed that activity of Peroneus Longus 13% ($p=0.006$), Gastrocnemius 9% ($p=0.01$) and Soleus muscles 9% ($p=0.03$) was lower in patient group than healthy group (Fig. 3). In relation to tibialis anterior muscle, the muscular activity was 26% ($p=0.001$) upper in patient group in compared to

Table 1: Mean ± standard deviation for demographic variables in both control and patient groups.

Variable	Patient group	Control group	P value
Age (year)	23.86±2.06	22.93±3.19	0.35
Height (cm)	175.93±7.35	176.46±6.79	0.83
Weight (kg)	76.86±7.76	74.26±7.51	0.35
BMI (kg/m^2)	24.91±2.79	23.89±2.50	0.30

Table 2: The values for Within group difference. Sign * indecates a statistically significant difference.

Variable	Effect size(95% CI)	T	P value
Gastrocnemius	0.18	-2.542	0.01*
Soleus	0.14	-2.172	0.03*
Tibialis anterior	0.33	3.725	0.001*
Peroneus longus	0.24	-2.980	0.006*
Anterior-posterior	0.81	10.982	0.00*
Medio-lateral	0.90	16.044	0.00*

healthy group (Fig. 3).

Discussion

Lateral ankle ligaments injury involves 85% of all injuries among lower extremity injuries[20]. This damage causes the changes in the muscular activity passing on the ankle joint[17]. The initial hypothesis of this study was on reduction the electrical activity of the muscles affecting on ankle joint in patients with ankle sprain in compared to healthy group after single-leg landing.

The ankle sprain can disrupt the affront messages[21]. The feedback response of nervous system will be ineffective, following the disorder in the messages[21]. The changes in musculoskeletal control in the ankle joint due this disorder, leads to change in the muscles activity located on the joint, which are responsible for the dynamic stability of the joint[21]. The primary role of the peroneus longus muscle is to control the speed and extra inversion of the ankle[22]. Therefore, the risk of excessive inversion and recurrence of ankle sprain increase during jump landing, considering to reduction of peroneus longus activity and reduction in neuromuscular control[7, 23]. Ferger et al, (2014) evaluated the electrical activity of the muscles during dynamic movements. They showed a significant reduction in the activity of peroneus longus muscle in the subjects with ankle sprain in compared to healthy subjects[24].

Figure 1. How to run the test.

Tibialis anterior muscle has a wave-like activity after jump landing, such as the peak of the GRF[25]. This muscle-that acts as an ankle dorsi flexor and inverter- is an anatomical antagonist of peroneus longus muscle[22]. The mentioned changes in the feedforward and feedback activities of these muscles lead to a disturbance in the agonist and antagonistic co-contraction relationship that this will lead to a difference in intensity of their contraction[18]. Braun et al, (2004) reported excessive dorsiflexion in subjects with ankle sprain in compared to subjects with healthy ankle after landing motion[18]. Considering to the functional duty of the tibialis anterior muscle (dorsi flexor), the excessive dorsi flexion is indicator additional activity of this muscle, as shown in this study.

The results showed a significant reduction for soleus and gastrocnemius muscles in subjects with ankle

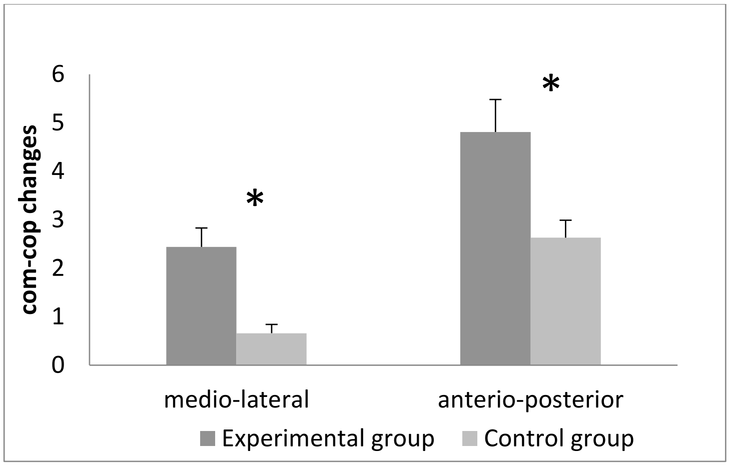

Figure 2. Mean ± standard deviation for postural control in both groups (Sign * indecates a statistically significant difference).

