Original Research Article

Effects of cluster vs. traditional plyometric training sets on maximal-intensity exercise performance

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\textbf{A R T I C L E \ I N F O}

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\textbf{A B S T R A C T}

Objective: The aim of this study was to compare the effects of 6-week cluster versus traditional plyometric training sets on jumping ability, sprint and agility performance.

\textbf{Materials and methods:} Thirteen college students were assigned to a cluster sets group (\textit{N} = 6) or traditional sets group (\textit{N} = 7). Both training groups completed the same training program. The traditional group completed five sets of 20 repetitions with 2 min of rest between sets each session, while the cluster group completed five sets of 20 \((2 \times 10)\) repetitions with 30/90-s rest each session. Subjects were evaluated for countermovement jump (CMJ), standing long jump (SLJ), \textit{t} test, 20-m and 40-m sprint test performance before and after the intervention.

\textbf{Results:} Both groups had similar improvements \((P < 0.05)\) in CMJ, SLJ, \textit{t} test, 20-m, and 40-m sprint. However, the magnitude of improvement in CMJ, SLJ and \textit{t} test was greater for the cluster group (effect size [\textit{ES}] = 1.24, 0.81 and 1.38, respectively) compared to the traditional group (\textit{ES} = 0.84, 0.60 and 0.55). Conversely, the magnitude of improvement in 20-m and 40-m sprint test was greater for the traditional group (\textit{ES} = 1.59 and 0.96, respectively) compared to the cluster group (\textit{ES} = 0.94 and 0.75, respectively).

\textbf{Conclusions:} Although both plyometric training methods improved lower body maximal-intensity exercise performance, the traditional sets methods resulted in greater adaptations in sprint performance, while the cluster sets method resulted in greater jump and agility adaptations.

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1. Introduction

Plyometric training (PT) is a high-intensity training technique that enables athlete’s muscles to generate an elevated strength value in a reduced time, allowing development of very high power values [1]. PT incorporates stretch-shortening cycle muscle action, where energy is stored and muscle spindles are stimulated during the eccentric loading phase to facilitate power production during the concentric phase of the action [1]. This training technique has shown to be very effective for the improvement of jumping, agility, strength, sprint and balance performance in different periods of athlete’s training season [2–6]. However, how to develop optimum PT design is not clear.

The design of optimum PT programs requires the control of training level, type of surface, type of exercises, program duration, volume (sets, repetitions, load), intensity, rest interval between training sessions and between-sets repetitions [1,5,6]. Regarding the latter acute program variable, recently it has been proposed the use of a cluster set configuration of rest intervals between sets-repetitions during PT sessions to facilitate restoration of the metabolic and excitatory cellular environment [7,8] for better management of fatigue during training sessions. Compared to a traditional set distribution of rest intervals, a cluster distribution usually implicates a higher number of shorter rest periods between repetitions or between groups of repetitions (sets), but with similar total training session duration. Thus, a cluster set configuration allows a reduced number of repetitions completed per set, therefore greater muscle power generation at each repetition [9]. In fact, compared to traditional set configuration, cluster set configuration allows greater peak power output, barbell velocity and barbell displacement [7,10]. These improvements have been attributed to the important role of a short rest periods between clusters to allow metabolic recovery resulting in improved kinematics and kinetics in the latter repetitions of the set when compared with traditional sets.

Thus, cluster set configuration allow greater muscle power output when compared to traditional set configuration [7–11], especially in latter repetitions of a training set. Therefore, might be better suited for explosive PT exercises [7,10], allowing greater kinematic and kinetic performance during high velocity movements, which might be related with intramuscular [12] and intermuscular [13] neural adaptations to ballistic performance. However, little is known about the effects of cluster set configuration during lower body PT programs.

Thus, the aim of this study was to compare the effects of cluster set configuration versus traditional set configuration on jumping, sprint and agility performance after six weeks of lower body PT. It was hypothesized a greater increase in jumping, sprint and agility performance with a cluster set configuration after six weeks of lower body PT.

