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The Effect of a Training Program Using the Ballistic Training Method on Developing Lower-Limb Explosive Power and Spike Accuracy among Senior Volleyball Players

أثر برنامج تدريبي باستخدام طريقة التدريب البالستي في تنمية القوة الانفجارية للأطراف السفلية ودقة الضرب الساحق لدى لاعبي الكرة الطائرة أكابر

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Abstract This research examined the impact of a training program using the ballistic method on developing lower-limb explosive power and spike accuracy among senior volleyball players. The experimental method was used with a two-group design (control and experimental) on a sample of 12 players from the Union Boussaâda team. The tests included vertical jump measurements (from static and motion) and a spike accuracy test. The results showed a tangible superiority for the experimental group in the post-measurements. The study concluded that ballistic training is a pivotal means for developing explosive power and improving field skill performance.

Keywords: ballistic training - explosive power- spike- volleyball

الملخص : تناول هذا البحث أثر برنامج تدريبي بالأسلوب الباليستي في تنمية القوة الانفجارية للأطراف السفلية ودقة الضرب الساحق لدى لاعبي الكرة الطائرة (فئة أكابر)، حيث استُخدم المنهج التجريبي بتصميم المجموعتين (الضابطة والتجريبية) على عينة قوامها 12لاعباً من فريق اتحاد بوسعادة. شملت الاختبارات قياسات القفز العمودي (من الثبات والحركة) واختبار دقة الضرب الساحق، وأظهرت النتائج تفوقاً ملموساً للمجموعة التجريبية في القياسات البعدية. وخلصت الدراسة إلى أن التدريب البالستي يعد وسيلة محورية لتطوير القدرة الانفجارية والارتقاء بالمستوى البدني والمهاري.

- **الكلمات المفتاحية :** التدريب الباليستي – القوة الانفجارية – الضرب الساحق- الكرة الطائرة

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1- Introduction and Research Problem

Volleyball, much like other competitive sports, is characterized by a diversity of fundamental skills that necessitate the adoption of well-planned, scientific training methodologies. Coaches must implement programmed approaches to enhance and develop performance levels, aiming to reach elite athletic achievement. This is particularly crucial for the physical and technical aspects; despite the small court size, volleyball demands rapid directional changes, explosive execution, and high-velocity acceleration from low-stance positions. Throughout a single match, a player may perform more than 100 jumps, which mandates the development of lower-limb explosive power. Fundamental skills are intrinsically linked to physical attributes, making the integrated training of both using modern techniques an urgent necessity in the training process. Among the core skills where the direct correlation between physical capacity and technical proficiency is most evident is the offensive skill, specifically the spike. The spike is considered the primary weapon for securing a team's victory (Faraj, 2011, p. 40).

The primary objective of the spike in volleyball is to score points during the match or to regain the serve. This skill necessitates a specific caliber of players characterized by speed, tactical decision-making, self-confidence, and significant height. Furthermore, it requires exceptional leg muscle strength, superior movement velocity, agility, and neuromuscular coordination. Successful execution is also dependent on high explosive power during both the jump and the hit, alongside technical precision in movement and the ability to direct strikes toward specific points, concluding with a proper landing technique (Fahmy, Iskandar, and Batris, 1998, pp. 54-55).

Lower-limb explosive power is a fundamental factor in determining the success and technical precision of this offensive skill. Based on the researcher's observations and a survey of coaches' opinions, a deficiency was identified in the players' physical output regarding explosive power. This weakness negatively impacts the required jumping height above the net and the ball's terminal velocity. Furthermore, it was noted that most coaches rely on traditional training methods to develop this attribute, or it is not given sufficient priority within training programs. Consequently, this lack of specialized focus has resulted in a negative impact on performance during athletic competitions.

