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**Original Research**

# Immediate Effects of Various Foot Orthoses on Lower Limb Muscles Co-Contraction during Single-leg Drop Jump

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**ABSTRACT**

The purpose of the present study was to determine the immediate effect of various foot orthoses on muscle co-contraction around the ankle and knee joint of the dominant leg during single-leg drop jump task. Thirteen healthy males participated in this quasi-experimental study. The electromyography activity of vastus medialis (VM), rectus femoris (RF), vastus lateralis (VL), biceps femoris (BF), semi tendinus (ST), tibialis anterior (TA), peroneus longus (PL), and gastrocnemius medialis (GM) muscles was recorded during single-leg drop jump movement. The relevant variables in pre-activation, eccentric, and concentric phases of single-leg drop jump task were calculated for each subject in four conditions: wearing shoe only, soft, semi-rigid, and rigid orthoses. There was no significant difference among four condition for the overall lower extremity muscle activity values during pre-activation, eccentric and concentric phases ($P>0.05$).No significant differences were also observed among the conditions in co-contraction values in the concentric phase. A significant difference was observed for the ankle joint muscles co-contraction between soft/semi-rigid and soft/rigid conditions in the pre-activation phase. There was also difference in medial muscles co-contraction of the knee joint between shoe only/semi-rigid conditions in the eccentric phase ($P<0.05$). We concluded that during single-leg drop jump in the competition or rehabilitation situations, awareness of changes caused by different types of foot orthoses can be beneficial and improve performance.

**Keywords:** Biomechanics, Foot orthoses, Electromyography, Jumping.

## Introduction

Different foot orthoses are designed based on biomechanical principles and can influence the motor pattern of the lower extremity [1, 2, 3]. Foot orthoses are also used in conventional treatment of a variety of lower extremity related injuries [2, 4, 5]. For example, Murley et al. (2010) reported that the use of foot orthoses could alter the pattern activity of the leg muscles in people with pes planus towards a pattern observed in people with normal-arched feet. They concluded that foot orthoses altered some lower limb muscles activity of people with pes planus to a pattern closer to that observed in people with normal-arched feet during walking [2].

Foot orthoses are classified into three sub-categories namely rigid, semi-rigid, and soft based on material manufacturing processes [6]. Previous studies have shown that the material and the shape of orthoses are effective factors in the kinematic and kinetic variables during various dynamic movements such as walking and running [7, 8]. For instance, Nigg et al. (2012) reported that the insole’s stiffness is an influential factor of lower extremity kinematics (spatial parameters) during walking [9]. Since any material produces a different level of vibration, therefore, the mechanical properties of soft tissues should be regulated and adjusted through proper muscles contraction before or during movement. Thus, it seems that the level of activity and the special motion reaction are affected by the type of foot orthoses [10]. Murley and Bird (2006) examined three different types of foot orthoses in the individuals with pes planus and demonstrated that different orthoses cause significant changes to tibialis anterior (TA) and peroneus longus (PL) muscles activity while walking [11]. In addition, Nigg et al. (2003) showed that changes in the materials of heel parts of insoles is associated with the change in oxygen consumption and the activity level of the muscles before the foot contact with the ground; thereby, they suggested that further research should be carried out on foot orthoses and their biomechanical benefits in order to help understand many aspects of human locomotion, such as performance, fatigue and possible injuries [10]. In another study, it was shown that the structure of unstable insoles can change the biomechanics and muscle activity of the lower limb and can help develop specific training and rehabilitation programs [1]. On the other hand, some studies have shown that the use of various foot orthoses can also affect inter-joint coordination in different ways and can change the coordination pattern of lower extremity joints [12, 13]. Considering the fact that the change in the motion kinematic causes a change in the limb coordination pattern [14], thus the stiffness of foot orthoses is an effective factor in the lower extremity motion patterns during different movement tasks. However, Alirezaei and Khoshraftar Yazdi (2017) showed that variation in the stiffness of insoles has no effect on lower extremity coordination patterns and variability during the jump-landing tasks [15]. Unfortunately, performing different motion tasks with different characteristics has limited the possibility of comparing the results of the studies and precise identification of the effects of different types of foot orthoses.

