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Does the jump performance level achieved during the preparatory phase carry over to the competition phase in elite footballers?

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ABSTRACT

Study aim(s): This study aims to validate changes in jump performance across different phases and propose a plyometric and general training program to maintain or enhance performance during the competition phase.
Methods: Key performance parameters such as height, weight, lever length, and leg length were measured using the My Jump 3 App. Participants performed several jump tests, including the Countermovement Jump (CMJ), Squat Jump (SJ), and Abalakov Jump, recorded with an iPhone 13 Pro at 240 frames per second. Data on force, flight time, average speed, and power were analyzed. Statistical evaluations were conducted using SPSS 26, the Shapiro-Wilk test applied to assess normality, and Repeated Measures ANOVA used to examine differences between tests.
Results: The CMJ tests revealed significant improvements following the preparatory phase ($p < 0.05$), but performance declined during the competition phase ($p > 0.05$). Trends in force, power, and flight phase suggest that the post-preparatory gains are primarily technique-based, with no further improvements during competition and even a slight decline in performance.
Conclusions: Jump performance improves after the preparatory phase but not during the competition phase, highlighting the importance of technique over strength. Training programs should emphasize refining technique, enhancing muscular elasticity, and improving mobility to sustain performance throughout the season.
Keywords: Performance, Footballers, Preparatory Phase, Competition Stage, High Jump

INTRODUCTION

Jump performance is a critical determinant of aerial play in football, reflecting a player's explosiveness and significantly influencing success in physical duels and challenges (Loturco et al., 2021). Given its high energy demands, it requires an intricate combination of explosive, repetitive, and maximal strength, as well as anaerobic endurance. Superior jump performance enables players to excel in aerial contests, high-intensity duels, and explosive movements, making it a key factor in maintaining consistency and endurance throughout competitive play (Turner et al., 2023).

The development of jump performance is primarily attributed to plyometric training and explosive strength exercises, with additional contributions from repetitive and maximal strength. Specific endurance also plays a crucial role in sustaining jump performance (Zhao & Zhang, 2022). Similar to other physical performance aspects in football, jump performance is most effectively enhanced during the preparatory phase. However, some evidence suggests that performance may continue to improve or stabilize during the competition phase, while in certain cases, it may decline due to the physical demands of prolonged competition (Donahue et al., 2023).

Addressing the constant demand for performance improvement, contemporary research emphasizes the role of plyometric exercises during both preparatory and competition phases. These training methods focus on maximizing muscle strength through stretch-shortening cycles and counter-movement patterns, utilizing the elastic properties of muscles and tendons, as well as the stretch reflex, to generate rapid and powerful movements (Wilt, 1978; Wilk, 1996). Incorporating such techniques is critical for optimizing football players' performance throughout the season (Comyns, 2023).

Functional movements and athletic performance are enhanced by the use of muscle power at speed, which links strength and speed (Wilk, 1996; Wilt1978). The increase in muscular power can be explained by two primary models: the mechanical model and the neurophysiological model. The neurophysiological model highlights the significance of the stretch reflex, which boosts muscle activity and enhances the force produced when concentric action follows immediately after stretching (Wilk, 1996). The Stretch-Shortening Cycle (SSC) leverages stored elastic energy and the stretch reflex to maximize muscle recruitment in minimal time, consisting of three key phases: the eccentric phase (lengthening of the agonist muscles), the amortization phase (the brief pause between the eccentric and concentric phases), and the concentric phase (shortening of the agonist muscle fibers) (NSCA, 2024; Wilk, 1996; Wilt1978). Combining plyometric exercises with resistance training is crucial for improving the efficiency and physical performance of football players. This combination should be thoughtfully structured to optimize benefits while minimizing the risk of injury. The training program should include up to five low- to moderate-intensity exercises, allowing for adequate recovery time.

This study focuses on maintaining the jump performance levels achieved during the preparatory phase throughout the competition phase in elite footballers. It highlights the need to enhance both vertical and horizontal jump performance during the competition phase, an outcome that is not always achieved and presents a significant challenge for many experts. Furthermore, the inability to sustain the performance gains from the preparatory phase often leads to performance decline, increased risk of injury, and diminished capacity to maintain high-level performance throughout the game.

