Enhancing explosive power in elite female basketball players through weightless circuit training

Mejora de la potencia explosiva en jugadoras de baloncesto de élite mediante entrenamiento en circuito sin pesas

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Abstract

Background: Explosive power is an important component of athletic performance in female basketball players and must be trained.
Objectives: To evaluate the effect of bodyweight circuit training on the explosive power of high-level female basketball players in Tirana, Albania.
Methodology: Total 46 players (mean age: 24-25 years) were divided into two groups: Experimental Group (EG) and Control Group (CG). Anthropometric measurements were taken from the experimental group (EG) (n = 13; 24.07 ± 2.1 years; 173.07 ± 5.3 cm; 70.99 ± 8.5 kg; and BMI 21.24 ± 1.6%) and the control group (CG) (n = 13; 25.3 ± 5.3 years; 175 ± 4.9 cm; 65.48 ± 9.7 kg; and BMI 21.4 ± 2.5%). The EG performed a circuit training program twice a week for 14 days (6 exercises). Both groups were assessed before and after the program using the following tests: squat jump (SJ), countermovement jump (CMJ), and 40 cm squat jump (DJ) at Gross Flow Repetition Potential (GFRP).
Results: Paired t-tests were used to assess within-group differences. A p-value < 0.05 indicates statistical significance. 95% confidence intervals were applied to the variables.
Conclusions: A 14-week circuit training program with six exercises improves explosive power in female basketball players. Significant improvements in the squat jump (SJ), countermovement jump (CMJ), and drop jump (DJ) demonstrate the program's practical impact on individual and team performance.

Keywords

Squat; basketball elite; explosive; training; strength.

Resumen

Antecedentes: La fuerza explosiva es un componente importante del rendimiento deportivo de las jugadoras de baloncesto, y debe entrenarse.
Objetivos: Evaluar el efecto del entrenamiento en circuito sin pesas sobre la potencia explosiva de jugadoras de baloncesto de alto nivel en Tirana, Albania.
Metodología: Nr.46 jugadoras (edad media: 24-25 años) en dos grupos: Grupo Experimental n.º 23 (GE) y Grupo Control n.º 23 (GC). Mediciones antropométricas del grupo experimental (GE) (n = 13; 24,07 ± 2,1 años; 173,07 ± 5,3 cm; 70,99 ± 8,5 kg; e IMC 21,24 ± 1,6 %) y del grupo control (GC) (n = 13; 25,3 ± 5,3 años; 175 ± 4,9 cm; 65,48 ± 9,7 kg; e IMC 21,4 ± 2,5 %). El GE realizó un programa en circuito dos veces por semana durante 14 (6 ejercicios). Ambos grupos fueron evaluados para salto vertical (SJ), salto con contra movimiento (CMJ) y Salto de caída de 40 cm (DJ) antes y después, en GFRP (Potencial de Repetición de Flujo Potencial).
Resultados: Se utilizaron pruebas t pareadas para evaluar las diferencias intragrupo. Un valor de p < 0,05 indica significación estadística. Se aplicaron intervalos de confianza del 95 % a las variables.
Conclusiones: Un programa de entrenamiento en circuito de 14 semanas con seis ejercicios mejora la potencia explosiva en jugadoras de baloncesto. Las mejoras significativas en el salto vertical (SJ), el salto con contra movimiento (CMJ) y el salto con caída (DJ) demuestran el impacto práctico del programa en el rendimiento individual y de equipo.

Palabras clave

Sentadilla; baloncesto élite; explosivo; entrenamiento; fuerza.

Introduction

Basketball is characterized by distinct anthropometric and physiological demands, with players typically exhibiting greater height, body mass, and limb length compared to athletes in many other sports. Within this context, body composition plays a crucial role in performance, particularly in relation to explosive strength of the lower extremities. One of the most fundamental expressions of this skill is the vertical jump (VJ), a key motor action underpinning both offensive and defensive skills such as shooting, rebounding, blocking, and passing. As an indicator of lower-limb explosive power, the vertical jump reflects the neuromuscular system's ability to generate maximal acceleration of the body and external loads (Jukić et al., 2005).

Game analysis has demonstrated the high physical demands associated with basketball performance. For instance, players perform over 1000 movements per game, including a substantial number of vertical jumps (McInnes et al., 1995). However, vertical jump performance varies considerably across athletes, influenced by factors such as testing protocols and competitive level (Ziv & Lidor, 2009). Gender-related differences have also been consistently reported, with male athletes typically achieving greater jump heights than female athletes (Mancha-Triguero et al., 2019). Nevertheless, lower-limb strength and vertical jump capacity remain critical determinants of performance in female basketball players (Canavan & Vescovi, 2004; Bobbert, 1990).

