

EFFECTS OF PLYOMETRIC TRAINING ON DYNAMIC BALANCE, HOP DISTANCE AND HAMSTRING QUADRICEPS RATIO IN FEMALE VOLLEYBALL ATHLETES

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ABSTRACT

The aim of this study was to investigate the effects of plyometric training on dynamic balance, hop distance and hamstring quadriceps ratio in female volleyball athletes. Thirty-four adolescent asymptomatic female volleyball athletes were included in the study. The athletes were randomly allocated into 2 groups. Group 1 received 6-week plyometric training and standard volleyball training. Group 2 received only standard volleyball training. Isokinetic dynamometer was used to measure the hamstring quadriceps ratio (H:Q). Star excursion balance test was used for assessing the dynamic balance and one leg hop test was used for measuring the hop distance. Repeated measures of ANOVA was conducted for statistical analysis. Plyometric training increased balance performance in only non-dominant limb and increased one leg hop distance in both dominant and non-dominant limb in female volleyball players ($p<0.05$). On the other hand, H:Q ratio of dominant limb was found increased ($p=0.04$) but it was similar between groups ($p=0.39$). The plyometric training could be used to enhance athletic performance in female volleyball players.

Key Words: neuromuscular training, adolescent, strength, functional performance

KADIN VOLEYBOL OYUNCULARINDA PLİOMETRİK EĞİTİMİN DİNAMİK DENGE, SIÇRAMA MESAFESİ VE HAMSTRING QUADRİCEPS ORANINA ETKİSİ

ÖZ

Bu çalışmanın amacı kadın voleybol oyuncularında pliometrik eğitimin dinamik denge, sıçrama mesafesi ve hamstring quadriceps oranına etkisini araştırmaktır. Çalışmaya 34 adolesan asemptomatik kadın voleybol oyuncusu dahil edildi. Sporcular rastgele olarak 2 gruba ayrıldı. Grup 1 standart voleybol antrenmanı ile birlikte 6 haftalık pliometrik eğitime katıldı. Grup 2 ise sadece standart voleybol antrenmanına katıldı. Hamstring quadriceps oranını ölçmek için izokinetik dinamometre, dinamik dengeyi değerlendirmek için star excursion balance test, sıçrama mesafesini ölçmek için ise one leg hop test kullanıldı. İstatistiksel analiz tekrarlayan ölçümlerde varyans analizi ile yapıldı. Pliometrik eğitim dominant olmayan tarafında dinamik dengesini ve her iki tarafından sıçrama mesafesini artırdı ($p<0.05$). Diğer yandan, hamstring quadriceps oranı her iki grupta artarken ($p=0.04$), gruplar arası farklılık bulunmadı ($p=0.39$). Sonuç olarak, pliometrik eğitim kadın voleybol oyuncularında sportif performansını arttırmak için etkin bir şekilde kullanılabilir.

Anahtar Kelimeler: nöromüsküler eğitim, adolesan, kuvvet, fonksiyonel performans

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INTRODUCTION

Female athletes participating in sports that require jumping and/or rapid changes in direction are more likely to suffer a knee injuries compared to their male counterparts (Ferretti et al., 1992; Lindenfeld et al., 1994; Renstrom et al., 2008). The researchers are more concern about anterior cruciate ligament (ACL) injuries due to higher incidence of ACL injuries are still observed in female athletes (Arendt and Dick, 1995; Hewett et al., 2008; Hewett et al., 1999). Although there are several factors leading ACL injuries in female athletes, neuromuscular factors such as strength balance between knee musculature, dynamic balance and knee valgus during jumping and cutting activities are important to prevent injuries (Renstrom et al., 2008).

Neuromuscular training (NMT) programs have been shown to decrease the rate of lower extremity injuries in female athletes (Hewett et al., 1999; Sugimoto et al., 2016). Hewett et al. (1999) demonstrated that female athletes who participated in a NMT had a 22% of decrease in the number of knee injuries. Plyometric training (PT) is one of the NMT components that aims to teach proper jumping techniques to the athletes so as to correct the lower extremity alignment, to decrease landing forces and to increase the joint stability during athletic activities (Asadi et al., 2015; Attene et al., 2015; Baldon et al., 2014; Bedoya et al., 2015). Plyometric exercises are characterised by stretch shortening cycle that start with a rapid stretch of a muscle (eccentric phase) and are followed by a rapid shortening of the same muscle (concentric phase) (Voight, 1991). These exercises are believed to lead neuromuscular adaptations to the stretch reflex, elasticity of the muscle and the golgi tendon organs that explain the muscular performance gains after PT trainings (de Villarreal et al., 2010; Voight, 1991).

