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Research article

Pre-activity modulation of lower extremity muscles within different types and heights of deep jump

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Abstract
The purpose of this study was to determine modulation of pre-activity related to different types and heights of deep jump. Sixteen male soccer players without experience in deep jumps training (the national competition; 15.0 ± 0.5yrs; weight 61.9 ± 6.1kg; height 1.77 ± 0.07m), who participated in the study, performed three types of deep jump (*bounce landing, counter landing, and bounce drop jump*) from three different heights (40cm, 60cm, and 80cm). Surface EMG device (1000H_z) was used to estimate muscle activity (maximal amplitude of EMG - AmaxEMG; integral EMG signal - iEMG) of five muscles (*mm.gastrocnemii, m.soleus, m.tibialis anterior, m.vastus lateralis*) within 150ms before touchdown. All the muscles, except *m.gastrocnemius medialis,* showed systematic increase in pre-activity when platform height was raised. For most of the lower extremity muscles, the most significant differences were between values of pre-activity obtained for 40 cm and 80 cm platforms. While the amount of muscle pre-activity in deep jumps from the heights above and beneath the optimal one did not differ significantly from that generated in deep jumps from the optimal drop height of 60 cm, the patterns of muscle pre-activity obtained for the heights above the optimal one did differ from those obtained for the optimal drop height. That suggests that deep jumps from the heights above the optimal one do not seem to be an adequate exercise for adjusting muscle activity for the impact. Muscle pre-activity in bounce drop jumps differed significantly from that in counter landing and bounce landing respectively, which should indicate that a higher amount of pre-activity generated during bounce drop jumps was used for performing take-offs. As this study included the subjects who were not familiar with deep jumps training, the prospective studies should reveal the results of athletes with previous experience.

Key words: Electromyography, programmed muscle activity, landings, drop jumps.

Introduction

During the flight phase of landing, a series of neuromuscular events occur in preparation for the impact, one of these being the so-called preparatory, or pre-landing, muscle activation. The term pre-landing muscle activity or pre-activity will be used in this paper to denote a continuous build-up of muscle activity occurring before touch down. Build-up of muscle force in a pre-contact phase appears in order: 1) to form initial stiffness of contractile component, which enables use of elastic energy from muscle-tendon structures in conjunction with the muscle contractile property (Dietz et al., 1981; Horita et al., 2002); and 2) to provide adequate deceleration of joint rotations during dynamic activities, which could be a mechanism acting to protect the ligaments and joints from injury (Neptune et al., 1999).

Muscle pre-activity has been noticed in all of the following types of movement: deep jumps from different heights; landings from different heights; hopping at different frequencies; running and walking at different paces; and cutting movements (Horita et al., 2002; Kyrolainen et al., 2003; Neptune et al., 1999). Interestingly, preparatory muscle activity has also been found in arm muscles when braking a forward fall with the arms (Dietz et al., 1981) and before catching a ball (Lacquaniti and Maioli, 1989).

Results of the previous studies (Chimera et al., 2004; Duncan et al., 2000) showed that EMG signal for the most of the lower extremity muscles appeared 150 ms before touch down. In most of the studies, this variable was not adjustable to changes of the platform height (McKinley et al., 1983). The results show approximately linear relationship between increasing drop height and EMG amplitude (Santelo, 2005), while the rate at which pre-landing EMG amplitude increases with the drop height is muscle-specific (mechanical action and anatomical characteristics of muscles) (Santelo et al., 2001). Therefore, this interesting phenomenon indicates to a general strategy used to modulate muscle force and prepare the muscles to absorb an impact, whose time of occurrence and magnitude are anticipated by the CNS.

Deep jumps (DJ) appear to be the most important training method for the explosive strength development, from the aspect of realizing neuromuscular potential (Bobbert et al., 1996; Finni et al., 2003; McBride et al., 2002). Muscle action during DJ is stretch-shortening cycle, which represents alternation of eccentric, isometric and concentric contractions in a short period of time. During deep jump exercise, the interaction between preprogrammed control (feedforward motor control) and natural stretch reflex (feedback motor control) leads to an appropriate muscle stiffness which corresponds to external impact forces (Horita et al., 2002; Kyrolainen et al., 2003; Santelo et al., 1998). The role of these two control mechanisms in the overall control of deep jump movement is still not well understood (Dietz et al., 1981; Duncan et al., 2000; Greenwood and Hopkins, 1976). The share of the two mechanisms in movement control depends on landing technique, drop height, landing surface compliance, and whether the fall is expected or unex-

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pected (Greenwood and Hopkins, 1976; Santelo et al., 2001; Thompson and McKinley, 1995). The studies on the subjects with previous experience in DJs suggest the presence of feedforward motor control before landing (Liebermann and Hoffman, 2005).

Clearly, revealing of how the CNS plans and controls impact absorption is essential for complete understanding of deep jump training method and non-contact injuries. Different heights and types of DJ cause impacts of different magnitudes. Accordingly, different amplitudes of muscle force are needed to control joint rotation caused by impacts of different magnitudes. These conditions require the whole body to prepare for absorption of impact, characterized by different and sometimes very large ground reaction force.

Based on previous studies, practice and skill play a significant role in determining the muscle pre-activity strategy used to control landing movements. (Chimera et al., 2004; Kyrolainen and Komi, 1995; Viitasalo et al., 1998). The fact that pre-activity is under influence of exercise suggests that it is a very important area of strength training research.