Previous research has highlighted that jump characteristics, including frequency and height, are influenced by players' physical abilities and tactical roles, rather than by competition level alone (Pleša et al., 2025). Biomechanically, jump performance is determined by factors such as take-off velocity, flight time, force impulse, and optimal joint angles (Coh & Supej, 2008). Consequently, standardized assessment protocols—such as Squat Jump (SJ), Countermovement Jump (CMJ), and Drop Jump (DJ)—are widely used to evaluate explosive strength and stretch–shortening cycle efficiency (Corredor-Serrano et al., 2023).

The relationship between explosive strength and other performance parameters, such as speed, has also been well established, with higher CMJ performance associated with greater on-court speed (Alemdaroğlu, 2012). These individual differences are largely attributed to long-term training adaptations (Izquierdo et al., 2002), while fluctuations in training intensity across the season may further influence performance outcomes (Montgomery et al., 2008). Therefore, monitoring and analyzing training load is essential for optimizing performance and designing effective training protocols (Petway et al., 2020).

In this regard, plyometric training (PT) has emerged as one of the most effective methods for enhancing explosive strength and vertical jump performance. Based on the stretch–shortening cycle, PT involves rapid transitions between eccentric and concentric muscle actions and includes exercises such as drop jumps, countermovement jumps, and other dynamic movements (Malisoux et al., 2005). Evidence suggests that PT can produce significant improvements in vertical jump performance, with increases ranging from approximately 4.7% to 8.7% depending on the test modality (Markovic, 2007).

Advancements in sports technology have further enabled precise assessment of performance variables. Devices such as force platforms (e.g., Leonardo® Ground Force Reaction Plate) allow detailed analysis of ground reaction forces and jump mechanics. However, accurate evaluation depends heavily on proper technique standardization and consistent testing protocols, emphasizing the importance of structured monitoring in both training and performance assessment.

Despite the growing body of literature, there remains a lack of empirical data on the effects of structured training programs on explosive strength development in elite female basketball players, particularly within the Albanian context. Addressing this gap is essential for improving evidence-based training practices and optimizing athletic performance.

Therefore, the present study aims to evaluate the effects of a specific training program on the development of explosive strength in elite female basketball players during the competitive season. By focusing on this underexplored population, the study seeks to provide practical and scientifically grounded recommendations for enhancing vertical jump performance through targeted training interventions.

Method

Participants

This study employed a randomized controlled experimental design to investigate the effects of a structured training program on explosive strength in elite female basketball players. A total of 46 athletes were recruited from three sports associations competing in the Albanian National Championship in Tirana and were randomly assigned to an experimental group (EXG, n = 23) and a control group (COG, n = 23).

All participants had a minimum of 13 years of competitive experience and followed a regular training schedule consisting of five sessions per week (90 minutes each) and one official match. The groups were comparable in terms of age, training experience, and workload. Participants who experienced injuries or illnesses during the study period were excluded from the analysis.

Anthropometric characteristics were assessed at baseline, and no statistically significant differences were observed between the groups (Table 1), indicating group homogeneity.

Table 1. Anthropometric measurements of the female elite basketball players

		Age	BH (cm)	BW (kg)	BMI kg/m²
EXG No=23	Ave.	24.07	173.07	70.99	21.24
	Max	27	182	94.6	24.7
	Min	20	162	62.3	18.23
	SD	±2.12	±5.38	±8.59	±1.63
COG No=23	Ave.	25.3	175	65.48	21.44
	Max	28	180	87.72	26.6
	Min	19	162	51.5	16.5
	SD	±5.38	±4.97	±9.71	±2.51

Procedure

All participants were informed about the study procedures prior to inclusion. Ethical approval was obtained from the Ethics Committee of the Sports University of Tirana, Albania (No. 2739/1, dated 08.10.2024), and written informed consent was obtained in accordance with the principles of the Declaration of Helsinki.

Performance testing was conducted in the Biomechanics Laboratory at the Sports University of Tirana before and after a 14-week intervention period, corresponding to the second competitive season (January–May 2025).

Instrument

Explosive strength performance was assessed using the Leonardo® Ground Reaction Force Plate (GRFP-e, Novotec Medical, Pforzheim, Germany), a validated system for measuring ground reaction forces and biomechanical parameters during movement. This device provides objective assessment of performance variables, including jump height, power output, and temporal characteristics.

Additionally, the system allows for the determination of the optimal drop height and the analysis of the relationship between contact time and flight time, which are critical indicators of stretch–shortening cycle efficiency.

