Effects of Lower Body Plyometric Training on Vertical Jump Performance and Pulmonary Function in Male and Female Collegiate Volleyball Players

Usman T & K B Shenoy*1
Department of Applied Zoology, Mangalore University,
Mangalagangotri- 574199, Mangalore, Karnataka, India.

Article history: Received May 2015; accepted August 2015

Abstract

Purpose: Plyometric exercises increase the speed of muscular contraction and elevates athletic prowess. The purpose of this study was to assess the effects of lower body plyometric training on vertical jump performance and pulmonary function in male and female collegiate volleyball players.

Methods: The programme was conducted twice a week, for an 8- week period on a group of 120 male and female collegiate volleyball players, 18-22 years of age. The samples were divided into four equal groups. All the players were tested for vertical jump height (VJH), forced vital capacity (FVC), and forced expiratory volume in one second (FEV1), using Sargent jump test and pulmonary function test prior to starting the training programme. Assessments were done at the end of 2, 4, 6, and 8 weeks of training period.

Result: The findings of the study showed significant change in vertical jump height, forced vital capacity, and forced expiratory volume in one second, at the end of 2 weeks onwards, and the highest response was obtained at the end of 8 weeks. The effect was significantly higher as compared to the control group (P<0.05), and male players showed greater improvement than females.

Conclusion: From the study, it can be concluded that lower body plyometric training twice a week, for 8 weeks showed significant improvement in vertical jump performance and pulmonary function in both male and female collegiate volleyball players.

Key words: Forced vital capacity; Forced expiratory volume in one second; Vertical jump height.

1* Mailing Address
Department of Applied Zoology, Mangalore University
Mangalagangotri- 574199, Mangalore, Karnataka, India
Email address: kshenoyb@gmail.com
Tel : +91- 8242284750, Mob : +91- 9449822657, Fax : +91-8242287367
Introduction

Volleyball is one of the most popular team sports, which is widely played and viewed all over the world. The ultimate aim of all athletes is to perform well in their sport. Leg muscle power, especially for the vertical jump performance, is a critical element for a successful athletic performance.\textsuperscript{1,2,3} Although various training methods have been effectively used for the improvement of vertical jump performance, plyometric training as an alternative method has been common in athletic training for several years to enhance vertical jump ability and leg muscle strength.\textsuperscript{4,5,6,7}

Plyometric exercises encompass a rapid stretching of muscles, which involve a high intensity eccentric contraction, immediately after a rapid and powerful concentric contraction.\textsuperscript{8} The lower body plyometric exercises include performance of various types of body weight jumping exercises.\textsuperscript{9} The effects of plyometric on vertical jump ability have been extensively studied; however, the studies reflected conflicting findings. Some studies showed enhancement in jumping performance and in neuromuscular control and balance while landing with plyometrics.\textsuperscript{10,11,12,13,14,15,16,18,19} Meanwhile, numerous studies reported no effect or negative effects of plyometric training on vertical jump height.\textsuperscript{20,21,22} Lehnert \textit{et al.}\textsuperscript{23} conducted a plyometric training programme for a group of female youth volleyball players twice a week during an eight-week period and reported that plyometric exercises were an effective tool in the development of explosive power and speed in young athletes. A six-week plyometric training, with 2-3 sessions per week, made significant contribution to jumping agility.\textsuperscript{24} A four-week plyometric training can improve the single leg vertical jumping ability and overall power endurance ability of basketball players.\textsuperscript{25}

Respiratory muscle strength and good lung functions are equally important factors from an athlete’s point of view. Several studies have shown significant improvement in pulmonary functions as a result of exercises. Cedric \textit{et al.}\textsuperscript{26} investigated the effects of short duration running training on resting and exercise lung function in healthy prepubescent children and reported that eight weeks of high intensity intermittent running training enhanced resting pulmonary function and led to deeper exercise ventilation reflecting better effectiveness in prepubescent children. Engaging in daily physical activity or sport can help in achieving better pulmonary function.\textsuperscript{27} Various studies strongly suggest that the intensity or severity of the sports engaged in by the athletes probably determines the extent of strengthening of the respiratory muscles with a resultant increase in the lung volume. However, there is insufficient data on the effect of plyometric exercises on lung functions.