To date, many studies have shown that different levels of training with various overground surfaces can create different biomechanical changes [8, 16, 17]. For instance, while running on surfaces with different stiffness, runners adjust themselves with kinematic features and the impact force of the surface [16]. Considering the neuromuscular changes associated with this adaptability, it is expected that certain individual and muscle reactions depend on the type and stiffness of different insoles. However, what kind of useful or harmful neuromuscular changes is generated following the use of different foot orthoses during exercise performances is a controversial issue. The single-leg drop jump is a common functional movement in different kind of sports that is used as a practice to enhance the neuromuscular ability of lower limb [18]. During the jump-landing task, athletes are taught to jump from a fixed height and to jump upwards immediately after contact with the ground [18]. In single-leg drop jump task, there is a significant increase in ground reaction forces and the resultant mechanical shock should be absorbed by muscular coordination to reduce the amount of shock transmitted to joints [19]. As a result, the functional level and co-contraction of ankle and knee joints are highly important in correct implementation of this technique in order to avoid injury. For this purpose, the role of muscle, activity level, and muscle coordination and movement pattern can be identified and compared using surface electromyography [20]. Electromyography activity is a function of the forces acting on the foot; in fact, the forces are sensory inputs that affect the muscle tone [21]. Nevertheless, despite a new perspective of EMG and its importance in contemporary studies, only a few studies have examined the effect of orthotic insoles on variables related to this area of movement during exercise performance. Due to biomechanical differences among different types of insoles, recognizing these changes may be beneficial in the selection of foot orthoses with appropriate stiffness for sports environments. In addition, the use of these orthoses aid probably helps design some specific training programs with the aim of reducing the level of muscle activity for people with injury. It can also help to enhance the level of muscle activity to increase the intensity of training or change in lower extremity joint stiffness. As a result, it is clear that previous studies have mainly investigated the effects of changes in the stiffness of orthotic insoles on tasks such as walking or running while less attention has been paid to the effect of this particular variable on the activity of lower limb muscles during performance in most sports like landing or jumping. Therefore, the purpose of this study was to determine the immediate effect of three types of orthoses namely soft, semi-rigid and rigid insoles on co-contraction of the muscles around the ankle and knee joints. Furthermore, this study tries to assess the levels of the electromyograpgy activity of vastus medialis muscles, rectus femoris, vastus lateralis, biceps femoris, semitendinus, tibialis anterior, peroneus longus and gastrocnemius medialis muscles of dominant leg of the subjects during pre-activation, eccentric and concentric phases of single-leg drop jump Movement.

## Material and Methods

Thirteen males (age: 24.8 ± 1.7 years, weight: 66.9 ± 7 kg, height: 176.3 ± 4.6 cm, dominant leg of all subjects: right leg) participated in this quasi-experimental study. None of the subjects had musculoskeletal disorders in the lower extremities and were able to perform a single-leg drop jump task from a 30 cm height [22]. Bu Ali Sina University Graduate Studies and Research Council in agreement with the Declaration of Helsinki approved all the procedures before the beginning of the study.

The electromyograpgy (EMG) activity of vastus medialis (VM), rectus femoris (RF), vastus lateralis (VL), biceps femoris (BF), semitendinosus (ST), tibialis anterior (TA), peroneus longus (PL) and gastrocnemius medialis (GM) muscles of participants' dominant leg was recorded using the 16 channel EMG (Biomonitor ME6000 T16, Finland) at the frequency of 2000Hz. Before preparing the skin and attaching electrodes according to the SENIAM recommendations for surface EMG [23], the subjects were briefed on the data collection procedure and signed the consent form. The electrodes were used in bipolar arrangement and in parallel with the direction of the muscle fibers, so that the center to center distance between the electrodes was 2 cm [24]. The ground electrode was placed on the tibia bone. Also, electrogoniometer was used to measure the angle change of the knee joint and for separation of eccentric and concentric phases of single-leg drop jump task. Electrogoniometer was placed on the outside of the thighs and leg in parallel line by double-sided adhesive so that it connected greater trochanter of femur bone, lateral epicondyle of the femur in the middle and lateral malleolus at the bottom [25]. A foot switch was attached under the first metatarsophalangeal joint in order to identify the exact moment of the foot contact with the ground [26]. Finally, the phases of single-leg drop jump task were defined as follows: pre-activation phase (100 ms prior to foot touch-down), eccentric phase (touch-down to maximum knee flexion angle), and concentric phase (maximum knee flexion angle to maximum knee extension angle or push-off) [22].

This study was conducted at the research laboratory of lower limb biomechanics at Bu Ali Sina University. Before starting the tests, the place was checked in terms of temperature, light, cleaning, and additional noise to ensure that it meets the requirements. The subjects were asked to perform the single-leg drop jump task from a 30 cm high wooden box and after ground contact with the dominant leg; the subjects rebounded immediately as high as they could [22]. Acceptable landing included the toe contact at first, balancing, and the ability to land without jumping at the site marked for the subjects (15 cm ahead of the edge of the box) [27]. Single–leg drop jump task was performed seven times for each condition (wearing shoe only; soft, semi-rigid, and rigid orthoses in shoes) and an average of five performances was calculated for each variable. The sequence of tests for each condition was random in order to avoid the occurrence of systematic error and also to eliminate the effects of learning. To eliminate the effects of fatigue, each test position was followed by a minimum 30-minute rest time to give sufficient recovery time to the subjects. The foot orthoses were selected according to differences in their stiffness level. All tests were conducted using standard shoes.

