THE EFFECTS OF A 6-WEEK OF PLYOMETRIC TRAINING ON ELECTROMYOGRAPHY CHANGES AND PERFORMANCE

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Abstract

The purpose of this study was to compare the effects of depth jump (DJ) and countermovement jump (CMJ) training on sand on electromyography (EMG) changes and performance in healthy subjects. Twenty-seven male collegiate students participated in this study and randomly divided into three groups: DJ, CMJ and control group (CG). Subjects in the DJ and CMJ groups performed 5 sets of 20 repetition jumps from a 45-cm box onto a 20-cm dry sand two days a week for 6 weeks. The EMG activities in the vastus medialis (VM), rectus femoris (RF) and vastus lateralis (VL) muscles, vertical jump (VJ) and 20-m sprint time were assessed pre and post training. The results showed significant increases in the EMG activities (IEMG) for the VM and RF following DJ and CMJ training on sand and compared with control group (P < 0.05). The DJ and CMJ groups showed significant improvement than control group in the VL muscle activities, and no statistically significant differences were found among groups (P > 0.05). The DJ and CMJ training on sand led to significant improvement in VJ and decreases in 20-m sprint time (P < 0.05). In conclusion, the DJ and CMJ training on sand improved EMG activities, power, and sprint performance and it is recommended that, coaches design plyometrics on sand for athletes or individuals, because these types of training on sand can be effective for increasing performance.

Key words: stretch shortening cycle, intense plyometric, motor unit, performance

Introduction

Plyometrics are training techniques used by athletes in all types of sports to increase strength and explosiveness (Chu, 1998). Plyometrics consists of a rapid stretching of a muscle (eccentric action) immediately followed by a concentric or shortening action of the same muscle and connective tissue (Baechle & Earle, 2000). Success in many sports depends heavily upon the athlete's explosive leg power and muscular strength. In jumping, throwing, track and field events and other activities, the athlete must be able to use strength as quickly and forcefully as possible. This display comes in the form of speed-strength or power (Yessia & Haltfield, 1986). Researchers have shown that plyometric training can improve muscular power (Gehri et al., 1998; McClenton et al., 2008; Saez Saez de Villarreal et al., 2008).

Muscle power depends on the amount of nerve stimulation and the number of active motor units. To evaluate the power production mechanism, muscle activities will be studied and compared through direct measurement techniques. Inter-muscular neural adaptations consist of using motor units, the amount of stimulation and intermuscular harmony. A qualitative procedure that can be used with the existing methods and can make needed quantitative measurements is the electromyography (EMG) (Rezaimanesh et al., 2011). It appears that plyometric training on land improved muscle activation and motor unite recruitment during depth jump and maximum voluntary isometric contraction (MVIC) (Chimera et al., 2004; Ebben et al., 2008; Pietrosimone et al., 2009).

Others have recommended that these exercises (e.g., plyometric exercise) be done on sand surface. Plyometric training on sand may increase motor unite recruitment because of the absorptive qualities of sand are likely to increase contraction time and allow the leg extensor muscles to build up active state and force prior to shortening. This can enable subjects to produce more work and force development on sand, than on the land (Bishop, 2003). Unfortunately, no study examined the effects of intense plyometric training on sand on MVIC and muscle power, and the effects of plyometric training especially depth jump and countermovement jump on MVIC, vertical jump and sprint performance are unknown. Therefore, the purpose of this study was to examine the effects of 6 weeks DJ and CMJ training on sand on MVIC (vastus medialis, rectus femoris and vastus lateralis), vertical jump and sprint performance in healthy subjects.

Methods

Subjects: Twenty-seven male collegiate students volunteered to participate in this study and randomly assigned to two treatment groups that performed 2 times per week: depth jump and countermovement jump. A control group of 9 subjects did not train and were tested before and after a 6-week period to assess the reliability of the observations. The subjects were healthy, free of lower body injuries and they had no medical or orthopedic problems. Subjects were carefully informed about the experiment procedures and possible risk and benefits associated with participation in the study and signed an informed consent document before the investigation.
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The Institutional Review Board of the University approved the research protocol. Subjects’ characteristics are displayed in Table 1.

