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EFFECTS OF PLYOMETRIC TRAINING ON BALANCE AND JUMPING IN FEMALE VOLLEYBALL PLAYERS BETWEEN THE AGES OF 15-18

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Abstract:
Objective: This study aimed to investigate the effects of plyometric training on balance and jump performance in female volleyball players aged 15-18 years. **Method and Materials:** Sixteen voluntary female volleyball players (experimental n=8, control n=8) playing volleyball in Bursa Nilüfer Municipality, with an average age of 16 years and no history of plyometric training, participated in the study. Before and after 8 weeks of plyometric training, long jump with platforms, dynamic balance with Y balance test and vertical jump with Optojump digital measuring devices were measured. Paired Samples T-Test and Independent Sample T-Test were used for statistical analysis. **Results and Conclusion:** As a result of the training, vertical jump, core strength and right leg balance values increased ($p<0.05$), while no significant change was found in long jump values. In the left leg balance ($p=0.060$) ($p>0.05$), the significance of the difference is open to discussion since this result is close to the significance limit. According to the results, significant improvements were observed in all physical parameters in the experimental group in the pre-test and post-test comparisons. According to the results of the study, it is possible to say that plyometric training has a significant effect on athletes' physical performance.

Keywords: plyometric, balance, jump, volleyball, physical performance

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1. Introduction

Balance refers to the ability of athletes to keep their body's centre of gravity under control. A balanced body posture in volleyball is necessary for players of all ages to perform at the highest level (Bompa, 2009). In volleyball, where sudden movements, rapid changes of direction and movements such as jumping are frequently repeated, balance is a factor that directly affects performance as well as reduces the risk of injury (Aktürk & Tutar, 2024). In addition, plyometric training improves the ability of athletes to maintain balance on the court by improving the body's balance mechanisms. It is supported by studies that plyometric training contributes to the improvement of balance in young female athletes. For example, Myer et al. (2005) reported that plyometric training programmes supported balance development in young athletes and also improved their coordination abilities (Moore et al., 2015).

Jumping height is a critical skill in volleyball performance; especially in movements such as blocking and spiking, jumping capacity is decisive (Andrejić, 2012). Plyometric training aims to increase jumping capacity by strengthening the elastic properties of the muscles and increasing their ability to contract rapidly. It is widely accepted in the literature that plyometric training, which contributes to athletes' ability to jump higher in a shorter time, provides a significant improvement in jump performance (Chu, 1998, Yılmaz, 2024). Research shows that a rapid and effective increase in jump performance can be achieved if the correct training programmes are applied, especially since young athletes have a high potential for development in muscle structure (Mutlu, 2023; Özlük, M. S., 2024). For example, in a study conducted by Arazi et al. (2012), it was revealed that a significant increase in jump height was achieved in young volleyball players who underwent plyometric training.

The aim of this study is to investigate in detail the effects of plyometric training on balance and jumping in female volleyball players aged 15-18 years. In this context, it will be analysed how the plyometric training programme, which is planned for a certain period of time and applied in a controlled manner, affects balance and jump performance. The research aims to provide original contributions to the physical development of athletes with the findings obtained as a result of the applied training programme. At the end of the study, specific recommendations that can be used in planning training programmes for young volleyball players will be presented. It is thought that these results will increase the efficiency of training programmes as well as support the physical development of athletes (Meriçli, 2024).

This study also aims to expand the knowledge in the literature by revealing the effects of plyometric training on the development of physical characteristics important for volleyball, such as balance and jumping, in young athletes.

This research focuses on one of the training methods used in the development of balance and jumping skills, which are among the basic elements of high performance for volleyball sport plyometric training. Plyometric training is a type of training that helps to develop speed, power, muscular strength and muscular endurance at the same time.

This training method, which includes high-intensity exercises and sudden, explosive movements, has found a wide place in the sports literature as an effective tool to improve the performance of athletes. It is emphasised that plyometric training has the potential to improve the performance of athletes in sports requiring speed, agility, jump height and balance, such as volleyball (Silva, 2019; Arazi, 2011).

