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The Effect of Plyometric Training on Speed, Agility and Balance Performance of Adolescent Volleyball Players

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ABSTRACT

It is aimed in this study to analyze the effect of plyometric trainings on the speed, agility and balance performance of adolescent volleyball players. The sample of the study includes 15 female licensed players playing in the leagues established by the Turkish Volleyball Federation. The average age of the participants was determined as $16,33 \pm 1,17$, average height as $167,53 \pm 0,08$ cm, average body weight as $53,67 \pm 6,11$ kg, average body mass index as $19,11 \pm 1,64$ kg/m² and average training age as $4,00 \pm ,092$ years. The group participated in the research was applied plyometric training method 3 days a week for 6 weeks, a total of 18 days. The performance data of the participants were obtained through flamingo balance test, 30 m sprint test and 10x5 shuttle run test. The normality of the data was analyzed by Shapiro-Wilk Test and it was seen that the data were revealed a normal distribution. Pretest and posttest measurements of within group were calculated by using Paired Sample T Test and the significance level was accepted as 0.05. The study was organized according to the pre-test and post-test results. As a result of the study, after the 6-week plyometric training program, it was determined that there was no significant difference in the mean values of the height, body weight, body mass index, flamingo balance test and 30 m sprint test ($p > 0,05$). It was found that there was a statistically significant difference in the mean values of the 10x5 shuttle run test in the comparison of the pretest and posttest results of the research group ($p < 0,01$). Consequently, we can state that plyometric exercises to be applied in the trainings of adolescent volleyball players will contribute the agility performance of the players in a positive way. The fact that trainers include plyometric exercises in the certain periods of the trainings will contribute to the increase of the performance of the athletes. It is recommended that plyometric exercises to be applied within a determined program and appropriate for the age groups of the athletes, especially in branches that require anaerobic performance.

Keywords: Adolescent, Plyometric Training, Volleyball Players



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INTRODUCTION

An athlete aims to continue his/her performance for a long time achieving successes in the sport branch s/he plays. This goal can be achieved under the light of science and through appropriate training (Hacıcaferoğlu et. al, 2017). If the physical characteristics of an athlete are not suitable for the sport being played, then it is difficult to achieve the desired performance no matter how much training s/he does. When physical structure and psychomotor skills are combined, the desired performance will emerge. Genotypes, age, ethnic structure, the sport branch performed, diet and gender can affect the physical characteristics (Yaprak and Durgun, 2009). In addition to improving the physical and physiological performance of training athletes, it also contributes positively to the development of their psychosocial characteristics. (Hacıseferoğlu & Güner, 2013).

Although volleyball is played in our country (Türkiye), it is also widely played. It has become a part of life by attracting attention of many young people especially through schools and clubs. It contributes the increase in the communication between individuals as well as creating fun and group dynamic and bringing physical and educational values besides it provides individuals to be healthy (Hacıcaferoğlu, 2022). It is seen that the performance of athletes who have the physical characteristics of the sports branch they practice increases faster.

Together with these characteristics, intense and appropriate training systems and a perfect technique increases the level of performance (Sevim, 2010). It is difficult to achieve the desired performance if an athlete is not suitable physically (Hacıcaferoğlu et. al, 2017).

Jumping skill is important for volleyball. Jumping skill is continuously used during hits, blocks and jump serve in the game. Athletes should jump to the highest point for success and a good performance. Jumping skill should produce strength in the quickest way in a very short time (Anil, et al.,2001; Apaydın & Kaya, 2022). The purpose of jumping in volleyball is to reach the highest point in the shortest and fastest way. Jumping can be performed by one or both feet (Brittenham, 1994).

Plyometric training is one of the muscles strengthening exercises that individuals perform using their own body weight. It is easily performed by body weight without the necessity of any other weight (Çelenk & Yıldırım, 2000; Doğru, 2019). Plyometric training is the training type that is performed with lower and upper limbs with the help of one's own body weight and the equipment such as medicine ball and includes various jumping exercises (Chu, 1994). Plyometric training is more effective in sport branches requiring quicker and more instant strength movement (volleyball, football, athletics and basketball). As in many training types, plyometric training contributes the increase in the muscle strength and is easily applicable in the sport branches requiring muscle strength (Bayraktar, 2006). It is stated in a different definition that plyometric training is the whole of movements including the combination of explosive strength and movement speed to increase and retain the performances of athletes (Chu, 2003). In fact, through plyometric training, it is provided to improve and retain rapid strength, vertical jumping, speed, anaerobic power and maximal power, which athletes need (Adıgüzel, 2017; Doğru, 2020). Fast and quick jumps in plyometric training significantly increase the development of explosive power and agility (Ateşoğlu & Hazar, 2005).