Therefore, the present study was conducted to assess the effects of lower body plyometric training on vertical jump performance, and also, on pulmonary functions in male and female collegiate volleyball players.
Materials and Methods

Participants

The study was carried out on a group of collegiate male and female volleyball players for an eight-week period (n=120; average age 19.2± 0.8; height 176± 8 cm; weight 66± 6 kg). The samples were recruited for the study only after approval from the institutional ethical committee, and also, written consent form was signed by all the players, prior to participating. None of the players had previously undergone plyometric training or were involved in professional sports. They had no history of any musculoskeletal, neurological, and cardio-pulmonary impairments, and had no recent injuries. The players were divided randomly into four groups with thirty players in each group.

Group I: Male players’ experimental group

Group II: Male players’ control group

Group III: Female players’ experimental group

Group IV: Female players’ control group

Training protocols

The players of the experimental groups (male and female) had two months of preparatory training programme and an orientation about the principles and techniques of lower body plyometrics, whereby, they became familiar with the techniques of plyometric exercises. The exercises were performed as per the guidelines described in High powered plyometrics by Jim28. The players of training groups underwent a ten minutes warm up protocol (Jogging, Static stretching, Calisthenics and Breathing exercises) prior to start of lower body plyometric training programme and the session was ended up with an eight minutes cool down activities (Brisk walking, Calisthenics and Breathing exercises). The lower body plyometric exercises were initiated with low intensity plyometrics (Squat Jumps and Jump to box) consisted of 3 sets of 10 repetitions, followed by moderate intensity plyometrics (Tuck Jumps, Split Squat Jumps and Lateral Hurdle Jumps) consisted of 3 sets of 8 repetitions and finally the high intensity plyometrics (Zigzag Jumps, Single Leg Tuck Jumps and Depth Jumps) consisted of 3 sets of 6 repetitions. The training programme was performed twice a week (Monday and Wednesday) for an eight-week period. The resting period between the exercise series was 1-2 minutes for low intensity, 2-3 minutes for moderate intensity and 3-5 minutes for high intensity plyometrics, with a rest of 5-10 seconds between repetitions (Table 1). The box height for low intensity exercise (Jump to box) and the high intensity exercise (Depth Jumps) was maintained at 30cm and 80 cm respectively. The volume and duration of the exercises were maintained constant throughout the training period. The players of the control group had not performed any kind of plyometric or strenuous exercises other than their routine volleyball training. All the players were tested for vertical jump height (VJH), forced vital capacity (FVC), and forced expiratory volume in one second (FEV1) using Sargent Jump Test29 and Pulmonary Function Test30, 31 respectively prior to the start of the training programme. The assessments were made at the end of 2, 4, 6, and 8 weeks of the training period. A spirometry device ‘nspire’ made by Nspire Health Ltd. (a computerized self-calibrating spirometer, which fulfills the criteria for standardized lung function tests) was used to analyze the lung mechanics (i.e., FVC and FEV1). FVC is the volume of air that can be forcibly blown out after full inspiration and FEV1 is the volume of
air that can be forcibly blown out in one second after full inspiration; both were measured in liters and the test scores were compared with the predicted normal values in percentage. The vertical jump height of the players was measured in centimeters for the difference in distance between the reach height and the jump height with a standard measuring tape.

Lower body plyometric training protocol performed by male and female experimental groups shown in Table 1.

<table>
<thead>
<tr>
<th>SL NO</th>
<th>Plyometric Drills</th>
<th>Intensity</th>
<th>Rest between repetition</th>
<th>Rest between set</th>
<th>Set</th>
<th>Jumps/ Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Squat jump</td>
<td>Low</td>
<td>5 second</td>
<td>1-2 minutes</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Jump to box</td>
<td>Low</td>
<td>5 second</td>
<td>1-2 minutes</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Tuck jump</td>
<td>Moderate</td>
<td>5 second</td>
<td>2-3 minutes</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Split squat jump</td>
<td>Moderate</td>
<td>5 second</td>
<td>2-3 minutes</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>Lateral hurdle jump</td>
<td>Moderate</td>
<td>5 second</td>
<td>2-3 minutes</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>Zigzag jump</td>
<td>High</td>
<td>10 second</td>
<td>3-5 minutes</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>Single leg tuck jump</td>
<td>High</td>
<td>10 second</td>
<td>3-5 minutes</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>Depth jump</td>
<td>High</td>
<td>10 second</td>
<td>3-5 minutes</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