The most relevant point of reference in DJ training is optimal drop height. Optimal platform height is deemed to be that from which the highest rebound was performed. Different results were obtained for the optimal drop height (from 0.40 to 0.60 m) depending on the category of subjects and the sports they practice (Asmussen and Bonde-Petersen, 1974; Komi and Bosco, 1978). Therefore, it is necessary to determine optimal drop height for different groups of subjects.

Among the numerous questions asked concerning control mechanisms for deep jumps, an important theme is the modulation of pre-landing EMG amplitude as a function of the task requirements, such as DJ height and DJ type (landing technique). Based on the previous studies, it is expected that pre-activity of lower extremity muscles will significantly differ in landings and bounce drop jumps. Moreover, significant statistical differences in pre-activity phase are expected in most of the lower extremity muscles when performing deep jumps from 40 cm, 60 cm, and 80 cm. Based on the optimal drop height obtained in this study, we will be able to determine possible changes in patterns of muscle activation during landings from heights other than the optimal one.

The main aim of this study is to define the modulation of muscle activation pattern before landing, depending on the change in the type and height of deep jumps.

Methods

In this study, EMG variables of muscle pre-activity (maximal amplitude - A_{max}EMG and integral EMG signal - iEMG) have been measured and compared with three types of deep jump (counter landing – CL, bounce landing - BL and bounce drop jump – BDJ). Three DJs were performed from 40 cm, 60 cm, and 80 cm respectively, in order to determine changes in muscle activation depending on the DJ height and DJ type.

Subjects and experimental protocol

Sixteen male soccer players (the national competition 15.0 ± 0.5 yrs; weight 61.9 ± 6.1 kg; height 1.77 ± 0.07 m) (± represents SD) with similar training experience participated in this study. The subjects did not use deep jumps in their previous training experience. The University of Belgrade Ethics Board approved the experimental procedures.

Warm-up included 8 to 10 minutes of slow running, and active stretching of lower extremity muscle groups. After a familiarization session, which consisted of several jumps from a specific height (*James et al., 2007*), testing DJ from different heights followed. When leaving the platform, a subject would step forward with one leg to an empty space, and with the other he would slide out of the platform, without making a take off from the platform. The values obtained from three properly performed DJs of each type were used for the statistical data processing. Counter landing, bounce landing, and bounce drop jump were performed. These three types of DJ were performed from 40 cm, 60 cm, and 80 cm in a randomized order.

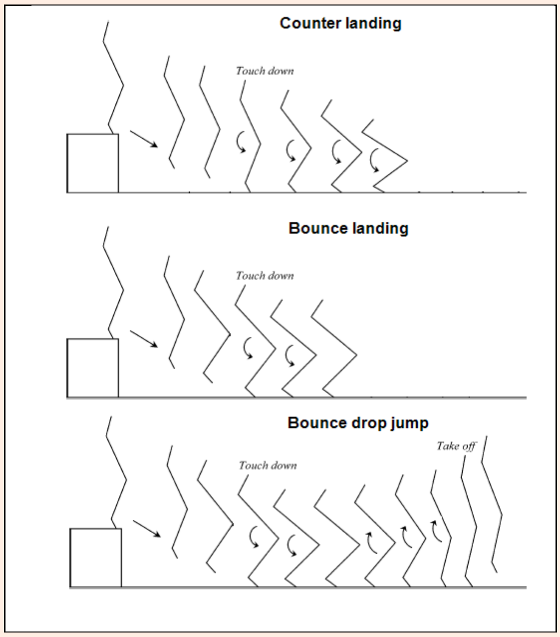

Figure 1. The illustration of proposed three types of deep jump (Modified illustration from Horita et al., 2002).

The first task for subjects was to softly land on a surface, making the smallest possible impact on landing (Figure 1). Hereinafter, this type of landing will be referred to as counter landing (CL). In the second type of landing, subjects were tasked to try, as soon as possible, to stop the movement of their centre of mass downwards after landing. Hereinafter, this type of landing will be referred to as bounce landing (BL). The third task, bounce drop jump (BDJ), was performed in a way that subjects were to try to rebound as fast and high as possible after a short amortization. Success criteria for this task were short contact with landing surface, and highly produced power. In order to achieve the effects of short contact with landing surface, the subjects were required to perform the rebound phase with their bodies erect. Counter drop jump (CDJ) was not considered within the type of DJ factor, as it is a demanding movement task in terms of coordination (Bobbert et al., 1987, Bosco et al., 1982). The subjects were not exposed to a training program of this nature, and, hence, the results that are not reliable cannot be taken into account.

Before the testing, several deep jumps were performed from different heights in order to make the subjects familiar with the movement technique and to increase the reliability of the test results (James et al., 2007). The pause between the jumps from the same height was between 15s and 20s, whereas the pause between the jumps from different heights was fairly longer. The pause between each series of jumps was 3 minutes.

Sample of variables

EMG recordings: To determine muscle activity, surface EMG signals from *m.gastrocnemius lateralis* (GL)*, m.gastrocnemius medialis* (GM)*, m.soleus* (S)*, m.vastus lateralis* (VL) and *m.tibialis anterior* (TA) were recorded from bipolar Ag/AgCl electrodes of eight-channel EMG device (Statokyn), at a sampling rate of 1000Hz. The diameter of electrodes was 0.8cm, and distance between bipolar electrodes was 2cm. After data collection, the EMG signals were rectified and low-pass filtered with a cutoff frequency of 7 Hz, by using a fourth-order Butterworth filter.