Table 1. Subjects' characteristics (means ± SD)

<table>
<thead>
<tr>
<th></th>
<th>DJ (n = 9)</th>
<th>CMJ (n = 9)</th>
<th>CG (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>20.5±0.7</td>
<td>20.6±0.7</td>
<td>20.4±0.3</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>70.6±5.0</td>
<td>69.5±4.2</td>
<td>69.5±5.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>180.6±7.0</td>
<td>176.5±4.2</td>
<td>174.8±3.0</td>
</tr>
</tbody>
</table>

DJ = depth jump; CMJ = countermovement jump; CG = control group

Plyometric training on sand: The plyometric training programs included 2 days a week for 6 weeks (Thomas et al., 2009). Each training session lasted 35 minutes, including 10 minutes warm-up (e.g., jogging, stretching and ballistic exercises), 20 minutes training (DJ or CMJ), and 5 minutes cooldown (e.g., jogging and stretching exercises). Subjects performed 5 sets of 20 repetitions (Miyama & Nosaka, 2004) of DJ or CMJ with an 8-second interval between jumps. A 2-minute and 72-hour rest period was given between sets and training sessions, respectively. Subjects performed DJ or CMJ onto a 0.2-m-deep dry sand surface from the height of a 45-cm box (Impellizzeri et al., 2008). Subjects in plyometric groups (DJ and CMJ) were instructed to perform exercises in each training session with maximal effort. During the training, all subjects were under direct supervision and were instructed on how to perform each exercise. During the intervention of 6 weeks; DJ, CMJ and CG continued their normal daily activities, and were not allowed to perform any other training (such as: resistance training and or plyometric training) that would impact the results. DJ procedure: Participants began by standing on a 45-cm box and were instructed to lead with one foot as they stepped down from the box and land with two feet on the sand. After sand contact, subjects were instructed to explode off the sand by jumping as quickly and as high as possible (Chu, 1998; Thomas et al., 2009). CMJ procedure: Participants in the CMJ group stopped from the 45-cm box and were instructed to drop on the sand with two feet.

After sand contact, subjects were instructed to flex their knees (countermovement) and then rebound upward in a maximal vertical jump (Chu, 1998; Thomas et al., 2009). EMG measurement: Subjects performed a five-minute warm up on a stationary bicycle at a self-selected pace, and some regular stretching of lower-extremity muscles before the skin was prepared for the application of surface electromyography electrodes. After setting up the instrumentation, a MVIC of vastus medialis (VM), rectus femoris (RF) and vastus lateralis (VL) were measured for subjects’ right legs in sitting position. During the MVIC, their right legs were fixed at 90° of knee flexion and subjects were verbally encouraged to extend their knees as hard as possible for a five-second bout. The better of two maximal effort isometric contractions per muscle were used for statistical analyses. There was a one-minute rest period between trials (Peng et al., 2010).

The EMG signals were acquired using 8-channel electromyography equipment (Muscle Tester ME 3000P8, Mega Electronic Ltd, Finland), consisting of signal conditioner with a band pass filter with cut-off frequencies at 20-500Hz, and amplifier gain of 2000x, and a common mode rejection ratio > 120dB. Pre amplified bipolar superficial electrodes of Ag/AgCl (Skintact®) with an interelectrode (center to center) distance of 20 mm were used. The EMG signal was full wave rectified and integrated (IEMG in µV). In order to achieve an optimal EMG signal and low impedance (< 5 kΩ), two 4 cm² areas of skin were shaved, abraded and cleaned (Chimera et al., 2004; Ebben et al., 2008). The electrodes of VM were located 20% of distance from the anterior superior iliac spine to the midpoint of the medical joint line. The RF electrodes were placed halfway between the greater trochanter and medial epicondyle of the femur. The VL electrodes were placed one quarter of the distance from the midpoint of the lateral line of the knee joint to the anterior superior iliac spine. A common reference electrode was placed over the proximal tibia (Chimera et al., 2004; Ebben et al., 2008; Peng et al., 2010; Fauth et al., 2010). Vertical jump test: This test involves measuring the difference between a person’s standing reach and the height recorded from a jump and reach. The difference between the standing height and the jump height is the vertical jump value. Subjects were instructed to perform two-foot vertical jump and peak vertical jump value was recorded in cm (McClenton et al., 2008). 20-m sprint: The 20-m sprint test was performed on a hard even surface on an indoor track. The subjects had standing start position on the start line, and on command they ran a 20-m sprint as fast as possible over the distance. When they crossed the finish line, the time was stopped on the handheld stopwatch (Joerex, ST4610-2) (Rimmer & Slevert, 2000).

