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Research Article / Araştırma Makalesi

Combined and comparative effects of plyometrics and dynamic stretching on vertical jump in volleyball players

Voleybol oyuncularında pliometriklerin ve dinamik germe egzersizlerinin kombine ve karşılaştırmalı etkileri

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ABSTRACT

Objective: Aim of this study was to investigate the combined and comparative training outcomes of plyometrics and dynamic stretching of lower limb muscle groups on vertical jump performance in male and female collegiate volleyball players.

Materials and Methods: The study was carried out as two training sessions in a week, for eight weeks duration. The total number of participants was 90 male and 90 female collegiate volleyball players aged 18-22 years. All the participants were recreational players and they were playing one hour daily in the evening. They were randomly distributed into three male groups (Group 1, Group 2 & Group 3) and three female groups (Group 4, Group 5 & Group 6) with 30 participants in each group. All the participants underwent Sargent vertical jump performance test before starting the training session it was repeated in every two weeks of training program.

Results: Plyometrics and plyometrics with dynamic stretching led to significant improvements in vertical jump height (VJH), and this improvement was progressed after every two weeks of training. However, the control groups did not display any improvement. The effect of training was significantly higher in male and female groups who have performed plyometrics with lower limbs dynamic stretching as compared with the groups that performed only plyometric exercises ($p<0.05$). Compared to females, male participants had a better improvement of VJH in both training groups ($p<0.05$).

Conclusion: It can be concluded that two sessions of plyometric exercise training per week for eight weeks can improve the ability of VJH in male and female collegiate volleyball players. However, combined training of lower body plyometrics and lower limbs dynamic stretching had better results in terms of vertical jump performance.

Keywords: *Dynamic stretching, plyometrics, vertical jump, volleyball*

ÖZ

Amaç: Bu çalışmanın amacı erkek ve kadın voleybolcularda alt ekstremite kas gruplarının dinamik gerdirme ve pliometrik egzersizlerinin kombine ve karşılaştırmalı sonuçlarının dikey sıçrama performansı üzerindeki etkilerini araştırmaktır.

Gereç ve Yöntem: Çalışma, sekiz hafta boyunca haftada iki antrenman seansı olarak gerçekleştirildi. Toplam katılımcı sayısı 18-22 yaşları arasında 90 erkek ve 90 kadın kolej voleybolcuydu. Tüm katılımcılar rekreatif sporcuydu ve günlük rutin oyunları akşamları günde bir saatti. Rastgele üçer gruba (erkek) (Grup 1, Grup 2 ve Grup 3) ve (kadın) (Grup 4, Grup 5 ve Grup 6) ayrıldılar, her grupta 30 katılımcı yer aldı. Altı grup katılımcısının tümüne antrenman seansına başlamadan önce Sargent dikey sıçrama performans testi uygulandı, her iki haftalık antrenman programından sonra test tekrarlandı.

Bulgular: Hem erkek hem de kadın gruplarında, iki haftalık pliometrikler ve dinamik germe antrenmanları ile dikey sıçrama yüksekliğinde (VJH) önemli iyileşme görüldü ve bu iyileşme sekiz hafta boyunca her iki haftalık antrenman sonrasında arttı. Ancak kontrol grupları herhangi bir gelişme göstermedi. Alt ekstremite dinamik germe ile pliometrik egzersizleri yapan erkek ve kadın çalışma gruplarında antrenmanın etkisi yalnızca pliometrik egzersizleri yapan gruplara göre anlamlı olarak daha yüksekti ($p<0.05$). Kadınlarla karşılaştırıldığında, erkek katılımcılarda her iki antrenman grubunda da VJH daha iyi gelişim gösterdi ($p<0.05$).

Sonuç: Sekiz hafta boyunca haftada iki seans pliometrik egzersiz eğitiminin erkek ve kadın kolej voleybolcularında VJH yeteneğini geliştirebileceği sonucuna varılabilir. Bununla birlikte, alt vücut pliometrik egzersizleri alt ekstremite dinamik gerdirmeleri ile kombine edildiğinde dikey sıçrama performansı açısından daha iyi sonuç alınmaktadır.

Anahtar Sözcükler: *Dinamik gerdirme, pliometrikler, dikey sıçrama, voleybol*

INTRODUCTION

Lower body explosive power performance is an essential part of many athletic activities, especially for the vertical jumps in volleyball. Plyometric exercises are among the most common techniques in volleyball trainings (1). These exercises are performed to improve muscular activities (2).