Previous studies indicate that PT improves muscle strength and power, balance and jump performance in athletic population (Asadi et al., 2015; Baldon Rde et al., 2014; Bedoya et al., 2015; Behrens et al., 2014; Behrens et al., 2016; Chelly et al., 2014; Chmielewski et al., 2006; Fernandez et al., 2016; Hewett et al., 1996; Markovic, 2007; Matavulj et al., 2001; Ozbar et al., 2014; Saez et al., 2010). Recent meta-analysis demonstrated that PT increased the maximal strength more than 20 kg in both professional athletes and untrained individuals (Saez-Saez de Villarreal et al., 2010) and improved vertical jump height (Markovic et al., 2007). Tsang et al. (2011) showed that hamstring strength increased and quadriceps strength did not change so H:Q ratio increased after PT in female individuals. However, there is an evidence indicating PT enhances quadriceps strength (Behrens et al., 2014; Vaczi et al., 2013). Although, one of the aim of the PT is to enhance the joint stability and the awareness of the joint, the effect of PT on balance is poorly understood. Asadi et al. (2015) found significant increase in balance performance in male basketball players that suggesting PT might be a preventative technique for lower extremity injuries.

The studies on PT were mostly performed on soccer (Bedoya et al., 2015; Ozbar et al., 2014; Vaczi et al., 2013) and basketball (Attene et al., 2015; Brown et al., 1986; Matavulj et al., 2001) players. Although volleyball also includes jumping and landing activities, there is limited information about how PT influence the athletic performance in volleyball players. Therefore, the aim of this study was to investigate the effects of plyometric training on dynamic balance, hop distance and hamstring quadriceps strength ratio in female volleyball athletes. It was hypothesized that plyometric training increase the balance and hop performance, and the hamstring quadriceps ratio in these athletes.

MATERIALS AND METHODS

Participants

Thirty-four adolescent asymptomatic female volleyball players (age: 15.5 ± 0.9 years, height: 172.5 ± 5.5 cm, body mass: 61.4 ± 7.2 kg, body mass index: $20.5 \pm 1.67 \text{ kg/m}^2$, time participating in sports activity: 5.3 ± 1.4 h/wk, experience in sport: 4.3 ± 2.0 years) were recruited from two different volleyball teams. The athletes were randomly allocated into 2 groups. Group 1 (n=17, age: 15.5 ± 1.0 years, height: 175.2 ± 4.3 cm, body mass: 64.2 ± 5.2 kg, body mass index: $20.9 \pm 1.5 \text{ kg/m}^2$) received 6-week plyometric training, Group 2 received (n=17, age: 15.6 ± 0.9 years, height: 169.8 ± 5.5 cm, body mass: 58.6 ± 7.9 kg, body mass index: $20.2 \pm 2.0 \text{ kg/m}^2$) standard volleyball training program.

Demographic characteristics of the participants (age, dominant leg, experience in sport, training hours) were examined through a questionnaire and body composition was assessed with TANITA (Tanita TBF-300 GS Pro Body Composition Analyzer, Japan). The dominant leg was defined as the jumping. The participants and/or their parents or guardians signed the informed consent forms before beginning the study.

Testing Procedures

Knee muscle strength
Concentric and eccentric quadriceps and hamstring strength were measured by isokinetic dynamometer (IsoMed®2000 D&R GmbH, Germany). The participants were instructed to sit on the isokinetic dynamometer with their hips flexed at 90° . Stabilization straps were placed across the trunk, waist and the distal femur of the limb to minimize compensatory movement. The axis of the dynamometer was aligned to the lateral femoral epicondyle while the knee was flexed at 90° and the dynamometer force arm was secured 2 cm above the lateral

malleolus. The distance from the dynamometer force arm to the axis of the dynamometer was recorded for each individual to allow the peak torque to be calculated.

