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Effects of Lace up Brace on the Ankle Muscles Activity in Different Foot Position during Drop Landing with and without Fatigue

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Abstract

Background and Purpose: Increasing participation in sports activities has increased the incidence of sports injuries. Considering the short and long term complications of sports injuries, the need to prevent them is one of the most important goals. The purpose of this study was to evaluate the effects of ankle bracing on the ankle plantar flexor muscles activity in different foot position during drop landing with and without fatigue. **Method:** Fourteen female college athletes participated in this study. Five models of 5 and 10 degrees medial, lateral and normal wedged insoles were used to simulate the position of the feet on the ground at the wrong landing technique. The Medial Gastrocnemius (MG) and Peroneus Longus (PL) muscles activity 100 ms before and 100 ms after landing in different foot position before and after muscles fatigue with and without ankle bracing was recorded with surface electromyography. Repeated measures ANOVA was used for statistical analysis ($p \leq 0.05$). **Results:** The results showed that the effect of time on the activity of MG and PL muscles in landing with brace was significant, so that the MG muscle before landing and PL muscle after landing had a higher activity in both times before and after fatigue ($p \leq 0.001$). The activity of this muscles was not significant when using the ankle brace during landing in different positions ($p > 0.05$). **Conclusions:** According to the results of this study, lace-up brace can help to increase muscles activity when they were fatigue, while the using of brace does not affect muscle activity when landing perform in different positions without fatigue. According to the results, In the case of a suggestion to use brace for athletes, all aspects of using this equipment should be considered.

***Keywords**:* Brace, Electromyography, Ankle, Drop landing, Fatigue

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INTRODUCTION

Participation in sport and physical activity is a global priority and encouraged by government agencies around the world according to numerous benefits, including increasing general health, resistance to non-communicable diseases, improving physical fitness, psychosocial impact, and economic effects (Kayani et al., 2018). However, participate in sport is not completely safe, and there is a risk of injury to those involved in physical activity (Raeisi & Yalfani, 2017). The occurrence of injury is one of the barriers to participation in sports activities and, consequently, a reduction in the level of participation of individuals. Among sports injuries, ankle sprain injury with an 86% rate of incidence is the most common musculoskeletal injury that occurs during exercise (Raeisi & Yalfani, 2017; Bahr and Krosshaug, 2005; Ashoury, Raeisi, & Khodabakhshi, 2016). Various risk factors are involved in the occurrence of ankle sprain injuries, including gender, fatigue, the use of different equipment, and the type of exercise activity (Doherty, Delahun, Caulfield, Hertel, Ryan, & Bleakley, 2014; Self and Paine, 2001). Some sports techniques cause more injury due to their particular circumstances. Landing is one of the techniques, which considered to be one of the essential aspects of many sports that require the coordination of movements of the upper limbs, trunk and lower limbs, the absorption of forces applied to the body, and maintenance the stability of hip, knee and ankle joints during movement (Raeisi & Yalfani, 2017; Louw, Grimmer, & Vaughan, 2006). High movement complexity, specific biomechanics of landing, and excessive pressure on the lower limbs during this action, has made the inappropriate landing from a jump during sports activities one of the most common mechanisms for lower limb injury (Louw, Grimmer, & Vaughan, 2006). Excessive loading and sudden decrease in acceleration during landing are often associated with injuries such as ankle sprain, cartilage injuries, stress fracture, patellar tendinopathy (PT), patellofemoral pain syndrome (PFPS), and anterior cruciate ligament (ACL) tear (Aerts, Cumps, Verhagen, Verschueren, & Meeusen, 2013; HUA, 2009; Zhang, Bates, & Dufek, 2000).