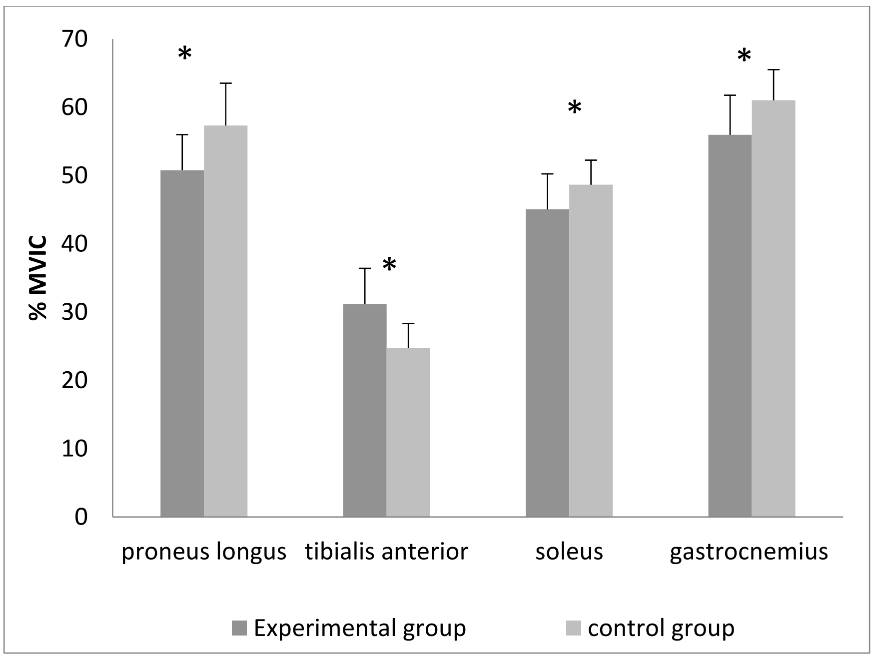

Figure 3. Mean ± standard deviation values for muscularactivity inboth groups (Sign * indecates a statistically significant difference).

sprain than control group. Muscular feedback activity plays an important role in appropriate force absorption[26]. The feedback activity of the muscles passing on the ankle joint is impaired in people with this injury [18]. The disorder will disrupt force absorption[18]. This indicates a reduction in muscles activity (muscles that are responsible for force absorption).

The main function of the gastrocnemius muscle is force absorption during jump landing[27]. The soleus muscle activity–that is functionally similar to gastrocnemius muscle- also reduces, following reduction in gastrocnemius muscular activity[27]. On the other hand, an excessive dorsi flexion after landing may indicate the reduction in soleus and gastrocnemius muscles activity (as plantor flexor). Braun et al, (2004) reported a significant reduction in soleus and gastrocnemius muscles activity after jump landing in people with ankle sprain[18].

The muscles passing through the ankle joint are responsible for joint stability during static and dynamic activities[16]. Therefore, any weakness in the electrical activity of these muscles directly effects on postural control and balance in different directions[16].

Considering to that tibialis anterior and proneus longus muscles act on the frontal plate (as invertor and evert or respectively) therefore we can say that any changes in the electrical activity of these muscles is directly related to the postural control in the medio-lateral direction. The increased in tibialis anterior muscle activity and the decreased in the peroneus longus muscle activity in people with ankle sprain, disrupt the muscular balance and reduces the postural stability in the medio-lateral direction. This argument also is valid in relation to gastrocnemius and soleus muscles with tibialis anterior muscle.