Bipolar surface electrodes of EMG device were placed according to anatomic location of muscles, longitudinally through the muscle (Pelagi and Peroto, 1981). The electrodes with an electrolytic gel interface were placed on the dominant leg. The skin was carefully prepared (shaved and cleaned with alcohol) to reduce skin impedance. Position of the electrodes was secured to the skin with elastic adhesive tape.

The time of muscle pre-activation is defined as 150 ms before touchdown. The measured EMG variables were integral EMG signal (iEMG) and maximal amplitude of EMG signal (A_{max}EMG). Both of EMG variables were used because of the following reasons: In the previous studies, it has been suggested that a given level of muscle pre-activation could be attained by a different EMG patterns whereas pre-landing EMG timing and EMG amplitude might be controlled as a unit (see review, Santelo 2005). In our paper the time of pre-activity is defined as 150 ms before touch-down. Based on this parameter two possible mechanisms might underlie the simultaneous modulation of these two variables. In the first mechanism, onset of EMG activity might occur later (for example 100ms before touch-down compared to 150 ms) and then modulation of pre-landing EMG amplitude would require a modulation of the rate at which EMG activity increases. This mechanism affects more AmaxEMG compared to iEMG (this is outlined by steeper slopes). A second, alternative mechanism might involve increasing the duration of pre-landing EMG activity to drop height (for example from 100 ms to 150 ms). Here the scaling of pre-landing EMG signal would result from setting a constant rate of EMG build-up starting at earlier onsets from foot contact. This mechanism affects more iEMG compared to Amax-EMG.

The moment of touchdown was detected by means of a trigger placed on the landing surface, which trigger was synchronized with one of the channels of the EMG device. At the moment of the touchdown, the channel signal showed real time values of muscle electric activity (Figure 2).

The EMG signals were not normalized for we did

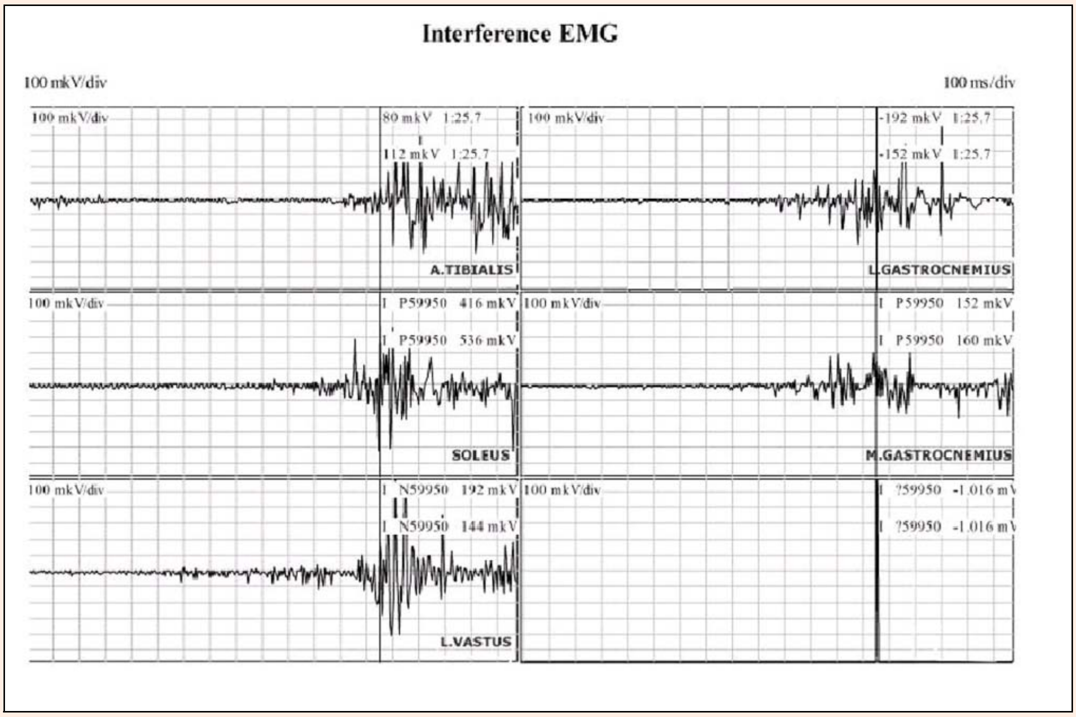

Figure 2. The illustration of raw EMG signal, with assigned moment of touchdown. The first five windows (three left, and two upper rights) represent EMG signal, while the sixth window detects the moment of the touch-down. Vertical line is the moment of touchdown.