2. Material and Methods

This study was planned to be carried out on 16 female volleyball players with an average age of 16 years who actively play volleyball in Bursa Nilüfer Municipality. The main aim of the study was to evaluate the effects of plyometric training on the balance, jump and vault performances of the athletes and to obtain scientific findings in this direction. Within the scope of the study, an 8-week plyometric training programme will be applied to the participants and physical performance tests will be performed before, after and during the four-week period following the completion of the programme. At the beginning of the research process, athletes, coaches, and their families will be informed in detail about the tests and training programme and voluntary participation consent documents will be obtained.

The research will be conducted in a controlled environment in Bursa Nilüfer Municipality Indoor Sports Hall. The indoor sports hall provides an ideal environment for the conditions of the study that require precise measurement. The training program is planned to be held three days a week between the specified dates, and tests will be administered after each training session to evaluate the progress of the athletes. This approach allows for monitoring both the immediate changes in athletes' performance and the overall effects of the training program.

In the study, various measurement tools and tests were used to evaluate the effects of plyometric training on balance and jump performance. Weight measurements were carried out accurately using a Tanita SC 330 S model digital scale. This scale has an accuracy of 0.01 kg and allows measurements to be made in kilograms. The athletes were allowed to step on the scale barefoot. During the measurement, the athletes wore only a T-shirt and tights. This is important to minimise additional weight in the measurement. Height was measured with millimetre precision using a stadiometer fixed on a flat surface with the participants standing upright and without shoes. These methods allowed for an accurate assessment of the physical characteristics of the athletes and contributed to the reliability of the study. The high precision of the equipment used in the measurements has a significant effect on the accuracy of the data obtained. Information about the other tests performed in the study is given below:

A. Balance Test

In the study, the Y Balance Test was used to measure dynamic balance skills. The Y Balance Test is a test used to evaluate the dynamic balance of individuals. The athletes were asked to stand on one foot at the intersection of three tape measures and then reach

to three different angles in the anterior, posteromedial and posterolateral directions. During the test, care was taken not to move the stabilised foot. The test was performed for both the dominant (usually stronger and more used leg) and the nondominant (less used leg). For each direction, the test was repeated three times with specific rest intervals. The best score for each direction was recorded. The scores were then normalised using the formula 'Maximum Reach Distance / Leg Length) x 100 = % maximum reach distance' (Coughlan et al., 2012).

B. Jump Test

With the help of Optojump digital measuring devices, the vertical jump capacities of the athletes were recorded. These devices evaluated the changes in jump height by analysing the data generated during each jump in detail. Optical sensors follow the movements of the jumper in an area between two flat bars placed on the ground. These sensors are used to calculate the jump height by measuring the time the person stays in the air. The process was carried out in the following sequence. When the person starts to jump, the optical sensors record the moment of separation from the ground. During the time the person stays in the air, the sensors measure this time. When the person lands on the ground, the sensors also record this moment.

C. Long Jump Test

The jumping skills of the athletes were measured by long jump tests with the help of platforms. During the measurement, it was paid attention that the students placed their toes just behind the line and their feet were in normal range. In this position, the athletes stood parallel to the ground and extended their arms forward. The athletes with bent knees tried to jump as far as possible with the swing of their arms. During the jump, it was important to touch the ground with both feet at the same time. This test was repeated twice for each student. After two attempts, the best distance reached by the students was recorded in centimetres (cm) (Yılmaz, 2014).

D. Statistical Analysis

The validity and reliability of the data obtained in the study were evaluated with carefully selected statistical analysis methods. Firstly, the normal distribution of the research variables was analysed and skewness and kurtosis values were examined in this process. All variables were found to be within the limits of normality, which indicates that the necessary conditions for the application of parametric tests are met. This situation revealed that the data obtained can provide reliable results in statistical analyses and provide a valid basis for testing the research hypotheses. Two main analysis methods were used to compare the performances of the experimental and control groups. The first one, the Paired Samples T-Test, was applied to evaluate the differences between the pre-test and post-test results of both groups. This test was used as a critical tool in understanding the effect of plyometric training on the participants. The second analysis method, the Independent Sample T-Test, was preferred to reveal the differences between

the post-test performances of the experimental and control groups. This test played an important role in assessing whether the differences in performance between the groups were statistically significant. As a result of the analyses, it was determined that plyometric training led to significant performance increases, especially in the experimental group.