Since ballistic training relies on performing movements with maximum possible acceleration without deceleration at the end of the range of motion, it is considered one of the most modern and effective training methods for developing muscular capabilities. This has been confirmed by the study of Hisham Ali Al-Aqra and Mohammed Hussein Al-Ajouri, which focused on the impact of ballistic training on developing lower-limb muscular power and the jump serve; they found that ballistic training improved lower-limb muscular capabilities by 12.39%, while the improvement in the jump serve reached 11.13%. Similarly, the study by Hussein and Hammad (2014) concluded that ballistic training positively influenced certain physical abilities and the performance level of the block for volleyball players. Furthermore, the study by Al-Dulaimi and Sabah (2013) indicated that muscular strength is highly correlated with the accuracy of the serve and the spike in volleyball.

This confirms that ballistic training is one of the most vital training methods for enhancing maximal muscular capabilities, as it involves explosive movements against resistance at maximum possible speed, including light-weight lifting exercises performed at high velocities. Consequently, the researcher deemed it necessary to design a training program to investigate the extent of this training

type's impact on developing physical abilities specifically lower-limb explosive power and its influence on the technical performance of the spike among elite (senior) volleyball players. Accordingly, the research question was formulated as follows:

- Are there significant differences in the post-tests between the experimental and control groups regarding the development of lower-limb explosive power and the spike among volleyball players, attributable to the training program using the ballistic training method?

2-Research Hypotheses:

- There are statistically significant differences in the post-tests between the experimental and control groups, favoring the experimental group, in the development of lower-limb explosive power among volleyball players, attributable to the training program using the ballistic training method.
- There are statistically significant differences in the post-tests for the experimental group in the development of the spike among volleyball players, attributable to the training program using the ballistic training method.

3-Significance of the Study:

The significance of this study stems from the immense evolution witnessed in the sport of volleyball, which necessitates exploring non-traditional training methodologies such as ballistic training. This method is considered an effective approach for developing explosive power, the fundamental pillar for both jumping and the spike.

The value of this research is manifested in providing a standardized training program that bridges the gap between the skill's kinematic path and high physical capacity. This offers coaches and researchers a scientific and field-based tool to enhance technical performance efficiency and secure points during

competitions. Consequently, the study contributes to bridging the gap between theoretical and applied aspects, establishing a modern training tool that ensures players reach elite performance levels through the most efficient and precise means.

Applied Research Procedures:

1. **Research Methodology**: Due to the nature of this study, the experimental approach was adopted, utilizing a two-group design (experimental and control groups) with pre-test and post-test measurements to ensure rigorous comparison and control over variables.

2. Research Population and Sample: The research population consists of elite (senior) volleyball players. The research sample was selected using the purposive (intentional) sampling method, comprising 12 players from the A. Boussaada senior volleyball team.

3-1 Sample Homogeneity:

Table (1) presents the statistical indicators for the homogeneity between the two research groups (experimental and control) regarding the variables of height, weight, and training age.

Variables	Sample	N	Mean	Std. Deviation	Levene's Test	Sig. Level	Significance (sig)
Height	Experimental	6	189.33	3.77	0.092	0.05	0.768
	Control	6	189.50	4.13			
Weight	Experimental	6	89.33	4.58	0.50	0.05	0.812
	Control	6	89	4.42			
Training Age	Experimental	6	9	1.09	0.06	0.05	0.496
	Control	6	8.66	1.36			

Table (1) illustrates the homogeneity between the experimental and control groups across the variables of height, weight, and training age. The statistical

analysis reveals that all significance values (Sig.) obtained via Levene's Test exceeded the assumed significance level of 0.05. Specifically, the values recorded were 0.768 for height, 0.812 for weight, and 0.496 for training age. These results indicate no statistically significant differences between the two groups, thereby confirming the homogeneity and equivalence of the research sample prior to the intervention.

3-2 Equivalence of the Research Groups:

Table (2) presents the statistical indicators for the equivalence between the experimental and control groups in the muscular power tests used in the study.