2. Materials and methods

2.1. Participants

Thirteen physically active college students were randomly divided into a cluster set configuration group (N = 6; age 20.5 ± 0.6 years; height 180.1 ± 4.5 cm; weight 78.4 ± 3.6 kg) and a traditional set configuration (N = 7; age 20.2 ± 0.5 years; height 179.6 ± 3.2 cm; weight 79.2 ± 2.8 kg). The participants were familiar with PT and stretch-shortening cycle training, but did not perform this form of training at least six months prior to inclusion in this study. A prior estimated sample size for β = 0.80 with α = 0.05 was calculated based on data from a previous research study [14]. Data on medical history, age, height, weight, injury history and supplementations were collected by means of a questionnaire before participation. All candidates were thoroughly screened by a physician, including the assessment of orthopedic and other conditions that might preclude participation in the study. Participants were found to be in good health, and no history of lower body injury and no history of any lower extremity trauma during the preceding 6 months were found. Before enrollment into the study, the subjects were fully informed about the experimental design, protocol, and a written informed consent was obtained from each subject before testing. The subjects were free to withdraw from the study without penalty at any time. The procedures were approved by the Institutional Ethics Review Committee of the University.

2.2. Study design

This study was designed to compare the effects of cluster set configuration versus traditional set configuration on jumping, sprint and agility performance after 6 weeks of lower body PT. The study was conducted between November and December. All measurements were carried out before and after the training period, including anthropometric and physical performance measurements. To determine the reliability of each test, 10 subjects completed two measurements in two separate (i.e., 48 h) days, 2 weeks before the initiation of the study.

2.3. Testing procedure

Height was measured using a wall-mounted stadiometer (Seca 222, Terre Haute, IN) recorded to the nearest 0.1 cm. Weight was measured to the nearest 0.1 kg using a medical scale (Tanita, BC-418MA, Tokyo, Japan).

Physical performance measurements included countermovement jump (CMJ), standing long jump (SLJ) agility t test, 20-m and 40-m sprint test. One week before physical performance measurements, the participants were familiarized with each test (during this session participants were also familiarized with depth jump exercise). Before physical performance measurements participants completed 10 min of general warm-up exercises (i.e., sub-maximal running, active stretching and jumping) and a specific warm-up (i.e., up to five sub-maximal trials for each maximal-intensity performance measurement). All physical performance measurements were in a single day, always at the same time of day (i.e., 14:00 and 16:00).

2.4. Countermovement jump

To assess the maximum height in a countermovement jump, all trials were performed on a Vertec (Power System, Knoxville, Tennessee) without arms akimbo. The test was begun from an
upright position, making a downward movement to a knee angle of 90° and simultaneously beginning to push-off. Three trials were allowed, each separated by a 1-min rest period. The highest height of the three trials was used in subsequent analyses [2] and expressed in centimeters (cm).

2.5. Standing long jump

For standing long jump measurements, a fiber glass metric tape endorsed to the floor was used. Subjects were instructed to use their arms to aid in the jump, positioning their foot shoulders wide apart and behind the zero point of the tape measure prior to jumping. In addition, subjects were instructed to perform a fast downward movement (approximately 120° of knee angles) followed by a maximal horizontal effort jump, landing with the whole foot surface over the tape measure secured to the floor, bending their knees after landing. Jump distance was measured between the zero point of the tape measure to the point at which the heel of the trial leg touched the ground. Three trials were allowed, each separated by a 1 min rest period [2,15]. The highest jump distance of the three trials was used in subsequent analyses [2] and expressed in centimeters (cm).

2.6. t test

The agility t test (Figure) was applied as previously described [16], to determine change of direction speed (i.e., right and left sides), forward sprinting and back-pedaling. In this test three cones were set 5 m apart on a straight line and a fourth cone was placed 10 m from the middle cone, forming a T shape. The test was performed on a hard surface in an indoor facility. Time was recorded by photocells (JBL Systems, Oslo, Norway) with an accuracy of 0.001 s. Two maximal trials were preformed, with five minutes of rest between trials. The lowest time (i.e., better performance) of the two maximal trials was selected for analysis [16].

2.7. 20-m and 40-m sprint times

The test was conducted on a wooden surface in an indoor facility. The starting position was standardized to a split standing position with the toe of the preferred foot forward and 0.5 m behind the starting line. Sprint start was initiated automatically as the subject passed the first gate at the 0-m mark, triggers the start of timing, with a second gate at 20 m and a third gate at 40 m. Running time was recorded using photocell gates (JBL Systems, Oslo, Norway) with an accuracy of 0.001 s, set approximately 0.7 m above the floor (i.e., hip level) to capture trunk movement and minimize false trigger from a limb. Three maximal trials were performed, with 2-min rest between trials. The lowest time (i.e., better performance) of the three maximal trials was selected for analysis [17].

