Comparison of eccentric and concentric training effects on improving explosive performance in elite female basketball players: a pilot study

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ABSTRACT

Objective: This study aimed to compare the effects of concentrically dominant (CD) and eccentrically dominant (ED) training programs on explosive abilities in elite female basketball players, focusing on vertical jump performance. **Methods:** A total of 10 elite female basketball players were divided into two groups, with five participants each. One group followed a concentrically dominant training program, while the other group followed an eccentrically dominant program. The training lasted six weeks, with two sessions per week. Vertical jumps were assessed using countermovement jumps (CMJ), squat jumps (SQJ), and drop jumps (DJ), focusing on parameters such as Relative Peak Power and Landing Rate of Force Development (RFD) and other parameters. Statistical analysis was performed using descriptive statistics, the Shapiro-Wilk test for normality, independent t-tests, and Cohen's d to assess effect sizes for the CMJ, DJ, and SQ tests. **Results:** The CD group demonstrated improvements in both Relative Peak Power (from 41.520 to 43.360 W/kg, Cohen's d = -0.824) and Jump Height (Cohen's d = -0.964) in the CMJ test, though the differences were not statistically significant. The ED group showed minimal improvement, and in some cases, slight reductions in performance parameters. In the DJ test, significant improvements in Landing RFD were observed in the CD group (Cohen's d = -1.533), while the ED group showed a large effect size in Landing RFD (Cohen's d = -0.858), though this effect was not statistically significant. **Conclusion:** Concentrically dominant training was more effective in improving explosive strength and jump height, as well as demonstrating a statistically significant improvement in Landing RFD. While eccentrically dominant training also showed a notable effect in landing control, it was not as pronounced or statistically significant. Based on these findings, incorporating both training modalities could enhance explosive performance and improve landing mechanics in elite female basketball players. Further research with larger sample sizes is recommended to solidify these conclusions.

KEY WORDS: basketball, concentric contraction, eccentric contraction, explosive strength, vertical jump

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INTRODUCTION

Basketball is a team sport that involves simultaneous offensive and defensive actions, characterized by a combination of aerobic and anaerobic activities. These activities encompass various neuromuscular and biomechanical actions that place significant physical and physiological demands on players in short bursts of effort (1, 2,3). Movements in basketball, such as sprints, decelerations, changes of direction, accelerations, and vertical jumps, are explosive in nature. Successful performance in the game depends on explosive leg power, upper body strength, agility, coordination, speed of cyclic and acyclic movements, anaerobic capacity, shooting accuracy, and ball-handling skills (4, 5). Explosive strength, jumping ability, speed, and agility significantly contribute to effective movement both with and without the ball, playing a crucial role in basketball techniques and tactics (6, 7).

Both male and female players perform an average of approximately 652 movements per game, including running, sprints, and changes of direction (8), covering a distance of 5000 to 6000 meters during a match (5). Male players complete about 3% of the total distance at speeds exceeding 18 km/h, whereas females sprint more frequently, approximately every 33 seconds, with most sprints being short and linear (Conte et al., 2015). Women also perform more jumps per minute (1.1) compared to men (0.6–0.7) (Delextrat et al., 2015; Fox et al., 2019). These differences suggest specific training requirements for female players, particularly in the area of explosive activities.

One method to enhance explosive abilities is plyometric training, which induces adaptations that improve muscle strength, running speed, dynamic stability, neuromuscular coordination, as well as increase the rate of muscle contraction and tendon stiffness across various sports (9,10, 11, 12), including basketball (13,14). Plyometric exercises consist of three phases: pre-activation (eccentric), amortization (isometric), and muscle shortening (concentric). They are characterized by a rapid transition from eccentric to concentric muscle contraction, known as the stretch-shortening cycle (SSC). This type of muscle work, common in many sports including basketball, enhances the ability of musculoskeletal units to generate maximum force in minimal time. Plyometric exercises can emphasize either concentric or eccentric muscle work depending on the type of jump (e.g., jumps onto or off a platform) (10, 15, 16).

