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Plyometric Training Combined with Jump Rope Training in Female Adolescent Volleyball Players

Genç Bayan Voleybol Oyuncularında İp Atlama ile Kombine Pilometrik Eğitim

Özge ÇINAR MEDENİ[a],
Elif TURGUT[b],
Fatma Filiz ÇOLAKOĞLU[c],
Gül BALTACI[d]

[a]Department of Physiotherapy and Rehabilitation,
Çankırı Karatekin University
Faculty of Health Sciences,
Çankırı, TURKEY
[b]Department of Physiotherapy and Rehabilitation,
Hacettepe University
Faculty of Health Sciences,
[c]Gazi University
Faculty of Sport Sciences,
[d]Private Ankara Güven Hospital,
Ankara, TURKEY

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Correspondence:
Özge ÇINAR MEDENİ
Çankırı Karatekin University
Faculty of Health Sciences,
Department of Physiotherapy and Rehabilitation, Çankırı,
TURKEY/TÜRKİYE
ozgecinar@gmail.com

ABSTRACT Objective: To investigate the effects of lower extremity plyometric training programme on jumping height, aerobic power, anaerobic power, sprint performance and balance in young female volleyball players. **Material and Methods:** Thirty five female adolescent volleyball players were included in the study. The participants were allocated to two groups: study group (lower extremity plyometric training combined with jump rope exercises; n=18) and control group (standard volleyball training; n=17). All subjects were evaluated before and after 12-week training. A vertical jump and reach test (VRJT) was performed to assess jump height. Anaerobic capacity was calculated using a formula by VRJT. Twenty meters shuttle run test, Y-balance test (YBT) and 20 meters sprint test were performed to assess aerobic capacity, dynamic balance and sprint performance, respectively. Statistical comparison was performed using an analysis of variance test. **Results:** Comparisons showed that aerobic capacity was improved in two groups ($p<0.05$). Jumping height, anaerobic power, sprint time and YBT distance to anterior direction was improved in study group ($p<0.05$), whereas no improvement was seen in control group ($p>0.05$). Y-balance test distances to posteromedial and posterolateral directions were more improved in study group than control group ($p<0.05$). **Conclusion:** Results of this study showed benefits of addition of plyometric exercises to standard training in young female volleyball players. This study will be a basis for developing training programmes.

Keywords: Adolescent; athletic performance; sports; plyometric exercise

ÖZET Amaç: Genç bayan voleybol oyuncularında alt ekstremite pilometrik eğitiminin sıçrama yüksekliği, aerobik güç, anaerobik güç, sprint performansı ve denge üzerine etkisini araştırmak. **Gereç ve Yöntemler:** Bu çalışmaya 35 bayan adölesan voleybol oyuncusu dahil edildi. Katılımcılar iki gruba ayrıldı: çalışma grubu (alt ekstremite pilometrik eğitimi+standart voleybol eğitimi; n=18) ve kontrol grubu (standart voleybol eğitimi; n=17). Bütün katılımcılar 12 haftalık eğitimin öncesinde ve sonrasında değerlendirildi. Sıçrama yüksekliğinin değerlendirilmesi için dikey sıçrama testi yapıldı. Anaerobik kapasite dikey sıçrama testi sonucuna göre formül kullanılarak tahmin edildi. Aerobik kapasite, dinamik denge ve sprint performansını değerlendirmek için sırasıyla 20 metre mekik koşu testi, Y-denge testi (YDT) ve 20 metre sprint testi yapıldı. İstatistiksel karşılaştırma varyans analizi testi kullanılarak yapıldı. **Bulgular:** Aerobik kapasite iki grupta da gelişti ($p<0.05$). Sıçrama yüksekliği, anaerobik güç, sprint süresi ve anterior yönde YDT mesafesi kontrol grubunda gelişmezken ($p>0.05$), çalışma grubunda gelişti ($p<0.05$). Posteromedial ve posterolateral yöndeki YDG mesafeleri çalışma grubunda kontrol grubundan daha çok gelişti ($p<0.05$). **Sonuç:** Bu çalışmanın sonuçları genç bayan voleybol oyuncularında pilometrik eğitimin standart eğitim programına eklenmesinin yararlarını göstermiştir. Bu çalışma antreman programlarının geliştirilmesinde temel oluşturacaktır.