The maximal voluntary isometric contractions (MVIC) were collected to normalize the EMG data from vastus medialis (VM), rectus femoris (RF), vastus lateralis (VL), biceps femoris (BF), semi tendinus (ST), tibialis anterior (TA), peroneus longus (PL), and gastrocnemius medialis (GM) muscles [28]. To determine the MVIC value for TA, each subject was seated on a chair with hip and knee flexed at 90 degrees. Subject was asked to activate TA muscle at maximal effort against resistance. The VM, VL and RF muscles were tested while the subjects were seated with their hip and knee flexed at 90 degrees and a resistance placed on the distal of tibia. Subjects maximally activated their knee extensors against resistance. The BF and ST muscles were tested while hip and knee flexed at 90 degrees and the resistance was applied to the distal aspect of the posterior portion of the shank during knee flexion. Subjects activated their knee flexors at maximal effort against resistance. In seated position on the examination table with the hip flexed at 90° and the knee and ankle in neutral position. Participants activated their plantar flexors at maximal effort against resistance to test MVIC for GM muscle. MVIC test for PL was performed against manual resistance while the subject was in a sitting position and attempting ankle eversion and plantar flexion.

The raw EMG data were processed with a band pass filter of 20-450 Hz. Root mean square (RMS) in three phases of pre-activation, eccentric and concentric was calculated for each muscle. Then the obtained value was divided by the maximum RMS in MVIC test of that muscle and then multiplied by 100. Finally, normalized muscle activity was calculated as a percentage of maximum muscle activity and compared between different types of insoles. Muscle co-contraction reflects the acquisition of motion skills without inhibiting motion-dependent additional muscle activity [29, 30]. Co-contraction is related to joint stability and is considered as an important factor which contributes to the inefficiency of human movement [29]. To calculate the amount of co-contraction of ankle and knee joints, the formula presented by Anbarian et al (2012) was used as follows:

**Co-contraction (oriented) = (the average activity of antagonist muscles) / (the average activity of agonist muscles) - 1**

In this equation, the closer the resulting number is to zero the co-contraction is greater and as it approaches 1 co-contraction will be smaller [30].

The Shapiro-Wilk test was used to examine normal distributions for all variables. To test for homogeneity of variance, Leven's test was used. Repeated measures ANOVA with were utilized to compare the level of total muscle activity in each phase among four conditions based on post hoc LSD test ($p < 0.05$).

## Results

### EMG variables of selected lower limb muscles in the pre-activation phase

The results showed no significant difference in the total normalized activity of lower extremity muscles in the four conditions (p= 0.998) (Fig. 1).

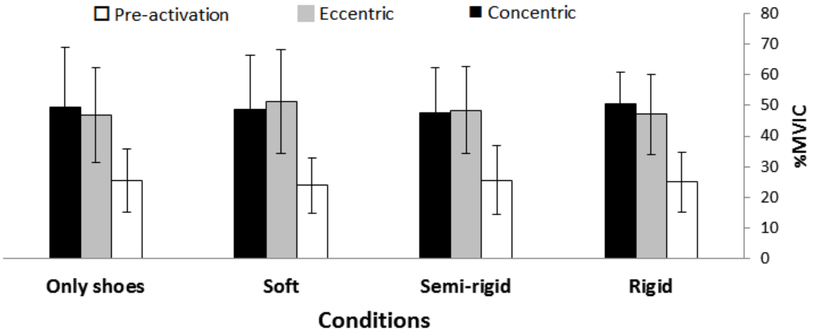

**Fig 1**. Mean and SD of the total normalized electromyography activity of lower limb muscles during pre-activation, eccentric and concentric phases of single-leg drop jump task

The results showed that in pre-activation phase there was no significant difference between the different conditions in the total co-contraction of the medial and the lateral part of the knee joint (p>0.05). There was a significant difference, however, the soft insole and semi-rigid orthosis conditions (p=0.035) between and between soft insole and rigid conditions (p=0.032) in co-contraction levels of ankle joint muscles (Table 1).

