Effect Of Plyometric Training On Vertical Jump Performance And Neuromuscular Adaptation In Volleyball Player

Dara Hosseini 1
1 Department of Physical Education and Sports SCience, Kurdistan University, Sanandaj, Iran

Abstract
The purpose of this study was to examine the effectiveness of 12-week plyometric training on vertical jump performance (Vj), maximal surface EMG, M-wave amplitude, M-wave latency, and nerve conduction velocity (NCV) in men volleyball player. Thirty junior high school volleyball players' volunteers (age: 17.53± 0.74; Height: 177.67± 3.14; Weight: 61.31 ± 5.32) were divided into plyometric training [PT] (n=15) and control group [c] (n=15). PT group trained s.o. w' but C group didn't participate in this training. Both groups were pre- and post tested in EMG, M-wave parameters, NCV and Vj test. Tow way ANOVA (group*time interaction) and Bonferroni post hoes test demonstrated significant differences (P<0.05) in PT group of pre to post test in VJ performance (9.67 %) and in M-wave latency 16.55 % t ; nerve conduction velocity 14.19 % t ; there is no significant differences in IEMG (4.6 5 % J,) and M-wave amplitude (20.91 % t ), but there is no significant improvement during this period in control group. Comparison between groups after 12wk showed that there was a significant improvement in Latency (16.74 % J,) and NCV (19.10% t ) in PT group during the course of the study than C group (P<0.05). based on the results of this study, it is possible to conclude that coaches and trainers consider PT as a strategy for increasing volleyball players' explosive performance that this may have taken place in neuromuscular responses such as; optimizing motor unites (MU) pattern, optimizing MUs recruitment, augmentation in nerve conduction velocity, decrement in reflex excitability of the motor pool.

Key word: plyometric training, EMG, M-wave amplitude, nerve conduction velocity
Introduction

Successful sporting performance at elite levels of competition often depends heavily on the explosive leg power of the athletes involved. Many team sports also require high levels of explosive power, such as Volleyball, Basketball, Football, and Rugby. Volleyball player rely heavily upon anaerobic energy system to supply energy demands during a match. Successful participation in the volleyball sport requires athletes be able to propel themselves into the air during both offensive and defensive maneuvers. These movements include the jump serve, spike, and block. During the execution of a jump serve or a spike, the player jumps high into the air and strikes the ball at the highest point of their jump in an effort to propel the ball rapidly down towards the opposing side of the net. Defensively, front row players defend against spikes by jumping into the air with their hands raised in an effort to impede the offensive attack (Tillman et al. 2004). Thus, some portion of volleyball training program should be included a training methods for developing muscular power, thereby, plyometrics are a training technique which utilize the stretch-shortening cycle (SSC) to produce energy (Bobbert et al 1996, Cronin et al 2000) for dynamic muscle contraction, and has been shown that to be a vital to the optimal development of explosive performance (Adams, et. al., 1992; Baur, et. al., 1990; Fatouros, et. al., 2000).

Basically a SSC consists of a plyometric muscle action in which an eccentric action immediately precedes a concentric action. The mechanisms involved in concentric enhancement may include: use of elastic energy, a stretch reflex, optimizing muscle length, optimizing muscle activation and muscle activation patterns (Bobbert et al. 1996, Bobbert 2001).

One of the most important issues existing in physiology and sport medicine is adaptation to exercise which includes adaptations among different body’s systems; respiratory system, cardiovascular system, and nervous system, etc. It seems that the most important cases of above is neuromuscular response to exercise. As we know, central nervous system (CNS) controls muscle force by motor unit (MU) recruitment and MU firing rate modulation (rate coding). These tow mechanisms differ based on the different body’s muscle. The possibility of investigation CNS control strategies by surface electromyography (EMG) signal analysis was addressed in previous researches (Walshe et al. 1998; Hakkinen et al. 2003; Aagaard et al. 2000). EMG is considered as a suitable index for illustrating the level of reflex excitability of the motor pool, which, in turn, is dependent on the facilitation of the transmission between the la fibers and α - motor neuron. Ikai and Fukunaga (1970) have been reported that increase in voluntary power at exercised organ relation to non-exercised organ may be related to nervous adaptation.

Previous researches has been shown that EMG to be a significantly higher in endurance performance than anaerobic sports (Rochcongar et al. 1979; Perot et al., 1991; Casabona et al.1990). This result may be related to recruit a large portion of the whole motor pool in
response to the electrically elicited la afferent volley. Also has been shown that reflex excitability is decreased by plyometric training in the rat (AlmeidaSilveira et al. 1996) which induces a decrease in type I soleus fibers, thereby suggesting a relationship between reflex excitability and muscle properties.