Anahtar Kelimeler: Adölesan; atletik performans; sporlar; pilometrik egzersiz

Volleyball is one of the most popular sports and requires speed, agility, aerobic and anaerobic power.[1-4] Jumping is a basic activity that is needed for successful performance in volleyball because volleyball specific technical-tactical elements such as, spiking, blocking and jump serving, are commonly performed while jumping.[5,6] Volleyball is predominantly anaerobic sport.[2] High intensity active stages of the game such as serving, service receive, setting, spiking, blocking and defending that last a few seconds, require improved anaerobic metabolism to produce energy.[7] Vertical jumping is a valid and reliable tool to estimate anaerobic power of players and because of high reproducibility and repeated measures of vertical jump measures power development.[8,9] Quickness is another physical fitness parameter which is important to improve to have success in team volleyball because a few seconds or milliseconds of time determines winning or losing.[1] Explosive sprint movements are frequently performed during volleyball.[5] The effect of such training programmes on sprint time was investigated by previous researchers.[10-12] Jumping and sprinting are the determinants of player quality of young female volleyball players.[5] In addition to above mentioned physical fitness parameters; aerobic power is thought to be a required physical fitness parameter in volleyball because of total duration of the game.[3,4] These plyometric exercises are also anaerobic however total duration of the exercises may require aerobic performance and the effect of plyometric training may have an impact on aerobic performance.[13]

Poor balance is a risk factor for injury in sports, and star excursion balance test (SEBT) predicts leg injuries.[14-16] Because leg injuries were the most common injuries in female volleyball players, measurement of balance is needed when evaluating the athlete's fitness level.[17]

The effects of plyometric training on volleyball players' fitness level (such as; vertical jump ability, muscle strength, sprint performance, flexibility) were investigated in previous researches.[18-21] Because of being prone to injury, young female players comprises an important population, and identification of optimal training methods to increase explosive performance is crucial to optimize performance in young female volleyball players.[17,18] Influences of an upper and lower extremity plyometric training programme on vertical jump and ball throwing performances were investigated in a previous research and found to be effective in young female volleyball players.[22] However effects of a plyometric training programme on jumping height, aerobic power, anaerobic power, sprint performance and balance were not comprehensively evaluated in young female volleyball players. Thus the objective of this study is to investigate the effects of lower extremity plyometric training programme on jumping height, aerobic power, anaerobic power, sprint performance and balance in young female volleyball players.

MATERIAL AND METHODS

A total of 35 female national adolescent volleyball players (age=15.6±0.94 years, weight=60.68±7.10 kg, height=171.02±5.16 cm, body mass index= 20.67±1.88 kg/m^2) were included. Inclusion criteria were not having an orthopaedic injury during the last 24 weeks, not having an orthopaedic surgery, not having an neurologic, rheumatologic or other systemic diseases. Players were separated randomly into two groups the study group (18 players) and the control group (17 players). Players in study group followed a 12-weeks supervised plyometric training programme combined with jump rope training in addition to regular volleyball programme (Table 1). Players in control group performed only regular volleyball training programme. Measurements were performed in two sessions with 2-days interval both before and after training. In the first session 20 meters shuttle run test and vertical jump and reach test (VJRT) were performed and in the second session SEBT and 20 meters sprint test were carried out. This study was conducted in line with Helsinki Declaration principles and approved by the ethical committee of the university. Republic of Turkey Selcuk University, Faculty of Sport Sciences, Ethics Committee of Non-Interventional Research, 14.01.2019 Decision number: 02.

Star excursion balance test (SEBT) was performed to evaluate dynamic balance of the players. Players stood on tested leg, in the middle of the grid formed by three lines (anterior (A), posterolateral (PL) and posteromedial (PM)).[23] Players reached as far as possible along each of the three lines, made a light touch on the line, returned back and stood on double legs. Before the test, players

TABLE 1: Plyometric training programme performed by study group.

	Program period (weeks)					
	1-2	3-4	5-6	7-8	9-10	11-12
Activity	repsXsets	repsXsets	repsXsets	repsXsets	repsXsets	repsXsets
1.Jump rope training with						
Double-leg jumps	8X2	8X2				
Double-leg jumps to forward and backward	8 X2	8X2				
Double-leg jumps to right and left	8 X2	8X2	8X2			
Single-leg jumps on dominant side	8X2	8X2	8X2	8X2	8X2	8X2
Single-leg jumps on nondominant side	8 X2	8X2	8X2	8X2	8X2	8X2
Scissor jumps			8X2	8X2	8X2	8X2
2. Tuck jumps	8X1	8X2	8X2	8X2	8X2	8X2
3. Kangaroo jumps		8X1	8X2	8X2	8X2	8X2
4. Drop jump to lateral direction				8X1	8X2	8X2
5. Drop jump to anterior direction					8X2	8X2

practiced six times for each line. Players performed SEBT test beginning with anterior direction and progressing to clock wise around the grid for three times in each direction. The distance was gauged with a tape. The distance that measured was divided to leg length for normalization.[24]