Prior to muscle strength recordings, the participants were allowed three maximal concentric quadriceps and eccentric hamstring tests to familiarize themselves with the testing procedures and to warm-up. The participants then performed maximal concentric quadriceps and eccentric hamstring contractions at $60^\circ/\text{s}$ (five repetitions) with a one-minute rest interval between each set. Standard verbal instructions were given regarding the procedures.

Quadriceps and hamstring peak torques for dominant and non-dominant limbs were recorded. The quadriceps and hamstring strength indexes were calculated by the torque produced by the dominant limb divided by the torque produced by the non-dominant limb, which were then expressed as a percentage. Hamstring quadriceps ratio was calculated by eccentric hamstring strength divided by concentric quadriceps strength for each limb.

Functional performance

One leg hop test was used to assess the hop performance. The participants stood on one leg with toes behind a mark on the floor. They were instructed to jump as far as possible with a controlled landing. The test was performed until three successful jumps were performed for each leg. The tests was performed with the non-dominant limb first and then the dominant limb. The distance was measured in centimeters and the average of the three trials was recorded.

The anterior (ANT), posteromedial (PM) and posterolateral (PL) directions of the SEBT were used to assess dynamic balance. Participants were instructed to stand in the middle of the grid with tapelines extending out 100 centimeters.

The angle between ANT and PM or PL directions was set at 135°, and between PM and PL was set at 90°. The participants were instructed to reach as far as possible along each of the three lines, make a light toe-touch on the line without shifting weight, and return to the center of the grid whilst maintaining single-leg balance. Measurements were taken from the most distal aspect of the toes. Three practice trials were given for each limb for each direction. The participants then performed three trials in the three directions for each limb. The average of the 3 reach distances in each direction was normalized to leg length (anterior superior iliac spine to medial malleolus) and was analyzed as percent leg length.

Training program

The 6-week plyometric training program that was designed by Hewett et al.(1996) was used in this study. Group 1 were trained this program 3 days in a week for 6 weeks. The training sessions lasted approximately 2 hours in a day on alternating days. In other days, they did the same volleyball standard training with Group 2 including resistive upper and lower body exercises, and core stability (2 days in a week), aerobic exercises (4

days in a week) and volleyball technical training (3 days in a week).

The plyometric training was designed to decrease the landing forces and to increase the knee joint stability by reorganizing the lower extremity neuromuscular control and increasing the knee muscle strength (Hewett et al., 1996). There were 3 phases in the program. In Phase 1 (1-2 weeks), proper jump techniques were taught. Phase 2 (3-4 weeks) aimed to increase strength, power and the ability with the jump techniques. Phase 3 (5-6 weeks) aimed to maximize the jump ability. Stretching and warming or cooling program (15-20 minutes) was performed before and after the training program.

Statistical analysis

SPSS 15.0 (SPSS Inc., Chicago, IL) was used for statistical analysis. Kolmogorov-Smirnov test was used to determine the normal distribution of the data. Repeated measures of ANOVA was used to determine significant time by group interactions for test parameters. Bonferroni post hoc test was conducted when significant interaction or main effect was found. The significance level was set at $p < 0.05$

RESULTS

Knee strength and functional performance outcomes at all time points for each group were shown in Table 1, Table 2 and Figure 1.

Dominant limb

Time by group interaction was not significant for H:Q ratio at 60°/s ($F_{(1,32)}=0.75$, $p=0.39$) but the H:Q ratio increased after trainings ($p=0.04$). (Table 1).

Table 1. Concentric quadriceps and eccentric hamstring strength (Nm/kg) at 60°/s before and after trainings for each group

| MUSCLE STRENGTH | TIME | GROUP 1 | GROUP 2 |
|---|------|------------|------------|
| Concentric Quadriceps Dominant | Pre | 2.68±0.81 | 2.66±0.60 |
| | Post | 2.82±0.96 | 3.02±0.90 |
| Concentric Quadriceps Non-Dominant | Pre | 2.25±0.61 | 2.58±0.60 |
| | Post | 2.62±0.88 | 2.75±0.73 |
| Eccentric Hamstring Dominant | Pre | 3.16±0.98 | 3.01±0.68 |
| | Post | 3.58±1.01 | 3.30±0.85 |
| Eccentric Hamstring Non-Dominant | Pre | 2.95±0.77 | 2.90±0.71 |
| | Post | 3.36±1.03 | 3.09±0.74 |
| Hamstring Quadriceps Ratio Dominant | Pre | 1.20±0.32 | 1.17±0.28 |
| | Post | 1.38±0.41* | 1.24±0.19* |
| Hamstring Quadriceps Ratio Non-Dominant | Pre | 1.36±0.41 | 1.17±0.32 |
| | Post | 1.30±0.24 | 1.16±0.28 |