Statistical analysis

All the data was presented as Mean ±SD. Statistical analysis was calculated via a two way ANOVA with post hoc analysis by Bonferroni test. The significance level was set at \( P < 0.05 \). With the help of the following formula, effect sizes (Cohen’s d) were calculated: effect size = \((1 - \mu_2)/\text{SD pooled}\), where 1 and 2 represent the means in each condition, and the SD pooled was calculated using \(\sqrt{(\text{SD}1^2 + \text{SD}2^2)/2}\). The interpretation of effect sizes was based on Hopkins criteria, where 0.2, 0.6, 1.2, and > 2.0 represented small, medium, large, and very large effect sizes, respectively.\(^{32}\)

Results

Table 2 shows the effect of vertical jump performance. At the earliest, a major, important, noteworthy change in vertical jump height (VJH) was seen at the end of 2 weeks in both male and female players \(P<0.05\), and these changes increased significantly with the training duration. The highest response was observed at the end of 8 weeks. The effect was significantly higher as compared to the control group \(P<0.05\). The change in VJH after exercise was significantly higher in males as compared to females from 4-week onwards \(P<0.05\), signifying that the effect of exercise was more on males than on females (Fig.1).
Effects of lower body plyometrics on vertical jump height in male and female volleyball players at different time points are shown in Table 2.

<table>
<thead>
<tr>
<th>Groups</th>
<th>VJH at the different time points (in centimeter)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
</tr>
<tr>
<td>Group I (Male experimental)</td>
<td>56.23±1.28</td>
</tr>
<tr>
<td>Group II (Male control)</td>
<td>56.67±1.17</td>
</tr>
<tr>
<td>Group III (Female experimental)</td>
<td>42.19±0.85</td>
</tr>
<tr>
<td>Group IV (Female control)</td>
<td>42.11±0.98</td>
</tr>
</tbody>
</table>

Mean ± SD of 30 subjects in each group. *p <0.001 (Highly Significant), when compared with baseline (Within group comparison Pre V/s Post) *p <0.001 (Highly Significant) when compared between groups (Group I V/s Group II) and (Group III V/s Group IV). Two way ANOVA with post hoc analysis by Bonferroni test were applied for comparison.

Fig.1: Comparison of mean change in vertical jump height within male and female players of experimental groups.

Table 3 shows the results of the lung functions. Significant change in FEV₁ and FVC were observed at the end of 2 week in both male and female players, and these significant changes improved with the training duration. The maximum effect of the training programme was obtained at the end of 8 weeks. The effect was higher in both male and female players as compared to the control group (P< 0.05). The change in FEV₁ and FVC after exercise was significantly higher in males as compared to females from 2- week onwards (P< 0.05), which showed that the effect of the training programme was more on males compared to females (Table 4).
Effects of lower body plyometrics on lung function (FEV$_1$ and FVC) in male and female volleyball players at different time points are shown in Table 3.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Parameter</th>
<th>FEV$_1$ and FVC at the different time points (in liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Baseline</td>
</tr>
<tr>
<td>Group I (Male experimental)</td>
<td>FEV$_1$</td>
<td>3.50±0.02</td>
</tr>
<tr>
<td></td>
<td>FVC</td>
<td>4.18±0.02</td>
</tr>
<tr>
<td>Group II (Male control)</td>
<td>FEV$_1$</td>
<td>3.52±0.02</td>
</tr>
<tr>
<td></td>
<td>FVC</td>
<td>4.22±0.03</td>
</tr>
<tr>
<td>Group III (Female experimental)</td>
<td>FEV$_1$</td>
<td>3.38±0.02</td>
</tr>
<tr>
<td></td>
<td>FVC</td>
<td>4.13±0.01</td>
</tr>
<tr>
<td>Group IV (Female control)</td>
<td>FEV$_1$</td>
<td>3.39±0.01</td>
</tr>
<tr>
<td></td>
<td>FVC</td>
<td>4.13±0.03</td>
</tr>
</tbody>
</table>