Vertical jump and reach test (VRJT) was carried out to evaluate jumping height and anaerobic power. Players stood near the wall at the dominant side. Keeping the feet flat on the ground, players reached as high as possible with the dominant hand and touched the wall with fingers while the non-dominant hand stayed near the body. The point of the fingertip was pointed out and this height was called the standing reach height. Then players stood away from the wall and jumped vertically as high as possible using both arms and legs to assist in projecting the body upwards and touched the wall again with fingers. The difference in distance between the standing reach height and the jumping height is the score. The best of three attempts is recorded. Because high jumping height enables successful volleyball performance, jumping height was set as an output. The Lewis formula (Average Power (Watts)=√4.9 x body mass (kg) x √jump-reach score (m) x 9.81) was utilized to determine average anaerobic power.[5,25]

Anaerobic power of the players was determined by the 20 meters shuttle run test. Players ran back and forth on a 20 meter course. They touched to the block at the 20 meter line when a sound signal was heard from a pre-recorded tape. The frequency of the sound signals increased 0.5 km/h for each minute starting from 8.5 km/h. The test was stopped when the subjects could not continue the test.[26] Maximal O_2 uptake was determined according to Ramsbottom et al.[27]

Speed of the players was analyzed by 20 meters sprint test.[28] Starting from a stationary position, with one foot in front of the other players performed a single maximum sprint over 20 meters and the time was recorded. With the front foot was placed behind the starting line, the starting position held for 2 seconds prior to starting, and no rocking movements were permitted. The tester encouraged subjects to continue running as fast as possible. An electronic timing system was used to measure sprint time (Newtest 1000 device, Newtest, Oy, Oulu, Finland). The time was recorded with 1/1000 s sensitivity.

STATISTICAL ANALYSIS

Statistical Package for the Social Sciences v22.0 software (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) was utilized to carry out statistical analysis. A one-sample Kolmogorov–Smirnov test was performed to assess the normality of data.

Comparisons of age, body weight, body mass and body mass index were performed via t-test between study and control groups. Comparisons were performed via repeated measures analysis of variance to detect the effects of time (pre-training, post-training) and group (study and control). Body weight and body height were set as covariates to analyze if those have an effect on outcome measures because pre-training values were different between groups. Post-hoc analysis was performed using the *t*-test. A p value of 0.05 was set as the threshold for statistical significance.

RESULTS

Demographic characteristics of the groups are given in Table 2. Body weight and body height were found to be different between groups ($p=0.04$, $p=0.002$, respectively). Group-by-time interaction was not significant for $MaxVO_2$ uptake ($F_{1,31}=0.68$, $p>0.05$). However main effect for time was significant for $MaxVO_2$ uptake ($F_{1,31}=49.09$, $p<0.0001$), so $MaxVO_2$ uptake was found to improve in both groups (Figure 1). Interaction of time and group was significant for anaerobic capacity ($F_{1,31}=13.26$, $p=0.001$), jumping height ($F_{1,31}=11.09$, $p=0.002$), sprint time ($F_{1,31}=15.26$, $p<0.0001$). Body height has an effect on jumping height ($F_{1,31}=4.41$, $p=0.04$) and body weight has an effect on sprint time ($F_{1,31}=5.68$, $p=0.02$) as covariates. Post-hoc comparisons showed that anaerobic power ($p<0.0001$, MD=5 watts (9.81%)) jumping height ($p<0.0001$, MD=3.55 cm (9.68 %)) and sprint time ($p<0.0001$, MD= -0.29 s (-7.85 %)) were improved in study group, whereas the results of control group were not significant ($p>0.05$) (Figure 1).

TABLE 2: Comparison of demographic information of groups.

	Study group (n=18)	Control group (n=17)	p
Age (years)	15.61±1.03	15.62±0.88	>0.05
Body weight (kg)	63.05±5.47	58.21±8.16	0.04*
Body height (cm)	173.66±3.74	168.50±5.11	0.002*
Body mass index (kg/m²)	20.90±1.66	20.42±2.12	>0.05

*Significant difference was found according to t-test results ($p<0.05$).

