Comparison of Electrical Activities of Lower Limb's Muscles during Landing on Different Surfaces in Elite Volleyball Players

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Abstract

Introduction: The importance of the surface on which a person moves has now been proven as a potential factor in the frequency and severity of lower limb injuries. The aim of the present study was to compare the electrical activities of lower limb's muscles during landing on Different surfaces in elite volleyball players. **Materials and Methods**: This was Quasi-experimental causal-comparative study. Participants were 14 volleyball players between 18 and 20 years old. Electrical activity of four selected lower limb muscles was recorded by 8-channel electromyography according to the SENIAM protocol during landing on three surfaces of tatami, grass and sand. **Results:** Repeated measurement tests showed a significant difference between the peak of muscle activity in Vastus lateral is biceps femora's muscles and during landing on tatami, grass and sand ($P>0.05$). However, the peak electrical activity during landing on different surfaces was significantly different in the tibia is anterior and gastrocnemius muscles ($P=0.00$). Also, there was no significant difference between knee and ankle joint's contractions ($P>0.05$). In the knee and ankle joint's, the highest and lowest mean contractions were observed on grass and sand, as well as tatami and sand, respectively. **Conclusion:** surfaces with higher stiffness are not the absolute factor to exert force applied to the muscles and joints. Conversely, a softer surface that reduces these forces and also reduces damage to bone elements.

Keywords: Biomechanics; Co-Contraction; Landing; Muscle; Surfaces

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Introduction

The key factors affecting the efficient implementation of jump and landing techniques in the block jump skills and different types of spikes include the jump height, the surface type, the segments kinematics, and the center of mass of the body. From a biomechanical point of view, speed and the correct timing of various steps of this skill, play a more significant role than jump height, the surface type, the segments kinematics, and the center of mass of body. Moreover, the coordination of the upper and lower limbs and trunk in absorbing the forces applied to the body as well as preserving the stability of the hip, knee, and ankle joints during movement is of paramount importance (1).

In sports activities, improper landing after jumping is a key cause of lower limb injuries. During the landing, the amount of reaction force applied to the body by the ground increases the amount of the individual's injury, so that when landing is done from the same height (on different surfaces), the ground reaction force is equal to 4-6 times of the individual's body force (2). Safety is one of the significant surface features in contact with humans, directly like flooring or indirectly like shoes, orthoses, and *etc*. (3). At present, the significance of the surface on which an individual moves has been proven as a potential factor in the lower limb injuries' frequency and severity (4). Furthermore, the simultaneous activities of agonist and antagonist muscles and the function of these muscles around the joints are biomechanically significant, since it will preserve the joints' stability (1, 2). Some studies have investiated the impact of level on injury prevalence during jumping - landing technique. Farzad Pezeshk *et a*l. (2) stated that moving on a surface with high stiffness would result in decrease of the lower limb's stiffness and vice versa. SoltaniEchi *et al.* (5) argued that to compensate for surface changes in order for preserving the natural pattern of movement of the center of mass associated with reduced energy consumption, the root of changes is considered in changing the person's reaction to landing on different surfaces accordingly, when a person moves on a soft surface, the stiffness of the joint and thus the stiffness of the body changes (5). Farzani *et al.* (3) pointed out that excessive loading and sudden decline in acceleration during landing may result in injuries like ankle sprain, cartilage injuries, fracture stress, patellar tendinopathy, patellofemoral pain syndrome, and anterior cruciate ligament injury. If an athlete moves on a high stiffness surface, the stiffness of his limb's will decrease and on the contrary, when he/she moves on a low stiffness surface, the stiffness of his limb's will increase. So the aim of the present study was to compare the electrical activity of the selected muscles of the lower limbs during landing on different surfaces in elite volleyball players.

Material and Methods

This was a quasi-experimental study which 14 young professional male volleyball players in the age range of 18 to 20 years old were participated.

Cochran's formula was employed to specify the statistical sample size (6). Since some participants might not be willing to continue to cooperate during the work, 10 to 20% more than the sample size was calculated to conduct the study. All participants were healthy, without any injuries or abnormalities in the lower limb in the past 6 months, and they were excluded from the study if they had any pain in their lumbar region and lower limb during the jump-landing action. Besides, those with acute injuries, fractures, or surgical history of the upper/lower limb and specific or genetic diseases were excluded from the study by means of a medical health questionnaire; their abnormalities were assessed and screened by the New York test (5). Then, all subjects completed the written informed consent to participate in this study. The subjects' dominant foot was determined using the blindfold falling test and The Waterloo Footedness Questionnaire-Revised (WFQ-R), and then their height and weight were measured by a tape measure and digital scale (7, 8).