Tests	Groups	Mean	Std. Deviation	T-value	df	Sig. Level	Significance (sig)	Interpretation
Vertical Jump from Standing	Control	36.33	7.65	0.299	10	0.05	0.771	Not Sig.
	Experimental	37.66	7.76					
Vertical Jump with Approach	Control	41.66	8.10	0.465	10	0.05	0.652	Not Sig.
	Experimental	43.83	8.01					

The results in Table (2) indicate no statistically significant differences between the control and experimental groups in the vertical jump tests (from standing and with approach). The significance values (0.771 and 0.652) are greater than the established level of 0.05, which confirms the equivalence and baseline stability between the two groups before implementing the training program.

4- Applied Physical Tests:

4-1 Vertical Jump Test (Sargent Jump Test)

Known as the "Sargent Test," it measures raw explosive power without relying on horizontal momentum.

- **Objective**: To measure the explosive power of the lower-limb muscles from a stationary position.
- **Equipment**: A flat wall, a measuring tape attached to the wall, and chalk (for marking).

- **Procedure:**
    1. The player stands sideways against the wall with feet flat on the ground.
    2. The player reaches up with the hand closest to the wall to the maximum height to determine the "Standing Reach Height."
    3. From a stationary stance, the player performs a semi-squat (knee flexion) and then jumps vertically as high as possible to mark the wall at the peak of the jump.
- **Performance Constraints**: No preparatory steps or foot movements are allowed prior to the jump.
- **Scoring**: The final score is the difference between the Reach Height during the jump and the Standing Reach Height.

4-2 Vertical Jump Test with Approach (Running Vertical Jump)

- **Objective**: To measure explosive power by utilizing neuromuscular coordination and horizontal momentum.
- **Equipment**: The same equipment used in the previous test.
- **Procedure:**
    1. The player stands facing or sideways to the wall.
    2. The player is permitted to take one, two, or more preparatory steps (approach).
    3. The player performs a powerful arm swing to assist in elevating the body's center of gravity.
    4. The player touches the wall at the highest possible point reached during the flight phase.
- **Performance Constraints:** The take-off must be executed with both feet simultaneously at the final moment (mimicking the volleyball jump technique).

- Scoring: The result is recorded as the maximum vertical distance traveled, calculated by subtracting the Standing Reach Height from the peak point touched during the jump.

4-3 Spike Accuracy Test

- **Objective**: To measure the player's ability to direct powerful spikes accurately into designated areas of the opponent's court.
- Operational Procedures:
    1. **Court Preparation**: The back row of the opponent's court (defensive zone) is divided into three main target areas using adhesive tape:
        - Right Corner (Area A): 1.5m × 1.5m
        - Left Corner (Area B): 1.5m × 1.5m
        - Deep Middle (Area C): The remaining area of the back court.
    2. **Scoring System:**
        - 5 Points: If the ball lands inside the square (A or B).
        - 3 Points: If the ball lands in the middle zone (C).
        - 1 Point: If the ball lands anywhere else within the legal boundaries of the court.
        - Zero: If the ball goes "out," hits the net, or fails to cross.
    3. **Procedure**: Each player is given 5 consecutive trials, performing spikes on set balls (tossed) from Position 4 (outside hitter) or Position 2 (opposite hitter), according to the player's specialization.

4-4 The Training Program

The proposed training program aims to develop the lower-limb explosive power and enhance the accuracy and performance of the spike among elite (senior)

volleyball players. This is achieved by capitalizing on the physiological and mechanical characteristics of the ballistic training method to improve neuromuscular efficiency.

Implementation Procedures: Based on the analysis of scientific literature and related previous studies, the researcher designed and implemented the program according to the following parameters:

- Duration: The program was implemented over a period of (08) consecutive weeks, with two training sessions per week, totaling (16) standardized training units.
- Session Timing: The duration of the main part of each training unit ranged between (35 – 45) minutes, with a high emphasis on performance quality and velocity.
- Implementation Phase: The program was applied during the Specific Preparation Phase (SPP) to ensure the transfer of gained explosive power into the kinematic path of the spike skill before entering the competition phase.
- Study Sample: The study included (06) elite players as the experimental group subjected to the ballistic program, while the control group continued their traditional (regular) program.
- Training Principles: The researcher relied on the principle of progressive overload in intensity and volume. Full consideration was given to individual differences among players as a fundamental factor in adjusting training load components to ensure maximum physical response and injury prevention.