Viitasalo and Komi (1981) clearly pointed out that the rise in motor unit activation as measured by EMG is associated with a rise in muscle force. Thus, the rate of force development is largely a function of the nervous system's ability to activate muscle. Typically, high rates of force development are necessary for success in "explosive and high power activities" such as sprinting, throwing and weightlifting.

In the research carried out by Kamen et al. (1984), motor nerve conduction velocity (NCV) of ulnar and posterior tibial nerves were studied in totally 91 athlete and nonathlete individuals that results showed NCV was significantly higher in weightlifters than marathon runners and non-athlete. They concluded that both genetic and environmental factors play important role in determining NCV.

Also, in the research carried out by Westgaard and De Luca (1999) confirmed that motor unit substitution and alternation occurs during submaximal isometric contractions. They speculated that efferent neural command patterns must have knowledge of the previous activation history and temporal variation in recruitment activity and that this substitution phenomenon protected motor units from excessive fatigue during sustained submaximal isometric contractions.

Although, in relation to enhance VJ performance, plyometric training have been helpful (Adams, et al. 1992; Luebbers et al. 2003, Rahimi & Behpur, 2005), but the effects of such training on neuromuscular responses have already received less attention from researchers. Because there is no specific research on the efficacy of plyometric training on neuromuscular responses, the purpose of this study was to examine the effects of plyometric training on vertical jump performance and neuromuscular adaptation in volleyball player.

Methods

Subjects

Thirty men-volleyball player (age: 17.53± 0.74; Height: 177.67± 3.14; Weight: 61.31 ± 5.32), how had a minimum tow-years volleyball training, volunteered to participate in a 12-week plyometric training program. Following a detailed explanation of the tests involved and training programs, the subjects signed a human subject's informed consent form before participating in this study and had completed a medical history questionnaire in which they were screened for any possible injury or illness spatially neuromuscular illness, then subjects based on vertical jump height divided into plyometric training (PT) - (n=15) and control (C) - (n=15) group. PT group participates in 12-week plyometric training, so. W, but C group didn't participate in plyometric training, also both groups had same volleyball training in this period.
that performed after plyometric training protocol.

**Training Program**

Plyometric training program performed in four station each station included 5sets*6repetitions specific plyometric training with medicine ball (MB) and recovery between sets and station was 2-minute. MBs used in this study were selected based on 5% of body weight for each athlete in 1-6 week and increased to 6% of body weight in the next 6-week. *First station:* instructed to subjects hold MB between thighs and performed vertical jump (VJ) and subsequently throw MB with flexion in thigh then get it an flight time with hands, immediately after their foots contacts to the earth again performed another VJ and touch hands to target tools (VJMB). *Second station:* trainer throws MB and subjects get it and performed a pivot (P), immediately, performed tow VJ with MB (PVJMB). *Third station:* subjects performed depth jumps (OJ) from box (70 cm) with MB on hands. *Forth station:* subjects performed depth jumps(OJ) form a box (70cm), trainer throw MB for subject while his on flight time get it with hands and after contact foots to earth immediately performed a vertical jump (OJMB). All subjects were instructed that performed VJ and OJ with their maximum power and try to decrease ground contact time to minimum as possible.

**Maximum voluntary contraction**

The isometric force exerted by the gastrocnemius muscle was measured in a dynamometer previously described. The subjects lay down in the apparatus with hip and knees extend and foot in 125° of dorsi- flexion. A strap attached to the dominate foot in distal to metatarsus phalangeal joint (Wilson, 1994). Subjects instructed to prevent inversion/eversion of foot and flexion of thigh and leg. This test was performed before and after the training period, after determining maximal voluntary contraction (MVC), 50% of MVC was selected to purpose the load used in EMG measuring (Rich, & Cafarelli, 2000). Subjects are required to give a maximal effort over 3 or 4 s periods. Maximal isometric strength tests have particularly high test-re-test reliability (Viitasalo et al. 1980).

**EMG measurements**

Surface Electromyography activity during unilateral isometric contraction (50 % MVC) of the gastrocnemius muscle was recorded form subjects’ dominant leg, when the skin over the muscle had been prepared by shaving, scrubbing and wiping with alcohol, then Bipolar silver-silver-chloride electrodes (1.0 cm diameter, NIHON KOHDEN, Germany) were fixed to the skin with an adhesive patch. Active stability, reference, and the ground electrode's were respectively placed in muscle belly, on junction of the tendon to the gastrocnemius, and one end of ground electrode placed on ankle and the other to the leg table. Electrodes' position were marked on the skin by small ink tattoos, this dotes measured the same electrode
positioning in each test over the 12-week experimental period. Ultimately, waves representing contraction of the motor unit's displayed on the monitor (NIHON KOHDEN, Germany) were amplified, band-pass filtered and sampled at 1000 Hz before being stored (Hakkinen et al. 1998).