2.8. Training procedures

Before the beginning of the training program, the participants were instructed regarding the proper execution of the depth jump exercise and all training sessions were supervised. The participants completed all PT sessions between 14:00 and 16:00 (in a resistance training facility).

The PT program was based on recommendations of intensity and volume from Mirzaei et al. [15] and Miyama and Nosaka [18]. From a physiological and psychological standpoint, 6 weeks of maximal intensity depth jump exercise is an optimal length of time for the central nervous system to be stressed without excessive strain or fatigue [19], and to induce neuromuscular adaptations that contributes to explosive power [19]. PT took place twice weekly (Sunday and Wednesday) for both training groups. Each training session lasted 45 min, including 10-min standard warm-up (5 min of sub-maximal running, 5 min stretching exercises, 10 sub-maximal vertical and 10 sub-maximal tuck jumps) and 5 min of cool-down (mainly stretching exercises).

Both training groups completed the same training program, including 100 maximal intensity depth jumps from 45-cm height boxes each training session, however, the traditional group completed five sets of 20 repetitions with 2 min of rest between sets, while the cluster group completed five sets of 20 [2 x 10] repetitions with 30/90-s rest each session. Participants were instructed to maintain their normal daily physical activities and dietary habits throughout the 6-week intervention period, avoiding additional forms of strength or conditioning training. No injuries occurred during training sessions.

2.9. Statistical analysis

Descriptive statistics (mean ± SD) were reported for all dependent variables. The intraclass correlation coefficient (ICC) was used to determine the reliability of the measurements. A 2 x 2 analysis of variance was used to analyze CMJ, SLJ, t test, and sprint measurement data. Effect sizes (ESs) were also calculated using Cohen’s d. Threshold values for assessing magnitudes of ES were 0.20, 0.60, 1.2 and 2.0 for small, moderate, large and very large, respectively [20]. Significance level was set at P ≤ 0.05. The statistical tests were performed using the SPSS statistical package version 16 (Chicago, IL, USA).

3. Results

High reliability (ICC) was observed for all maximal-intensity performance measurements (CMJ = 0.97; SLJ = 0.99; agility t test = 0.98; 20-m sprint test = 0.94; 40-m sprint test = 0.97).
Table 1 – Pre-to-post changes in dependent variables for the cluster and traditional groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cluster group</th>
<th>Traditional group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Countermovement jump (cm)</td>
<td>43.5 ± 4.43</td>
<td>42.71 ± 6.39</td>
</tr>
<tr>
<td>Pre</td>
<td>49 ± 3.82</td>
<td>48.14 ± 7.31</td>
</tr>
<tr>
<td>Post</td>
<td>1.24</td>
<td>0.84</td>
</tr>
<tr>
<td>% of change</td>
<td>12.64</td>
<td>10.1</td>
</tr>
<tr>
<td>Standing long jump (cm)</td>
<td>201.2 ± 15.4</td>
<td>192 ± 20.8</td>
</tr>
<tr>
<td>Pre</td>
<td>213.7 ± 14.3</td>
<td>204.7 ± 19.5</td>
</tr>
<tr>
<td>Post</td>
<td>0.81</td>
<td>0.60</td>
</tr>
<tr>
<td>% of change</td>
<td>6.2</td>
<td>6.2</td>
</tr>
<tr>
<td>t test (s)</td>
<td>11.31 ± 0.73</td>
<td>11.06 ± 1.66</td>
</tr>
<tr>
<td>Pre</td>
<td>10.30 ± 0.82</td>
<td>10.14 ± 0.52</td>
</tr>
<tr>
<td>Post</td>
<td>1.38</td>
<td>9</td>
</tr>
<tr>
<td>% of change</td>
<td>0.55</td>
<td>8.31</td>
</tr>
<tr>
<td>20-m sprint (s)</td>
<td>3.46 ± 0.22</td>
<td>3.54 ± 0.14</td>
</tr>
<tr>
<td>Pre</td>
<td>3.24 ± 0.14</td>
<td>3.11 ± 0.44</td>
</tr>
<tr>
<td>Post</td>
<td>0.94</td>
<td>1.59</td>
</tr>
<tr>
<td>% of change</td>
<td>6.35</td>
<td>12.14</td>
</tr>
<tr>
<td>40-m sprint (s)</td>
<td>6.29 ± 0.61</td>
<td>6.33 ± 0.62</td>
</tr>
<tr>
<td>Pre</td>
<td>5.82 ± 0.40</td>
<td>5.73 ± 0.53</td>
</tr>
<tr>
<td>Post</td>
<td>0.75</td>
<td>0.96</td>
</tr>
<tr>
<td>% of change</td>
<td>7.47</td>
<td>9.47</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation. ES, effect size. * Significant differences between baseline and posttraining values (P ≤ 0.05).