Nowadays, due to the high prevalence of injuries and various related complications, injuries prevention is essential, considerable, and before treatment, and provide preventive strategies to reduce the number of the injury has become one of the essential priorities. Concerning the prevention of primary injury and recurrence of injury, the use of protective and supportive equipment such as brace and tape highly recommended to athletes by therapists, doctors, and coaches of the teams (Bahr and Krosshaug, 2005). Meanwhile, the use of the ankle brace has expanded because of its availability, ease of use, and cost-effectiveness. Different studies have examined the effectiveness of this tool and different results have been obtained. Kofotolis et al. (2007) reported that the incidence rate of ankle injury was 2.48 times higher among players who did not wear external ankle support (Kofotolis & Kellis, 2007). Pedowitz et al. (2008) conducted a prospective study between 1998 and 2005 whom they found that the use of semi-rigid ankle brace reduced the incidence of ankle injuries (Pedowitz, Reddy, Parekh, Huffman, & Sennett, 2008). On the other hand, the results of review study by Raymond et al. (2012) revealed that the use of ankle brace did not affect the proprioception of participants with a history of recurrent ankle sprain injury or those with functional ankle instability (Raymond, Nicholson, Hiller, & Refshauge, 2012).

Moreover prophylactic ankle support like tape and brace in prevention of sprain injury have been identified as important stabilizers of dynamical stability against external forces, and it is believed that the reaction time and the level of electromyographic activity of these muscles play a key role in preventing the ankle sprain (Cordova & Ingersoll, 2003). Meanwhile, PL activity is known as one of the key defense mechanisms against ankle inversion movement, and MG muscle is also one of the main ankle plantar flexor muscles and the principal acting muscle in absorbing shock during landing (Raeisi & Yalfani, 2017). Examining the activity of the ankle muscles when the foot after landing does not access the ground in the correct position can predispose a better insight into the mechanism of the ankle sprain and the role of the muscles in this concern. On the other hand, fatigue is known as a risk factor for various injuries (Bahr and Krosshaug, 2005). Not only the mechanisms adopted by the central nervous system to control the movement and the level of muscle activity in different landing positions, but also understanding of how to change the level of muscle activity in the use of brace can be useful in obtaining better insight into the effectiveness of this preventive tool. Thus the present study was conducted to determine the effect of the ankle brace on the electromyographic activity of the MG and PL muscles of the ankle joint in different foot landing positions with and without fatigue.

METHOD

Participants

The present controlled laboratory study was conducted on 14 female volunteer students in physical education and sport sciences in Hamadan, Iran. Sample size estimated sing G*power software, for effect size of 0.5, the alpha error probability of 0.05, and power of 0.7. Inclusion criteria were no history of neurological or neuromuscular diseases, skeletal deformities, lower limb injuries (such as fractures and previous sprains on the ankle), and pelvic or spinal injuries. Exclusion criteria were a difference of more than 5 mm along the legs (leg length measured from the anterior superior iliac spine (ASIS) to the medial malleolus using a tape), excessive supination and pronation (navicular drop in one or both of feet based on the Brody's navicular drop test for pronation> 10 mm and for supination <4 mm), lateral pelvic tilt> 2.5 and transverse plane pelvic rotation (Raeisi & Yalfani, 2017; Ntousis, Mandalidis, Chronopoulos, & Athanasopoulos, 2013; Yalfani, Amini Semiromi, & Raeisi, 2015). The study methodology, objectives, and all details were first fully explained to the subjects and, if they interested to participate in the study, they would sign the consent form before the tests began.

Laboratory steps

The initial evaluations included the demographic characteristics of the subjects, as well as the measurement of pelvic symmetry, navicular drop, and foot length. Five samples of semi-rigid ethyl vinyl acetate (EVA) insoles (normal wedged, 10 degrees medial and lateral wedged and 5 degrees medial and lateral wedged) were used to induce different foot landing positions during landing technique. The same shoes of NIKE AirMax were also used for all subjects throughout the test.