The gastrocnemius and soleus muscles activity decreased as planter flexor of ankle, and the tibialis anterior muscle activity increased as dorsi flexor of ankle. Given the fact that both dorsi flexion and plantar flexion are performed on the sagittal plane, therefore the changes in the muscles activity cause muscular imbalance in the anterior-posterior direction and decrease the postural control in this direction.

The present study showed significant reduction on in postural control in patient group in both anterior-posterior and medio-lateral directions. The study's results of Russian and Goswick (2004), Cross et al. (2016), Wextrom et al. (2010) and Rose et al. (2005) were consistent with the results of present study[8, 28-30]. In the meanwhile, a study by Kachap et al. (2000) was inconsistent with the results of this study[31,32]. The reason for the difference can be in choosing the subject type and the Measurement tool. The subjects were athletes with ankle sprain of both sexes in Kachup's study. Because of more strength and muscular endurance in these subjects, the postural control was not significantly reduced. The Biodex instrument was measurment tool in Kachup's study, while the force plate in present study calculated the changes in com-cop.

The obtained results confirmed the hypotheses. In this study, the effect of muscle activity (in regarding to their anatomical position) which were changed after sprain injury was measured on the stability and balance of individuals. Therefore, the present study can be an information source for research's that attempt to design rehabilitation programs or preventing ligament and muscular injuries such as ankle sprain.

Conclusion

The ankle sprain causes changes in the muscles activity affecting the ankle joint. These changes will disrupt the postural control in various movement plans, given the functional tasks and the anatomical position of them.

Acknowledgment

The authors thank the participants for participating in this research.

References

1. Kim BJ, Lee JH, Kim CT, Lee SM. Effects of ankle balance taping with kinesiology tape for a patient with chronic ankle instability. J Phys Ther Sci. 2015; 27(7):2405-6.
2. Johannsen DL, Welk GJ, Sharp RL, Flakoll PJ. Differences in daily energy expenditure in lean and obese women: the role of posture allocation. Obesity. 2008;16(1):34-9.
3. Coventry E, O'Connor KM, Hart BA, Earl JE, Ebersole KT. The effect of lower extremity fatigue on shock attenuation during single-leg landing. Clin Biomech. 2006;21(10):1090-7.
4. Roos KG, Kerr ZY, Mauntel TC, Djoko A, Dompier TP, Wikstrom EA. The epidemiology of lateral ligament complex ankle sprains in National Collegiate Athletic Association sports. Am J Sports Med. 2017;45(1):201-9.
5. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. J Athl Train. 2007;42(2):311.
6. Anandacoomarasamy A, Barnsley L. Long term outcomes of inversion ankle injuries. Br J Sports Med. 2005;39(3):e14-.
7. Hertel J, Buckley WE, Denegar CR. Serial testing of postural control after acute lateral ankle sprain. J Athl Train. 2001;36(4):363.
8. Ross SE, Guskiewicz KM. Examination of static and dynamic postural stability in individuals with functionally stable and unstable ankles. Clin J Sport Med. 2004;14(6):332-8.
9. Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E. Recovery from a first-time lateral ankle sprain and the predictors of chronic ankle instability: a prospective cohort analysis. Am J sports med. 2016;44(4):995-1003.
10. Determan JJ, Frederick EC, Cox JS, Nevitt MN. High impact forces in skateboarding landings affected by landing outcome. Footwear Sci. 2010;1;2(3):159-70.
11. Beynnon BD, Renström PA, Alosa DM, Baumhauer JF, Vacek PM. Ankle ligament injury risk factors: a prospective study of college athletes. J Orthop Res. 2001;19(2):213-20.
12. Ashton-Miller JA. Proprioceptive thresholds at the ankle: implications for the prevention of ligament injury. Proprioception and neuromuscular control in joint stability. 2000:279-91.
13. Simpson JD, Stewart EM, Macias DM, Chander H, Knight AC. Individuals with chronic ankle instability exhibit dynamic postural stability deficits and altered unilateral landing biomechanics: A systematic review. Phys Ther Sport. 2018.