**Table 1.** Mean and SD of normalized electromyography activity and muscle co-contraction from selected leg-dominant lower limb muscles during pre-activation phase of single-leg drop jump task.

| | **Conditions** | | | |
|---|---|---|---|---|
| Muscle | Shoe only | Soft | Semi-rigid | Rigid |
| Vastus medialis | 32.0 ± 14.3 | 33.2 ± 18.7 | 34.2 ± 13.6 | **32.8 ± 16.3** |
| Rectus femoris | 21.1 ± 7.4 | 23.1 ± 10.3 | 23.4 ± 9.1 | **24.8 ± 11.3** |
| Vastus lateralis | 34.5 ± 16.5 | 35.5 ± 17.8 | 35.8 ± 14.2 | **33.4 ± 15.9** |
| Biceps femoris | 15.2 ± 8.4 | 12.7 ± 5.5 | 14.1 ± 5.7 | **13.5 ± 6.1** |
| Semi tendinus | 13.3 ± 9.9 | 11.2 ± 6.6 | 13.4 ± 7.5 | **12.4 ± 8.9** |
| Tibialis anterior | 16.1 ± 8.5 | 12.8 ± 6 | 17.1 ± 7.9 | **16.8 ± 6.8** |
| Peroneus longus | 29.6 ± 12.1 | 24.4 ± 12.4 | 25.5 ± 15.3 | **26.6 ± 13.8** |
| gastrocnemius Medialis | 40.9 ± 16.3 | 39.5 ± 15.7 | 41.5 ± 16.2 | **38.8 ± 17.4** |

| | | | | |
|---|---|---|---|---|
| Total co-contraction of the knee | 0.54 ± 0.2 | 0.54 ± 0.29 | 0.55 ± 0.19 | **0.56 ± 0.22** |
| Co-contraction of medial knee muscles | 0.62 ± 0.20 | 0.60 ± 0.26 | 0.60 ± 0.19 | **0.61 ± 0.21** |
| Co-contraction of lateral knee muscles | 0.50 ± 0.31 | 0.58 ± 0.26 | 0.57 ± 0.21 | **0.57 ± 0.20** |
| Total co-contraction of the ankle | 0.53 ± 0.24 | 0.58 ± 0.2*^ | 0.50 ± 0.24* | **0.49 ± 0.25^** |

*=Difference between soft & semi-rigid conditions; ʌ=Difference between soft & rigid conditions.

### EMG variables of selected lower limb muscles in eccentric phase

The findings pointed to no significant difference in the total normalized activity of lower extremity muscles between the four conditions of wearing only shoes, soft insole, semi-rigid and rigid orthoses (p= 0.992) (Figure 1). Also, in this phase, no significant difference was observed between the different conditions in the total co-contraction levels and lateral part of knee joint muscles as well as the co-contraction levels of ankle joint muscles (p>0.05). A significant difference was only found in co-contraction levels of medial part of the knee joint between the two conditions of no insole and semi-rigid insole (p=0.009) (Table 2).

**Table 2.** Mean and SD of normalized electromyography activity and muscle co-contraction from selected leg-dominant lower limb muscles during eccentric phase of single-leg drop jump task.

| | Conditions | | | |
|---|---|---|---|---|
| Muscle | Shoe only | Soft | Semi-rigid | Rigid |
| Vastus medialis | 65.6 ± 30.1 | 71 ± 33.5 | 61.8 ± 21.9 | **67.4 ± 28.4** |
| Rectus femoris | 54.3 ± 24.9 | 55 ± 22.5 | 52.5 ± 19.9 | **51.9 ± 18** |
| Vastus lateralis | 72.4 ± 36.5 | 84.2 ± 35.9 | 76.5 ± 29.1 | **72 ± 27.8** |
| Biceps femoris | 32.8 ± 16.7 | 32.1 ± 16.4 | 34.9 ± 20.7 | **29.6 ± 17** |
| Semi tendinus | 30.5 ± 12.4 | 36.6 ± 17.1 | 31.6 ± 9.8 | **30.3 ± 11** |
| Tibialis anterior | 25.8 ± 14.4 | 28.9 ± 16.4 | 31.4 ± 18.6 | **27.6 ± 15.3** |
| Peroneus longus | 41.6 ± 15.5 | 44.2 ± 16.9 | 43.1 ± 18.7 | **45.3 ± 13.6** |
| gastrocnemius Medialis | 52.6 ± 22.7 | 58.3 ± 30.2 | 56.1 ± 24.9 | **52.5 ± 21** |
| Total co-contraction of the knee | 0.49 ± 0.18 | 0.51 ± 0.17 | 0.47 ± 0.17 | **0.51 ± 0.17** |
| Co-contraction of medial knee muscles | 0.52 ± 0.22* | 0.47 ± 0.19 | 0.45 ± 0.22* | **0.49 ± 0.26** |
| Co-contraction of lateral knee muscles | 0.52 ± 0.21 | 0.59 ± 0.21 | 0.55 ± 0.19 | **0.58 ± 0.16** |
| Total co-contraction of the ankle | 0.54 ±0.22 | 0.54 ± 0.22 | 0.51 ± 0.23 | **0.53 ± 0.17** |

*=Difference between soft & semi-rigid conditions.