Significant improvements were recorded in physical performance parameters such as vertical jump height, core strength and balance in the experimental group. These findings clearly demonstrated the potential of plyometric training to improve jumping and balance skills, especially in dynamic sports such as volleyball. In the control group, the improvements in these parameters were limited and showed low statistical significance. The analyses used in the study were evaluated according to the statistical significance criterion at 95% confidence interval and $p < .05$ level. This approach was carefully structured to increase the scientific validity of the results and to provide support for the hypotheses. The measurement and evaluation process shows that the research findings are intended to prove the effect of plyometric training in a scientific framework. This comprehensive process allowed the research to reach reliable and valid results, confirming that plyometric training is an effective strategy for improving athletes' physical performance.

3. Results

According to the demographic findings of the study, the basic variables such as age, height and weight of the participants were analyzed in detail. When the mean age of the participants was evaluated, the mean age of the experimental group was 16.73 (SD = 1.03), while the mean age of the control group was 16.87 (SD = 1.19). These findings indicate that the age range of both groups was quite close to each other and that the study was conducted with participants with a homogeneous age distribution. In terms of height, the average height of the experimental group was 168.33 cm (SD = 6.63), while the average height of the control group was 170.53 cm (SD = 5.22). Although the mean height of the control group was slightly higher than the experimental group, this difference was not considered statistically significant and indicates that the general characteristics of the groups were similar. When the findings for the weight variable were analyzed, the mean weight of the experimental group was calculated as 59.13 kg (SD = 7.28), while this value was 61.27 kg (SD = 7.26) in the control group. This difference observed between the groups in terms of weight indicates that the physical characteristics of the participants in the study were generally similar and that there was no significant imbalance between the groups.

Table 1: Demographic data of the participants

	Group			
	Experimental		Control	
	Mean	SD	Mean	SD
Age, year	16.73	1.03	16.87	1.19
Height, cm	168.33	6.63	170.53	5.22
Weight, kg	59.13	7.28	61.27	7.26

Table 2: Skewness-Kurtosis values of the participants

Variables	Skewness		Kurtosis	
	Mean	SD	Mean	SD
Pre-Vertical Jump (cm)	,513	,427	1,775	,833
Pre- Long Jump (cm)	,104	,427	-,444	,833
Pre - Core (sec)	,202	,427	-,180	,833
Pre – Left Balance (score)	,296	,427	-,014	,833
Pre – Right Balance (score)	-,185	,427	-,833	,833
Post-Vertical Jump (cm)	,587	,427	,915	,833
Post-Long Jump (cm)	,462	,427	-,405	,833
Post-Core (sec)	-,394	,427	-,455	,833
Post-Left Balance (score)	,153	,427	-,844	,833
Post-Right Balance (score)	-,024	,427	-,368	,833

In the table above, the skewness and kurtosis values of the normal distribution analysis of the research variables are presented. In order for a distribution to be considered normal, skewness and kurtosis values should be within ±2 (George & Mallery, 2010). It was observed that the skewness and kurtosis values of all variables in the table were within these limits. For example, the skewness value of the Pre-Vertical Leap variable was reported as .513, and the kurtosis value as 1.775. These values are within the limits of normality. Similarly, the skewness and kurtosis values of the other variables are within ±2 limits, and it is concluded that they meet the normality assumption.

Table 3: Comparison of Post-test Measurements (Independent Sample T-Test)

Variables	Group	Mean	Ss.	t	p
Vertical Jump (cm)	EG	34,20	5,659	2,049	,050
	CG	30,40	4,421		
Long Jump (cm)	EG	155,20	8,428	,726	,474
	CG	153,00	8,168		
Core (sec)	EG	45,20	4,246	2,248	,033
	CG	41,20	5,427		
Left Balance (score)	EG	89,67	10,224	1,957	,060
	CG	82,87	8,749		
Right Balance (score)	EG	92,47	7,927	2,196	,037
	CG	86,40	7,189		