The plyometric training program is implemented with different variations. For example, where we are, it can be applied using various materials such as side-to-side and upward jumps, bounces, crates and bosu balls. Studies reveal that there is a significant relationship between strength and jumping performance (Charoenpanicha et.al., 2013). During a five-set volleyball match, each athlete makes an average of 250 jumps (Martinez, 2017). Therefore, jumping performance is one of the most important factors that determine performance in volleyball.

In this context, the aim of our study is to investigate the effects of plyometric training applied 3 days a week on the basic skills, speed, balance, and agility of adolescent volleyball players between the ages of 14-17. The originality and uniqueness of our study in this age group, where physical development and performance will increase to the highest level and the development of athletes will gain positive momentum. increases its importance.

METHOD

Research Model

This study was conducted according to the pre-test post-test design, which is one of the quantitative research methods, since it was aimed to determine the effects of plyometric training applied 3 days a week on the basic skills, speed, balance and agility of adolescent volleyball players aged 14-17 years. The researched was designed as one group. Two measurements were taken before and after the training. Measurements were taken again after the 6-week training.

Research Group

In the study, the average age of those studying at a sports high school in Siirt province was 16.33±1.17, their height average was 167.53±.08, their body weight average was 53.67±6.11, their body mass index average was 19.11±1.64 and 15 female volleyball players with an average training age of 4.00 ±.092 years participated. Plyometric training method was applied to our study group 3 days a week for 6 weeks, along with weekly volleyball training. Informed Voluntary Consent Forms were obtained from the athletes. Necessary permissions were received from the families of the athletes and school management.

Table 1. The Descriptive Statistics of the Participants

| Variable | n | min | max | mean± sd. |
|-------------------------|----------|------------|------------|------------------|
| Age (Year) | 15 | 14 | 17 | 16,33±1,17 |
| Height (cm) | 15 | 153 | 180 | 167,53±,08 |
| Body Weight (kg) | 15 | 42 | 62 | 53,67±6,11 |
| BMI (kg/m2) | 15 | 16,79 | 22,41 | 19,11±1,64 |
| Training age | 15 | 3 | 6 | 4,00 ±,092 |

Table 2 presents the descriptive statistics of the participants, providing a comprehensive overview of the demographic and physical characteristics of the 15 female volleyball players aged 14-17 years who participated in the study. The cohort exhibited an age spectrum ranging from 14 to 17 years, with a central tendency (mean) age of 16.33 years and a standard deviation (SD) of 1.17 years. This suggests a relatively uniform age distribution amongst the participants.

Participants demonstrated a mean stature of 167.53 cm. The minimal standard deviation of 0.08 cm indicates a notably homogeneous height distribution amongst the participants, spanning from a minimum of 153 cm to a maximum of 180 cm.

The body weight of the participants was distributed with a mean value of 53.67 kg and a standard deviation of 6.11 kg, reflecting a moderate variability amongst the players, with individual weights ranging from 42 kg to 62 kg.

The participants' Body Mass Index (BMI) was observed to be within a healthy range, with a mean value of 19.11 kg/m2 and a standard deviation of 1.64 kg/m2. The BMI values spanned from 16.79 kg/m2 to 22.41 kg/m2, indicating a moderate dispersion around the mean.

The training age, indicative of the duration of structured training undertaken by the participants, was averaged at 4.00 years with a standard deviation of 0.92 years. The range of training age amongst the participants was demarcated between 3 and 6 years.

Data Collection Tools

Height Measurement: The heights of the subjects included in the study were measured by a stadiometer.

Body Weight Measurement: Body weight measurements of the subjects were taken by an electronic scale with a precision of 0.1. Subjects were measured as they were on a vertical position, hands were at two sides and the weight distributed to both feet equally and the values were recorded as kg.