Interaction of time and group was significant for also SEBT test (for ND, PL, $F_{1,32}=9.04$, $p=0.005$; ND, PM, $F_{(1,32)}=8.82$, $p=0.006$; ND, A, $F_{1,31}=32.78$, $p<0.0001$; D, PL, $F_{1,31}=14.28$, $p=0.001$; D, PM, $F_{1,31}=13.32$, $p=0.001$; D, A, $F_{1,31}=25.76$, $p<0.0001$). The comparison between initial and 12-week follow-up showed that SEBT distance for anterior direction was improved in dominant ($p<0.0001$, MD= 11.76%) and nondominant ($p<0.0001$, MD=15.78 %) legs in study group, whereas in control group it did not improve ($p>0.05$). SEBT distance for posteromedial direction was more advanced in the study group in dominant ($p < 0.0001$, MD=18.18%) and nondominant ($p<0.0001$, MD=18.18%) legs whereas statistical significant result was found for control group in dominant ($p=0.008$, MD=7.77%) and nondominant ($p=0.02$, MD=5.55%) legs. Star excursion balance test (SEBT) distance for posterolateral direction was more improved in the study group in dominant leg ($p<0.0001$, MD=16.14%) whereas a statistical significant result was found for control group in dominant leg, too ($p=0.005$, MD=5.23). Star excursion balance test (SEBT) distance for posterolateral direction was improved in the study group in nondominant leg ($p<0.0001$, MD=16.56) whereas there was no difference for control group in nondominant leg ($p>0.05$) (Figure 2).

DISCUSSION

In this study, an important population consisting of young female volleyball players were trained with lower extremity plyometric exercises and posivtie effects were observed on several physical fitness parameters.

We hypothesized that in spite of being anaerobic exercises, plyometric training may improve aerobic capacity due to total duration of exercise series. Additionally improved muscle power characteristics by plyometric training may have an impact on aerobic power.[29] However this effect was not seen in this study supporting previous research; instead, standard training improved aerobic performance in training and control groups.[30]

Plyometrics are a popular training method for improving anaerobic performance.[13] Better volley-