Test protocol

Prior to testing, participants performed a standardized 10-minute warm-up. Vertical jump performance was evaluated using three widely accepted tests: Squat Jump (SJ), Countermovement Jump (CMJ), and Drop Jump (DJ) from a height of 40 cm. All tests were conducted before and after the 14-week intervention period.

Each test was performed three times, and the best performance was selected for analysis, as recommended in previous research (Mema et al., 2025). A 95% confidence interval (CI) was applied to all performance variables.

Squat Jump (SJ): Participants performed the jump from a static semi-squat position (knee angle of approximately 90°), with hands placed on the hips to eliminate arm contribution. This test evaluates concentric explosive strength without the contribution of elastic energy (Mema et al., 2025).

Countermovement Jump (CMJ): The CMJ was performed starting from an upright position, followed by a rapid downward movement and an explosive upward jump, with hands on hips. This test assesses explosive strength utilizing the stretch–shortening cycle (Mema et al., 2025).

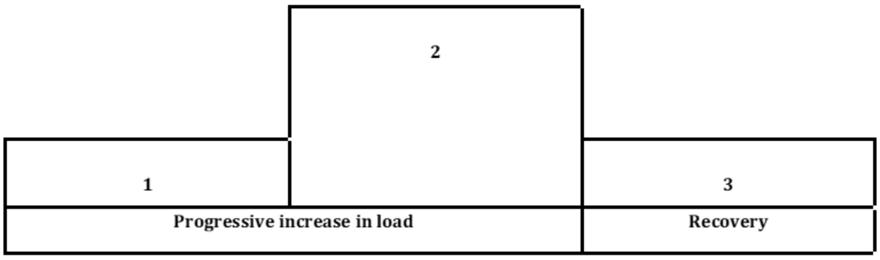
Drop Jump (DJ, 40 cm): Participants stepped off a 40 cm platform, landed on the force plate, and immediately performed a maximal vertical jump. This test evaluates reactive strength and neuromuscular efficiency within the stretch–shortening cycle (Mema et al., 2025).

Intervention

The experimental group (EXG) participated in a structured training program conducted twice per week (Monday and Tuesday) for approximately 20 minutes per session over a 14-week period, integrated into their regular training schedule. The program was supervised by the research team, while additional training sessions and matches were conducted under the guidance of team coaches.

The intervention was based on the principles of circuit training with a progressive approach of "step loading" (figure 1), allowing for gradual increases and decreases in intensity to optimize adaptation and recovery (T. Bompa & Carrera, 2015; Bompa & Sarandan, 2022). a method known in the field of training as an effective method that helps to systematically increase the intensity of training, gradually increasing the load during the training period according to the authors . Circuit training is considered an effective and practical method for improving physical performance within a relatively short time.

Figure 1. Principle of progressive "step loading".



Data analysis

Data were analyzed using IBM Statistics 26 (Corp., Armonk, NY, USA). Paired-sample t-tests were used for within-group comparisons, and two-way repeated measures ANOVA assessed between-group differences and interaction effects. The study also examined the means, standard deviation (SD), and effect sizes before and after the test, expressed with a 95% confidence interval. Comparison between the experimental and control groups was performed using a significance level of $p > 0.05$.

Results

The descriptive analysis of explosive strength performance in elite female basketball players is presented in Table 2, including Squat Jump (SJ), Countermovement Jump (CMJ), and 40-cm Drop Jump (DJ) tests conducted before and after the 14-week intervention.

At baseline, the control group (COG) displayed slightly higher values compared to the experimental group (EXG) across all variables, although differences were minimal: Squat Jump (SJ): EXG Pre = 0.33 m, COG Pre = 0.34 m: Countermovement Jump (CMJ): EXG Pre = 0.31 m, COG Pre = 0.34 m: Drop Jump (DJ 40 cm, TA/TC): EXG Pre = 1.83 s, COG Pre = 1.92 s After the 14-week training program, the EXG demonstrated notable improvements in jump performance, whereas the COG remained relatively stable: Squat Jump (SJ): EXG Post = 0.34 m, COG Post = 0.35 m:Countermovement Jump (CMJ): EXG Post = 0.33 m, COG Post = 0.35 m: Drop Jump (DJ 40 cm, TA/TC): EXG Post = 1.91 s, COG Post = 1.92 s.