5. Scientific Validity of the Tests:

5-1 Test Reliability:

The researcher calculated the reliability coefficient using the Test-Retest method, with a one-week interval between the two applications. The test was conducted on the same pilot sample, which consisted of (5) players selected from outside the original study sample. The reliability coefficient between the first and second applications was calculated using Cronbach's Alpha. Table (3) illustrates the reliability coefficients for the tests under study:

Table (3): Reliability Coefficients for the Muscular Power Tests and the Spike Accuracy Test used in the study.

Test Name	Unit	Application	Mean	Std. Deviation	Reliability Coefficient (α)	Sig.	Interpretation
Vertical Jump from Standing	cm	First	37.83	2.48	0.97	0.000	Sig. at 0.05
		Second	38.50	2.73			
Vertical Jump with Approach	cm	First	46.33	5.68	0.98	0.000	Sig. at 0.05
		Second	46.83	5.77			
Spike Accuracy Test	Degree	First	13.16	2.85	0.96	0.000	Sig. at 0.05
		Second	13.50	2.94			

Table (3) reveals that the reliability coefficients for all tests are high, ranging between 0.96 and 0.98. These values are statistically significant at the 0.05 level, confirming the high stability and consistency of the selected tests.

5-2 Test Validity:

5-2-1 Intrinsic Validity:

To ensure the validity of the tests, the Intrinsic Validity coefficient was utilized. This method assesses the validity of experimental scores relative to true scores

and is calculated by finding the square root of the reliability coefficient. The results, calculated at a significance level of 0.05 and with (05) degrees of freedom, are presented in the following table:

Table (4): Validity Coefficients for the Muscular Power Tests and the Spike Accuracy Test under study.

Test Name	Reliability Coefficient	Validity Coefficient
Vertical Jump from Standing	0.97	0.98
Vertical Jump with Approach	0.98	0.99
Spike Accuracy Test	0.96	0.97

Table (4) demonstrates that the validity scores are highly significant, having been determined by calculating the square root of the reliability coefficients. These findings indicate that the applied tests possess a high degree of validity, providing the researcher with the necessary confidence regarding their accuracy and suitability for measuring the intended variables in this study.

6. Presentation and Analysis of Results

6-1 Analysis of Vertical Jump Test from Standing

Statistical Findings The post-test results indicate that there are statistically significant differences between the experimental and control groups, favoring the experimental group. These findings demonstrate a superior development in lower-limb explosive power among volleyball players, which is directly attributed to the implemented ballistic training program.

Table (05): Shows the differences between the control group and the experimental group in the pre-measurement of the Vertical Jump Test from Standing.

Group	Mean	Std. Deviation	T-value	df	Sig. Level	Significance (sig)	Interpretation
Control Group	36.33	7.65	0.299	10	0.05	0.771	Not Sig.
Experimental Group	37.66	7.76					

Table (05) shows that the mean scores for the control and experimental groups were 36.33 and 37.66, respectively. The calculated T-value (0.299) and the significance value (Sig = 0.771) indicate that Sig > 0.05 Therefore, there are no statistically significant differences between the two groups,

Table (06): Differences between the Pre and Post-measurements for the Control Group in the Vertical Jump Test from Standing.

Measurement	Mean	Std. Deviation	T-value	df	Sig. Level	Significance (sig)	Interpretation
Pre-test	36.33	7.65	-3.841	5	0.05	0.012	Significant
Post-test	38.16	7.13					

Table (06) shows a slight improvement in the control group's mean scores, from 36.33 in the pre-test to 38.16 in the post-test. With a significance value of (Sig = 0.012), which is less than 0.05, the differences are statistically significant.

Table (07): Differences between the Pre and Post-measurements for the Experimental Group in the Vertical Jump Test from Standing.