The table above presents the results of the analysis conducted to compare the pre-test and post-test scores of the control group. There are significant differences between the pre-test and post-test results of the control group in some variables. In some variables, no significant differences were observed. The difference between the pre and post-vertical jump scores was .000 (SD = 2,360), and this difference was not statistically significant (t(14) = .000, p = 1,000). A difference of -2,133 (SD = 3,852) points was observed between the long jump scores, and this difference was borderline significant (t(14) = -2,145, p = .050). In the core strength variable, the difference between the pre and post-test was 1.667 (SD = 4.169), and this difference was not statistically significant (t(14) = 1.548, p = .144). A difference of -,533 (SD = 2,800) points was observed in the left leg balance scores, but this difference was not significant (t(14) = -,738, p = ,473). The difference between the right leg balance scores was calculated as -1.467 (SD = 1.642), and this difference was statistically significant (t(14) = -3.460, p = .004). These results show that there was a significant difference only in the right leg balance score in the control group, while there were no significant changes in the other variables.

4. Conclusion and Discussion

While the study's results revealed the effects of plyometric training on the physical performance of female volleyball players, the findings obtained are in parallel with other studies in the literature. The 8-week plyometric training programme applied in the experimental group provided significant improvements in parameters such as jumping, balance and core strength, while limited changes were observed in the control group. This confirms that plyometric training is a more effective approach compared to traditional methods.

The vertical jump performance of the experimental group increased from 30.20 cm to 34.20 cm. This increase coincides with the results reported by Kanbak (2021) in his study on volleyball players. Kanbak stated that plyometric training optimised the jump height and speed skills of athletes. Similarly, in a study conducted by Gür (2024) on artistic gymnastics athletes, it was reported that plyometric training increased jump height and explosive power. In the control group, no significant change was observed in jump performance, which more clearly demonstrates the effect of plyometric training. In terms of long jump performance, a significant increase from 146.47 cm to 155.20 cm was recorded in the experimental group. Ceylan (2022), in his study on female volleyball players, emphasised the effectiveness of plyometric training in improving long jump performance. Ceylan's study shows that this type of training improves the performance of athletes by increasing leg muscle strength and flexibility. In a study conducted by Karasu (2024) on volleyball players, the effect of plyometric training on anaerobic power and long jump distance was confirmed.

The core strength parameter stood out as an important criterion showing the effect of plyometric training. The core strength values of the experimental group increased from 40.20 seconds to 45.20 seconds. Yalvaç (2024), in his study on kickboxing athletes,

reported that plyometric training made significant contributions to balance and stability by strengthening the central muscle groups. Akbulut (2024), in a study on child gymnasts, emphasised the positive effects of plyometric training on balance and core strength. In the control group, no significant improvement was observed in this parameter. In terms of balance performance, left leg balance increased from 80.20 to 89.67, and right leg balance increased from 82.87 to 92.47 in the experimental group. These results are consistent with the findings reported by Karakuş (2024) in his study on female gymnastics coaches. Karakuş stated that plyometric training increased individuals' balance control and stabilisation skills. Hıncal (2024) examined the effects of plyometric training on dynamic balance in a study on swimmers and found that this type of training increased the movement efficiency of athletes.

In the study, the improvements in jump and balance parameters of the experimental group showed significant differences compared to the control group. This shows that the improvements observed in the athletes of the experimental group confirm the effect of plyometric training. Similar results were reported in the study conducted by Merkit (2024), Aktürk (2024) on volleyball players. Merkit emphasised that plyometric training provided significant improvements in the general physical performance of athletes. The parametric test analyses used in the study revealed that the differences between the pre-test and post-test results of the experimental group were statistically significant. Obtaining optimum results once again reveals the importance of training planned according to the specific needs of athletes. Akbulut (2024) stated that plyometric training is an effective method to increase the athletic capacity of young athletes and reached similar findings in his study.