### EMG variables of selected lower limb muscles in concentric phase

In this phase, there was no significant difference in the total activity of lower extremity muscles among different conditions (p= 0.998) (See Fig. 1). No significant difference was also observed between the different conditions in total co-contraction level, medial and lateral parts of knee joint muscles as well as the co-contraction level of ankle joint muscles (p>0.05) (Table 3).

**Table 3.** Mean and SD of normalized electromyography activity and muscle co-contraction from selected leg-dominant lower limb muscles during concentric phase of single-leg drop-jump task.

| | Conditions | | | |
|---|---|---|---|---|
| Muscle | Shoe only | Soft | Semi-rigid | Rigid |
| Vastus medialis | 66.6 ± 21.5 | 66 ± 23.7 | 64.2 ± 23.2 | **67.4 ± 28.3** |
| Rectus femoris | 61.2 ± 12.5 | 59.5 ± 18 | 60.5 ± 17.3 | **65.5 ± 17.5** |
| Vastus lateralis | 71.5 ± 19.2 | 73.3 ± 23.5 | 69.6 ± 24.8 | **74 ± 23.1** |
| Biceps femoris | 22.2 ± 9.6 | 20.2 ± 7.4 | 18.9 ± 5.3 | **21 ± 5.2** |
| Semi tendinus | 22.6 ± 15 | 24.5 ± 16.1 | 22.4 ± 14.8 | **21.8 ± 14.6** |
| Tibialis anterior | 15.1 ± 6.6 | 15.3 ± 8 | 14.8 ± 7.4 | **15.2 ± 7.3** |
| Peroneus longus | 58.7 ± 18.7 | 54.7 ± 22.8 | 55.8 ± 17.5 | **62.1 ± 16.8** |
| gastrocnemius Medialis | 78.5 ± 21.3 | 76.5 ± 20.6 | 75.1 ± 20.5 | **76.7 ± 20.1** |
| Total co-contraction of the knee | 0.64 ± 0.22 | 0.64 ± 0.2 | 0.66 ± 0.18 | **0.67 ± 0.16** |
| Co-contraction of medial knee muscles | 0.62 ± 0.29 | 0.60 ± 0.31 | 0.61 ± 0.29 | **0.63 ± 0.28** |
| Co-contraction of lateral knee muscles | 0.69 ± 0.15 | 0.68 ± 0.22 | 0.69 ± 0.16 | **0.69 ± 0.14** |
| Total co-contraction of the ankle | 0.77 ± 0.11 | 0.76 ± 0.11 | 0.77 ± 0.13 | **0.78 ± 0.09** |

## Discussion

The aim of this study was to determine the immediate effects of three types of foot orthoses namely soft, semi-rigid and rigid on co-contraction of the ankle and knee joints muscles. In addition, this study aimed to assess the level of the electrical activity of the lower extremity muscles in the dominant leg of individuals in three phases including pre-activation, eccentric and concentric during the single-leg drop jump task.

The results revealed no significant difference in the total amount of normalized activity level of the lower extremity muscles between the four conditions in pre-activation, eccentric and concentric phases. Previous studies have demonstrated that foot orthoses are used as a common treatment for controlling the extra movements. For example, Eslami and colleagues (2009) showed that the use of semi-rigid foot orthoses reduces the movement of subtalar joint and is also associated with reduced knee joint adductor torque [5]. They also concluded that the use of foot orthoses can reduce additional loads imposed on the knee joint in the frontal plane. However, the effect of different types of foot orthoses (based on the stiffness) was not evaluated in their study. Furthermore, material and shape of insoles affect kinematic and kinetic variables during different tasks such as walking and running [7, 8, 9]. In this regard, Nigg and colleagues (2012) reported that the stiffness of foot orthoses is an effective factor in kinematics of lower extremity (spatial location of thighs, legs and feet) during walking [9]. However, few studies have investigated the effects of foot orthoses on electromyography of muscles during functional tasks. Nigg and colleagues (2003) showed that changes in the materials of the heel part of footwear is associated with changes in oxygen consumption and the activity level of muscles before foot contact with the ground (Heel strike). Thus, they suggested that further research should be conducted to evaluate the application of these changes in different tasks, sports skills, and recognizing sport-related injuries [10]. Murley and Bird (2006) also investigated the effect of three different levels of foot orthoses on people with pes planus showing that the change of insoles causes significant alteration in tibialis anterior (TA) and peroneus longus (PL) muscles activity [11]. In addition, Wang and colleagues (2014) examined the activity of lower limb muscles while running on a treadmill in comparison with other surfaces such as cement, natural grass and synthetic rubber and showed that there was a significant change in the activity of lower limb muscles while running on different surfaces, which result from kinematic adaptability of body to running surfaces [16]. In another study, it was shown that the structure of unstable insoles can alter kinematics and muscle activity of the lower limb and help develop specific training and rehabilitation programs [1]. However, the results of this study are inconsistent with the results of aforementioned studies. This is probably due to the type of task performed in this study (doing a sports performance), assessment of immediate effects of different types of insoles or using different statistical methods for data analysis.