Statistical analyses: All data are presented as mean ± SD. A one-way analysis of variance (ANOVA) was used to determine significant differences among groups. In the event of a significant F ratio, Tukey post hoc tests were used for pairwise comparisons. Paired t-test was used to identify any significant differences between the groups at the pre and post tests for the dependent variables. A criterion a level of P ≤ 0.05 was used to determine statistical significance. All statistical analyses were performed through the use of a statistical software package (SPSS®, Version 16.0, SPSS., Chicago, IL).

Results

There were significant increases in the EMG activities (IEMG) for the VM and RF following DJ and CMJ training on sand and compared with control group (P < 0.05) (Figure 1. A, B). The DJ and CMJ groups only showed significant improvement than control group in the VL muscle activities, and no statistically significant differences were found among groups (P > 0.05) (Figure 1. C). The DJ and CMJ training on sand led to significant improvement in VJ and decreases in 20-m sprint time (P < 0.05) (Figure 2 and 3).
Discussion

The novel approach of this study was to investigate the effects of DJ and CMJ training on sand on EMG activities, VJ and 20-m sprint time. The finding of the present study showed that 6 weeks of DJ and CMJ training increased motor unite recruitment during MVIC in the VM, RF and VL muscles. Also, CMJ training showed significant differences in the VM and RF compared to CG. These findings are not in line with Mehdipour et al’s (2008) study. They examined the effects of 6 weeks plyometric training on RF muscle activity and did not find significant difference. Some of the reasons for such a variety of results may be noted as the difference in type and intensity of exercise. These findings are in line with Rezaimanesh et al., (2011) and Hakkinen et al., (1986) who reported significant changes in the motor unit recruitment and rate of force development for the lower body muscle. It appears that plyometric exercises add much force and tension to muscle cords. Performing such activities or tolerating extreme force and tension may lead to needed physiological or biological changes in muscle cords and other parts of the contraction system and can also cause muscle EMG changes to rise (Rezaimanesh et al., 2011).