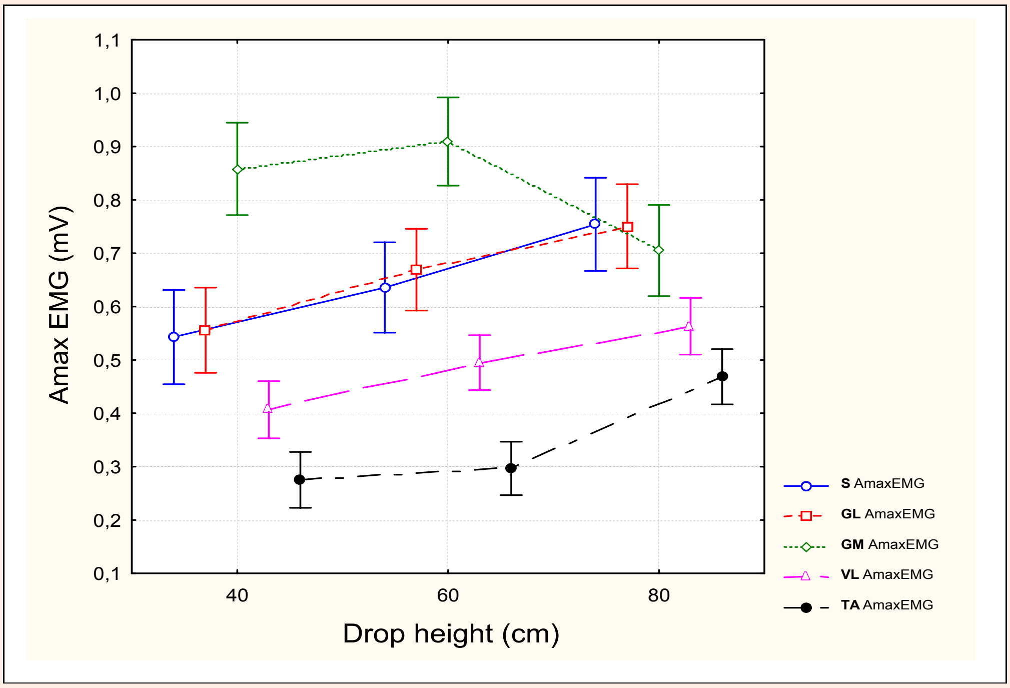

Figure 3. Modulation of maximal EMG amplitude (AmaxEMG) related to drop height, for all observed muscles (GL, GM, S, VL, TA). Vertical bars denote 0.95 confidence intervals.

not follow up differences between individual muscles, but tendencies of change in muscles' activation during deep jumps in different conditions (different platform heights and different DJ types). Had we divided the values of EMG variables with their maximum values, no change in the values of electric activation of muscles would take place.

Kinematics and Kinetics of BDJ: These variables were detected by a computerized platform connected with an electronic timer (*Ergo-jump Bosco System*). Four values were followed with this system: jump (rebound) height – h (cm); duration of the contact – tCONT (ms); duration of the flight phase – tFLY (ms); power output– P (W).

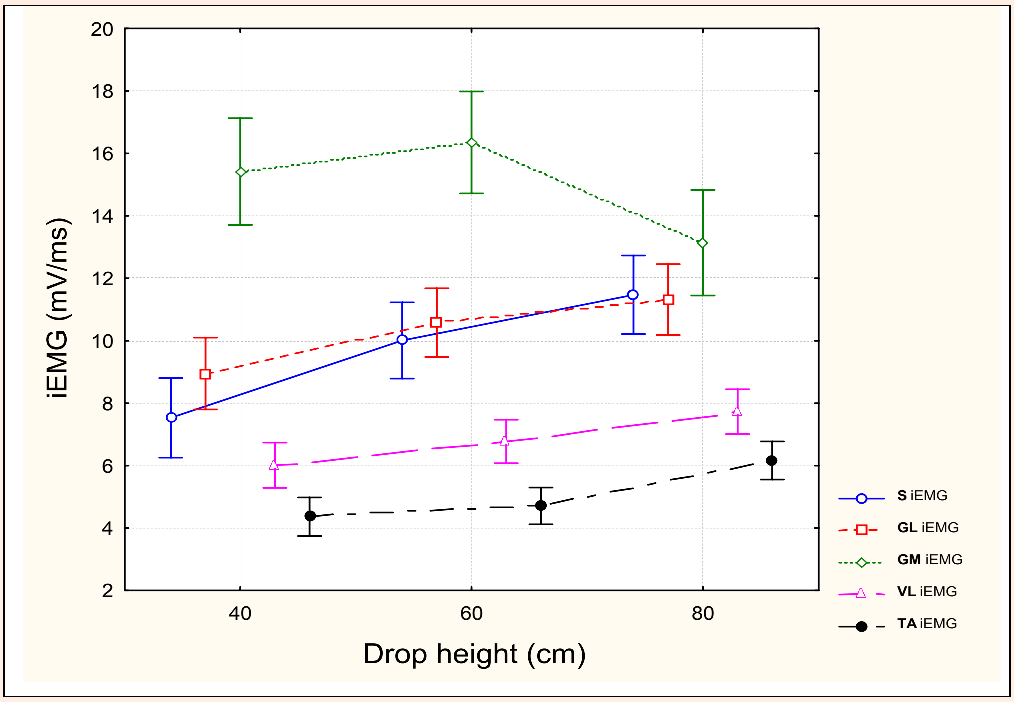

Figure 4. Modulation of integral EMG (iEMG) related to drop height, for all observed muscles (GL, GM, S, VL, TA). Vertical bars denote 0.95 confidence intervals.