Measurement	Mean	Std. Deviation	T-value	df	Sig. Level	Significance (sig)	Interpretation
Pre-test	37.66	7.76	-23.597	5	0.05	0.000	Significant
Post-test	49.33	7.50					

The experimental group showed a significant increase in mean scores, rising from 37.66 in the pre-test to 49.33 in the post-test. The calculated T-value was -23.597 at 5 degrees of freedom. Since the significance value (Sig = 0.000) is less than the alpha level (0.05), there are statistically significant differences between the pre and post-measurements. This clearly confirms the positive impact of the training program on the experimental group's performance.

Table (08): Differences between the Control and Experimental Groups in the Post-measurement (Vertical Jump Test from Standing).

Group	Mean	Std. Deviation	T-value	df	Sig. Level	Significance (sig)	Interpretation
Control Group	38.16	7.13	2.641	10	0.05	0.025	Significant
Experimental Group	49.33	7.50					

Table (08) shows that in the post-measurement, the experimental group achieved a significantly higher mean score (49.33) compared to the control group (38.16). The calculated T-value (2.641) and the significance value (Sig = 0.025), which is less than 0.05, confirm that there are statistically significant differences favoring the experimental group.

Based on the aforementioned results, the researcher concludes that the standardized training program using the ballistic training method was significantly more effective in developing lower-limb explosive power.

The ballistic exercises enhanced the muscular strength of the volleyball players, leading to a direct improvement in jumping power (take-off force). This is evidenced by the superior mean scores achieved by the experimental group in the post-tests.

In contrast, the control group, which followed a traditional training regimen without specific explosive power exercises, did not show significant progress. Therefore, the marked difference in results confirms that the implemented

ballistic program was the primary factor in achieving these advanced performance levels.

6-2 Presentation and Analysis of the Vertical Jump Test with Approach:

Statistical Findings The post-test results show statistically significant differences between the experimental and control groups, favoring the experimental group. This advancement in lower-limb explosive power among volleyball players is attributed to the efficacy of the proposed training program using the ballistic training method in the vertical jump test with approach.

Table (09): Differences between the Control and Experimental Groups in the Pre-measurement (Vertical Jump Test with Approach).

Group	Mean	Std. Deviation	T-value	df	Sig. Level	Significance (sig)	Interpretation
Control Group	41.66	8.10	0.465	10	0.05	0.652	Not Sig.
Experimental Group	43.83	8.01					

According to Table (09), the control group recorded a mean of 41.66 (SD = 8.10), while the experimental group recorded a mean of 43.83 (SD = 8.01). The calculated T-value was 0.465 at 10 degrees of freedom.

By comparing the significance value (Sig = 0.652) with the alpha level (0.05), Sig. (0.652) > (0.05)

Consequently, there are no statistically significant differences between the control and experimental groups in the pre-measurement for the Vertical Jump Test with Approach,

Table (10): Differences between the Pre and Post-measurements for the Control Group in the Vertical Jump Test with Approach.

Measurement	Mean	Std. Deviation	T-value	df	Sig. Level	Significance (sig)	Interpretation
Pre-test	41.66	8.01	-1.581	5	0.05	0.175	Not Significant
Post-test	42.33	7.81					

Table (10) shows that the control group's mean scores slightly increased from 41.66 to 42.33. However, the significance value (Sig = 0.175) is greater than 0.05, indicating that there are no statistically significant differences between the pre and post-measurements.

Table (11): Differences between the Pre and Post-measurements for the Experimental Group in the Vertical Jump Test with Approach.

Measurement	Mean	Std. Deviation	T-value	df	Sig. Level	Significance (sig)	Interpretation
Pre-test	43.83	8.10	-22.361	5	0.05	0.000	Significant
Post-test	53.83	8.63					

The experimental group achieved a mean of 43.83 (SD = 8.10) in the pre-measurement, which increased significantly to 53.83 (SD = 8.63) in the post-measurement. The calculated T-value was -22.361 at 5 degrees of freedom. By comparing the significance value (Sig = 0.000) with the alpha level (0.05), we find that: Sig. (0.000) < a (0.05)

Consequently, there are statistically significant differences between the pre and post-measurements for the experimental group in the Vertical Jump Test with Approach.