Mean ± SD of 30 subjects in each group. *$p$ < 0.001 (Highly Significant) when compared with baseline (Within group comparison Pre V/s Post) # $p$ < 0.01 (Highly Significant) when compared between groups (Group I V/s Group II) and (Group III V/s Group IV). Two way ANOVA with post hoc analysis by Bonferroni test were applied for comparison.
Comparison of Mean change in lung functions (FEV₁ & FVC) within male and female volleyball players are shown in Table 4.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Parameter</th>
<th>Mean change (FEV₁ &amp; FVC) at the different time points (in liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2 weeks</td>
</tr>
<tr>
<td>Group I (Male</td>
<td>FEV₁</td>
<td>0.08 ±0.08*</td>
</tr>
<tr>
<td>experimental)</td>
<td>FVC</td>
<td>0.06 ±0.06#</td>
</tr>
<tr>
<td>Group III (Female experimental)</td>
<td>FEV₁</td>
<td>0.02 ±0.01</td>
</tr>
<tr>
<td></td>
<td>FVC</td>
<td>0.03 ±0.00</td>
</tr>
</tbody>
</table>

Mean ± SD of 30 subjects in each group. *p <0.001 (Highly Significant) and # p <0.05 (Significant) when compared between groups (Group I V/s Group III).

According to the age, sex, height, and weight of the players, the baseline values of FEV₁ and FVC were normal compared to the predicted normal values. The percentage of predicted values of the players were compared and analyzed with the percentage values obtained after the eight-week training programme, and the results showed that the percentage of FEV₁ and FVC after the eight-week training were substantively significant in both male and female players of the experimental groups as compared to the control groups (Fig 2).

Fig.2: Percentage of FEV₁ and FVC of male and female players of experimental groups at predicted and changes after 8 week training.
Discussion

To our knowledge, this might well be the first study to provide information on the effects of lower body plyometric training on vertical jump performance with lung functions in male and female collegiate volleyball players. The results of the study proved that lower body plyometric training provides both, statistically significant and practically relevant enhancement in vertical jump performance and lung functions with large effect size of 4.8 in males and females at the end of 8 weeks. The study also suggests that the effects of lower body plyometric training are likely to increase with the training duration.

Our study results are in line with the published results, which concluded that plyometric training improves vertical jumping ability. In a meta analysis by Markovic.33 the eccentric muscle contraction quickly followed by concentric contraction of the same muscle(s) are responsible for increased muscle recruitment, which allows force production to be maximized during the concentric action.

Interestingly, the results of the present study also visualized a higher gain in male players as compared to females, which is similar to the study conducted by De Villarreal et al. They reported that the causes for this differentiation were not very clear, but it could be proposed that males generate more power output and better co-ordination than females.

It is important to mention that the eight-week lower body plyometric training results also found significantly higher improvement in FEV₁ and FVC, in both male and female players. These higher values could be attributed to better strengthening of respiratory muscles as a result of physical training. Fanta et al.36 conducted a study to find whether normal subjects could increase their vital capacity by appropriate training and concluded that in response to appropriate training stimuli inspiratory muscles can contract to shorter minimal lengths.

Other studies comparing respiratory function among men engaged
in various sports, found that sportsmen have higher levels of function than sedentary people. Among the various groups of participants, swimmers had the maximum lung function in this cross-sectional study. In another cross-sectional study, male and female swimmers had larger FEV₁ values than both land-based athletes and sedentary controls.

In terms of practical application, the present study demonstrated that the effects of plyometric training could vary because of a number of variables that included training programme design, determination of subjects (gender), and type and duration of the training programme. These factors are important and should be taken into account by the athletes to get optimum benefits of the plyometric training. The findings of the present study also highlighted that plyometric training should be specific to the athlete’s sport. Lower body plyometric training should be more sports’ specific for athletes like volleyball players.

**Conclusion**

In conclusion, the present study highlights that eight weeks lower body plyometric training with constant volume and duration, significantly enhances vertical jump height and lung functions of male and female collegiate volleyball players. The observed mean effect was more than 10% and could be considered as practically relevant. From this perspective, lower body plyometric training can be recommended as an effective form of physical conditioning for augmenting the vertical jump performance of male and female volleyball players, and also, for other athletes involved in sports with vertical jump performance. Keeping in mind the importance of increased leg muscle power and lung functions in an athlete’s performance, the vital findings of this study should be taken into account by the sports professionals to get the optimum benefits of plyometric training.

**Acknowledgments**

The authors would like to thank the players for their participation. No funding was received for this study.

**References**

7. Markovic, G., Jukic, I., Milanovic, D. et al. Effects of sprint and
24. Stojanovic, N., Jovanovic, N., Stojanovic, T. The effects of plyometric training on the