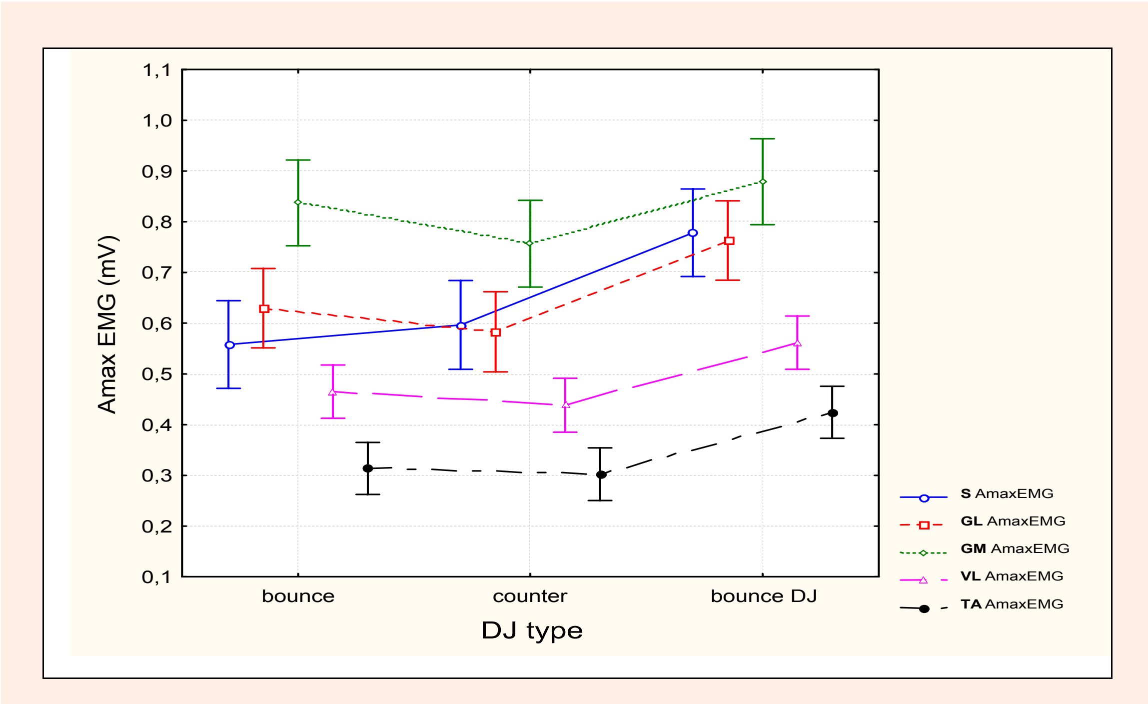

Figure 5. Modulation maximal EMG amplitude (AmaxEMG) related to DJ type, for all observed muscles (GL, GM, S, VL, TA). Vertical bars denote 0.95 confidence intervals.

Statistical procedure

The average value of three successfully performed deep jumps was taken for further data analysis for each of the subjects. Descriptive analysis of the obtained statistical series was made by calculating arithmetic mean and standard deviation.

To reveal the effects of DJ height factor and DJ type factor on two dependent variables (integral EMG signal – iEMG, and maximal amplitude of EMG signal – A_{max}EMG), and their interaction, two-factor ANOVA statistical procedure was used.

In order to define significant differences among the three levels of the height factor (40 cm, 60 cm, and 80 cm) and the three levels of the DJ type factor (BL, CL, and BDJ), post-hoc analysis was made using *Fisher's LSD* procedure. Statistical analysis was made with statistical software STATISTICA (Version 6.0).

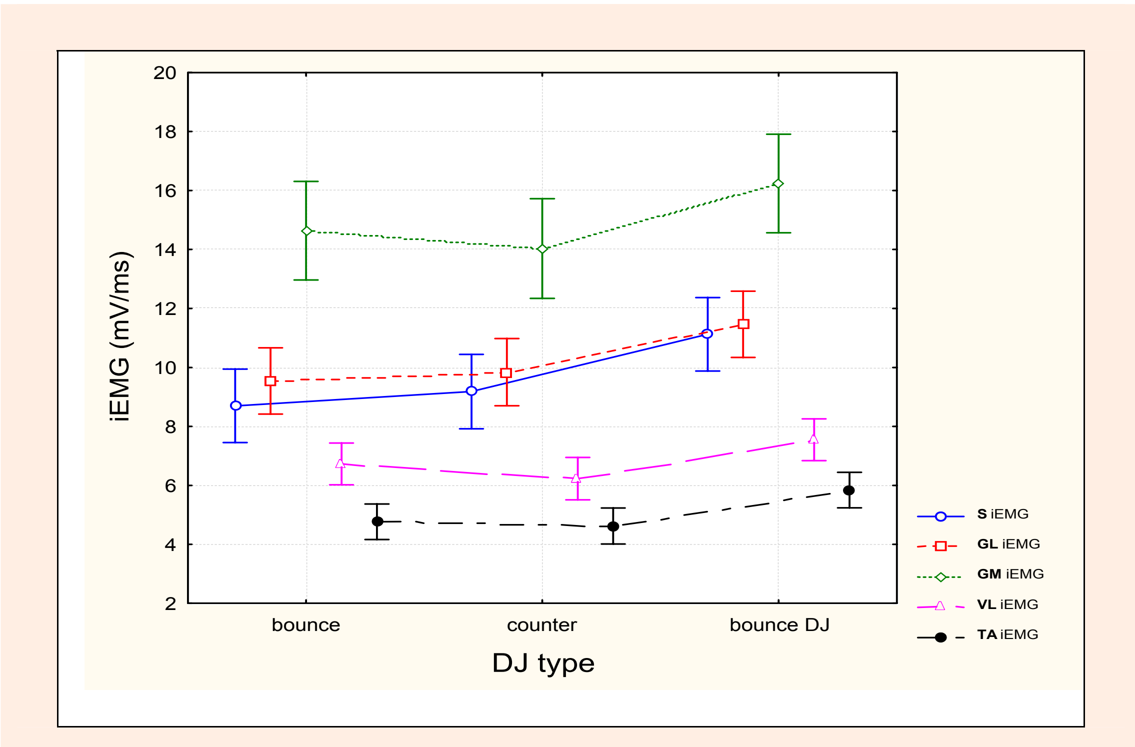

Figure 6. Modulation of integral EMG (iEMG) related to DJ type, for all observed muscles (GL, GM, S, VL, TA). Vertical bars denote 0.95 confidence intervals.