30 m Sprint Test: The 30-meter running durations of the athletes were measured by a photocell. Three measurements were taken, and the best result was recorded (Rakovic et. al, 2018).

10x5 m Shuttle Run Agility Test: The test is conducted to measure the running speed of an individual. Cones or lines are prepared with 5-meter intervals. The subject gets prepared behind the scratch line. With the instruction of start, the subject runs as fast as possible as both feet pass the line, passes the opposite line and returns back to the start point. S/he repeats 10 times until completing a total of 50 meters and the running duration is recorded (Özer, 2013).

Flamingo Balance Test: Students tried to keep balance on the beam for 1 minute. The balance foot was on the beam and the other foot was held by hand towards the hip. When students lost their balance or fall off the beam, the time was stopped. Total balance time obtained in 1 minute was recorded as the score (Jakobsen et. al., 2011).

Table 2. Plyometric Training Program

Plyometric training method was applied to our study group 3 days a week for 6 weeks, along with weekly volleyball training. The training program is shown in the table below.

| | | | |
|----------------------------|------|---|------|
| Vertical jump | 10x3 | Jump rope | 10x3 |
| Side-to-side ankle hops | 10x3 | Standing long jump | 8x3 |
| Kangaroo hops | 10x3 | Lateral hop over hurdle | 12x3 |
| Shuttle with medicine ball | 8x3 | Zigzag drill | 12x3 |
| Stairs jump down | 8x3 | Hurdle hops with change of direction sprint | 10x3 |
| Stairs forward hop one leg | 10x3 | Squat jump | 8x3 |
| Stairs squat jump | 10x3 | Lateral jump to the side over hurdle | 8x3 |
| Two-foot forward jump | 10x3 | | |

Statistical Analysis

The data were analyzed by the package program SPSS 21. The normality of the data was tested by Shapiro-Wilk test and it was seen that the data were distributed normally. Normality coefficient is in the range of -2,+2 (George & Mallery, 2010).The within group values were calculated by using Paired Sample t-Test, and the significance level was taken as 0.05

FINDINGS

This section presents the measured findings of various variables to evaluate the physical performance of the participants in the study.

Table 3. The Comparison of the Physical Performances of the Participants Through Paired Simple t-Test

| Variable | Group | n | min | max | mean± sd. | t | p |
|-----------------------------|-----------|----|-------|-------|--------------|-------|--------------|
| Body Weight (kg) | Pre-test | 15 | 42 | 62 | 53,67 ± 6,11 | 1,702 | ,111 |
| | Post-test | 15 | 45 | 58 | 52,47 ± 4,40 | | |
| BMI (kg/m ²) | Pre-test | 15 | 16,79 | 22,41 | 19,11 ± 1,64 | 1,615 | ,129 |
| | Post-test | 15 | 16,81 | 20,94 | 18,71 ± 1,27 | | |
| Balance (number) | Pre-test | 15 | 1 | 5 | 2,80 ± 1,14 | 1,871 | ,082 |
| | Post-test | 15 | 1 | 4 | 2,40 ± 1,12 | | |
| 10x5 Shuttle run test (sec) | Pre-test | 15 | 14,47 | 18,80 | 17,03 ± 1,36 | 4,667 | ,001* |
| | Post-test | 15 | 13,87 | 20,02 | 15,90 ± 1,59 | | |
| 30 m Sprint Test | Pre-test | 15 | 4,26 | 5,37 | 4,71 ± ,028 | ,896 | ,385 |
| | Post-test | 15 | 4,18 | 5,32 | 4,65 ± ,368 | | |

p<0,01, p< 0,05

Table 3 delineates a meticulous comparative analysis of the physical performances of the participants, employing a Paired Sample t-Test to discern statistical significance in the observed variations from pre-test to post-test across various physical metrics. The participants exhibited a mean body weight of 53.67±6.1153.67±6.11 kg in the pre-test, which slightly decreased to 52.47±4.4052.47±4.40 kg in the post-test. The t-value of 1.702 and p-value of 0.111 suggest that this reduction was not statistically significant.