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In plyometric exercises, muscles undergo a fast and sudden lengthening followed by a shortening mechanism, utilizing the elastic energy stored during the stretching phase (3). The main benefit of plyometric training is that it enhances functional power and enables muscle fibers to reach a higher level of power output than with maximum volitional strength (4). It also reduces the reflex inhibition action of muscles, elevates the Golgi tendon organ sensitivity, increases muscle spindles sensitivity, generates muscle tension and reduces injury risk (5,6).

The effects of plyometric exercises may differ with dynamic stretching of muscles (7). Dynamic stretching enhances the speed and power of muscle contraction, and also improves the endurance, balance, co-ordination and mental preparedness (8). These beneficial effects of dynamic stretching are considerably due to the increased neuromuscular function (9).

Studies on plyometric exercise have reported to enhance explosive effects of muscle power output (10). Some studies have revealed significant improvement in vertical jump height (VJH) after dynamic stretching exercises (11). However, relevant data regarding the comparative effects of plyometrics alone and combined with dynamic stretching on VJH with gender differentiation is not sufficient. Hence, the current study has been carried out to assess outcomes based on gender differentiation and these training modalities.

MATERIALS AND METHODS

Participants

The present study was conducted with 90 male (average age 19.6±0.9 years; height 176±8 cm; body weight 66±6 kg) and 90 female (average age 19.2+0.9 years; height 168±6 cm, body weight 62±6 kg) college student volleyball players for a period of eight weeks. All the participants were recreational players and their daily routine play was one hour in the evening. The recruitment of all participants was carried out only after ethical committee approval of the institution (YMCH/EC-28/17, dated 24.03.2017). All the recruited participants signed a written consent form before starting the study program. None of the participants had attended any type of plyometric training before. All the participants were without any comorbidities and pregnancy, including negative history of any recent injuries and any musculoskeletal or neurological impairments. All the participants were randomly divided into control and experimental groups with 30 members in each group accordingly:

Group 1 : Male control group

Group 2 : Male plyometric group

Group 3 : Male plyometrics with dynamic stretching group

Group 4 : Female control group

Group 5 : Female plyometric group

Group 6 : Female plyometrics with dynamic stretching group

Experimental Design

Players of the experimental groups underwent a preparatory training program about the rules and regulations of plyometric exercises and dynamic stretching of lower limb muscles before starting the actual training program. Apart from routine daily tasks, the experimental groups of plyometric training (Groups 2 & 5) underwent a lower body plyometric training program and the experimental groups of plyometrics with dynamic stretching (Groups 3 & 6) underwent an additional training of lower body dynamic stretching prior to plyometric exercises. The control groups (Groups 1 & 4) just performed the usual volleyball session and did not undergo any specific training program.

Plyometric Exercise Training Protocols

Protocols of plyometric exercise training were adopted from the guidelines given by James and Robert (12) (Table 1). It was started with low intensity exercises (squat jump & jump to box) consisting of three sets of 10 repetitions (reps), followed by moderate intensity plyometrics (tuck jump, lateral hurdle jump & split squat jump) involving three sets of eight reps and ended up with high intensity exercises (zigzag jump, single leg tuck jump & depth jump) consisting of three sets of six reps. A rest period between the exercise sets were given as 1-2 minutes for low intensity plyometrics, 2-3 minutes for moderate intensity plyometrics and 3-5 minutes for high intensity exercises. The rest period between each repetition was 5-10 seconds, and that between exercise series was 10 minutes. The height of box for performing the low and high intensity plyometrics were 30 cm and 80 cm respectively.

Protocols of Dynamic Stretching

The protocols of dynamic stretching were adopted from Yamaguchi and Ishii (Table 2) (7). The participants of groups 3 & 6 carried out dynamic stretching exercises prior to plyometric exercises for various lower limb muscle groups mainly responsible for vertical jump performance; the gluteal muscles, muscle groups of hip adductors, quadriceps muscles, muscle groups of hamstrings and calf muscles. As per the protocols, all participants underwent 10 stretches of each muscle group for 20 seconds. Dynamic stretching begun with right lower limb first and followed by the left lower limb. The rest period between right and left limbs stretching was 10 seconds. Control groups participants (Group-1 & Group-4) were strictly not permitted to carry out any kind of plyometric and dynamic stretching exercises and

they were only allowed to perform their regular volleyball games. All participants were asked to perform 10 min of warm up exercises before starting the training session and 8 min of cool down exercises at the end of training. All the training sessions were carried out as two sessions in a week for a period of eight weeks.