*p<0.05

There was no significant time by group interaction for SEBT anterior direction ($F_{(1,32)}=0.02$, $p=0.88$). The main effect for time was also not significant ($F_{(1,32)}=0.34$, $p=0.56$). Time by group interaction was not significant for SEBT posteromedial direction ($F_{(1,32)}=1.30$, $p=0.26$) and SEBT posterolateral direction ($F_{(1,32)}=0.02$, $p=0.88$). The main effect for time was significant for SEBT_PM direction ($F_{(1,32)}=8.57$, $p=0.006$) and SEBT_PL

direction ($F_{(1,32)}=7.47$, $p=0.01$). Reach direction increased after trainings. (Table 2).

A significant time by group interaction was observed for OHLT ($F_{(1,32)}=7.31$, $p=0.01$). Hop distance increased in both groups (Group 1: $p<0.001$, Group 2: $p=0.02$) but it was greater in Group 1 when compared to Group 2 ($p=0.02$). (Figure 1).

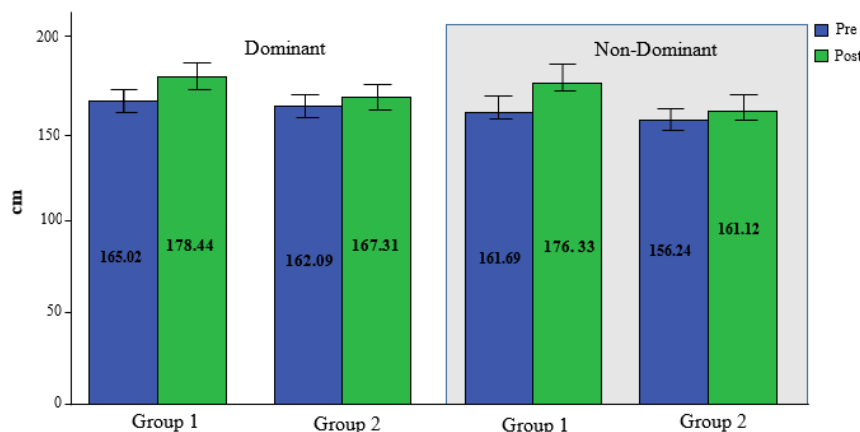


Figure 1. One leg hop test outcomes (cm) after trainings for each groups

Non-dominant limb

Time by group interaction was not significant for H:Q ratio at 60°/s ($F_{(1,32)}=0.23$, $p=0.64$) and the H:Q ratio did not change after trainings ($p=0.48$). (Table 1).

Time by group interaction was found significant for non-dominant limb in SEBT

anterior reach direction ($F_{(1,32)}=4.85$, $p=0.03$) and posteromedial direction ($F_{(1,32)}=6.81$, $p=0.01$). After training, reach distance increased in Group 1 (ANT: $p=0.004$, PM: $p<0.001$) but it did not change in Group 2 (ANT: $p=0.29$, PM: $p=0.50$). There was no significant time by group interaction for SEBT_PL direction ($F_{(1,32)}=0.02$, $p=0.89$).

The main effect for time was found significant ($F_{(1,32)}=19.57$, $p<0.001$).

SEBT_PL distance increased after the training. (Table 2).