A subtle decrement in BMI was observed from the pre-test mean of 19.11±1.6419.11±1.64 kg/m² to the post-test mean of 18.71±1.2718.71±1.27 kg/m². However, the t-value of 1.615 and p-value of 0.129 indicate that this diminution does not attain statistical significance. Balance, quantified as a number, demonstrated a mean value of 2.80±1.142.80±1.14 in the pre-test, which marginally reduced to 2.40±1.122.40±1.12 in the post-test. The statistical analysis yielded a t-value of 1.871 and a p-value of 0.082, thereby not substantiating a statistically significant difference.

A notable enhancement in the 10x5 shuttle run test was observed, with the mean time reducing from 17.03±1.3617.03±1.36 seconds in the pre-test to 15.90±1.5915.90±1.59 seconds in the post-test. This improvement was substantiated as statistically significant with a t-value of 4.667 and a p-value of 0.001. The 30 m sprint test times exhibited a slight improvement from a pre-test mean of 4.71±0.284.71±0.28 seconds to a post-test mean of 4.65±0.3684.65±0.368 seconds. However, with a t-value of 0.896 and a p-value of 0.385, this improvement was not statistically significant.

In summation, Table 3 provides a meticulous comparative analysis of the physical performance metrics of the participants, revealing a statistically significant improvement in the 10x5 shuttle run test post-intervention, while changes in body weight, BMI, balance, and 30 m sprint test did not attain statistical significance.

DISCUSSION

The primary aim of this study was to investigate the effects of plyometric training on anthropometric characteristics, balance, speed, and agility in adolescent volleyball players studying at a sports high school. Plyometric training, as described by Wang and Zhang (2016), enables muscles to stretch rapidly and dynamically, leading to concentric contraction. Furthermore, numerous studies, including Yarayan and Müniroğlu (2020), have highlighted its contributions to enhancing strength, jump performance, agility, and sprint performance in athletes.

Our findings, derived from a rigorous comparative analysis using the Paired Sample T-Test, revealed that participants exhibited an average body weight of 53.67 ± 6.11 kg at the pre-test, which decreased to 52.47 ± 4.40 kg at the post-test. However, with a t-value of 1.702 and a p-value of 0.111, this decrease was not statistically significant.

While our study did not observe a significant change in body weight, the broader literature supports the benefits of plyometric training. For instance, a systematic review found that plyometric training appears to enhance vertical jump performance, strength, horizontal jump performance, flexibility, and agility/speed in volleyball players (Silva et al., 2019). Another study emphasized that aquatic plyometric training can effectively improve speed, endurance, and explosive power in volleyball players (Kamalakkannan, Azeem, & Arumugam, 2011).

Moreover, the combination of agility and plyometric training, as well as balance and plyometric training, has been shown to result in significant improvements in various measures for young soccer players (Makhlouf et al., 2018). This suggests that integrating plyometric training with other training modalities can further enhance its benefits. When the studies on this field are viewed, we can say that there is an increase in the body weights after the training but this increase does not create a difference (Kaya & Öztürk, 2023). In the study Öztin et. al. conducted, it was stated that there was no significant difference in the experimental and control groups (Öztin, et. al, 2003). Our study is similar to the others conducted in this field.

In the context of volleyball, it's noteworthy that specific plyometric, strength, and change of direction (COD) training over a 7-week period produced medium to large improvements in physical fitness in high-school basketball players (Sáez De Villarreal et al., 2021). This underscores the potential of plyometric training in enhancing performance metrics crucial for volleyball players.

The secondary objective of our study was to assess the impact of plyometric training on the Body Mass Index (BMI) of adolescent volleyball players. Our results indicated a slight reduction in BMI from a pretest mean of 19.11 ± 1.64 kg/m² to a posttest mean of 18.71 ± 1.27 kg/m². However, with a t-value of 1.615 and a p-value of 0.129, this reduction did not achieve statistical significance.

While our study observed a non-significant change in BMI, the broader literature provides insights into the effects of plyometric training on various physical attributes in athletes. For instance, a systematic review highlighted that plyometric training seems to enhance vertical jump performance, strength, horizontal jump performance, flexibility, and agility/speed in volleyball players (Silva et al., 2019). Another study emphasized the positive effects of plyometric training on upper- and lower-body explosive strength in adolescent male basketball players (Santos & Janeira, 2011). Furthermore, research has shown that specific plyometric, strength, and change of direction (COD) training over a 7-week period produced medium to large improvements in physical fitness in high-school basketball players (Sáez De Villarreal et al., 2021). This suggests that plyometric training can have a broad range of benefits for athletes, even if the impact on BMI is subtle.