Based on these details, this study aims to validate the progression of jump performance from the preparatory phase to the competition phase. Additionally, it aims to propose a plyometric training program, and a general training regimen designed to maintain, and potentially enhance, jump performance throughout the competition phase.

METHOD

Anthropometric and compositional measurements

Body Height: Body height is measured as the vertical distance from the ground to the highest point of the head when the individual stands upright with their head level and looks straight ahead. The measurement is taken barefoot, with the head aligned in the Frankfurt plan (where the lower edge of the eye and the upper part of the ear are horizontally aligned). The body must be fully extended and positioned against the wall (Lohman 1988). A stadiometer, with a measurement range of 80 cm to 200 cm and an accuracy of 1 mm, was used for this purpose.

Body Composition: Participants stood barefoot on the scale, holding the handles with both hands while wearing light clothing. A range of metrics was recorded, including weight, body fat percentage (for ages 5 to 99), body water percentage, muscle mass, physique rating, bone mineral mass, basal metabolic rate, metabolic age, body mass index, visceral fat, visceral fat range indicator, segmental fat distribution across five segments, and segmental muscle characteristics across five segments. The Tanita BV 545 N Innerscan Segmental Personal Body Analysis device was used for these measurements.

Metric Measurements of the My Jump 3 App

The methodology of this study commenced with the collection of key performance parameters using the My Jump 3 application. The data gathered included height, weight, height at 90°, lever length, and leg length, parameters essential for analyzing jump performance results. Each participant executed a series of jumps, including the Countermovement Jump (CMJ), Squat Jump (SJ), and Abalakov jump, all recorded using an iPhone 13 Pro at 240 frames per second, ensuring high-resolution video capture.

Within the My Jump 3 application, jump recordings were uploaded, and specific frames for take-off and landing were manually selected. To ensure accuracy, clear criteria were established in advance: for take-off, the first frame where both feet were off the ground was chosen, free of motion blur or shoe deformation; for landing, the frame where one foot made contact with the ground, without any visible gap between the shoe and the surface, and also without motion blur, was selected. Utilizing these defined events, the application calculated jump height based on flight time (Whiteley, 2023).

It is important to note that the validity of the My Jump 3 application has been confirmed by several studies Turan, 2022; Cruvinel-Cabral, 2018; Balsalobre-Fernández, 2015).

Leg Length: Leg length is measured as the distance from the greater trochanter of the femur (or the iliac crest) to the tip of the toes, with the athlete lying on their back and maintaining plantar flexion of the foot. Ensure that the greater trochanter or iliac crest is marked for greater accuracy.

Kneeling height (Lever): This measurement is taken from the height at the beginning of the exercise, specifically from the knees to the head. This measurement aids in determining the lever length, which is essential for calculating torque.

Height at 90 Degrees (cm): The vertical distance is measured from the greater trochanter of the narrow spine (or the anterior iliac spine) to the ground while in an optimal knee flexion position for executing the highest jump, with the knee angle at approximately 90 degrees.

Free Arm Countermovement Jump (CMJ) Technique Tested with My Jump 3

The take-off moment is identified as the first frame where both feet leave the ground, and the landing moment is marked as the first frame where at least one foot makes contact with the ground. Be sure to record the external weight used; if no load was applied, enter 0. The recording is performed from the front of the athlete while standing.

This single jump test measures jump height along with key derived parameters such as force, velocity, power, and the Reactive Strength Index, offering accuracy comparable to force platforms.

Parameters tested in the high jump technique that indicates the height in centimetres

Force (N): Force is measured in newtons (N) and describes the action exerted by one body on another. In jumping, it refers to the muscular effort used to propel the body upward into the air.

Flight Phase (FT m/s): This is the period when the body is airborne during a jump, without any ground contact. The average speed of the body during this phase is typically measured in meters per second (m/s).

Mean Velocity (MV m/s): Mean velocity refers to the average speed of the body throughout the entire movement cycle, including both upward and downward phases. It is measured in meters per second (m/s) and offers a general assessment of performance during the movement.

Power (Watt): Power, measured in watts (W), reflects the rate at which work is performed. In jumping, it is calculated as the product of force and velocity, indicating how efficiently an athlete generates the energy required for the jump.