Eight-channel surface biomonitor apparatus (Mega Co., Finland) was applied to record Electromyography (EMG) activity of selected muscles (MG and PL) in the dominant foot (the foot that used to kick the ball) of all participants (Raeisi & Yalfani, 2017). After preparing the skin for mounting the self-adhesive surface electrodes, the electrodes were placed on the PL and MG muscles according to the SENIAM protocol (Yalfani & Raeisi, 2016). Before starting the test, the maximum voluntary isometric contraction (MVIC) was recorded twice for five seconds every time. For the PL subject was in supine position and performed eversion with plantar flexion (Suda, & Sacco, 2011). The MG was assessed with the standing unilateral plantar flextion (Rutherford, Hubley-Kozey, & Stanish, 2011). The moment of foot contact with the ground during landing movement was determined using the footswitch, a sensitive electronic sensor connected to the bio-monitoring device.

The ankle lace-up brace level three (Mc-David Co.) was used in this research. Some of the features and benefits of this brace include light feel, the use of metal for maximum ankle protection and injury prevention, the use of lattice double-layered polyester/vinyl for airflow, adjustable, and coated along with pores (lace mode) to enhance the air condition. The material used to make this model of the brace was 50% PVC, 49% polyester and 1% rubber (Cordova & Ingersoll, 2003). The ankle lace-up brace OPPO 4007 (OPPO Medical Co.) was used in this research. The material used to make this model of brace was 50% Cotton, 40% polyester and 10% rubber.

A pre-test step included a landing test with different insoles in ankle bracing conditions from a stair up to 20 cm high and with the same standard shoe. After that, the fatigue protocol was executed and immediately followed by a post-test step. Following the arrival of the subjects in the laboratory, the researcher described the test steps. The subjects were then ready for the pretest. At first, the warm-up movements were performed for three minutes and the subjects were trained three times by the correct movement of landing. The right landing movement was performed from a stair in a place previously specified by the examiner with each of the insoles three times (with and without ankle bracing). In explaining the procedures of landing movement, the subjects were asked to place their non-dominant foot on the stair and perform a single-foot landing movement while inflicting their body weight on that foot and without jumping on their dominant foot. They should keep their balance at least one second after landing (Image 1).

We applied Bruce fatigue protocol for examining the fatigue, and Borg rating of perceived exertion scale (up to grade 17), as well as Polar Heart Rate Monitor (80% of maximum heart rate) for controlling heart rate and determining the time of reaching the fatigue. Then, the subjects performed cooling down movements for two minutes at a speed of their selection. After completion of the test, the fatigue protocol was applied, and immediately afterward, all tests were repeated (post-test).

Image 1: Landing test while wearing an ankle brace

The analysis of EMG data was done using MegaWin and MATLAB software. The artifact effects of electrodes and other unwanted signals were eliminated by a 20-500 Hz bandpass filter (Raeisi & Yalfani, 2017). Then, the root means square (RMS) of data obtained from the activity of desired muscles in the phases of 100 ms before and 100 ms after landing for normalization was divided by the MVIC RMS. The final data of the mean muscle activity in three replications of landing movement were recorded before and after fatigue, calculated as MVIC percentage (Fayson, Needle, & Kaminski, 2015).

Finally, after data collection, SPSS version 20 software was used to analyze the data. Shapiro-Wilk test was utilized to check the data normality. The hypotheses were explored by the statistical test of repeated measures ANOVA. The hypothesis test was also performed at a significance level of 95% with $\alpha \leq 0.05$. Also, to avoid repeating the times and prolonging the report to better understand, the times are briefly listed as follows: Time 1 = 100 milliseconds before landing before fatigue, Time 2 = 100 milliseconds after landing before fatigue, Time 3 = 100 milliseconds before landing after fatigue and Time 4 = 100 milliseconds after landing after fatigue.

RESULTS

Table 1 presents the demographic characteristics of the subjects in the study.

Table 1: Mean ± SD demographic profile of subjects

BMI (kg/cm^2)	Weight(kg)	Height (cm)	Age (years)	N
20.55±1.3	53.4±77.65	164.4±32.13	23.1±48.86	14

The data normality as determined by the Shapiro-Wilk test. Then, concerning the normal distribution of the data ($P > 0.05$), the repeated measures ANOVA test at the significance level of 0.05 was used to determine the difference between the factors. If there were significant differences, the Bonferroni post-hoc test would be applied. In the results of statistical analysis, the effect of time was significant on the activity of MG muscle when landing in different conditions that were used by the brace ($F = 26.70$, $P = 0.000$). The pairwise comparison of times showed significant differences between times 1 with 2 and time 2 with 4 (Table 1, Figure 1). The results of the repeated-measures ANOVA test found no significant difference between the effects of different landing positions on MG muscle activity while using the brace ($F = 0.27$, $P = 0.91$).