**M wave measurements**

Subjects were examined under lay down on the table, with extension on the hip, knee and ankle joint. As in EMG test, active electrode was placed on muscle belly, reference electrode on the junction of the tendon to gastrocnemius muscle, and stimulating electrode was placed on the tibial nerve dominate leg, then tibial nerve was stimulated by using a cathode ball electrode with supper maximal stimulation; the time base was adjusted to 20 ms, sensitivity to 2.0 mV and filters to 10-500 Hz. The signals were amplified and filtered before being stored in a personal computer for later off-line analysis. Then the maximum peak-to-peak amplitude (mV), latency (ms) and NCV (m/s) were used for statistical evaluation. Nerve conduction velocity (NCV) was evaluated by using this formula: NCV= d(m)/t(s), d-distance between stimulating and active electrode (mm), M-wave latency (ms). Electrodes' position were marked on the skin by small ink tattoos, this dotes measured the same electrode positioning in each test over the 12 week experimental period. Ultimately, waves representing contraction of the motor unit's displayed on the monitor were saved and after performing needed measurements were printed.

**Vertical jump measurement**

Vertical jump height was measured by the stand and reach test (Chu, 1996). A vertical jump test was completed from a 2-foot standing position without a step into the jump. The subjects were allowed to use their hands as they desired. Three test jumps were completed, and the highest of these was recorded. This test was selected because it has high validity (0.80) and reliability (0.93) coefficients (Safrit, 1990) and because it allows arm movement and a squat motion before the jump, such as those performed in sports.

**Statistical analysis**

Data are expressed as mean ± SO. Statistical evaluation was performed with SPSS 12.0 for windows and tow way ANOVA (group*time interaction) with Bonferroni post hoes and independent samples t test were used for analyzing data. The alpha level was set at 0.05 in order for a difference to be considered significant.

**Results**

Independent sample t test showed that there is no significant differences between group at pre tests (P<0.05). As has been shown in table 1., tow way ANOVA showed significant
differences between pre and post test plyometric training group in M wave parameters: Latency (ms) [P=0.014, 16.55 % J,] Nerve conduction velocity (rn/s) [ P=0.013, 14.19 % r ] and vertical jump height [P=0.01, 9.67 %1’ ], but there is no significant difference in IEMG (mV/ms) [P=0.586, 4.6 % J,] and Amplitude (mv) [ P=0.068, 20.91 % r ]; and also this test showed that there is no significant differences between pre and post test control group in: IEMG (p=0.559, 2.06 % r ), Latency (p=0.934, 0.66 % r ), Amplitude (p=0.825, 2.23 %J, ) and Nerve conduction velocity (p=0.551, 3.25 % J, ).

But after training period more significant differences in Latency (p=0.015, 16.74 % J, ), NCV (p=0.002, 19.10 %1’) and VJ height (p=0.02, 11.29 %1’) observed in PT group than C group, also there is no significant differences in Amplitude (p=0.1 09, 17.40 % r ) and IEMG (p=0.789, 2.57 % J, ) between tow groups observed (P<0.05), (table 1).

Discussion

It is known that exercise cause structural change in skeletal muscle as well as an increase in excitability of motor units (Hoppeler, 1988), it is appear that plyometrics are the most important for increasing neuromuscular activity due to use of SSC (Kilani et al. 1989). Also it is a popular form of training for improving explosive performance (Adams, et al. 1992; Luebbers et al. 2003) and anaerobic power (Fatouros et al. 2000). However, to our knowledge no studies have addressed for the effects of plyometric training on neuromuscular response in volleyball player.