Table 2. Star excursion balance test outcomes (cm) before and after trainings for each group.

| DIRECTION | TIME | GROUP 1 | GROUP 2 |
|-----------------------------|------|------------|-----------|
| Anterior Dominant | Pre | 0.73±0.05 | 0.75±0.03 |
| | Post | 0.73±0.05 | 0.76±0.04 |
| Anterior Non-Dominant | Pre | 0.71±0.05* | 0.75±0.04 |
| | Post | 0.74±0.03 | 0.75±0.04 |
| Posteromedial Dominant | Pre | 0.91±0.08 | 0.91±0.08 |
| | Post | 0.95±0.06 | 0.93±0.08 |
| Posteromedial Non-Dominant | Pre | 0.89±0.09* | 0.90±0.09 |
| | Post | 0.95±0.06 | 0.91±0.08 |
| Posterolateral Dominant | Pre | 0.86±0.06 | 0.80±0.08 |
| | Post | 0.90±0.07 | 0.83±0.09 |
| Posterolateral Non-Dominant | Pre | 0.85±0.06 | 0.82±0.07 |
| | Post | 0.90±0.05 | 0.87±0.07 |

* $p<0.05$

A significant time by group interaction was observed for OHLT ($F_{(1,32)}=7.83$, $p=0.009$). After training, hop distance increased in both groups (Group

1: $p<0.001$, Group 2: $p=0.04$) but it was greater in Group 1 when compared to Group 2 ($p=0.003$). (Figure 1).

DISCUSSION

The main findings of this study showed that plyometric training increased balance performance in only non-dominant limb and increased one leg hop distance in both dominant and non-dominant limbs in female volleyball players. On the other hand, H:Q ratio of dominant limb improved in both groups. Therefore, we could not completely support the hypothesis of the study.

Plyometric training can lead improvements in athletic performance and lower extremity biomechanics and reduce ACL injury risk in female athletes (Hewett et al., 1999; Hewett et al., 1996). The studies have shown that relatively large lower extremity valgus excursions at low knee flexion angles with forceful quadriceps contractions during landing from a jump cause excessive stress on ACL especially in female athletes (Olsen et al., 2004; Renstrom et al., 2008). In addition, quadriceps dominance is an indicator of ACL injuries in female athletes. Hamstring muscles' function is crucial for knee joint stability as they

control excessive anterior tibial translation and decrease the load on the ACL. Therefore, the balance between hamstring and quadriceps strength is thought to important for knee stability and prevention of the knee injuries (Hewett et al., 2008; Hewett et al., 1996). Tsang et al. (2011) reported that plyometric training enhanced H:Q ratio in female individuals. Since hamstring strength increased and quadriceps strength did not change after training, H:Q ratio increased in their study. In present study, we observed no difference between plyometric training group and control group in terms of H:Q ratio. However, H:Q ratio increased in both groups after trainings. In Tsang et al.'s study, the control group did not receive any training program but in our study control group attended strengthening program for upper and lower body, core stability, balance and volleyball technical trainings so the different findings between two studies might be due to variation of the training programs.

Plyometric training has shown to enhance postural stability via improving the

sensitivity of afferent feedback pathway (Borghuis et al., 2008). Asadi et al. (2015) found that 6-week plyometric training improved SEBT outcomes in basketball players. They suggested that joint position sense and joint motion awareness might be enhanced by plyometric training which cause improvements in all directions of SEBT. We found improvements in non-dominant limbs' balance performance after plyometric training. There was no difference between groups in balance performance of dominant limb but balance performance was found increased in both groups. Therefore, according to our findings, plyometric training might be more effective for non-dominant limb balance performance.

As plyometric training could enhance the ability to show maximum force for the shortest time (Bedoya et al., 2015), we expected to see an increase in one leg hop distance after plyometric training. It was found that hop performance increased after both training in the present study but plyometric training was found more effective than conventional

training. Previous study postulated that plyometric exercises lead to rapid changes from eccentric contractions to concentric contractions of the movement so it resulted in an increase explosive power. Similar to our findings, Baldon et al. (2014) demonstrated an increase in triple hop test and 6-meter timed hop test outcomes in recreational female athletes after 6-week plyometric training.

We used Hewett et al.'s (1996) plyometric training program in this study. This program aimed to teach the athletes proper jump and landing maneuvers and to decrease peak landing forces after jump. We did not measure landing forces and lower extremity biomechanics as we only aimed to investigate whether plyometric training would enhance athletic performance in volleyball players.

In conclusion, 6-week plyometric training increase balance and hop performance in female volleyball players but it had no effect on hamstring quadriceps strength ratio. This training could be useful to enhance athletic performance and prevent lower extremity injuries in volleyball players.

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