In the analysis of results from the activity of PL muscle, the effect of time on the activity of this muscle was significant ($F = 27.14$, $P = 0.000$). The pairwise comparison of the times showed that there is a considerable difference between the levels of PL muscle activity when using the brace at times 1 with 2 and 3 with 4 (Table 1, Figure 2). The results of repeated measures ANOVA test showed no significant difference between the effects of different landing positions on PL muscle activity when using the ankle brace ($F = 1.78$, $P = 0.09$).

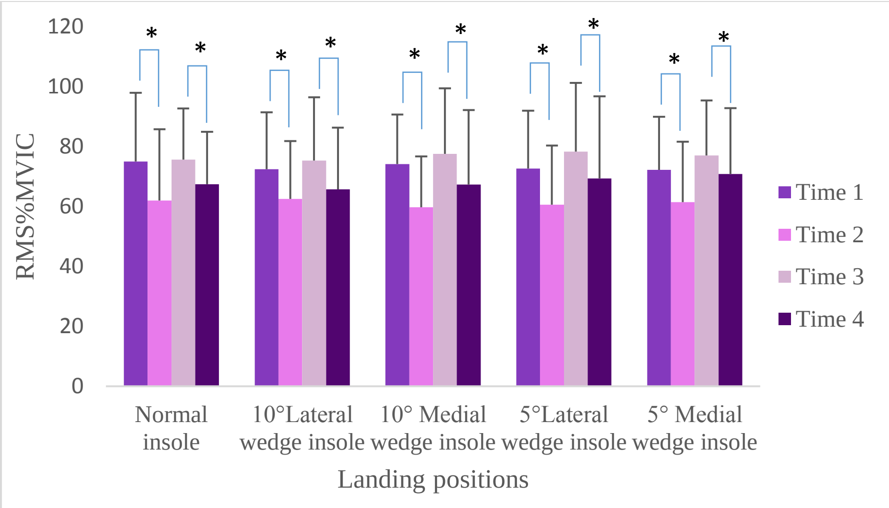

Figure 1: The activity levels of MG muscle during landing with different positions and using the ankle brace

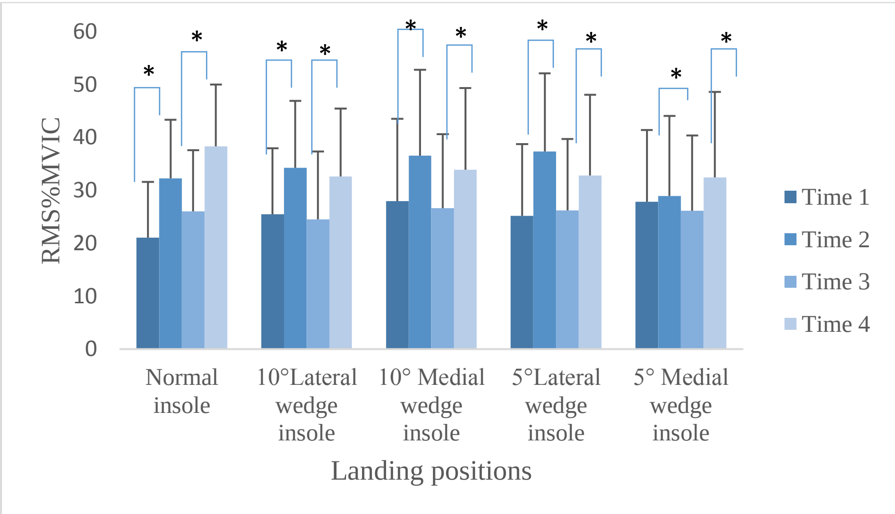

Figure 2: The activity levels of PL muscle during landing with different positions and using the ankle brace