Our results showed that 12-week plyometric training increased vertical jump performance, this change may have taken place in muscular and/or in neural levels. in this study motor unites activation were measured by EMG and results showed 4.6% decrement in lEMG during isometric contraction (50% MVC) in gastrocnimus muscle after this training program, this training increases the force output of the whole ensemble of the motor unites, thereby compensating for the lower efficacy of the reflex transmission between la spindle afferent input and a -motoneruon (Maffiuletti et al. 2001) and also may be related to FT motor unites excitability level that are not easily excited by la afferent volley. This in line with previous research (Casabona et al. 1990; Almeida-Silveira et al. 1996), that reported power training decrease the relative number of MNs activated by electrically evoked la afferent volley. It is known, that power trained athletes have a predominance of fast-twitch or type II muscle fibers (Clarkson et al. 1980) and has been shown that fast motor unites are less easily excited by the la afferent volley than are slow motor units (Almeida-Silveira et al. 1996), therefore, this findings support that PT have caused decrement in MUs recruitment by altering in MUs activation pattern in the end resultant increase explosive performance by increasing more fast-twitch muscle fibers activation, and 11.29% augmentation in vertical jump height in PT group is confirmed this findings.

In the present study significant decreases (16.55 %) was observed in M wave latency
after 12-wk plyometric training, it can be concluded that this training have had positive effects on the reflex excitability that is in accordance with previous studies (Casabona et al. 1990; Perto et al. 1991). They reported that reflex excitability decrease after explosive training. Also, decrement in M wave latency is accompanied by an augmentation in vertical jump height, which may be accompanied by muscle activation, attributed to the rapid stretch of interfusal muscle fibers an the resultant afferent activation; the latency of the reflex response determines the augmentation to improved VJ height is the result of direct contribution to the motor pool. The improvement observed in explosive performance during the present PT indicate that considerable training-induced changes may have taken place in the voluntary and/or reflex induced rapid neural activation of the motor units of the trained muscles.

Results showed that this training is caused significant increase in nerve conduction velocity (14.19 %) that is accordance with result obtained by Kamen et al (1984) that clearly pointed out that the rise in NCV is related to specific mode of training used, for example athlete was involved in resistance training had significantly higher NCV than endurance athlete. Thereby improvement in VJ performance in PT group may be due to NCVaugmentation.

Although, there is no significant difference in M wave amplitude but results showed that PT results in 17.4% increase in amplitude, this finding is accordance with previous research (Moritan and Devries, 1979).

For many sports, the ability to produce force rapidly may be more important than maximum force production. Rate of force production is a change in force/ change in time. As previously noted, the rate of force development is primarily a function of the rate of increase in muscle activation by the nervous system (Vitasesalo and Komi 1981). The mechanism(s) by which concentric force can be augmented by a previous stretch is not completely clear but involves several possibilities including: a) muscle elastic properties, b) a myototic reflex, c) returning the muscle to its optimum length or d) optimizing the muscle activation pattern (Bobbert 2001). As indicated earlier, volleyball players need a high anaerobic capacity to supply energy demands during a match. Therefore, some portion of the training program of this athlete must involve plyometric training in order for him to improve his performance.

Based on the results of this study, it is possible to conclude that coaches and trainers considered PT as a strategy for increasing volleyball players’ explosive performance that this may have taken place in neuromuscular responses including: optimizing motor unites (MU) pattern (intra-muscular activation), optimizing MUs recruitment, augmentation in nerve conduction velocity, decrement in reflex excitability of the motor pool.
Reference


Ikai, M. and T. Fukunaga, (1970) A study on training effects on strength perunit cross-sectional area of


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### Table 1

<table>
<thead>
<tr>
<th>Jump vertical parameters</th>
<th>Wave M (mV)</th>
<th>EMG Amplitude (mV)</th>
<th>Latency (ms)</th>
<th>NCV (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Training</td>
<td>37.05 ± 8.33</td>
<td>4.53 ± 1.39</td>
<td>5.86 ± 2.27</td>
<td>38.11 ± 15.47</td>
</tr>
<tr>
<td>Post-Training</td>
<td>43.76 ± 5.07*11</td>
<td>3.78 ± 0.75*11</td>
<td>7.41±2.6</td>
<td>36.33 ± 10.52</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Training</td>
<td>36.33 ± 10.52</td>
<td>7.41±2.6</td>
<td>3.78 ± 0.75*11</td>
<td>43.76 ± 8.07*11</td>
</tr>
<tr>
<td>Post-Training</td>
<td>36.52 ± 11.58</td>
<td>6.26±2.75</td>
<td>4.51±1.19</td>
<td>36.63 ± 7.99</td>
</tr>
<tr>
<td>Post-Training</td>
<td>37.29 ± 8.83</td>
<td>6.12±1.49</td>
<td>4.54±0.8411</td>
<td>35.40 ± 5.1311</td>
</tr>
</tbody>
</table>

* Significant differences between pre and post Plyometric group (P<0.05).
| Significant differences between Plyometric and Control group (P<0.05). |

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**Means**

1. **Plyometric**

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**Control**