Data collection:

The electrical activity of the muscles was recorded by an 8-channel bio-D electromyography device and silver chloride surface electrodes on three surfaces of Aeolian sand, artificial grass, and exercise mat according to the European standard SENIAM protocol on four selected lower limb muscles including biceps femoris, vastus lateralis, gastrocnemius, and tibialis anterior muscles with a distance of 20 mm from the center to the center of the electrode on the subjects' dominant legs. The tests were performed in 20 minutes for each person and three jumps on three different surfaces with standard features for each subject. The artificial grass surface is made of polymer and plastic-like fibers. Accordingly, it may be argued that artificial grass is made of plastic and these fibers are technically employed in the production of green grass flooring. The strongest and toughest type of artificial grass is plastic artificial grass (4). This type of grass can maintain its original shape regardless of traffic density, pressure, and individual weight. Plastic material is highly resistant to heat so much that it can withstand a great deal of heat, thus being the best option in tropical countries. The surface of the exercise mat, made of Eva foam, is soft, flexible, and portable. This type of flooring is made by the combination of waterproof foams called EVA with other polyethylene foam compounds [2]. Exercise mats are produced in various models, thicknesses, and fixed and standard dimensions, with extraordinary damping properties. The Aeolian sand surface has a soft and light feature and the number of common injuries in sports with a lot of jumping and landing is much less than the surface of the gym, i.e. a horizontal and flat surface designed for volleyball and other indoor sports. All this data was recorded and the subjects were asked not to make any extra movements during the tests, such as talking, since it would cause errors in recording the data and tests. Subjects individually warmed up, including running at an optional speed, exercise, and landing. Subsequently, a Maximum Voluntary Contraction (MVC) test was performed on the selected muscles, followed by a 30-minute rest before testing the landing test. Then, the electrode pairs were placed along the direction of the Muscles, being fixed with bandages in order for the electrodes and cables to be stabilized on the skin to avoid errors and disturbances.

Data Processing

To process the data, the raw data was initially entered into MATLAB software. A fourth-order mid-pass butter worth filter with a cutoff frequency of 10-500 Hz then was performed [6]. The RMS of EMG signal was calculated after normalization of the maximum MVC value. At the end, the maximum amount of RMS was extracted. Hence, the maximum voluntary muscle contraction was individually tested for each subject. Before conducting the maximal voluntary contraction test, the subjects contracted their

Table 1. Mean (SD) of demographic characteristics of the participants (N=14)

Variable	Age (year)	Weight (kg)	Height
Young male volleyball players	18.23 (2.3)	12.64 (14.12)	183.19 (6.3)

Table 2. Results of one-way repeated measurement to compare the peak muscle activity when jumping and landing on three surfaces of tatami, grass, and sand

Muscle	Surface	Mean (SD)	F	*P*-value
Vastus lateralis	Tatami	2.01 (0.99)	2.76	0.07
	Grass	2.21 (0.93)		
	Sand	2.82 (0.95)		
Biceps femoris	Tatami	1.16 (0.89)	1.06	0.35
	Grass	1.43 (1.31)		
	Sand	0.90 (0.53)		
tibialis anterior	Tatami	1.74 (0.89)	5.20	0.01*
	Grass	2.82 (4.88)		
	Sand	2.47 (0.96)		
Gastrocnemius	Tatami	2.01 (1.03)	33.51	0.00*
	Grass	4.50 (0.72)		
	Sand	4.18 (0.85)		

*Significant differences at (P≥0.05)**

Table 3. Descriptive information on the time of the end of muscle activity when jumping and landing on three surfaces of tatami, grass, and sand

Muscle	Surfaces	Mean (SD)	F	*P*-value
Vastus lateralis	Tatami	39.88 (15.61)	5.15	0.00*
	Grass	40.56 (10.39)		
	Sand	50.89 (11.04)		
Biceps femoris	Tatami	40.49 (13.31)	5.01	0.01*
	Grass	45.00 (12.82)		
	Sand	51.84 (10.08		
Tibialis anterior	Tatami	50.42 (13.46)	1.85	0.16
	Grass	44.21 (8.41)		
	Sand	51.91 (13.04)		
Gastrocnemius	Tatami	46.01 (11.37)	2.55	0.08
	Grass	40.46 (8.94)		
	Sand	48.50 (10.81)		

*Significant differences at (P≥0.05)**

muscles several times to ensure that the test was correctly performed. In each test, while recording the electromyography signal, subjects performed a maximal voluntary contraction for five seconds. All statistical analysis stages were carried out by SPSS softwar (R2009a versio). The mean and standard deviation (SD) were employed for descriptive statistics, for assessing the normality of data distribution the Shapiro Wilk test was used, inferential statistics and repeated measures analysis of variance (repeated measurement) test was used for examining the effect of surface type on the studied variables, Bonferroni post hoc test was used for assessing the differences, and the following equation was used for

$$CI = \frac{2I_{\text{ant}}}{I_{\text{Total}}} \times 100\%$$

calculating the Co-contraction index (CI), the ratio between antagonist muscles and total muscle activity respectively.