In the context of volleyball, it's noteworthy that athletic volleyball training provides a more efficient stimulus for muscle compared to tendon adaptation, which results in an increased demand placed upon the tendon by the working muscle in adolescent volleyball athletes (Mersmann et al., 2017). This could potentially explain the subtle changes in BMI observed in our study.

Our study's third finding pertained to the evaluation of balance in adolescent volleyball players post plyometric training. The results showcased a slight decrement in balance, quantified numerically, from a pretest mean of 2.80 ± 1.14 to a posttest mean of 2.40 ± 1.12 . However, the statistical analysis, with a t-value of 1.871 and a p-value of 0.082, did not confirm this reduction as statistically significant.

While our study observed a non-significant change in balance, the broader literature provides insights into the effects of plyometric training on balance and other physical attributes in athletes. For instance, a study by Ringhof et al. (2018) emphasized the importance of selecting appropriate balance exercises to achieve rapid and desired training outcomes, especially in team sports interventions. Another study by Pau, Loi, and Pezzotta (2012) explored the potential benefits of balance training (BT) on young athletes, suggesting that while BT might have a beneficial effect, further investigations are required to clarify its actual impact on balance performance in comparison to regular volleyball training. In the context of volleyball, balance is a critical component, especially when considering the dynamic movements and jumps involved in the sport. A study by Mersmann et al. (2017) concluded that athletic volleyball training provides a more efficient stimulus for muscle compared to tendon adaptation, which could influence balance performance in adolescent volleyball athletes.

Moreover, the combination of plyometric training with balance exercises has been shown to yield significant improvements in various measures for athletes. A study by Bouteraa et al. (2020) highlighted that the addition of balance and plyometric training to regular in-season basketball training enhanced balance, agility, and other physical attributes in female adolescent basketball players. Okludil and Serin stated that the balance performance increased after the study they conducted (Okludil & Serin, 2022). Dilek et. al. reported in their study that there was a statistically significant difference in the balance performance after the 8-week training (Dilber et. al, 2016). In the study conducted on basketball players, it was stated that the balance performance increased in a positive way (Nugraha et. al, 2022). We can state that plyometric training contributes the balance performance of the athletes positively. The fact that volleyball training does not includes balance exercises may be the reason of that the balance values in our study were not different. Our research is not similar to the other studies conducted in this field.

The fourth finding of our study delved into the effects of plyometric training on the 10x5 shuttle run and 30 m sprint test performances in adolescent volleyball players. A significant improvement was observed in the 10x5 shuttle run test, with the meantime reducing notably from the pretest to the posttest. Conversely, while the 30 m sprint test times showed a slight improvement, this change was not statistically significant. Our results align with the broader literature on the effects of plyometric training on athletic performance. A systematic review by Silva et al. (2019) indicated that plyometric training seems to enhance agility/speed, among other attributes, in volleyball players. This supports our observed enhancement in the 10x5 shuttle run test. Additionally, Lockie et al. (2014) emphasized that sprint and plyometrics training can improve acceleration, primarily through increased step length and a greater emphasis on vertical force production, which might explain the observed improvements in our study.

Furthermore, a study by Houghton et al. (2013) concluded that plyometric training had possible benefits on intermittent shuttle running times and improved jump performance. This is consistent with our findings of improved shuttle run times post plyometric training. On the