The results of this study indicated that in the pre-activation phase, there was a significant difference in co-contraction level of the ankle joint muscles between soft/semi-rigid and soft/rigid orthoses conditions. Besides, in the eccentric phase, a significant difference was only observed in co-contraction level of medial part of the knee joint between the two conditions of wearing shoe only and semi-rigid condition. In the concentric phase, no significant difference existed in co-contraction levels between any of the four conditions. Muscle co-contraction reflects the acquisition of motion skills without inhibiting motion-dependent extra muscle activity. The co-contraction can cause joint stability and is considered as an important factor for demonstrating the inefficiency of human movements [29]. During the jumping and landing movements, lower limb muscles are activated ahead of landing and the intensity and timing of this activation is determined on the basis of the predicted impact [31]. Therefore, the lower extremity muscles must properly contract before landing to absorb the impact force and maintain dynamic stability of the joints [32]. This pre-landing activity is a feed-forward mechanism of the central nervous system that ensures stability of the lower body joints [33]. Nigg et al. (2003) pointed out that each material produces different levels of vibration and mechanical properties of soft tissues must be adjusted and regulated through suitable contraction of muscles before or during movement. Therefore, one should expect muscle and subject specific reactions for each type of foot orthoses (insole) [10]. On the other hand, some studies have shown that the use of various medical insoles can differently affect the inter-joint coordination and can change lower extremity joints coordination pattern [12]. Thus, since the change in the motion kinematics can change the patterns of coordination [14], the stiffness of insoles is probably an effective factor in the lower limb movement patterns during the performance of different movement tasks. Khezri (2014) reported that foot orthoses with different degrees of stiffness can affect the angular movements of lower limbs and cause alteration in the coordination patterns and variability of limbs and joints through changing the angular momentum of the limbs [12]. Changes in co-contraction levels in response to different types of foot orthoses may be related to the results of study by Khezri. However, Ferber and colleagues (2005) showed that the use of foot orthoses had no effect on the pattern and variability of motion coordination between the tibia and rear foot [34]. Given the significant improvement of co-contraction level of ankle joint following the use of semi-rigid and rigid insoles in pre-activation phase and semi-rigid insole in the eccentric phase, the use of these insoles can be beneficial in different steps of rehabilitation or in sports environments. Taken together, further studies including kinematic and kinetic assessments are suggested to help better interpret and utilize the results of this study in clinical settings and sports environments. The present study was constrained by some limitations that afford discussion. Firstly, a group of able-bodied individuals were enrolled in this study. Therefore, our findings cannot be generalized to people with foot pathologies. The second limitation was related to not collecting kinematic and kinetic parameters simultaneously with electromyographic data for more accurate interpretation of the results. More importantly, long-term effects of foot orthoses have not been assessed in this study.

## Conclusion

According to the results of this study, there were no significant differences between different types of foot orthoses during pre-activation, eccentric and concentric phases in the total activity of the lower limb muscles. Also, there was a significant difference in the co-contraction level of ankle joints between soft/semi-rigid and soft/rigid foot orthoses in the pre-activation phase. Moreover, a meaningful difference was observed in co-contraction level of medial part of the knee between no insole/semi-rigid conditions in the eccentric phase. During the exercise performance (such as single-leg drop jump task), and particularly in competitions or rehabilitation programs, knowledge of different variations created by different types of foot orthoses (insoles) can be beneficial and can be utilized to improve motion performance.

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## References

1. Gu, Y., et al., *Effects of different unstable sole construction on kinematics and muscle activity of lower limb*. Human Movement Science, 2014; **36**: 46-57.
2. Murley, G, Landorf, K. and Menz H, *Do foot orthoses change lower limb muscle activity in flat-arched feet towards a pattern observed in normal-arched feet?* Clinical Biomechanics, 2010; **25**: 728-36.
3. Bonifácio, D., et al., *Influence and benefits of foot orthoses on kinematics, kinetics and muscle activation during step descent task.* Gait & Posture, 2018; **65**:106-111.
4. van Raaij, T.M., et al., *Medial knee osteoarthritis treated by insoles or braces*. Clinical Orthopaedics and Related Research, 2010; **468**: 1926-32.