Data Analysis

The data collected from My Jump 3 were analyzed using the SPSS 26 software package. The normality of the data distribution was evaluated with the Shapiro-Wilks test to ensure it met the required statistical assumptions. Descriptive statistics, including frequencies and percentages, were calculated to provide a clear overview of the data's distribution and characteristics. Additionally, a one-way Repeated Measures ANOVA was used to assess differences between the three tests conducted at different time intervals.

FINDINGS

The findings of this study examine the effects of preparatory and competition phases on various performance metrics, including jump height, force, flight speed, and power. The results provide insights into performance changes over time, highlighting significant improvements during the preparatory phase and variations during the competition phase.

Table 1. Normality Test of the Data

Variables	Shapiro-Wilk		
	Statistic	Df	Sig.
Wkg	.942	16	.369
BMImkg2	.943	16	.381
Hcm	.947	16	.439

Table 1 presents the results of the normality test based on the Shapiro-Wilk test, indicating that the significance is statistically insignificant ($p > 0.05$). This suggests that the distribution of the results is normal.

Table 2. Descriptive Analysis of the Compositional Factors of the Test Subjects

Tests	Min	Max	x̄	SD	Skew	Kurt
Wkg	58.10	91.60	75.9211	8.48689	.221	.163
BMImkg2	20.80	26.80	23.2737	1.46471	.559	.654
Hcm	168.00	192.00	180.5952	6.26694	-.020	-.576

Table 2 displays the descriptive statistics of the compositional factors of the body. Based on the minimum and maximum values, we observe a homogeneity of the compositional parameters. Additionally, based on skewness and kurtosis, the results are mesokurtic, indicating symmetry and normal values of the data.

Table 3. The difference in jump height (cm) between the preparation phase and the competition phase

Factors	x̄	SD	x̄ diff	Sig[b]	Greenhouse-Geisser F	Greenhouse-Geisser Sig	Partial Eta Squared
Hcm1	40.9417	5.36817	-3.733*	Hcm1<Hcm2 (.003)	9.749	.003	.470
Hcm2	44.6750	5.20928					
Hcm3	41.9750	4.93008					

*Mauchly's Test of Sphericitya: Sig: .204, Greenhouse-Geisser: .786, *The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.*

Table 3 presents the results of the differences among the three repeated high jump tests (CMJ). The findings indicate that the difference between the first and second tests, reflecting the comparison between the pre-preparation phase and the post-preparation phase, is statistically significant, with the second test demonstrating a meaningful increase ($p < 0.05$).

Meanwhile, the difference between the second and third tests, which reflects the impact of the competition phase, reveals no statistically significant differences ($p > 0.05$). This indicates a decrease in average jump height, leading to the conclusion that jumping performance did not improve during the competition phase; rather, it declined over time compared to the preparation phase, where the improvement in jumping was statistically significant.

Table 4. *Difference in Force (N) between jumps during the preparation phase and the competition phase.*

Factors	x̄	SD	x̄ diff	Sig[b]	Greenhouse-Geisser F	Greenhouse-Geisser Sig	Partial Eta Squared
Fn1	1.9038	.32083	-	-	1.283	.295	.104
Fn2	1.9421	.27441					
Fn3	1.9062	.31980					

*Mauchly's Test of Sphericitya: Sig: .307, Greenhouse-Geisser: .826 *The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.*

Table 4 shows that the difference in jump force among football players is not statistically significant during the preparation phase (14 days) or the competition phase ($p > 0.05$). Given that, no statistically significant difference was observed, and considering the previous table (3), which indicates an improvement in jump performance during the preparation phase, we can conclude that jump performance did not improve solely due to enhancements in motor parameters. Instead, the improvement in jump technique appears to have played a significant role.

Table 5. The difference in flight speed (m/s) of jumps between the preparation phase and the competition phase.

Factors	x̄	SD	x̄ diff	Sig[b]	Greenhouse-Geisser F	Greenhouse-Geisser Sig	Partial Eta Squared
FTm/s1	576.75	38.63142	-25.917*	FTm/s1>FTm/s2 (.003)	9.735	.002	.470
FTm/s2	602.66	35.40245					
FTm/s3	584.25	34.75401					

*Mauchly's Test of Sphericitya: Sig: .273, Greenhouse-Geisser: .814, *The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.*

Table 5 shows the results of three repeated tests conducted during the flight phase of the countermovement jump (CMJ). The findings reveal a statistically significant difference between the first and second tests, representing performance before and after the preparation phase, with the second test demonstrating a meaningful improvement ($p < 0.05$).