Numerous studies (17,18, 16, 19) have compared the effectiveness of concentric and eccentric training in improving performance. Eccentric contractions, which involve active lengthening of muscle fibers under load, can produce 20–60% more force than concentric contractions (18). Eccentric training also promotes phenotypic adaptations such as strength gains and hypertrophy and is critical in sports requiring rapid changes of direction, as it enables effective deceleration and body stabilization (20). Moreover, eccentric training may reduce the risk of muscle injuries by enhancing the muscles' ability to absorb energy during eccentric loading (21). Benford et al. (19) found that concentric training leads to greater increases in muscle thickness in the mid-region of the muscle, whereas eccentric training significantly affects the distal portion of the muscle and lengthens fascicles, potentially indicating an increase in the number of sarcomeres in series. These regional adaptations highlight the distinct effects of each contraction type.

Currently, there is still insufficient literature addressing the impact of training that emphasizes either eccentric or concentric contractions in the context of explosive exercises. The study by Staniszewski et al. (16), which compared plyometric stair training focusing on concentric (upward jumps) and eccentric (downward jumps) contractions, provides an important contribution to this area. Their findings revealed that eccentric training led to greater improvements in knee extensor torque and vertical jump height (an increase of more than 8%, $p < 0.001$), confirming its importance for enhancing lower limb explosiveness and strength.

Thus, the aim of our study was to contribute to the expansion of knowledge in this field by comparing the effects of two distinct modes of rapid muscle work—concentric and eccentric contractions—on the explosive parameters of lower limb muscles. The analysis aimed to determine which training type (dominated by either concentric or eccentric muscle work) leads to greater improvements in the explosiveness and performance capabilities of lower limb muscles.

METHODS

Research Sample

The research included 11 elite female basketball players. Due to insufficient participation in the experiment, one participant was excluded, reducing the final number of participants to 10. The average decimal age of the participants was 20.72±2.94 years, with an average height of 178.8±8.39 cm and an average body weight of 68.64±10.73 kg. Participants were purposefully divided into two experimental groups. The allocation criterion was based on baseline test results to ensure maximal performance homogeneity within both groups. Participants were ranked according to their test performance and alternately assigned to the experimental groups. The concentrically dominant group (CD) consisted of five participants, as did the eccentrically dominant group (ED). The training program was tailored such that each group performed explosive exercises emphasizing their respective phase of muscle contraction—concentric or eccentric. Inclusion criteria for the study required active membership in a basketball club, participation in the top Slovak league, and the ability to perform the prescribed exercises without pain. Participants were required to achieve at least 75% attendance at training sessions. Exclusion criteria included an inability to meet training requirements due to injuries or other health limitations. All participants provided written informed consent to participate in the study.

TRAINING PROTOCOL

The training program included a combination of dynamic exercises (jumps and landings) and strength exercises emphasizing the speed of muscle contraction. One group followed a concentrically dominant training protocol, while the other followed an eccentrically dominant protocol. Training sessions occurred twice weekly (Tuesdays and Thursdays) over six weeks, at the same time (15:30–16:45), in the same indoor location. The main experimental session lasted approximately 30 minutes, preceded by a warm-up following the RAMP protocol (raise, activate, mobilize, potentiate) (22).

Progressive overload was ensured by increasing intensity after three weeks. Step-up exercises involved increased loads, and deceleration lunges incorporated increased resistance from bands. Box heights for jumps and landings in the first three weeks were set as follows: bilateral drop jumps/jumps 45 cm, unilateral jumps 15–30 cm (based on individual baseline performance). After three weeks, box heights were increased to 60 cm for bilateral exercises and 30–45 cm for unilateral exercises. All training sessions were supervised by an experienced strength and conditioning coach to ensure proper exercise technique.

TESTING PROCEDURES

Baseline testing was conducted on August 9, 2024, at 9:00 indoors, while post-intervention testing occurred on September 23, 2024, at 10:00 in the same environment. Testing was carried out under controlled conditions. Participants were instructed to refrain from engaging in strenuous physical activity 24 hours before testing to minimize the influence of fatigue.

Testing was conducted using VALD equipment, selected for its high reliability and validity (23). Explosive performance was assessed using Force Decks by VALD, performing the following tests: countermovement jump (CMJ), squat jump (SQ), and drop jump (DJ) from a height of 39 cm. The height was chosen based on previous in-season testing to allow for result comparisons. Instructions for the drop jump emphasized minimizing ground contact time and maximizing jump height. For the squat jump, participants started from a position with knees at a 90° angle. In the countermovement jump, participants were free to choose their preferred depth based on comfort. All tests were conducted under the supervision of an experienced coach to ensure consistent instructions across participants and to maximize performance outcomes.