Table 2. Descriptive statistics for EXG & COG basketball players before and after

Tests Pre and Post	Variable	EXG (Ave) ±SD	COG (Ave) ±SD
SJ-Pre_	Vmax m/s	2.16 ± 0.13	2.31 ± 0.22
	Fmax *fg	1.99 ± 0.19	2.11 ± 0.32
	Pmax w/kg	34.49 ± 2.55	38.85 ± 6.98
	JH m	0.33 ± 0.04	0.34 ± 0.04
SJ-Post_	Vmax m/s	2.23 ± 0.05	2.37 ± 0.19
	Fmax *fg	2.08 ± 0.16	2.11 ± 0.31
	Pmax w/kg	36.01 ± 1.59	38.84 ± 6.71
	JH m	0.34 ± 0.03	0.36 ± 0.02
CMJ-Pre_	Vmax m/s	2.16 ± 0.17	2.28 ± 0.28
	Fmax *fg	2.67 ± 0.42	2.73 ± 0.43
	Pmax w/kg	40.37 ± 3.78	41.8 ± 6.50
	JH m	0.31 ± 0.04	0.35 ± 0.04
CMJ-Post_	Vmax m/s	2.21 ± 0.16	2.28 ± 0.27
	Fmax *fg	2.72 ± 0.37	2.73 ± 0.41
	Pmax w/kg	41.48 ± 3.40	41.8 ± 0.41
	JH m	0.33 ± 0.02	0.36 ± 0.02
DJ-Pre_	Fmax kg	50.83 ± 8.25	56.75 ± 6.46
	Pmax kg	27.08 ± 5.96	27.77 ± 9.05
	TA\TC	1.83 ± 0.33	1.92 ± 0.41
DJ-Post_	Fmax kg	51.73 ± 7.15	56.89 ± 6.23
	Pmax kg	28.28 ± 5.24	27.79 ± 8.15
	TA\TC	1.91 ± 0.34	1.92 ± 0.38

Notes: Average (Ave) and Standard Deviation ± SD. (SJ-Squat Jump, CMJ-Countermovement Jump and DJ-Drop Jump in: Pmax-Power max, Vmax-Velocity max, Fmax-Force max, JH-Jump Height), (DJ-40 m-Drop Jump; TC-Contact Time/TA-Air Time=TA/TC).

These results indicate consistent enhancements in all assessed measures of explosive lower-limb strength in the EXG, while the control group-maintained baseline performance.

Test reliability was confirmed using a "test–retest" method, minimizing the effect of uncontrolled variables. Statistical analysis of the key explosive strength parameters is summarized in Table 3.

Paired comparisons between the EXG and COG using t-tests revealed significant improvements in jump performance following the intervention: Squat Jump (SJ – Pmax, W/kg): EXG = 34.49 ± 2.56 W/kg, COG = 38.85 ± 6.99 W/kg (t-test, p = 0.024), indicating a significant effect of the training program on SJ power.

Countermovement Jump (CMJ – Jump Height, m): EXG = 0.31 ± 0.04 m, COG = 0.35 ± 0.04 m (t-test, p = 0.009), demonstrating a statistically significant increase in vertical jump performance in the experimental group.

Table 3. Explosive Strength Performance Before and After 14-Week Intervention

Variables	Groups	Pre (Mean ± SD)	Post (Mean ± SD)	t-test / p-value
SJ – Pmax (W/kg)	Experimental (EXG)	34.49 ± 2.56	36.12 ± 2.78	0.024
	Control (COG)	38.85 ± 6.99	39.05 ± 7.01	–
CMJ – Jump Height (m)	Experimental (EXG)	0.31 ± 0.04	0.34 ± 0.04	0.009
	Control (COG)	0.35 ± 0.04	0.35 ± 0.04	–

Notes: SJ = Squat Jump; CMJ = Countermovement Jump; DJ = Drop Jump; TA/TC = contact time ratio. Mean ± SD values are reported. Paired-sample t-tests were used to assess within-group changes; p < 0.05 indicates statistical significance

A two-way repeated measures ANOVA was conducted to examine the effects of time (T1 vs. T2) and group (experimental vs. control) on test performance. The analysis showed a significant main effect of time for SJ ($F(1,24) = 10.04$, $p = .004$, $\eta^2 = 0.033$), indicating an overall change from T1 to T2. The η^2 value suggested a small effect size, whereas Cohen's d indicated a small-to-moderate effect (d = -0.44, 95% CI [-1.21, 0.35]). However, because the confidence interval included zero, the magnitude of the effect should be interpreted with caution. Similarly, a significant main effect of time was observed for CMJ ($F(1,24) = 15.66$, $p < .001$, $\eta^2 = 0.052$), indicating overall changes between the two measurement occasions. The η^2 value again suggested a small effect size, while Cohen's d indicated a small effect (d = -0.34, 95% CI [-1.11, 0.44]). As the confidence interval included zero, the magnitude of this effect should also be interpreted cautiously.