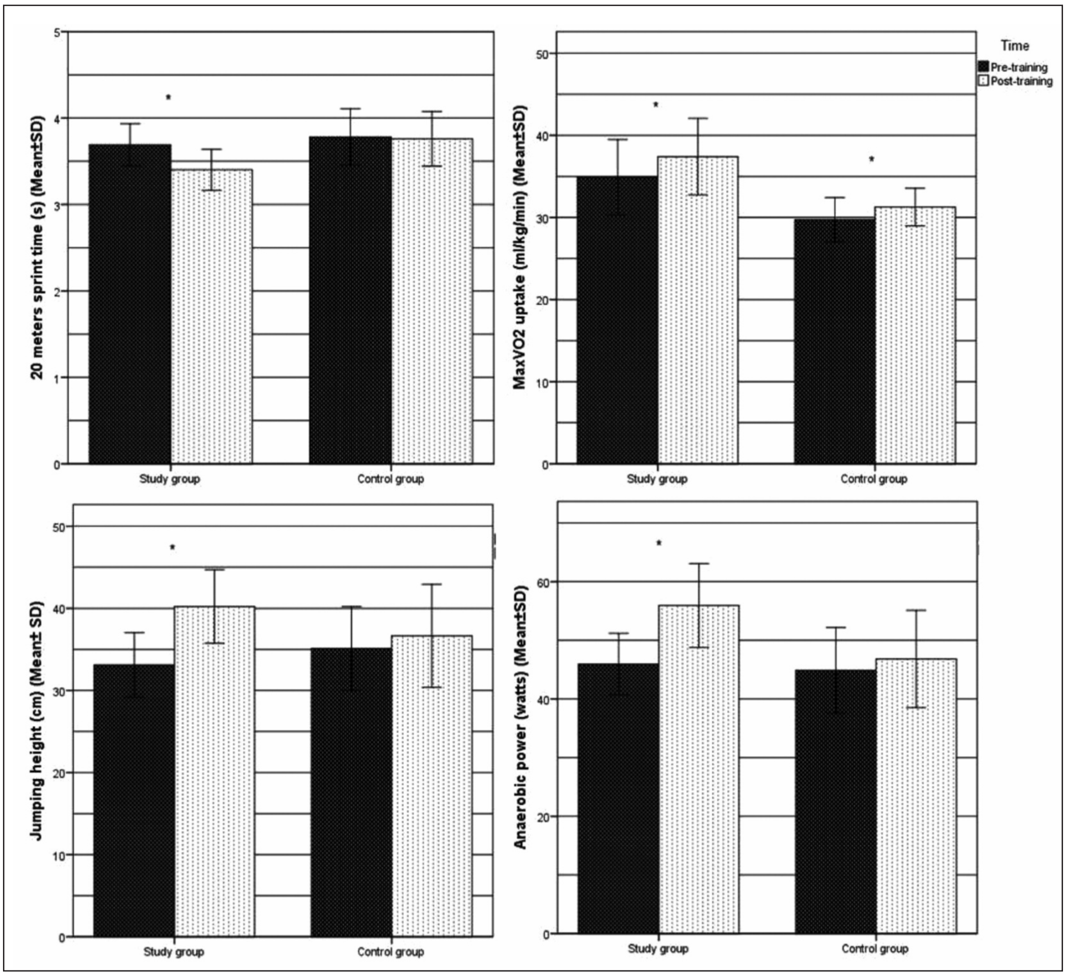

FIGURE 1: Physical fitness parameters of study and control groups.
*Significant difference was found between pre and post training (p<0.05)

ball performance depends on improved anaerobic performance.[2] Standard volleyball training programme including skill-based activities does not improve jumping and sprint performances because players are accustomed to these exercises.[19] So no improvement in jump and sprint performance with standard training could be explained by this. This study added that no improvement was seen in anaerobic performance with standard training may be because of the same reason. Therefore it is crucial to implement plyometric training to regular training programme of young female volleyball players to improve anaerobic performance.

Plyometric training improved jumping performance and sprinting performance in various populations.[30] Plyometric training has positive effects on jump and sprint performance in young soccer and handball players.[31] Jumping height and 20-meters sprint time improved 24.5% and 7.6% respectively with plyometric training in high level adult volleyball players.[19,32] In this study young female volleyball players' improvement of jumping height (21.47%) and sprint time (7.85%) was similar to that in the study of Gjinovc et al.[19] The underlying mechanisms of improvement in jumping, sprinting and anaerobic performances by plyometric training were interpreted in previous studies.[30] These mechanisms are that plyometric training improves tendon elongation, stored elastic energy, and stretch-shortening cycle.[33] Plyometric exercise also includes rapid eccentric and concentric muscle contractions, thus decreased duration of amortiza-