Statistical Analysis

Statistical analysis was performed using JASP (version 0.18.3.0). For each group (ED and CD), descriptive statistics were calculated, including mean, median, standard deviation, and coefficient of variation for all variables in the CMJ, DJ, and SQ tests.

Data normality was assessed using the Shapiro-Wilk test, confirming a normal distribution. Independent t-tests were used to compare groups, with a significance level set at $p < 0.05$. Differences in various performance parameters before and after the intervention were analyzed for each group individually and subsequently compared between groups. Effect size was evaluated using Cohen's d coefficient to quantify the practical significance of differences between groups or measurements. Cohen's d values were interpreted as follows: $d \geq 0.2$ for a small effect, $d \geq 0.5$ for a medium effect, and $d \geq 0.8$ for a large effect (24).

RESULTS

Countermovement Jump Test

In the ED group, no statistically significant differences were observed between pre- and post-test values across any measured parameters. Relative Peak Power (W/kg) showed a slight decline from 45.000 to 44.160, with $t(4) = 0.642$ and $p > 0.05$ indicating a non-significant difference. The effect size, expressed as Cohen's $d = 0.287$, suggested a small effect. Similarly, other parameters, such as Concentric Peak Force ($t(4) = –0.11$, $p > 0.05$, Cohen's $d = –0.05$), Concentric Rate of Force Development (RFD) ($t(4) = –0.75$, $p > 0.05$, Cohen's $d = –0.34$), and Eccentric Peak Force ($t(4) = –0.24$, $p > 0.05$, Cohen's $d = –0.11$), also showed no significant changes. Jump Height remained virtually unchanged ($t(4) = –0.05$, $p > 0.05$, Cohen's $d = –0.02$), indicating no measurable training effect on this parameter.

In the CD group, some improvements were observed, though they were not statistically significant. Relative Peak Power increased from 41.520 to 43.360 W/kg, with $t(4) = –1.843$ and $p > 0.05$ indicating no statistical significance. However, Cohen's $d = –0.824$ suggested a large effect, indicating a potentially meaningful practical improvement. Jump Height also improved

($t(4) = –2.155$, $p > 0.05$, Cohen's $d = –0.964$), with the effect size indicating a large practical significance. Other parameters, such as Concentric Peak Force and Concentric RFD, did not show significant differences, with small to negligible effect sizes.

When comparing the two groups, no statistically significant differences were observed across any CMJ parameters ($p > 0.05$). Nevertheless, the effect size for Relative Peak Power (Cohen's $d = –1.029$) indicated a large effect in favor of the CD group, suggesting that concentrically dominant training may have had a greater practical impact on CMJ performance.

Drop Jump Test

The ED group did not exhibit statistically significant improvements in any parameters. Relative Peak Power increased from 151.600 to 158.800 W/kg ($t(4) = –0.705$, $p > 0.05$), but the effect size was small (Cohen's $d = –0.315$). Jump Height showed a slight increase, but it was not statistically significant ($t(4) = –1.533$, $p > 0.05$, Cohen's $d = –0.686$). An interesting finding was observed in the Drop Landing RFD parameter, where Cohen's $d = –0.858$ suggested a large effect, even though $p > 0.05$ indicated no statistical significance. This result may reflect certain physiological adaptations related to force absorption during landing.

In the CD group, a statistically significant improvement was observed in Landing RFD, with $t(4) = –3.429$, $p < 0.05$, and Cohen's $d = –1.533$ indicating a large effect and statistical significance. This result suggests a substantial positive impact of training on the ability to generate force during landing. Other parameters, such as Relative Peak Power and Jump Height, did not show statistically significant differences, though small effects indicated modest improvements.

When comparing the groups, Landing RFD emerged as a parameter with a large effect size (Cohen's $d = –1.293$) favoring the CD group, although statistical significance was not achieved ($p > 0.05$). This indicates a potentially meaningful practical difference in the rapid force development capability during landing between the groups.