No significant group by time interaction were observed after plyometric training for the CMJ (F = 0.006, P = 0.942), SLJ (F = 0.002, P = 0.965), t test (F = 0.13, P = 0.91), 20-m (F = 1.93, P = 0.198) and 40-m (F = 0.319, P = 0.586) sprint. Compared with pre-test values, greater performance values were observed after plyometric training for both training groups in CMJ (F = 132.088, P = 0.001), S/LJ performance (F = 28.989, P = 0.001), t test (F = 5.89, P = 0.038), 20-m (F = 137.604, P = 0.002) and 40-m (F = 20.05, P = 0.002) sprint times (Table 1).

4. Discussion

The result of this study indicates that after 6 weeks of PT the cluster and the traditional training groups had similar maximal intensity performance adaptations in the countermovement jump (ES = 1.24 and 0.84, respectively), standing long jump (ES = 0.81 and 0.60, respectively), t test (ES = 1.38 and 0.55, respectively), 20-m (ES = 0.94 and 1.59, respectively) and 40-m sprint times (ES = 0.75 and 0.96).

The positive effects of short-term (i.e., 6 weeks) PT on jumping ability such as CMJ and SLJ have been previously supported [2,15,19,21,22]. However, a novel finding from this study was to similar improvements in the cluster and the traditional PT groups. The positive effects of PT observed in both groups may be explained mainly by neural adaptations (e.g., improved intermuscular coordination, changes in the muscle-tendon mechanical-stiffness characteristics, changes in muscle architecture, changes in single fiber mechanics, greater ability to use the muscles stretch-shortening cycle) rather than to morphological changes (e.g., fiber size) [2,15,21,22].

Another novel finding from this study was the similar improvement of agility t test performance for both the cluster and the traditional PT groups. Although, some studies have found no effect of PT on agility performance [23,24] measured by the 505 test and the shuttle run test, when agility was measured with test similar to the one used in this study, significant improvements in agility were observed after PT [2,4,15,16]. An increased agility after PT may be explained by greater muscles power output and force development ability [2,4], achieved by neuromuscular adaptations such as greater motor unit recruitment [1,4,15,16]. Moreover, PT may increase eccentric strength of the thigh muscles, reduce foot contact time with ground through increased muscular force output [22,25,26], improve the rate of force development and, the ability to efficiently utilize the stretch-shortening cycle in ballistic movements [1,3,15], key elements for agility tasks.

Both PT groups improved sprint performances, with no significant differences between groups. Similar results have been previously reported after PT [5,15,17,23]. However, no significant improvements in sprint performance after PT have been reported [27,28]. This discrepancy could be explained due to reduced horizontal PT exercises in the latter studies (i.e., poor training specificity for horizontal sprints). In the current study PT program included drills with an emphasis on stride length and stride frequency (i.e., skipping, jumping with horizontal displacement), key for sprint performance enhancement [5].

Aside from training frequency, the increased sprint performance may be related to improvements in explosiveness (i.e., vertical and broad jump) [15,29] and or reduced ground contact times [24]. Moreover, as PT increases strength [15,19] and lower body strength is positively transferred to sprint performance [29], the increased sprint performance may also be related with improvements in muscle strength.

5. Conclusions

Cluster and traditional plyometric training sets improve jumping, agility and sprint performance. In addition, the improved maximal-intensity exercise performances occur after a short-term (i.e., 6 weeks) for both the cluster and the traditional PT groups. It is recommended that coaches incorporate PT in the athletes’ regular training schedule improving maximal-intensity exercise performance adaptations. Also, current results have considerable practical relevance for the optimal design of PT programs (with cluster or traditional sets configuration), offering valuable information for more efficient improvements of muscular performance of the lower extremities. To what extent the present results are also applicable to more experienced trained athletes deserves further attention. Notably, no dropouts attributable to injury or injury symptoms were experienced in treatment groups throughout the training period.
Conflict of interest

All authors state that they have no any conflict of interest.

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