The findings of the study showed that plyometric training significantly increased the physical performance development in the experimental group compared to the control group. The results of the experimental group clearly demonstrated the effects of plyometric training on basic physical skills such as jumping, balance and core strength. On the other hand, the performance of the control group showed limited and generally statistically insignificant improvements. These results show that plyometric training is much more effective in increasing the physical capacity of athletes compared to traditional methods. Vertical jump performance in the experimental group increased from 30.20 cm to 34.20 cm and this increase was found to be statistically significant. This finding is parallel to the study of Arazi and Asadi (2011), in which the effects of plyometric training on land and water environments were investigated in young basketball players. Arazi and Asadi revealed that plyometric training significantly increased the jumping performance of athletes. Similarly, Hernandez-Martinez (2023) and Aktürk (2024) examined the effect of plyometric training at different frequencies on jump height and stated that correctly programmed training provided a significant improvement in performance (Şener, 2024).

In the control group, no significant change was observed in vertical jump values. In the long jump performance, a significant increase from 146.47 cm to 155.20 cm was observed in the experimental group, while this increase was limited in the control group.

The systematic review of Silva et al. (2019) emphasises that plyometric training is effective in improving the performance of athletes in movements that require explosive power, such as long jump. In addition, Majeed et al. (2016) and Hukanoğlşu (2024) showed in their study that plyometric training optimised athletes' explosive power and agility skills. The limited improvement in the control group reveals that the effectiveness provided by plyometric training cannot be achieved by traditional methods (Eylen et al., 2017; Ürer 2023).

The core strength parameter stood out as one of the criteria that showed the effect of plyometric training on athletes most clearly. In the experimental group, core strength increased from 40.20 seconds to 45.20 seconds, while no significant change was recorded in the control group. Harput et al. (2017) stated that plyometric training has a direct effect on core strength, and these trainings strengthen the central muscle groups of athletes. Similarly, Alikhani et al. (2019), in their study on badminton players, emphasised that plyometric training increased the stabilisation of the central muscle groups and made significant contributions to balance performance. In terms of balance performance, left leg balance increased from 80.20 to 89.67, and right leg balance increased from 82.87 to 92.47 in the experimental group. These findings show that the experimental group made significant improvements in balance performance and plyometric training was effective on this parameter. Sitti and Köroğlu (2023), Meriçli (2024) stated that plyometric training provided noticeable improvements in balance and agility skills of young athletes. In the control group, no significant improvement was observed in other parameters except right leg balance. The limited results of the control group coincide with the findings of Hernandez-Martinez et al. (2023). This study emphasises the ineffectiveness of traditional methods in improving balance performance and the importance of plyometric training. It was observed that the post-test results of the experimental group were superior to the control group, and there was a significant difference especially in vertical jump, core strength and leg balance parameters. Sarı (2025), Andrejić (2012), and Yüksel (2016), in their study with young basketball players, stated that plyometric and strength training was effective in increasing the general physical performance of athletes. This finding supports the significant improvements in the post-test results of the experimental group. Turgut et al. (2017) stated that even low-intensity plyometric training provided significant increases in the balance performance of athletes.

In conclusion, this study has comprehensively demonstrated the effects of plyometric training on the physical performance of athletes and obtained results consistent with previous studies in the literature. The improvements observed in the experimental group clearly proved the contribution of plyometric training in basic skills such as jumping, balance and strength, while the limited improvements of the control group once again showed the superiority of these trainings. The findings of the study are an important guide for coaches and sport scientists who want to optimise athlete performance and gain competitive advantage in dynamic sports.

5. Recommendations

Considering the positive effects of plyometric training on the physical performance of female volleyball players, it is recommended to include this type of training in the development process of young athletes. Significant improvements observed, especially in basic parameters such as jumping, balance and core strength, confirm the performance-enhancing effect of plyometric training. In this direction, it can be said that sports clubs and coaches should regularly include plyometric training in their programmes to improve the physical capacity of young athletes. It is important to design programmes in accordance with the individual differences and needs of athletes in order to provide maximum benefit. According to the results of the study, the effect of plyometric training increases with the provision of continuity and appropriate loading principles in athletes' training programmes. In this context, it is recommended that coaches should structure their training programmes based on scientific findings and consider loading-recovery cycles appropriate to the physiological capacities of athletes. In order to increase the effect of training, variables such as frequency, intensity and duration should be regularly reviewed and updated according to individual performance feedback.

Conflict of Interest Statement
The authors declare no conflicts of interest.

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