14. Gribble PA, Kelly SE, Refshauge KM, Hiller CE. Interrater reliability of the star excursion balance test. J athl Train. 2013;48(5):621-6.
15. Sung PS. The ground reaction force thresholds for detecting postural stability in participants with and without flat foot. J Biomech. 2016; 4;49(1):60-5.
16. Kennedy A, Hug F, Bilodeau M, Sveistrup H, Guével A. Neuromuscular fatigue induced by alternating isometric contractions of the ankle plantar and dorsiflexors. J Electromyogr Kinesiol. 2011;21(3):471-7.
17. Suda EY, Amorim CF, Sacco ID. Influence of ankle functional instability on the ankle electromyography during landing after volleyball blocking J Electromyogr Kinesiol. 2009;19(2):e84-93.
18. Brown C, Ross S, Mynark R, Guskiewicz K. Assessing functional ankle instability with joint position sense, time to stabilization, and electromyography. J Sport Rehab. 2004;13(2):122-34.
19. Winter DA. Biomechanics and motor control of human movement. John Wiley & Sons. 2009;100-120
20. Fong DT, Chan YY, Mok KM, Yung PS, Chan KM. Understanding acute ankle ligamentous sprain injury in sports. BMC Sports Science, Med Rehab. 2009;1(1):14.
21. Riemann BL, Lephart SM. The sensorimotor system, part II: the role of proprioception in motor control and functional joint stability. J Athl Train. 2002;37(1):80.
22. Murley GS, Landorf KB, Menz HB, Bird AR. Effect of foot posture, foot orthoses and footwear on lower limb muscle activity during walking and running: a systematic review. Gait & posture. 2009;29(2):172-87.
23. Monaghan K, Delahunt E, Caulfield B. Ankle function during gait in patients with chronic ankle instability compared to controls. Clin Biomech. 2006;21(2):168-74.
24. Feger MA, Donovan L, Hart JM, Hertel J. Lower extremity muscle activation during functional exercises in patients with and without chronic ankle instability. PM&R. 2014; 1;6(7):602-11.
25. McKinley P, Pedotti A. Motor strategies in landing from a jump: the role of skill in task execution. Exp Brain Res. 1992;90(2):427-40.
26. Canavan PK, Roncarati M, Lyles K, Kenney R. Off-Season Screening of an NCAA Division 1 Men’s Basketball Team. Int J Athl Ther Train. 2012;17(5):28-32.
27. Fu SN, Hui-Chan CW. Are there any relationships among ankle proprioception acuity, pre-landing ankle muscle responses, and landing impact in man?. Neurosci Lett. 2007;417(2):123-7.
28. Kros W, Keijsers NL, van Ochten JM, Bierma-Zeinstra SM, van Middelkoop M. Center of pressure during stance and gait in subjects with or without persistent complaints after a lateral ankle sprain. Gait & posture. 2016; 1;48:24-9.
29. Wikstrom EA, Tillman MD, Chmielewski TL, Cauraugh JH, Naugle KE, Borsa PA. Dynamic postural control but not mechanical stability differs among those with and without chronic ankle instability. Scand J Med Sci Sports. 2010;20(1):e137-44.
30. Ross SE, Guskiewicz KM, Yu B. Single-leg jump-landing stabilization times in subjects with functionally unstable ankles. J Athl Train. 2005;40(4):298.
31. Cachupe WJ. Effect of previous ankle sprain on dynamic balance among athletes.
32. Hashemi M, Taheri M, Adlkhoo H, Dadkhah P, Abbasian MR. Comparison of the Effect of Intra-Articular Injection of Autologous (Orthokine) Interleukin-1 Receptor Antagonist (IL-1Ra) and Hyaluronic Acid in Pain Control of Knee Osteoarthritis. Novel Biomed. 2019;7(4):218-24.