Table 1 . Descriptive statistics of kinematics and kinetics variables of BDJ. Data are means (±SD).

	40 cm	60 cm	80 cm
tFLY (ms)	430.5 (52.7)	463.3 (127.2)	405.7 (93.5)
H (cm)	23.0 (5.9)	38.9 (6.3)	23.0 (6.5)
P (W)	46.1 (16.9)	43.0 (15.9)	37.0 (12.6)
tCONT (ms)	140.1 (41.9)	151.4 (36.3)	183.9 (44.9)

tFLY: duration of the flight phase, H: jump height, P: power output, tCONT: duration of the contact.

Results

The platform height proved to be a factor which systematically changed the values of pre-activity of all muscles, except GM (Figures 3 and 4). The factor of the DJ type also proved to be important for defining the level of pre-activity (Figures 5 and 6).

The highest values of the power output were achieved from the height of 40cm, while the highest rebounds were achieved from the height of 60cm (Table 1). Platform height of 60cm was denoted as optimal drop height.

MANOVA – Effects of the height factor and DJ type factor, and their interaction

Concerning the effects of different factors on the EMG variables, the values of the maximal and integral EMG refer to all muscles analyzed.

Table 2. Effects of the DJ height factor and DJ type factor on AmaxEMG.

	Test	p	F
Drop height	Wilks	<.001	3.785
DJ type	Wilks	.069	1.758
Drop height x Type	Wilks	.994	.375

Height factor proved to be the most relevant to the change in A_{max}EMG variable in the period before landing ($p < 0.001$) (Table 2). The DJ type factor, and interaction of type and height factors, did not affect this phenomenon in any way. As in the previous case, height factor proved to be the most relevant for the change in iEMG variable in the phase before contact with the landing surface ($p = 0.003$) (Table 3). Generally speaking, the DJ height as a factor proved to be more important than DJ type. That means that pre-activity systematically changed with different heights, irrespective of the DJ type, while the pre-activity in different DJ types depended on the height of the platform.

Table 3. Effects of the DJ height factor and DJ type factor on iEMG

	Test	p	F
Drop height	Wilks	.003	2.712
DJ type	Wilks	.412	1.038
Drop height x Type	Wilks	1.000	.137

Effects of the height factor on pre-activity

Further post-hoc statistical procedure determined the extent of change in each EMG variable, depending on the level of height factor (Table 4). All muscles, except GM, marked significant statistical difference in the values of A_{max}EMG obtained for the 40 cm and 80 cm platforms (GL, $p = 0.028$; S, $p = 0.030$; VL, $p = 0.009$; TA, $p = 0.001$). Statistically significant difference between A_{max}EMGs for the platform of 60 cm and the one of 80 cm was noted only TA ($p = 0.003$). A_{max}EMG for GM differed significantly for the heights of 80 cm and 60 cm ($p = 0.029$), where A_{max}EMG for 80 cm was significantly lower than that for 60 cm (see descriptive statistics).

Table 4. p-values for the differences into electric activity (maximal amplitude of EMG - AmaxEMG; integral EMG signal - iEMG) from different drop heights (40cm, 60cm and 80cm), for the five muscles: m.gastrocnemius laterlis (GL), m.gastrocnemius medialis (GM), m.soleus (S), m.vastus lateralis (VL) and m.tibialis anterior (TA).

	40-60cm	60-80cm	40-80cm
GL AmaxEMG	.191	.342	**.028**
GM AmaxEMG	.593	**.029**	.103
S AmaxEMG	.327	.212	**.030**
VL AmaxEMG	.130	.237	**.009**
TA AmaxEMG	.710	**.003**	**.001**
GL iEMG	.189	.550	.062
GM iEMG	.618	.081	.221
S iEMG	.072	.285	**.005**
VL iEMG	.339	.222	**.034**
TA iEMG	.602	**.029**	**.008**

Generally, modulation noted in iEMG was similar to that in A_{max}EMG, although iEMG of GM did not change when the height increased from 60 cm to 80 cm. Both EMG variables (iEMG and A_{max}EMG) for TA changed identically with the increase in the platform height, while the values statistically differed between DJ from 60 cm and 80 cm (A_{max}EMG, $p = 0.003$; iEMG, $p = 0.029$), as well as from 40cm and 80cm (A_{max}EMG, $p = 0.001$; iEMG, $p = 0.008$).

Effects of the DJ type factor on pre-activity

In the further post-hoc statistical procedure it was determined to what extent each EMG variable changed depending on the DJ type (Table 5). Although this factor was observed not to be as significant as the height factor, it affected muscle pre-activation nevertheless.

Table 5. p-values for the differences into electric activity (maximal amplitude of EMG - AmaxEMG; integral EMG signal - iEMG) from different DJ types (bounce landning - BL, counter landing – CL and bounce drop jump – BDJ) for the five muscles: m.gastrocnemius laterlis (GL), m.gastrocnemius medialis (GM), m.soleus (S), m.vastus lateralis (VL) and m.tibialis anterior (TA).