Table 1: Effects of time on muscle activity (EMGRMS) of GM and PL in different conditions during drop landing

Condition	Time 1 (I)	Time 2 (J)	P-value (MG muscle)	P-value (PL muscle)
Normal insole	1	2	0.000*	0.000*
	1	3	1	0.58
	3	4	0.000*	0.000*
	2	4	1	0.42
10° Lateral wedge insole	1	2	0.000*	0.000*
	1	3	1	1
	3	4	0.000*	0.004*
	2	4	1	1
10° Medial wedge insole	1	2	0.000*	0.000*
	1	3	1	1
	3	4	0.000*	0.01*
	2	4	0.89	1
5° Lateral wedge insole	1	2	0.000*	0.000*
	1	3	1	1
	3	4	0.000*	0.02*
	2	4	0.56	1
5° Medial wedge insole	1	2	0.000*	0.05*
	1	3	1	1
	3	4	0.006*	0.04*
	2	4	0.43	1

* Significant p ($p \leq 0.05$).

DISCUSSION

In recent years, the recommendations of health advisers to increment the level of exercise and to take advantage of all aspects of exercise therapy have been accompanied by elevated awareness of individuals and the continued increase in the number of participants in sports activities. It seems necessary to prevent injury to reduce short-term and long-term consequences. The landing maneuver is one of the essential aspects of many sporting events. Due to the complexity of the movement, the inappropriate landing of the jump during sports activities has become one of the common mechanisms of lower limb injury (Louw, Grimmer, & Vaughan, 2006). According to previous studies, during a landing motion, the athlete's body could experience more than 6,000 Newton ground reaction forces (GRF) (Wallace et al., 2010). The estimate of GRF in the study of McNair et al. (2000) was equivalent to 4 to 6 times of body weight (McNair, Prapavessis, & Callender, 2000). The amount of GRF that receives on the body during the landing will potentially affect the injury (Kabacinski, Murawa, Dworak, & Maczynski, 2017). Due to the magnitude of these forces, a high percentage of the ankle and lower extremity injuries occur during the landing technique. Regardless of the previous history of an ankle sprain, many athletes wear an ankle brace to prevent further injury (Yi, Brunt, Kim, & Fiolkowski, 2003).

The present study examined the role of ankle bracing on the activity level of MG and PL muscles in different positions during landing, as well as its effect on muscle activity after fatigue. The results showed that the effect of time on the activity of MG muscle in landing with a brace was significant, so that the MG muscle before landing had higher activity than after landing in both times before and after fatigue. Different landing positions had no significant effect on the MG muscle activity when using a brace. Regarding the effect of time on the PL muscle activity during landing with an ankle brace, the results revealed a significant difference, and this muscle had a higher activity in the times of 2 and 4 compared to the times of 1 and 3, respectively. The effect of the landing position on the activity of this muscle was not significant when using the ankle brace.

The activity level of MG muscle before landing and the activity of the PL muscle after landing in the present study seem to be attributed to the role of these muscles in controlling the foot during movement. The higher activity level of MG muscle about 100 ms before landing is due to the role of this muscle in controlled landing, to manage the plantar flexion, and to perform the more relaxed landing. Results of the activity level of PL muscle at different times indicated increased activity of this muscle in the times of 2 and 4. Due to the primary function of this muscle, it appears that its feedback activity increases for feet placement on the ground during landing and balance control (Yalfani & Raeisi, 2016).