Results

The demographic characteristics of young male volleyball players are presented in Table 1.

The results of (repeated measurement) test between the two Variable revealed no significant difference between the peak muscle activity in Vastus lateralis and biceps femoris muscles when jumping and landing on tatami, grass, and sand (*P>0.05*): however, a significant difference was observed on the performance of the tibialis anterior and gastrocnemius muscles on different surfaces (*P*=0.00). According to the results of Bonferroni post hoc test, there was only a significant difference in performance of tibialis anterior muscle on the tatami and grass surfaces (*P<0.05*). Similarly, in gastrocnemius muscle, there was a significant difference was shown between tatami and sand surfaces (*P*=0.00): tatami and grass surfaces (*P*=0.00) too.

The results of (repeated measurement) test between the two Variable revealed no significant difference in the onset of performance of biceps femoris, tibialis anterior and gastrocnemius muscles on three surfaces of tatami, grass, and sand (*P>0.05*): nevertheless, vastus lateralis is showed significant differences (*P<0.05*): in the onset of activity on different surfaces. Moreover, the results of Bonferroni post hoc test on the two surfaces of tatami and sand (*P*=0.01): and grass and sand (*P*=0.01).

The results of descriptive statistics on the end of the activity between the biceps femoris, vastus lateralis muscles showed that there were significant differences when jumping and landing on three surfaces (Table 3).

Discussion

The purpose of the present study was to compare the peak and range of electrical activity of the selected muscles of the male volleyball players on three different levels when landing behind the tour. There is no significant difference between the peak function of the muscular activity in the outer muscles and the two heads when jumping and landing at three levels of tatami, grass and sand. But in the tibialis anterior muscle and Gastrocnemius muscle function, there was a significant difference in muscle function between the two levels of tatami and grass (1). Also, there is no significant difference between simultaneous performance in the knee joint with the highest average percentage on the grass surface and the lowest average on the sand surface. And there was no significant difference in the ankle joint. Similarly, the lowest average was related to the ankle joint on the sand surface and the highest average was seen on the tatami surface (9).

The results of the study found in addition to any other research in this regard and were inconsistent with other study too.

Baghbani and his colleagues found that people with ankle sprains will experience less flexion in the ankle joint during landing than healthy people (6). There was an angular speed in healthy people than people with ankle torsion using kinsotype (2).

Farjad pezesk *et al.* (2) came to the conclusion that the interaction between surface stiffness and body stiffness came to the results that by increasing surface stiffness (force plate), the lowest peak of the ground reaction force applied and the body stiffness decreases and reaches its lowest level and reaches its lowest level. The softest level (200 kg/m) of body stiffness reaches its highest level. And at three levels of 300, 400 and 500 kN/m will also increase with the rigidity of the ground reaction (10).

Soltani E. Chi *et al.* (11) found that the electrical activity of the right muscles, exterior and two heads in the pre -preparation phase after the landing was 21 cm high compared to 71 cm; post-execution and landing levels from 71 cm to landing above 71 cm in altitude increased significantly. The jump rate after the plyometrics and landing above 21 cm above landing has increased significantly from 21 cm high. And muscle power, explosive power is a key determinant for success in many sports competitions.

Fatahi *et al* (10) stated that the time of the early peak force was not as important as the secondary peak and the time taken between peak times in shock absorption. Increasing the time of the secondary peak force as an important determining factor in the injury which will increase the landing time and the interval between peak times and subsequently absorbs the appropriate and optimized shock.

Yelfani *et al.* (1) stated that in landing on a smooth surface, the Tibialis anterior muscle activity increased compared to the other muscles under consideration. Also, the activity of the ProneusLangus on the two levels of invert and the composition of the invert and the plantar flexion was significantly more significant than the flat surface and the internal muscle activity at the invert and plantar flexion surface compared to the invert surface (10).

Shokrian *et al.* stated that there is a significant difference between the peak of the internal and external Gastrocnemius muscle contraction and the peak of the internal gastrocnemius musle contraction, which was between 50-50% and 100-50% significant differences, and the significant difference in the peak of the domain. The internal Gastrocnemius muscle contraction was caused by jumping three different heights, which was significant between the heights of 75-75% and 50-20%. And in the peak of the contractile range of the muscles caused by the jump of three heights, there was a significant difference% (5).

Conclusion

The findings of the present study showed that surfaces affect the electrical activity of the lower limb muscles and there is a significant difference between the tibialis anterior muscle and Gastrocnemius muscles function when jumping and landing on tatami, grass and sand surfaces, but at the onset of muscle activity, there was no difference in the tibialis anterior muscle and Gastrocnemius at three levels. Also, a superficial surface is a factor in increasing the force applied to joint bone elements. In contrast, the softer surface will reduce the damage to the bone elements.

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