The difference between the second and third tests, which reflects the impact of the competition phase, is not statistically significant (p > 0.05), although the flight phase shows a slight decrease in the average compared to the previous test.

Table 6. The difference in average flight speed (m/s) of jumps between the preparation and competition phases

Factors	x̄	SD	x̄ diff	Sig^b	Greenhouse-Geisser F	Greenhouse-Geisser Sig	Partial Eta Squared
MVm/s1	1.4142	.09258	-.064*	MVm/s1>MVm/s2 (.003)	9.476	.003	.463
MVm/s2	1.4783	.08953					
MVm/s3	1.4333	.08467					

Mauchly's Test of Sphericitya: Sig: .173, Greenhouse-Geisser: .77 The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.

Table 6 presents the results of the differences in flight phase speed across three repeated tests of the countermovement jump (CMJ). The findings indicate a statistically significant difference between the first and second tests, reflecting performance before and after the preparation phase, with the second test showing a decrease in flight phase duration (p < 0.05).

Meanwhile, the difference between the second and third tests, which reflects the impact of the competition phase, is not statistically significant (p > 0.05), despite the flight phase demonstrating a decrease in the average compared to the previous test.

Table 7. The variation in average jump power (W) between the preparatory phase and the competition phase

Factors	x̄	SD	x̄ diff	Sig^b	Greenhouse-Geisser F	Greenhouse-Geisser Sig	Partial Eta Squared
Pw1	2.7117	.55878	-.189*	Pw1<Pw2 (.035)	5.227	.015	.322
Pw2	2.9003	.50864					
Pw3	2.7468	.55536					

*Mauchly's Test of Sphericitya: Sig: .891, Greenhouse-Geisser: .978, *The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.*

Table 7 shows the results of the differences between the three repeated power (W) tests. The data indicate that the difference between the first and second tests, representing the pre– and post- preparatory phases, is statistically significant, with the second test showing a notable increase in power (p < 0.05).

The difference between the second and third tests, which reflects the impact of the competition phase, shows no statistical differences (p > 0.05). There is a decrease in average jump power, suggesting that during the competition phase, power did not improve; instead, it declined over time. This contrasts with the preparatory phase, where the increase in power was statistically significant.

DISCUSSION AND CONCLUSION

The results indicate that the difference between the first and second tests, representing the change before and after the preparatory phase, is statistically significant. The second test shows a significant increase in jump height, measured in centimeters.

Meanwhile, the difference between the second and third tests, which reflects the impact of the competition phase, reveals no statistically significant differences. Specifically, there is a decline in average jump performance, leading to the conclusion that during the competition phase, jump performance did not improve; it decreased over time. This contrasts with the preparatory phase, where the improvement in jump performance was statistically significant.

The difference in jump strength among football players is not statistically significant during the preparatory phase (14 days) or the competition phase. Since no significant difference was observed, and considering the jump performance measured in centimeters, we note an improvement in jump performance during the preparatory phase. Therefore, it can be concluded that jump performance is not solely enhanced by improvements in motor parameters; rather, advancements in jump technique also play a significant role.

In analyzing the spatial parameters of the Countermovement Jump (CMJ) and Squat Jump (SQJ), it was found that there are generally no significant differences in jump height or the position of the sacral axis between the two techniques (P > 0.05). This indicated that the performance in height is similar for both jumps, and the position of the sacral axis does not significantly impact the results. Additionally, the speed of the legs during takeoff and landing does not show significant differences ($P > 0.05$), indicating that the contact with the ground and the lifting of the legs do not contribute to noticeable differences between CMJ and SQJ jumps. Significant differences were observed in the trunk angle at the lowest point of the center of mass ($P < 0.05$), indicating that the trunk plays a key role in shaping the form and technique of the jump. Furthermore, notable differences emerged in the left and right knee joint angles during the CMJ ($P < 0.05$), as well as in the knee and ankle angles at the moment of toe-off ($P< 0,05$). These findings suggest that joint positions and angles respond differently to variations in jumping technique, leading to distinct differences between CMJ and SQJ. In conclusion, while some spatial parameters are similar between the two jumps, the differences in body and joint angles suggest that technique and body positioning are influenced differently by these two types of jumps

The results of the differences among the three repeated tests in the flight phase of the jump (CMJ) reveal significant differences between the first and second tests, which represent the variations before and after the preparatory phase. This difference is statistically significant, with the second test demonstrating a notable increase. In contrast, the difference between the second and third tests, reflecting the impact of the competition phase, shows no statistical differences, despite the flight phase displaying a decrease in average performance compared to the previous test.