5. Eslami, M., et al., *Effect of foot orthoses on magnitude and timing of rearfoot and tibial motions, ground reaction force and knee moment during running.* Journal of Science and Medicine in Sport, 2009; **12**: 679-84.
6. Payehdar, S., et al., *Comparing the immediate effects of UCBL and modified* foot orthoses *on postural sway in people with flexible flatfoot.* Prosthetics and Orthotics International, 2016;**40**(1):117-22.
7. Chen, Y., et al., *Effects of foot orthoses on gait patterns of flat feet patients*. Clinical Biomechanics, 2010; **25**: 265-70.
8. Nester, C.J., van der Linden, M.L., & Bowker, P., *Effect of foot orthoses on the kinematics and kinetics of normal walking gait.* Gait & Posture, 2003; **17**(2): 180-7.
9. Nigg, B.M, Baltich, J., and Maurer, C., *Federolf P. Shoe midsole hardness, sex and age effects on lower extremity kinematics during running.* Journal of Biomechanics, 2012; **45**(9): 1692-7.
10. Nigg, B.M., et al., T*he effect of material characteristics of shoe soles on muscle activation and energy aspects during running*. Journal of Biomechanics, 2003; **36**: 569-75.
11. Murley, G., & Bird, A,. *The effect of three levels of orthotic wedging on the surface electromyographic activity of selected lower limb muscles during gait*. Clinical Biomechanics, 2006; **21**: 1074-80.
12. Khezri, D., *Effect of variation in stiffness of shoe sole on coordination pattern and variability in lower extremity joints during stance phase of running*., in Faculty of Physical Education and Sport Sciences. 2014, University of Mazandaran.
13. Jafarnezhadgero, A.A., Shad, M.M., and Majlesi, M., *Effect of foot orthoses on the medial longitudinal arch in children with flexible flatfoot deformity: A three-dimensional moment analysis.* Gait & Posture, 2017; **55**: 75-80.
14. Hamill, J., et al., *A dynamical systems approach to lower extremity running injuries.* Clinical Biomechanics, 1999; **14**(5): 297-308.
15. Alirezaei, F., & Khoshraftar Yazdi N., *Assessment of patterns and variability in lower extremity coordination between genders with different shoe insole stiffness during jump-landing tasks.* Human Movement Science, 2017; **18**(1): 1899-1955.
16. Wang, L., Hong, Y., and Li, JX., *Muscular activity of lower extremity muscles running on treadmill compared with different overground surfaces*. American Journal of Sports Science and Medicine, 2014; **2**(4): 161-5.
17. García-Pérez, J.A., et al., *Effect of overground vs treadmill running on plantar pressure: Influence of fatigue*. Gait & Posture, 2013; **38**(4): 929-33.
18. Peng, H.T., Kernozek, T.W., and Song, C.Y., *Quadricep and hamstring activation during drop jumps with changes in drop height.* Physical Therapy in Sport, 2011; **12**: 127-32.
19. McNitt-Gray, J., *Kinematics and impulse characteristics of drop landings from three heights.* International Journal of Sport Biomechanics, 1991; **7**: 201-24.
20. Cè, E., et al., *Combined effects of fatigue and temperature manipulation on skeletal muscle electrical and mechanical characteristics during isometric contraction*. Journal of Electromyography and Kinesiology, 2012; **22**: 348-355.
21. Nigg, B.M., and Wakeling, J.M., I*mpact Forces and Muscle Tuning: A New Paradigm*. Exercise and Sport Sciences Reviews, 2001; **29**(1): 37-41.
22. Schmid, S., Moffat, M., and Gutierrez, G.M., *Effect of knee joint cooling on the electromyographic activity of lower extremity muscles during a plyometric exercise*. Journal of Electromyography and Kinesiology, 2010; **20**: 1075-81.
23. Hermens, H.J., et al., *Development of recommendations for sEMG sensor placement procedures.* Journal of Electromyography and Kinesiology, 2000; **10**: 361-74.
24. Winter, D.A., and Yack, H.J., *EMG profiles during normal human walking: stride - to- stride and inter - subject variability*. Electroencephalography and clinical neurophysiology, 1987: **67**(5): 402-11.
25. Felson, D.T., et al., *The effects of impaired joint position sense on the development and progression of pain and structural damage in knee osteoarthritis.* Arthritis & Rheumatology, 2009; **61**(8): 1070-6.
26. Hargrave, M., et al., *Subtalar pronation does not influence impact forces or rate of loading during a single-leg landing.* Journal of Athletic Training, 2003; **38**(1): 18-23.