Table (12): Differences between the Control and Experimental Groups in the Post-measurement (Vertical Jump Test with Approach).

Group	Mean	Std. Deviation	T-value	df	Sig. Level	Significance (sig)	Interpretation
Control Group	42.33	7.81	2.419	10	0.05	0.036	Significant
Experimental Group	53.83	8.63					

Table (12) reveals that in the post-measurement, the experimental group achieved a significantly higher mean score (53.83) compared to the control group (42.33). The calculated T-value (2.419) and the significance value (Sig = 0.036), which is less than the alpha level (0.05), confirm the existence of statistically significant differences favoring the experimental group.

Based on the statistical findings, the researcher concludes that the standardized program using the ballistic training method was highly effective in developing lower-limb explosive power during the vertical jump with approach. This training approach enhanced the muscular capacity of the players, directly improving their take-off force, which is a critical component for performing skills such as spike hits (smashing). The results clearly favor the experimental group, which achieved superior mean scores in the post-test.

In contrast, the control group followed a traditional regimen and failed to show significant progress in this specific physical attribute. This disparity confirms that the effectiveness of the ballistic training program lies in its ability to bridge the gap between raw strength and the functional explosive movements required in competitive volleyball.

6-3 Presentation and Analysis of the Spike Accuracy Test Results:

Statistical Findings There are statistically significant differences in the post-test results for the experimental group regarding the development of spike accuracy

among volleyball players. These differences are attributed to the implementation of the training program using the ballistic training method.

Table (13): Statistical Significance of the Differences between Pre and Post-measurements for the Research Sample in the Spike Accuracy Test.

Variable	Pre-test Mean	Post-test Mean	Calculated (Z) Value	Sig. Level	Interpretation
Spike Accuracy	12.16	17.00	2.20	0.027	Statistically Significant

Table (13) reveals statistically significant differences between the pre and post-measurements for the "Spike Accuracy" variable. The calculated (Z) value reached 2.20, which is statistically significant at a p-value of 0.027 a value lower than the established alpha level of 0.05.

These results clearly indicate that the improvement in the players' performance is directly attributed to the impact of the independent variable (the proposed training program).

7. Conclusions

Based on the statistical analysis of the pre and post-test results, the following conclusions were reached:

- The results showed statistically significant differences in the post-tests favoring the experimental group. This improvement confirms that ballistic training successfully developed the lower-limb explosive power, granting players a superior capacity for vertical jumping. These findings align with the study of Hisham Ali Al-Aqra and Mohammed Hussein Al-Ajouri (2017), which concluded that ballistic training effectively enhances the muscular capacities of the lower extremities in volleyball players.
- The results demonstrated a significant superiority in the accuracy and performance of spike hits (smashing) in the experimental group's post-

test. This is attributed to the program's ability to achieve a transfer of training effect from physical development to skill execution. The acquired explosive power contributed to increased stability and force during the hit, leading to better control and precision in directing the ball. This is consistent with the study of Hussein and Hammad (2014), which found that ballistic training positively impacts physical capacities and the performance level of the blocking skill in volleyball players.

8. Recommendations

- It is essential to adopt the ballistic training method as a core component of the annual training plans for volleyball teams, particularly during the specialized preparation phase.
- Coaches must ensure precise regulation of training loads when implementing ballistic exercises to prevent overtraining (over-exhaustion), given its high intensity and significant demand on the nervous system.
- Conduct similar studies to investigate the impact of ballistic training on other fundamental volleyball skills, such as setting, serving, or defensive floor movements.
- Apply this training method to different age categories, such as U17 youth players, while carefully considering the physiological characteristics of each stage to ensure a sound physical foundation.
- It is necessary to provide essential training aids (e.g., jump platforms/plyo boxes, medicine balls, and appropriate free weights) to ensure ballistic exercises are executed with the correct biomechanical trajectory.

- Encourage coaches to utilize accuracy and vertical jump tests periodically to monitor players' progress and adjust training programs based on objective data.

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