Table 1. Plyometric exercise intensity and setting in the experimental groups

Plyometric exercises	Exercise intensity	Sets x jumps(n)	Rest btw sets (min)	Rest btw reps (s)
Squat jump	Low	3 x 10	1-2	5-10
Jump to box	Low	3 x 10	1-2	5-10
Tuck jump	Moderate	3 x 8	2-3	5-10
Split squat jump	Moderate	3 x 8	2-3	5-10
Lateral hurdle jump	Moderate	3 x 8	2-3	5-10
Zigzag jump	High	3 x 6	3-5	5-10
Single leg tuck jump	High	3 x 6	3-5	5-10
Depth jump	High	3 x 6	3-5	5-10

Table 2. Dynamic stretching exercises performed by groups 3 & 6

Muscle groups	Stretching techniques
Gluteal muscles	While walking, lift the knee towards the chest & raise the body on the toes of the opposite extended leg.
Hip adductors	While walking forward, raise the trailing leg and place the hip in flexion (90^0) in an adducted and externally rotated position, with the knee flexed at 90^0. In this position, the limb is displaced forward as though the participants are stepping over an object just below their waist height and returned to normal walking stride position.
Quadriceps	Heel ups. Rapidly kick heels towards buttocks while moving forward.
Hamstrings	While walking, swing the leg actively to be stretched forward into hip flexion until a stretch is felt in the posterior thigh while keeping the knee extended and the ankle in plantar flexion.
Calf muscles	Tip toe walking. Walking forward while completing alternating plantar flexion (tip toe) with every step forward. The aim is to raise the body as high as possible through tip toeing.

Assessment of VJH

The vertical jump height ability of all participants were tested through the Sargent jump test (13) before starting the training session, and also these assessments were repeated again at the end of every two weeks of each training program till the end of eight weeks. Each participant jumped three times and the mean value was taken for analysis.

Statistical analysis

The data was presented as Mean±SD (standard deviation). They were calculated with standard statistical methods. A three-way ANOVA describing groups in time were put to test with post hoc analysis by Bonferroni test for analyzing the effects of the training program. Significance was set at $p<0.05$ for all analyses.

RESULTS

Table 3. demonstrates the training effects in plyometric groups. A significant change was observed on VJH at the end of 2^{nd} week of training in both male and female players ($p<0.05$) and increase in VJH continued till the end of eight weeks duration. Compared with the control group, the effects of increased VJH was significantly higher ($p<0.05$). The effects of training also displayed better changes on VJH in male participants than the female players from the 4^{th} weeks of training ($p<0.05$), which indicates that the effects of training are better in male participants than the females (Fig 1).

Table 3. Time course of vertical jump height changes in volleyball players with lower body plyometrics training in the eight weeks study

Groups	Baseline	2 weeks	4 weeks	6 weeks	8 weeks
Group-1 (M)	56.7 ± 1.2	56.0 ± 1.0	56.2 ± 1.0	56.2 ± 1.0	56.2 ± 1.1
Group-2 (M)	56.2 ± 1.3	57.4 ± 1.4$^{*\#}$	60.9 ± 1.6$^{*\#}$	63.3 ± 2.0$^{*\#}$	66.3 ± 1.6$^{*\#}$
Group-4 (F)	42.1 ± 1.0	42.2 ± 1.0	42.3 ± 1.0	42.3 ± 1.1	42.4 ± 1.1
Group-5 (F)	42.2 ± 0.9	43.2 ± 1.8$^{*\#}$	45.9 ± 2.3$^{*\#}$	47.8 ± 2.5$^{*\#}$	50.1 ± 1.8$^{*\#}$

Figures are Mean ± SD in cm of 30 subjects in each group; M: male, F: female; *: $p<0.05$, within-group compared with baseline; $^{\#}$: $p<0.05$, comparing Group 1 vs Group 2 and Group 4 vs Group 5. Three-way ANOVA with post hoc analysis by Bonferroni test were applied for comparison.

Table 4 displays VJH results of the plyometrics training program with dynamic stretching. An important change on vertical jump performance was noticed after the 2^{nd} weeks of training in both genders, and these changes continued till the completion of the training program. The effect on increase of VJH was significantly better in males than in female participants from 4^{th} weeks onwards ($p<0.05$) (Fig 2). Changes in both male and female experimental groups

were significantly higher than that in the control groups ($p<0.05$).

According to the present study results, when compared to the control groups, the experimental groups of plyometrics and plyometrics with dynamic stretching in male and female volleyball players displayed statistically significant changes on their vertical jump performance. Furthermore, plyometrics with dynamic stretching training groups showed better changes on VJH than the groups that performed only plyometric exercises (Table 5).