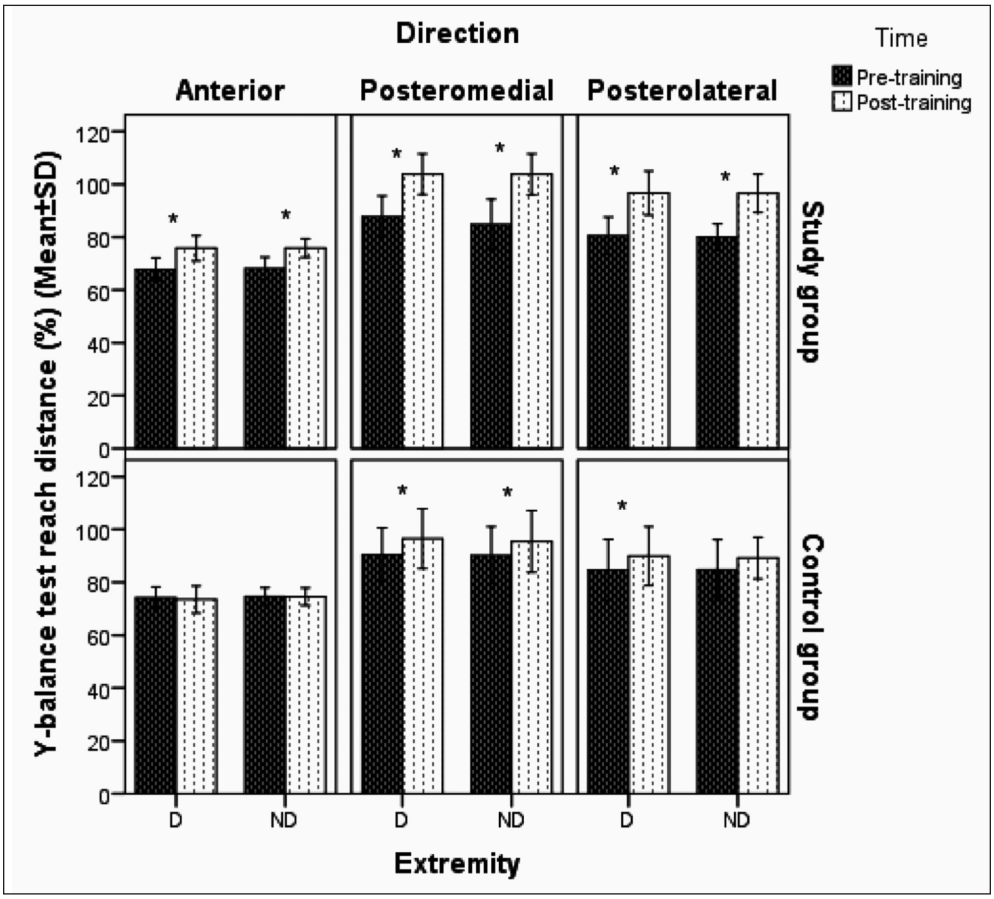

FIGURE 2: SEBT reach distances of study and control groups.
*Significant difference was found between pre and post training (p<0.05)
SEBT: Star excursion balance test; D: Dominant; ND: Nondominant.

tion phase provides emerging of the power greater concentric exercise.[34] We could not find any study about the effect of body height on jumping height. Because jumping height was not a normalized value, the existence of this effect might be normal. However further research is needed to conclude about the effect of body height on jumping height. It was stated previously that body fat was related with sprint time in soccer players and our study supported this finding in volleyball players.[35] This finding should be noted to improve sprint performance in young female volleyball players.

Because poor dynamic lower extremity balance is related with lower extremity injury, improving balance is important to volleyball players.[36] In a previous study which did not include a control group, a single session plyometric training programme reduced SEBT distances approximately 4 to 6% in young female volleyball players and authors stated that reduction could result from the fatigue of the lower extremity.[37] However with completion of the training programme, improved center-of-mass stabilization was observed when landing from a jump thus showing that completion of plyometric training dynamic balance improves and our results supported the study of Myer et al.[38] Balance-specific exercises improved SEBT reach distances approximately 9 to 10% in young female volleyball players.[39] In our study improvements in SEBT reach distances are higher than that study showing that plyometric training improves SEBT reach distances more than balance-specific exercises in young female volleyball players.[39]

One of the limitations of this study was that the results could be generalized to only young female volleyball players and do not provide information about other populations. In addition to this, study group participated in a greater volume of work and some positive results could have resulted from this. On the other hand, vigorous work is often associated with overuse injuries however we limited number of foot contacts as defined previously.[40] Also there is no passive control group which did not perform any training to monitor changes in physical fitness parameters due to maturation.

In conclusion, this study shows that a 12-week lower extremity plyometric training combined with jump rope exercises improves jumping height, anaerobic capacity, sprint performance and dynamic balance of the young female volleyball players. Lower extremity plyometric training may be performed to have gains in jumping height, anaerobic power, speed and balance in young female volleyball players. The observed gains in this study should be of great interest of coaches because the parameters we investigated are the important determinants of volleyball performance. Besides, improved balance reduces lower extremity injury so prevents the athlete from being out of the season. This plyometric training programme is easy to carry out. However the number of foot contacts should be limited in adolescent volleyball players as in this study.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Özge Çinar Medeni, Elif Turgut, Fatma Filiz Çolakoğlu, Gül Baltacı;* ***Design:*** *Özge Çinar Medeni, Elif Turgut, Fatma Filiz Çolakoğlu, Gül Baltacı;* ***Control/Supervision:*** *Fatma Filiz Çolakoğlu, Gül Baltacı;* ***Data Collection and/or Processing:*** *Fatma Filiz Çolakoğlu, Özge Çinar Medeni, Elif Turgut;* ***Analysis and/or Interpretation:*** *Özge Çinar Medeni, Elif Turgut, Fatma Filiz Çolakoğlu, Gül Baltacı;* ***Literature Review:*** *Özge Çinar Medeni, Elif Turgut;* ***Writing the Article:*** *Özge Çinar Medeni, Elif Turgut, Gül Baltacı;* ***Critical Review:*** *Özge Çinar Medeni, Elif Turgut, Gül Baltacı;* ***References and Fundings:*** *Fatma Filiz Çolakoğlu, Gül Baltacı;* ***Materials:*** *Fatma Filiz Çolakoğlu, Gül Baltacı.*

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