Table 1. Results of the Independent Samples T-Test Comparing CD and ED Group

							95% CI for Cohen's d	
		t	**df**	**p**	**Cohen's d**	**SE Cohen's d**	**Lower**	**Upper**
CMJ	Peak power	-1.628	8	0.142	-1.029	0.711	-2.337	0.333
	Con Peak Force	-0.045	8	0.965	-0.029	0.633	-1.267	1.212
	Concentric RFD	0.487	8	0.639	0.308	0.640	-0.950	1.547
	EccDec RFD	0.235	8	0.820	0.149	0.634	-1.098	1.386
	EccPeak Force	0.184	8	0.859	0.116	0.634	-1.128	1.353
	Jump Height	-1.012	8	0.341	-0.640	0.664	-1.899	0.656
	Peak Landing Force	-0.625	8	0.549	-0.395	0.645	-1.638	0.871
DJ	Peak Power	0.044	8	0.966	0.028	0.633	-1.213	1.266
	Jump Height	0.598	8	0.566	0.378	0.644	-0.886	1.620
	RSI	0.206	8	0.842	0.130	0.634	-1.115	1.367
	Drop Landing RFD	-1.068	8	0.317	-0.675	0.668	-1.938	0.625
	Landing RFD	-2.044	8	0.075	-1.293	0.753	-2.648	0.126
	Peak Landing Force	-0.780	8	0.458	-0.493	0.651	-1.741	0.784
SQJ	Concentric RFD	-1.478	8	0.178	-0.935	0.698	-2.229	0.409
	Jump Heigh	-0.432	8	0.677	-0.273	0.638	-1.512	0.981

Note. Student's t-test.

Squat Jump Test

In the ED group, no statistically significant differences were observed. Relative Peak Power slightly increased from 44.720 to 45.620 W/kg (t(4) = –0.416, p > 0.05, Cohen's d = –0.186), indicating a small effect. However, Jump Height showed a large effect (Cohen's d = –0.865), despite the difference being statistically non-significant (t(4) = –1.933, p > 0.05). This result suggests a practically significant improvement in explosive strength.

The CD group exhibited similar trends. Relative Peak Power increased from 40.700 to 43.140 W/kg (t(4) = –1.943, p > 0.05), with Cohen's d = –0.869 indicating a large practical effect. Jump Height also demonstrated a large effect (Cohen's d = –0.865) without reaching statistical significance.

When comparing the groups, a large effect size was observed in favor of the CD group for Concentric RFD (Cohen's d = –0.935), although statistical significance was not achieved (t = –1.761, p > 0.05). This suggests that the CD group may have experienced greater practical improvements in the ability to generate force from the squat position.

DISCUSSION

The primary aim of this study was to evaluate and compare the effects of concentrically and eccentrically dominant training programs on the explosive abilities of elite female basketball players, with a focus on their vertical jump performance.

The results suggest that concentrically dominant training (CD) had a greater practical impact on improving lower limb explosive abilities in elite basketball players compared to eccentric training (ED). Although statistical differences between groups were not significant, effect sizes (Cohen's d) for parameters such as Relative Peak Power and Jump Height in the Countermovement Jump (CMJ) test indicated practically significant improvements in the CD group. Specifically, Relative Peak Power increased from 41.520 to 43.360 W/kg (Cohen's d = –0.824), and Jump Height showed an improvement with an effect size of Cohen's d = –0.964. While these improvements were not statistically significant, the large effect sizes suggest a meaningful practical impact on performance. The ED group did not exhibit statistically significant improvements, and in some parameters, such as Relative Peak Power, there was even a slight decline. Other parameters, such as Concentric Peak Force and Concentric RFD, also showed no significant changes in this group.

These findings contrast with those of Staniszewski et al. (16), who demonstrated that eccentrically dominant training (downward jumps) was more effective in enhancing knee extensor and plantar flexor strength, leading to a significant 8% increase in vertical jump height after four weeks. Conversely, in our study, the ED group displayed only minimal changes in explosive parameters. The lack of significant improvement in the ED group in this study also diverges from findings by Fiorilli et al. (20), who emphasized the efficacy of iso-inertial eccentric training for sports requiring rapid changes of direction (COD) and force absorption. However, a key methodological difference exists: Fiorilli et al. employed iso-inertial training, which provides constant resistance throughout the range of motion, whereas our research focused on rapid eccentric and concentric contractions in plyometric exercises, which may have led to differing performance outcomes and adaptations.