	BL-CL	CL-BDJ	BL-BDJ
GL AmaxEMG	.588	**.038**	.122
GM AmaxEMG	.384	.197	.670
S AmaxEMG	.701	**.041**	**.022**
VL AmaxEMG	.643	**.038**	.103
TA AmaxEMG	.854	**.037**	**.042**
GL iEMG	.808	.195	.122
GM iEMG	.731	.231	.389
S iEMG	.715	.164	.078
VL iEMG	.532	.100	.303
TA iEMG	.843	.072	.106

A_{max}EMG of BDJ statistically increased compared to that of CL. That change was noticed in the majority of the observed muscles (GL, p = 0.038; S, p = 0.041; VL, p = 0.038; TA, p = 0.037). Statistically significant increase in BDJ A_{max}EMG compared to BL A_{max}EMG was noted for S (p = 0.022) and TA (p = 0.042).

Discussion

We expected landings and drop jumps to produce significantly different muscle pre-activity. As far as the height factor is concerned, significant difference in muscle pre-activity was expected to exist between 40 cm and 60 cm, and 60 cm and 80 cm, in majority of the lower extremity muscles. Generally speaking, different types of deep jumps were characterized by significant difference in A_{max}EMG between landings and drop jumps for majority of lower extremity muscles. Highest rebound was achieved from 60 cm platform, which was an optimal drop height for this group of subjects. Statistically significant differences in muscle pre-activity for 40 cm and 80 cm platforms compared to the pre-activity from the optimal drop height (60 cm) were observed only for EMG variables of a few muscles and not for the majority of them as it was expected (Table 4). Therefore, muscle pre-activity was not statistically greater in magnitude for drop heights above the optimal, and was not statistically lesser in magnitude for drop heights beneath the optimal.

Considerable effect of the height factor on the pre-activity level implies that the EMG variables changed systematically with the change in the platform height, whereas the effect of the DJ type factor showed that the change in pre-activity depended on the platform height. In addition, the presented results show that pre-activity modulation was muscle-specific (mechanical action and anatomical characteristics of muscles), as revealed in some previous studies as well (Santelo et al., 2001). It should be noted that the results were obtained from athletes who were not familiar with the described jumping techniques, and that athletes with previous experience might have produced different results.

Regarding the DJ type factor, only BDJ stood out with its muscle pre-activity values which were significantly higher than those in CL and BL. This result was anticipated, given the requirements of the movement task. BDJ requires amortization of impact force, followed by quick and explosive take off, which calls for stiff contractile component enabling utilization of elastic energy stored in the muscle-tendon complex (Finni et al., 2000; Kawakami et al., 2001). It is indicative of the fact that a certain amount of the generated pre-activity in BDJ should be used in performing the take-off.

To determine whether such high pre-activity is related to creation of stable landing conditions or to subsequent reactive muscle activity, further studies are required. In these (BDJ) conditions, higher pre-activity is considered to be related (at least partly) to the take-off phase (not to the breaking phase), or otherwise, the same pre-activity would be achieved for BL, too. Hence, we cannot consider muscle pre-activity merely from the aspect of creating stable landing conditions. Movement characterized by longer phase of amortization before taking off (counter drop jump - CDJ) should be included in further studies. This type of DJ is more demanding in terms of coordination, from the aspect of the muscle force modulation (Bobbert et al., 1987; Bosco et al., 1982). It was assumed that in these conditions higher pre-activity would be used in the contact phase to absorb impact force and create stable conditions during braking phase. Patterns of muscle force development during CDJ should enable the performance of higher rebound, compared to BDJ.

The results imply that A_{max}EMG, as an indirect index of achieved muscle force (Santelo, 2005) is significantly higher for BDJ than for CL in the period before touchdown. This phenomenon was noticed in the majority of observed muscles. Unlike CL, the BL did not show any significant change in muscle pre-activity compared to BDJ. The first important conclusion was that BL was very similar to BDJ in reaching optimal muscle force during flight phase, i.e. in the moments just before the contact with the landing surface.

Significantly higher activity of A_{max}EMG for BDJ compared to BL was noticed only in activity of m.soleus (p = 0.022) and m.tibialis anterior (p = 0.042). High activity of m.tibialis anterior was necessary for building a co-activation mechanism. This mechanism creates a stiff system which provides stability of ankles in the initial stages of contact with the surface (Chimera et al., 2004; Kellis et al., 2003), which may have an adverse impact on take-offs. Earlier studies, however, showed that the activity of m.tibialis anterior changed under the influence of reciprocal inhibition (Kellis et al., 2003). Therefore, we can assume that this mechanism functions during the take-off. The measured values for m.tibialis anterior may also be influenced by the sample of subjects. The soccer players had not been exposed to these training methods prior to the study, and consequently they were not capable of performing adequate patterns of muscle activation, since the motor program had not been created (Kyrolainen and Komi, 1995, Viitasalo et al., 1998).

The height factor proved to be most responsible for determining the pre-activity defined by A_{max}EMG and iEMG. The results of this study confirmed the results of previous studies from the viewpoint that the muscle activity is well adjustable to the change in platform height, where increase in pre-activity followed the increase in platform height (Liebermann and Hoffman, 2005; Santelo et al., 1998; 2001). Change in muscles' electric activity was not the same for all muscles. Therefore, role of each muscle in the preparatory phase for landing should be analyzed separately. There appears to be a general strategy for adapting muscle force to the corresponding platform height, irrespective of anatomical structure and mechanic action of the lower extremity muscles (Santelo, 2005).

Medial head of m.gastrocnemius showed inconsistency in adjusting electric activity to the height. Unlike the medial head, electromyographic response of lateral head showed higher sensitivity to changes of platform height. It was capable of finely adjusting the force of contractile component in pre-contact phase. Since the previous research showed that m.gastrocnemius medialis and m.gastrocnemius lateralis had a separate mechanical function (Wolf et al., 1998), we can conclude that they also have a distinct function in preparing lower leg for a specific movement. Indeed, this conclusion should be verified in future studies.