27. Mahaki, M., et al., *The comparsion of the electromyography of leg muscles and peak vertical ground reaction forces during single leg drop landing between men with genu varum deformity and normal knee.* Sport Med, 2012; 9: 87-106.
28. Jafarnezhadgero, A.A., Anvari, M., and Granacher, Urs., *Long-term effects of shoe mileage on ground reaction forces and lower limbmuscle activities during walking in individuals with genu varus.* Clinical Biomechanics, 2020; **73**: 55-62.
29. Kellis, E., Arabatzi, F., and Papadopoulos, C., *Muscle co-activation around the knee in drop jumping using the co-contraction index*. Journal of Electromyography and Kinesiology, 2003; **13**: 229-38.
30. Anbarian, M., et al., *Comparison of knee joint muscles' activity in subjects with genu varum and the controls during walking and running*. Journal of Research in Rehabilitation Sciences, 2012; **8**(2): 298-309.
31. Gillis, G.B., Akella, T., and Gunaratne, R., *Do toads have a jump on how far they hop? Pre-landing activity timing and intensity in forelimb muscles of hopping*. Biology Letters, 2010; **6**: 486-489.
32. Huber, C., et al., *Muscular timing and inter-muscular coordination in healthy females while walking*. The Journal of Neuroscience Methods, 2011; **201**: 27-34.
33. Sadeghi Goghari, M., et al., *Test-retest reliability of the onset of lower limb muscles' preactivation during landing from a Jump in volleyball players with functional ankle instability.* Indian Journal of Physiotherapy & Occupational Therapy, 2011; **5**(4): 119-21.
34. Ferber, R., Davis, I.M., and Williams, D.S. 3rd., *Effect of foot orthotics on rearfoot and tibia joint coupling patterns and variability.* Jornal of Biomechanics, 2005; **38**(3): 477-83.

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## چکیده فارسی

# اثرات فوری انواع کفی طبی بر میزان هم‌انقباضی مفاصل مچ‌پا و زانو و فعالیت الکتریکی عضلات منتخب اندام تحتانی پای برتر حین حرکت فرود-پرش تک‌پا

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هدف از انجام مطالعهٔ حاضر، تعیین اثر فوری سه نوع کفی طبی بر میزان هم‌انقباضی اطراف مفاصل مچ‌پا و زانو پای غالب حین اجرای وظیفهٔ فرود-پرش تک‌پا بود. تعداد سیزده مرد در این مطالعهٔ نیمه‌تجربی شرکت کردند. فعالیت الکترومایوگرافی عضلات پهن‌داخلی، راست‌رانی، پهن‌خارجی، دوسررانی، نیمه‌وتری، ساقی‌قدامی، نازک‌نئی طویل و دوقلوی داخلی حین اجرای حرکت فرود- پرش تک‌پا ثبت گردید. حرکت فرود-پرش در ۴ وضعیت پوشیدن تنها کفش، کفی نرم، نیمه‌سخت و سخت اجرا و متغیرهای مربوطه برای هر فرد در فازهای پیش‌فعالیت، اکسنتریک و کانسنتریک محاسبه شد. نتایج مطالعهٔ حاضر در فازهای پیش‌فعالیت، اکسنتریک و کانسنتریک تفاوت معناداری بین میزان کل فعالیت عضلات اندام تحتانی بین ۴ وضعیت را نشان نداد. تفاوت معناداری بین هیچکدام از وضعیت‌های مختلف در مقادیر مختلف هم‌انقباضی در فاز کانسنتریک نیز مشاهده نشد (P>۰/۰۵). تفاوت معناداری در هم‌انقباضی مفصل مچ‌پا بین وضعیت‌های کفی نرم/ نیمه‌سخت و کفی نرم/کفی سخت در فاز پیش‌فعالیت مشاهده شد. هم‌انقباضی بخش داخلی مفصل زانو بین وضعیت پوشیدن تمها کفش/ کفی نیمه‌سخت در فاز اکسنتریک وجود داشت (P<۰/۰۵). نتیجه اینکه، هنگام انجام حرکت فرود- پرش تک‌پا در شرایط رقابت ورزشی و یا توانبخشی، آگاهی از تغییرات مختلف ایجاد شده توسط انواع مختلف کفی طبی می‌تواند مفید بوده و به‌عنوان راهکاری برای بهبود عملکرد قرار گیرد

**واژه‌های کلیدی**: بیومکانیک، کفی طبی، الکترومایوگرافی، پرش.