The results indicate that the difference in average jump speed between the first and second tests, representing the preparatory and post-preparatory phases, is statistically significant, with the second test demonstrating a decrease in the duration of the flight phase. In contrast, the difference between the second and third tests, reflecting the effect of the competition phase, reveals no statistically significant differences, despite the flight phase showing a decrease in average performance compared to the previous test.

The difference between the second and third tests, which reflects the impact of the competition phase on power (W), is statistically insignificant and indicates a decrease in average jump performance. This suggests that during the competition phase, power did not improve; instead, it declined over time. This contrasts with the preparatory phase, where the increase in power was statistically significant.

It is essential to understand how changes in jump parameters impact players' performance throughout the season. Research indicates significant differences in the influence of strength and power on jump height and athletic performance between the preparatory phase and competitive events.

In this context, a study by MF Robert (1986), found that the minimum angles of the hip and knee joints are larger during the Drop Jump (DJ) compared to the Countermovement Jump (CMJ). These differences impact the range of the motion and the duration of the push-off phase. While the hip joints contribute less work during the DJ, the knee joints experience a similar workload in both jumps, driven by the higher output power observed in the DJ.

Loturco et al Loturco (2021) found that average force and power during the push-off phase are higher in the Squat Jump (SJ) compared to other jump types, emphasizing the role of these metrics in achieving greater jump heights. Their findings suggest that coaches should prioritize both maximal and average strength development to optimize performance during training and competition phases.

Studies by Zhao (2022) emphasize that variations in body and joint angles during jumping are essential for understanding the impact of different techniques on performance. Differences observed in trunk, knee, and ankle angles suggest that these parameters play a key role in jump execution and can be optimized to improve performance throughout the competitive season.

Enhancing athletic performance in explosive sports hinges on effective jumping techniques. Research indicates that squat jumps (SQJ) and countermovement jumps (CMJ) influence muscle strength and jump height. Zhao and Zhang (2022) found no performance differences between SQJ and half-squat jumps, suggesting individualized training is essential (Zhao, 2022). Hengyuan et al. (2024) noted the benefits of post-activation potentiation (PAP) from back squats, recommending their use pre-competition. Strength in ankle and knee joints is crucial for jump performance (Comyns, 2023). Turner et al. (2023) advocated for simpler jump height measurement methods. Rismayanthi et al. (2024) highlighted the effectiveness of plyometric training like Knee Tuck Jumps for female volleyball players. Lastly, Donahue et al. (2023) emphasized that peak velocity differences between CMJ and SQJ can affect jump height. In summary, understanding jump techniques and training emphasizes the need for evidence-based, individualized approaches, highlighting the necessity for further research.

In conclusion, the study examined the jumping performance of football players across two distinct phases: the preparatory phase and the competition phase. The findings reveal a significant increase in jump height following the preparatory phase compared to the period before it. However, during the competition phase, no statistically significant changes in jump performance were observed relative to the preparatory phase, indicating a potential decline in performance. Additionally, differences in jump strength and power between the two phases were not statistically significant, suggesting that jumping performance is influenced more by technique than by motor parameters alone.

The analysis of spatial parameters reveals no significant differences in jump height or leg speed between the CMJ and SQJ techniques, while notable differences are observed in body and joint angles. These findings suggest that technique and body positioning play a key role in jump performance. Additionally, other studies highlight the importance of average force and elasticity in improving jump performance, indicating that training should focus on enhancing these parameters to optimize athletic performance throughout the season.

RECOMMENDATIONS

Future studies should explore the interplay between technique and motor parameters in jump performance across diverse sports and populations, focusing on optimizing training strategies to enhance both technical execution and physical capacities.

CONFLICT OF INTERESTS

No potential conflict of interest was reported by the authors.

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