Discussion

The present study investigated the effects of a 14-week circuit training program on explosive lower-limb strength in elite female basketball players. The main findings indicate that the experimental group (EXG) demonstrated significant improvements in Squat Jump (SJ – Pmax, W/kg; p = 0.024) and Countermovement Jump (CMJ – Jump Height, m; p = 0.009), while the control group (COG) showed minimal changes. Improvements in the 40-cm Drop Jump (DJ) contact time ratio (TA/TC) in EXG suggest enhanced reactive strength and neuromuscular efficiency, which are critical for basketball-specific actions (Coh & Supej, 2008).

These results align with previous studies demonstrating that plyometric and circuit-based interventions can improve explosive strength and vertical jump performance (Markovic, 2007; Alemdaroğlu, 2012; Malisoux et al., 2005). Specifically, gains in CMJ height indicate improved utilization of the stretch–shortening cycle (SSC), which underlies powerful jumps, rebounds, and rapid changes of direction in basketball (Jukić et al., 2005; Bobbert, 1990). Improvements in DJ performance further reflect enhanced reactive strength and neuromuscular coordination, which are closely associated with on-court performance, including acceleration, deceleration, and landing mechanics (Pleša et al., 2025).

Although baseline values in COG were slightly higher, the EXG achieved greater relative improvements, highlighting the efficacy of targeted training interventions in compensating for initial performance differences (Izquierdo et al., 2002; Montgomery et al., 2008). This finding supports the importance of structured, evidence-based training for optimizing explosive power in elite female athletes, particularly during the competitive season (Petway et al., 2020).

Our findings are consistent with research emphasizing lower-limb explosive power as a key determinant of basketball performance, enabling powerful accelerations, winning jumps, and overall competitive effectiveness (Hoffman et al., 1999; Castagna et al., 2009; Canavan & Vescovi, 2004). The improvements observed in SJ, CMJ, and DJ without external weights indicate that bodyweight-based circuit training is a practical and accessible method for in-season strength development, especially when time is limited (Bompa & Carrera, 2015).

Interestingly, no significant differences were observed among playing positions, in line with Cabarkapa et al. (2023), suggesting that the benefits of this circuit-based program are broadly applicable across positional roles. This has practical implications for coaches, as it allows for uniform implementation of explosive strength training regardless of an athlete's role on the court.

Despite the positive outcomes, the study has limitations. The relatively small sample size and short intervention period may limit statistical power and generalizability, potentially increasing variability in results.

Previous basketball literature has often reported positional differences in anthropometric and physical performance characteristics, particularly among guards, forwards, and centers. However, the relatively small sample size within each positional subgroup may have limited the statistical power to detect such differences. Additionally, participants belonged to the same competitive level and training environment, which may have reduced positional variability in the current sample.

Future research should consider longer-term interventions with larger cohorts and examine the transfer of gains to game-specific performance, such as sprinting, agility, and rebounding. Additionally, combining performance measures with biomechanical analysis could provide deeper insight into the mechanisms driving improvements in explosive strength.

Research on the development of explosive strength in elite female basketball players, particularly in Albania, remains limited. Most studies have focused on volleyball players, and few have examined longitudinal changes in explosive performance across the season (Lleshi & Kurti, 2024). Establishing test batteries for elite female basketball athletes would enable long-term monitoring and the definition of minimum physical requirements for playing positions and competitive levels. In conclusion, the results of this study support the use of structured, circuit-based training to enhance explosive strength in elite female basketball players. By integrating this intervention early in the season, coaches can optimize neuromuscular performance, improve individual and team outcomes, and provide an evidence-based framework for strength development in women's basketball (Vilela et al., 2020).

Limitations

The menstrual cycle phase was not controlled during pre- and post-testing because the main aim of the study was to evaluate the overall effectiveness of the training intervention under real-world team sport conditions. Testing sessions were scheduled according to the competitive calendar and team training programme, which limited the possibility of aligning testing with specific menstrual cycle phases. In addition, variability in cycle length, irregular cycles, and possible hormonal contraceptive use made standardisation difficult. Nevertheless, hormonal fluctuations may influence neuromuscular performance and jump outcomes; therefore, this should be considered a limitation of the study.

Conclusions

A 14-week circuit training program with six exercises effectively enhances explosive strength in elite female basketball players. Significant improvements in SJ, CMJ, and DJ performance demonstrate the program's practical impact on both individual and team performance. This model offers a time-efficient, evidence-based strategy for coaches to implement targeted strength development during the season. While the small sample size limits generalizability, the results highlight the potential of structured circuit training to optimize explosive power in female basketball athletes.

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