Change of A_{max}EMG with the increase in platform height was in accordance with the data obtained in previous studies (Santelo, 2005). Statistically significant differences were identified between the values for DJs from 40 cm and 80 cm (Kyrolainen and Komi, 1995; Liebermann and Hoffman, 2005). From the functional point of view, very large impact magnitudes in drops from 80 cm require high muscle force in order to prepare locomotor system for the contact with the surface. Accordingly, the intensity of deep jump trainings should increase gradually. This seems to be the only way to fine tune muscle activity in order to achieve the effects of the exercise. EMG amplitudes of m.tibialis anterior were observed to increase significantly for the 80 cm drop height, as compared to that of 40 cm and 60 cm (table 4). This is another indicator showing that DJ from 80 cm was rather demanding with respect to preparation of neuromuscular mechanism, causing high level of co-activation in these conditions (Kellis et al., 2003; Santelo et al., 2001).

The significant decrease in the activity of m.gastrocnemius medialis for deep jumps from 80 cm, compared to 60 cm was detected for AmaxEMG ($p = 0.029$). The basic task for a subject during deep jumps from 80cm was to provide a level of muscle force which was sufficient to absorb the actual momentum on the contact with the surface. Significant decrease in pre-activity of m.gastrocnemius medialis might be explained to be a compensation for the increase in activity of other two plantar flexors - m.soleus and m.gastrocnemius lateralis. From the mechanical viewpoint, this mechanism was disadvantageous for performing the take-off, and advantageous for stable landing. When ankle is under pressure, all muscles behave synergically. Given that condition, it becomes irrelevant which of the heads has a dominant role. Capability of the CNS to anticipate the moment of landing is inversely proportional to the platform height. The ability to anticipate is not related only to the length of flight, but also to the momentum which a body has on contact with the ground (Santello and McDonagh, 1998). Both values (duration of the flying phase and the momentum which a body has at the moment of touchdown) correlate to the platform height (Santelo et al., 1998). Since the possibility of anticipating the moment of landing is smaller, the stabilization effects are provided by synergetic effect of the lower extremity muscles. Impossibility of anticipating is partly related to the timing of turning the motor units on, and mostly to unsystematic variability of muscle force gained just before the landing (Santelo et al, 2001). The above mechanism affected the ability to take off after landing from higher platforms, because the entire activity of extensors was used solely to perform the landing. Researchers have implied that many motor tasks are controlled by motor system generally (globally), rather than individually (locally) (Santelo, 2005). Under these circumstances, m.triceps surae did not have the ability to determine which of its heads had the stabilization role, and which one provided for the push-off phase. Since m.gastrocnemius medialis and m. gastrocnemius lateralis have independent mechanical functions (Wolf et al., 1998), it could be argued that m.gastrocnemius medialis and m.gastrocnemius lateralis functioned independently in preparation for landing, too.

Pre-activity (iEMG) of m.soleus had a tendency to be sensitive to change from 40 cm to 60 cm ($p = 0.072$), whereas significant pre-activity difference was detected when height was changed from 40 cm and 80 cm ($p = 0.005$). In the semi-flexion phase, when it is necessary to perform explosive movement of the body from one position to another (such as cutting movements and deep jumps), anterior cruciate ligament is at the highest risk of being injured (Griffin et al., 2000; Hewett et al., 1999). M.soleus is agonistic (agonist) to anterior cruciate ligament, and it plays an important role in preventing injuries of passive knee structures (Elias et al., 2003). Increase of the platform height from 40 cm to 60 cm, and from 60 cm to 80 cm, resulted in an increase in body momentum which was likely to cause progressive disturbances in knee. In order to ensure the stiffness of the system, it is necessary to achieve high level of muscle force before landing, especially in the jumps from 80 cm. Considering the role of m.soleus in the stabilization of knee and ankle joints, its activity should mark high values, and most of this muscle's pre-activity might be used to prevent ligament injuries.

Conclusion

The purpose of this study was to determine variability of programmed muscle activity depending on conditions of deep jump. It revealed that change of deep jumps conditions has significant effect on pre-activity modulation. Systematic changes in muscle pre-activity imply great significance of this phenomenon for efficient and effective performance of these movement tasks. Deep jumps from the heights above the optimal are not adequate exercises for fine tuning of the muscle activity for the impact. One of the assumptions of this study was that important training effects, from the aspect of neural component, cannot be achieved in these conditions. Additionally, the initial effects of adjusting neural component to jumping exercises are expected to be generated by practicing landings. This assumption, however, remains to be proven in subsequent studies. Previous studies showed that there was a potential risk of injury in the conditions of lack of adequate amount of pre-activity before the contact with the surface (Elias et al., 2003).

Further studies should investigate whether a muscle activity pattern providing adequate muscle force before landing is likely to improve and what would be the most effective exercises to achieve such improvement. This study included the subjects who were not familiar with deep jumps training and the prospective studies should reveal the results of athletes with previous experience.

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Key points

- Height factor proved to be more relevant for the change in pre-activation level compared to the drop jump type factor.
- There is evident qualitative difference in pattern of pre-activation from lower and higher drop heights, compared to pattern of pre-activation obtained from optimal drop height.
- Drop jumps from the heights above the optimal one are not adequate for nicely preparing muscle activity for the impact.

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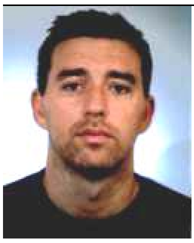

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