In the CD group, a statistically significant improvement was observed in the Drop Jump (DJ) test, specifically in the Landing RFD parameter (Cohen's d = –1.533; $p < 0.05$), indicating a substantial positive effect of concentric training on the ability to absorb force during landing. This effect was more pronounced than in the ED group, where Landing RFD showed a large effect (Cohen's d = –0.858) but did not reach statistical significance. This difference could be attributed to factors such as the lower box height used for drop jumps or the smaller volume of exercises, which may have generated lower peak forces during landing. Although overall jump performance in the ED group did not improve significantly, the observed improvement in force absorption during landing highlights the beneficial effects of eccentric training, particularly for injury prevention and improved force control during landing, as confirmed by Marušič et al. (21).

The study by Staniszewski et al. (16) is the only known research that has examined rapid eccentric and concentric muscle contractions in a manner similar to our study. Most other researchers, including Mike et al. (18), focused on slower contractions, particularly in strength exercises, analyzing the duration of the eccentric phase. Unlike Mike et al. (18), where participants were divided into groups based on the length of the eccentric phase (2 seconds, 4 seconds, 6 seconds), our study targeted rapid and isolated concentric and eccentric contractions. Their study demonstrated that a shorter eccentric phase (2 seconds) led to a statistically significant increase in vertical jump height ($p = 0.02$), whereas longer eccentric phases (4 and 6 seconds) did not yield significant changes. This suggests that shorter eccentric phases may be more effective for developing explosive power. Similar to their findings, our research recorded improvements in Relative Peak Power for both eccentric and concentric contractions in the Squat Jump (SQJ) test, although these improvements were not statistically significant. The effect sizes, however, indicate practically significant improvements, aligning with the findings of Mike et al. (18), where increases in Peak Power were similarly practically significant.

Friedmann-Bette et al. (17) also investigated eccentric and concentric contractions, with training groups emphasizing either eccentric overload or traditional concentric-eccentric contractions. They found that the group with eccentric overload (CON/ECC+) demonstrated a significant increase in Squat Jump height (by 2–3 cm), whereas the group with traditional training (CON/ECC) showed no substantial improvements. In our study, improvements in explosive power were observed for both contraction types in the same test, with a large effect size for Relative Peak Power indicating practically significant improvements, despite the lack of statistical significance.

PRACTICAL RECOMMENDATIONS

Our study demonstrated that concentrically dominant training (CD) had a large practical effect on improving Relative Peak Power and Jump Height in the Squat Jump test (Cohen's $d > 0.8$), even though the results were not statistically significant. This finding suggests that training focused on concentric muscle contraction may be particularly effective for enhancing explosive power in basketball players, especially in movements requiring quick, explosive propulsion from the ground, such as defensive jumps or rapid offensive movements. Conversely, eccentrically dominant training (ED) showed a large effect in parameters such as Drop Landing RFD and the ability to absorb and control landings (Cohen's d > 0.8), which is crucial for players during jump landings or rapid direction changes. This training approach may be particularly beneficial for reducing injury risk, as improved landing control decreases stress on the lower limbs and joints. Based on these results, we recommend that coaches incorporate both concentric and eccentric training modalities into basketball players' preparation. While concentrically dominant exercises can enhance explosiveness during jumps and sprints, eccentric exercises are critical for improving landing safety and directional changes, reducing injury risk, and supporting long-term athletic performance.

STUDY LIMITATIONS

Several limitations were identified in this study. The first is the relatively small sample size, which may have affected the statistical power and ability to detect significant differences between groups. The small number of participants also limits the generalizability of the findings to a broader population of elite basketball players. Another limitation may be the program duration. While a six-week program is often considered sufficient to induce training adaptations (Gonzalo-Skok et al., 2019; Staniszewski et al., 2020; Pechlivanos et al., 2024), a longer training period with higher frequency might yield more pronounced results. Due to the players' preparatory phase, additional training sessions were not feasible.

CONCLUSION

In conclusion, while concentric training appears to be more effective for improving explosive strength in elite basketball players, eccentric training remains essential for enhancing landing control and injury prevention. A balanced approach that integrates both training methods may provide the best overall outcomes for athletes.

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