other hand, the slight improvement in the 30 m sprint test times without statistical significance in our study might be attributed to various factors. As highlighted by Turner et al. (2015), plyometric exercise can enhance sprint acceleration performance in athletes during pre-competition practices, provided there is adequate recovery between activities. The study conducted by Civan, Karhan, and Civan (2022) investigated the effects of an 8-week plyometric training program. Their results indicated that, although there was no significant difference observed between the different plyometric training groups, the experimental group that underwent the 8-week plyometric training exhibited a positive enhancement in both vertical jump and anaerobic power parameters. It is stated that 6-week plyometric training has increased the speed performances of the athletes (Kaplan, 2021). In the study conducted by Taşkan, it is stated that plyometric training had a positive contribution to the speed performances of the athletes (Taşkan, 2020). It is indicated that plyometric training increased the speed performance in the athletes between the age ranges of 11-12 (Akçınar, 2014). When the studies conducted on this field are examined, it is seen that there are no similar results to our study. It is thought that this situation may have resulted from the application of different training programs to different age groups and the short weekly training duration. In our findings, it is seen that the 6-week plyometric training program contributed the agility performances of the athletes. It was reported that 4-week plyometric training positively affected the agility values of the futsal players (Arı, et. al, 2021).

Güzel stated that the study conducted on the athletes at the age range of 12-14 contributed the agility values of the athletes (Güzel, 2020). In the study conducted by Atacan, it was reported that there was a statistically significant difference in the agility values of the experimental group when compared to the control group (Atacan, 2010). Improvement of the agility performance does not increase only through the improvement of a single skill, but also the improvement of strength, speed, balance and coordination skills together. Our study is similar to the other studies conducted in this field. In the context of volleyball, where agility, speed, and quick directional changes are paramount, plyometric training can be a valuable tool.

Conclusion

The comprehensive investigation of plyometric training's effects on adolescent volleyball players at a sports high school has provided valuable insights into its potential benefits and limitations. Our study's findings, in conjunction with the broader literature, underscore the multifaceted benefits of plyometric training, particularly in enhancing agility, speed, jump performance, and potentially balance.

While certain metrics, such as body weight and BMI, did not exhibit statistically significant changes post-training, other performance measures, notably the 10x5 shuttle run, demonstrated marked improvements. These results highlight the nuanced effects of plyometric training, suggesting that while it may not significantly alter anthropometric characteristics, it can substantially enhance athletic performance attributes crucial for volleyball players.

Our study's alignment and occasional divergence from existing literature emphasize the importance of individualized training regimens, considering factors like age, training duration, and specific athletic requirements. For instance, the non-significant changes in balance and sprint times in our study, despite being contrary to some literature, underscore the need for tailored plyometric training programs, potentially integrated with other training modalities for optimal results. Furthermore, the consistent emphasis across various studies on the benefits of plyometric training, whether standalone or combined with other training forms, indicates its indispensable role in athletic training, especially for sports like volleyball that demand agility, speed, and power.

In conclusion, while plyometric training offers a plethora of benefits to adolescent volleyball players, its effects can vary based on the training's specifics and the athletes'

individual characteristics. Future research should delve deeper into optimizing plyometric training regimens for volleyball players, ensuring a holistic improvement across all desired metrics. This study serves as a foundation for such endeavors, emphasizing the importance of evidence-based training approaches in enhancing athletic performance.

Limitations

Our study was conducted on a specific group of adolescent volleyball players studying at a sports high school. The results might not be generalizable to volleyball players of different age groups, skill levels, or those from non-sporting schools. The plyometric training program spanned a duration of six weeks. Longer or shorter training durations might yield different results. The study did not account for participants' dietary habits, sleep patterns, or other lifestyle factors, which could influence the outcomes of plyometric training. Factors such as participants' mental health, stress levels, and external physical activities outside of the study were not controlled for, which might have influenced the results. The uniform intensity of plyometric training might not cater to the individual needs of each participant. Personalized training intensities could yield different outcomes.

Recommendations

Future studies should consider a more diverse sample, encompassing different age groups, skill levels, and backgrounds to enhance the generalizability of the findings.

Investigating the effects of plyometric training over longer durations, such as several months, could provide insights into its long-term benefits and potential plateaus in performance improvements.

Incorporating tools to monitor participants' dietary habits, sleep patterns, and overall lifestyle can provide a more comprehensive understanding of plyometric training's effects.

Combining plyometric training with other training forms, such as strength training or balance exercises, might yield synergistic benefits.

Future research should explore the effects of individualized plyometric training programs tailored to each participant's needs and capabilities.

Implementing a feedback mechanism where participants can share their experiences, challenges, and suggestions during the training can provide qualitative insights to complement the quantitative data.

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