The results indicated that plyometric training on sand increased EMG activities. The absorptive qualities of sand are also likely to increase contraction time, thus allowing the leg extensor muscles to build up an active state and force prior to shortening (Bishop, 2003). As sand, is mobile and uneven in nature it may be important to consider the role of postural muscles in relation to the co-ordination required for jumping (Impellizzeri et al., 2008). The compliance of sand surface made it hard for the ankle to push along the vertical axis of the movement of the body and as a result it slipped behind in an attempt to maximize population. As a result, the body tries to balance and equalize this movement and move the hip to larger extension (Giatsis et al., 2004). Perhaps above mechanisms of sand plyometric become effective on the contraction elements and the muscle physiology changes. Also, changes in the IEMG following plyometric training on sand can be increases in firing rate and motor unite recruitment. The CMJ training indicated significant changes than CG. The reason of this result can be mechanical characteristic of exercise. Knee flexion during DJ was lesser than CMJ (30 ° vs. 90 °), and maybe muscle fiber and motor unit did not use properly (Gehri et al., 1998). Overall, plyometric training (DJ and CMJ) on sand can lead to enhance in the rate of force development and motor unite recruitment, and consequently, leg extensor muscle activity increased using IEMG.
The current study indicated that 6 weeks of DJ and CMJ training on sand induced positive effects on VJ, but no significant differences between two modalities of training. These results are in agreement with Thomas et al., (2009) who reported gains in jumping ability after a 6-week of DJ or CMJ training on firm surface in youth soccer players. They also didn’t find any significant differences between DJ and CMJ. Gehri et al., (1998) examined the effects of 12 weeks of DJ and CMJ training on jumping and energy production. They found significant increases in VJ for both training groups. None of the training methods improved utilization of elastic energy. It appears that high intensity plyometrics (e.g., DJ and CMJ) can improve jumping ability in men and women (McClenton et al., 2008; Saez-Saez de Villarreal et al., 2008, 2009). Previous studies recommended that plyometric training drills should be performed on the firm surface, because compliance of surface like sand may reduce elastic energy following plyometric training such as DJ or CMJ (Impellizzeri et al., 2008; Miyama & Nosaka, 2004). In this study, we not only found significant improvements in jumping abilities but also found 15 % increases in VJ for DJ and 13.5 % for CMJ training after 6 weeks of training on sand. A possible explanation for the jump enhancement in the present study could be the rate of force development, stiffness and power enhancement (Kotzamanidis, 2006). Improved muscle performance (VJ) due to a plyometric training program like DJ and CMJ may be in part increased motor unit functioning (McClenton et al., 2008). It has been suggested that DJ and CMJ training are more effective in improving jump performance in stretch shortening cycle jumps because it enhances the ability of individuals to use the elastic and neural benefits of the stretch shortening cycle (Saez-Saez De Villarreal et al., 2009). Another finding of the present study was that DJ and CMJ training improved the results of the 20-m sprint time after 6 weeks of training on sand. These findings are in line with Kotzamanidis (2006) who found significant improvement in sprint (30-m) following 20 sessions (10 weeks × 2 sessions per week) of plyometric training. In contrast of our results, Markovic et al., (2007) examined the effects of 10 weeks plyometric training (e. g., DJ and hurdle jumps) on 20-m sprint time and found no significant changes. Recently, Thomas et al., (2009) compared the effects of DJ and CMJ training on 5, 10, 15 and 20-m sprints, and found no statistically significant improvements. It seems that, the differences in intensity of training, training volume and sample size could be the reason of the discrepancy in results (Markovic et al., 2007). Several studies have suggested that plyometric training may enhance sprint ability because the use of stretch-shortening cycles during DJ and CMJ performance has been shown to have a significant relationship to sprint (Nesser et al., 1996; Saez-Saez De Villarreal et al., 2008). The greatest improvements in sprinting will occur at the velocity of muscle action that most closely approximates the velocity of muscle action of the plyometric exercises employed in training (Rimmer & Sleveret, 2000). Other mechanisms that improved sprint performance could be changes in stride length and stride frequency following plyometric training (Rimmer & Sleveret, 2000; Schmidtbleicher et al., 1988). In conclusion, the results of this study are very encouraging the benefits of DJ and CMJ plyometric training on sand for improving EMG activities, power, and sprint. It is recommended that, coaches design plyometrics on sand for athletes or individuals, because these types of training on sand can be effective for improving performance.

**Literature**


Sažetak

Svrha ovog istraživanja bila je usporedba učinaka treninga skoka u dubinu (DJ) i povratnog skoka (CMJ) u pijesku na elektromiografske (EMG) promjene i rezultat kod zdravih subjekata. U istraživanju je sudjelovalo dvadeset i sedam muških studenata koledža lutano podijeljenih u tri grupe: DJ, CMJ i kontrolnu (CG). Ispitanici u DJ i CMJ grupama izvodili su 5 serija po 20 ponavljanja skokova s kutije od 45-cm na 20-cm suhog pijeska dva dana u tjednu kroz 6 tjedana. Praćene su EMG aktivnosti vastusa medialisa (VM), rectusa femorisa (RF) i vastusa lateralisa (VL), vertikalni skok (VJ) i vrijeme za 20-m sprinta prije i nakon trenažnog procesa. Rezultati su pokazali značajno povećanje EMG aktivnosti (IEMG) za VM i RF nakon DJ i CMJ treninga u pijesku i u usporedbi s kontrolnom grupom (P < 0.05). DJ i CMJ grupe u odnosu na kontrolnu pokazale su značajniji napredak u aktivnosti VL a između njih nije bilo značajnih razlika (P > 0.05). DJ i CMJ trening u pijesku vodi prema značajnom poboljšanju VJ i smanjuje vrijeme kod 20-m sprinta (P < 0.05). Zaključno, DJ i CMJ trening na pijesku poboljšava EMG aktivnosti, snagu i sprintersku izvedbu pa se preporuča da treneri dizajniraju pliometrijski trening na pijesku za sportaše ili pojedince jer ova vrsta treninga može biti učinkovita za povećanje rezultata.

Klíjučne riječi: istezanje skraćenog ciklusa, intenzivna pliometrija, motoričke jedinice, izvedba

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