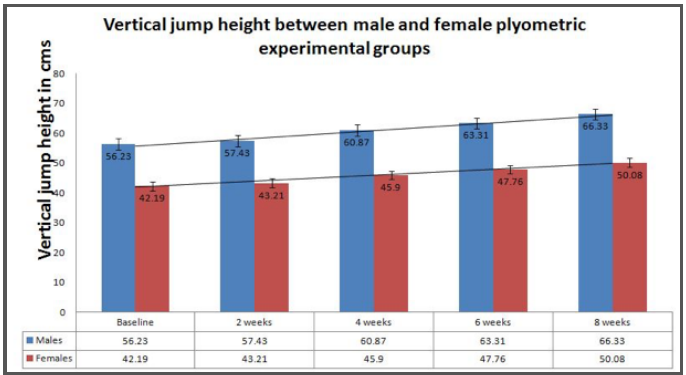

Figure 1. Comparision of mean change in vertical jump height with in male and female players of plyometrics experimental groups

Table 4. Time course of vertical jump height changes in volleyball players with lower body plyometrics training plus dynamic stretching in the eight weeks study period

Groups	Baseline	2 weeks	4 weeks	6 weeks	8 weeks
Group-1 (M)	56.7 ± 1.2	56.0 ± 1.0	56.2 ± 1.0	56.2 ± 1.0	56.2 ± 1.1
Group-3 (M)	56.4 ± 0.9	58.1 ± 0.9*#	62.3 ± 0.9*#	66.2 ± 0.8*#	69.2 ± 0.9*#
Group-4 (F)	42.1 ± 1.0	42.2 ± 1.0	42.3 ± 1.0	42.3 ± 1.1	42.4 ± 1.1
Group-6 (F)	42.1 ± 0.8	43.4 ± 0.8*#	46.3 ± 1.0*#	48.1 ± 0.9*#	50.2 ± 0.9*#

Figures are Mean ± SD in cm of 30 subjects in each group; M: male, F: female; *: $p<0.05$, within-group compared with baseline; #: $p<0.05$, comparing Group 1 vs Group 3 and Group 4 vs Group 6.Three way ANOVA with post hoc analysis by Bonferroni test were applied for comparison.

Table 5. Comparative effects of lower body plyometrics and lower body plyometrics with dynamic stretching training on time course of vertical jump height changes in volleyball players in the eight weeks study period

Groups	Baseline	2 weeks	4 weeks	6 weeks	8 weeks
Group I (M)	56.7 ± 1.2	56.0 ± 1.0	56.2 ± 1.0	56.2 ± 1.0	56.2 ± 1.1
Group II(M)	56.2 ± 1.3	57.4 ± 1.4*#	60.9 ± 1.6*#	63.3 ± 2.0*#	66.3 ± 1.6*#
Group III (M)	56.4 ± 0.9	58.1 ± 0.9*#	62.3 ± 0.9*#	66.2 ± 0.8*#	69.2 ± 0.9*#
Group IV (F)	42.1 ± 1.0	42.2 ± 1.0	42.3 ± 1.0	42.3 ± 1.1	42.4 ± 1.1
Group V (F)	42.2 ± 0.9	43.2 ± 1.8*#	45.9 ± 2.3*#	47.8 ± 2.5*#	50.1 ± 1.8*#
Group VI (F)	42.1 ± 0.8	43.4 ± 0.8*#	46.3 ± 1.0*#	x48.1 ± 0.9*#	50.2 ± 0.9*#

Figures are mean ± SD in cm Mean ± SD of 30 subjects in each group. *: $p<0.05$, when compared within group with baseline; #: $p<0.05$, when compared between Group 2 & Group 3, and Group 5 >& Group 6. Three-way ANOVA with post hoc analysis by Bonferroni test were applied for comparison.

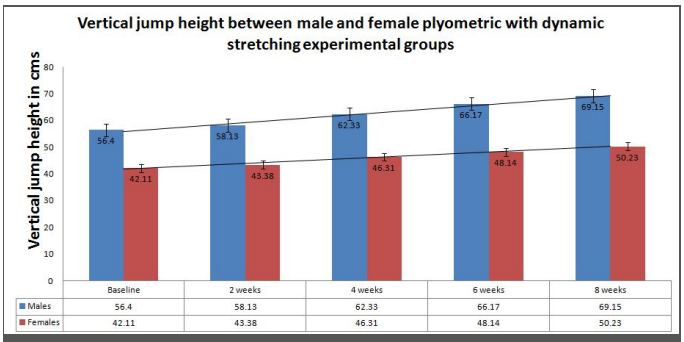

Figure 2. Comparision of mean change in vertical jump height with in male and female players of plyometrics with dynamic stretching experimental groups

DISCUSSION

The present study outcomes prove that eight weeks of training with two sessions per week of plyometric exercises, or dynamic stretching of lower limb muscles along with plyometric exercises provide highly noticeable improvement on the performance of vertical jump in male and female collegiate volleyball players at the end of week 2nd onwards, and also these changes continued to increase till the end of eight weeks. In addition, lower limb dynamic stretching with plyometric exercise groups reached a comparatively better performance, and also comparing with female players, the male players displayed a greater improvement on VJH performance at the end of 4th weeks onwards in both the training groups.