The results of the present study are consistent with Cordova, Cardona, Ingersoll, and Sandrey (2000) who observed no differences in the results obtained from the effect of control position and brace usage on delayed PL muscle activity (Cordova, Cardona, Ingersoll, & Sandrey, Cordova and Ingersoll (2003) who reported no effect on increased PL stretch reflex following the immediate or prolonged use of brace (Cordova & Ingersoll, 2003), and Gribble et al. who found no change in the activity level of PL muscle following the use of brace (Gribble, Radel, & Armstrong, 2006). Our results are in disagreement with the results of the studies by Thedon et al. (2011) (Thedon, Mandrick, Foissac, Mottet, & Perrey, 2011), and Ochsendorf et al. (2000) (Ochsendorf, Mattacola, & Arnold, 2000). In the results of these studies, the reduction in the number of injuries was often considered, and the research subjects were those with a history of an ankle sprain.

On the other hand, the present results showed that the level of study muscle activity was maintained when using ankle brace as much as before fatigue. Some of the effects associated with fatigue in various studies include decreased muscle activity, reduced afferent inputs, and increased postural sway (Yaggie & McGregor, 2002; Webster, Pietrosimone, & Gribble, 2016). The fatigue has a negative effect on muscle spindles through the activation of pain receptors and secondary inflammations that, in turn, change and decrease the muscle spindle discharge pattern. Therefore, during exercise and sports competitions, the fatigue may affect stability and, by changing neuromuscular control, will reduce the body's ability to maintain stability (Shaw, Gribble, & Frye, 2008). plantar flexor muscles fatigue condition yielded increased absolute and variable errors relative to the no fatigue condition and observed less accuracy and adaptability in matching forces during fatigue (Vuillerme & Boisgontier, 2009). The results of a study by Gimmon et al. (2011), entitled "the effect of plantar flexor muscle fatigue on postural control," revealed a clear relationship between muscle fatigue and impaired postural control, and concluded that the slow transmission of afferent signals due to fatigue could reduce the emission of efferent signals to help maintain the status (Gimmon, Riemer, Oddsson, & Melzer, 2011). The results of these studies confirm that significant changes in postural control strategies occur during fatigue and need to be specifically addressed in activities such as landing, which requires proper postural control.

There are two main explanations for how brace works in preventing injury. The first reason is mechanical support, and the second one is an increase in proprioceptive feedback. The mechanical support means increased joint strength, and the increased proprioceptive feedback refers to the assumption of increasing the production of stimulants for skin mechanoreceptors. Increasing proprioception may further enhance the activity of sensory receptors such as muscle spindle and facilitate response to fast stretches, thereby enhancing the muscles in faster response to disturbances and preventing the ankle sprain (Stafford, 2012). The question of whether the ankle brace actually prevents the ankle sprain is still debatable, because long-term use of devices such as prophylactic ankle brace is associated with concerns about harmful adaptations of the musculoskeletal system, such as muscle atrophy and reduced neuronal responses (Stafford, 2012).

Based on scientific evidence, the use of the ankle brace helps to utilize motor units. According to the results of this study, it can be assumed that the ankle brace may be able to employ skin mechanoreceptors during fatigue. In turn, these mechanoreceptors may be able to stimulate motor units in conditions of fatigue and lead to increased muscle activity and improved postural control. A significant difference in landing with the brace before and after fatigue shows the supportive role of brace when landing. The results obtained in this section are aligned with the study by Shaw et al. (2008), who found it practical to use the lace-up brace to help maintain the ankle in safe conditions during fatigue (Shaw, Gribble, & Frye, 2008).

The results regarding the muscle activity in different foot landing positions had no significant effect on using the brace. It seems that the brace had no preventive effects when landing improperly due to a change in muscle activity.

Limitations

One of the limitations in the present study was that only two muscles were examined, and also one model of ankle brace was used. Furthermore all participants of our study had no history of ankle sprain injuries, while the future research may indicate different results in athletes with a history of ankle sprain injury.

CONCLUSIONS

In general, the results of this study are significant in two aspects. In the first place, the use of the brace selected in this study helped to increase the activity of the muscles under fatigue; this could be effective in preventing sprain injury whose cause is the loss of muscle activity during fatigue. On the other hand, no changes were observed in the activity level of examined muscles in different landing positions when using the ankle brace. Hence, recommend more significant consideration in using the results of this study. It should also not ignore the positive psychological impact of using supportive equipment like a brace on athletes.

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