The results of our study were in line with previously published work (14), which concluded that plyometric training led enhancements in VJH. An eight week plyometric training program was conducted by Chelly et al. (15), and they have reported an increase of vertical jump ability after training. A significant gain of vertical jump performance was reported by Hosseini (16) following 12 weeks of plyometric training. Usman and Shenoy (17) published that eight weeks of lower body plyometric exercise training significantly improved the ability of vertical jump height and pulmonary

function in collegiate volleyball players. On the strong supporting background of earlier studies, the significant enhancement of VJH reported in our training programs can be a good practical application for participants who perform sports or games in which the ability to jump vertically is crucial.

The main reason for the VJH improvement achieved in our study might be the physiological outcome of plyometric exercises such as the adaptation of neural components, specifically with an enhanced agonistic muscular neural drive and the muscular activation potentiation changes or mechanical changes in the characteristics of muscle-tendon complex. According to Potach and Chu (18), the activity of quick eccentric contraction of muscle followed by the same muscular concentric contraction are the responsible factors for increased muscle recruitment, which produces a maximum amount of muscular force at the time of concentric action of muscle. Plyometric exercises enhance intermuscular coordination and thereby change the mechanical activity of the tendo-muscular complex (19).

As expected, the outcomes of these training displayed a better vertical jump performance in both male and female participants of lower limbs dynamic stretching with plyometric exercise groups. The factor for the achievement of this enhanced effect on VJH is probably due to the effect of increased neuro-muscular function. The production of muscle power and increased speed of action may be due to the occurrence of post activation potentiation (8).

The present training results were in accordance with a study (20) that evaluated the immediate changes after static and dynamic exercises on vertical jump and flexibility in children, and reported that comparing with static exercises, the ability of vertical jump performance was markedly increased after dynamic exercises. Thattarauthodiyil and Shenoy (21) reported that vertical jump height performance markedly increased with plyometric exercises combined with dynamic stretching training in male collegiate volleyball players. John and Saluja (22) conducted a study to find out the comparative effects of plyometric exercises and dynamic stretching in male collegiate basketball players, and have reported that the combined training group has produced noticeable improvement of their vertical jump performance.

Thattarauthodiyil and Shenoy (23) conducted an eight weeks study to find out the effects of lower body plyometrics combining with dynamic stretching exercises in female volleyball players, and concluded that a significant positive effectwas present on vertical jump height from the week 2nd onwards. In addition, the response of these training programs has revealed significantly higher effects on vertical jump performance in male participants than in female players. These results are in line with study results reported by Villarreal et al (24) who have attributed the reason for gender differentiation to the greater capacity of male athletes to generate more power output and better coordination than female players.

Muscle power and strength are two important performance factors in sports. In volleyball, the vertical jump capacity of players is crucial. Findings of this study highlight that a number of factors that can affect the results of plyometric exercises including the design of training, gender of participants, and the duration of training program. These factors must be taken into consideration to gain maximum training profit.

CONCLUSION

Two sessions of plyometric training per week for a period of eight weeks has significantly enhanced vertical jump performance in male and female collegiate volleyball players. However, the study period of eight week was considered short to derive concrete outcomes. Hence, it is recommended to perform the same study with longer duration intense training periods for better statistical understanding. Furthermore, the effects of training on VJH ability in male and female participants who underwent combined training of dynamic stretching of lower limb muscles followed by plyometrics exercises were markedly better than that in participants who have undergone only plyometrics training. From this point of view, we would like to recommend for taking advantage of this special effect of training for augmenting the performance of volleyball players as well as athletes who perform sports with vertical jumping aspects.

Ethics Committee Approval / Etik Komite Onayı

The approval for this study was obtained from Institutional Ethics Committee of YMCH, Mangalore, Karnataka, India, (Decision no: YMCH/EC-28/17 dated on 24 - 03 - 2017.

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

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Author Contributions / Yazar Katkıları

Concept All authors; Design All authors; Supervision BS; Materials UT; Data Collection and/or Processing UT; Analysis and Interpretation BS,UT; Literature Review UT,BS; Writing Manuscript UT; Critical Reviews BS.

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