ORIGINAL ARTICLE

Effects of accentuated eccentric loading on explosive strength and agility in basketball players

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Abstract

Background and Study Aim Basketball performance depends on the development of physical qualities that support fast and efficient movement. Explosive strength and agility contribute to rapid acceleration, jumping, and changes in direction during gameplay. Despite the use of various training methods, their relative effectiveness in improving these qualities remains a subject of practical interest. This study aimed to determine the effectiveness of Accentuated Eccentric Loading training in enhancing explosive strength and agility among collegiate basketball players.

Material and Methods Thirty-two state-level male collegiate basketball players (age 18–25 years) were assigned into experimental and control conditions representing both rural and urban training environments. The experimental groups completed a six-week Accentuated Eccentric Loading program performed three times weekly, with eccentric overload initialized at 30% of body mass and progressively increased across sessions. Control groups continued regular basketball practice without additional eccentric loading. Explosive strength was assessed using the Vertical Jump Test, while agility was measured through the Agility T-Test. Performance was evaluated pre- and post-intervention. Data analysis included paired t-tests to examine within-group change and ANCOVA to compare post-intervention outcomes between groups while controlling for baseline values.

Results Accentuated Eccentric Loading led to measurable improvements in explosive strength and agility ($p < 0.05$). AEL groups demonstrated greater progress than controls, indicating that eccentric loading produced a stronger training effect than regular practice. Post-hoc comparisons showed a consistent advantage of AEL in both rural and urban subgroups. This suggests that the effectiveness of the method was similar across different training environments. Overall, AEL improved jump performance and directional movement capacity within a six-week training cycle.

Conclusions The findings indicate that AEL training is effective in improving explosive strength and agility in collegiate basketball players. The results support its practical application for coaches and trainers aiming to enhance performance in competitive basketball.

Keywords: explosive strength, agility, accentuated eccentric loading, eccentric phase, vertical jump

Introduction

Basketball performance is shaped by physical, technical, and tactical demands that require athletes to sustain dynamic activity throughout gameplay. Explosive strength and agility influence acceleration, vertical force production, and rapid directional transitions during offensive and defensive actions. These qualities interact within a high-speed environment, where any delay or loss of power may affect the outcome of an episode and the overall course of the game. For athletes, speed and explosive strength are essential qualities that form the basis of success in sports requiring quick reflexes and high-energy bursts. These characteristics are important in sports where rapid direction changes, quick acceleration, and controlled deceleration are required. In games like basketball, explosive strength and agility play a central role [1, 2].

In muscular contraction, two phases are observed: concentric and eccentric, referring to muscle shortening and lengthening, respectively [3]. Physiological study of eccentric muscle work has a long research tradition. The concept of eccentric muscle action as distinct from concentric work is well established in the literature [4]. Eccentric or negative resistance training focuses on the lengthening phase of contraction. In strength and conditioning programs, eccentric exercises are applied to load muscles in the opposite direction of the pull using external resistance [5]. It has long been recognized that skeletal muscles generate greater force during eccentric activity compared with concentric movements [6]. Eccentric loading can overload the

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muscular system with comparatively low energy expenditure [7]. Therefore, eccentric training is considered a meaningful component of strength and conditioning programs aimed at improving performance or reducing injury risk in sport [4].

An approach used to improve physical characteristics in athletes is Accentuated Eccentric Loading (AEL), a training method focused on the lengthening phase of movement. AEL is considered an extension of eccentric exercise concepts. It involves applying a greater load during the eccentric phase compared with the concentric phase of a coupled eccentric–concentric action [8, 9]. Earlier work suggests that increasing external load in the eccentric phase of a jump may influence the stretch-shortening mechanism and affect jump execution and performance [10]. By emphasizing muscle lengthening under resistance, AEL may promote changes in neuromuscular function and muscle performance [11]. This has contributed to its growing use among coaches and conditioning professionals seeking to enhance training outcomes.

Explosive strength refers to the short-term ability to generate maximal muscle force and accelerate movement of the whole body or its segments. Explosive muscle force may be described as the capacity to overcome external resistance within a rapid force-producing action [12, 13]. This quality reflects the quick development of force through fast muscular contraction during actions that require high output over a brief time. Sports requiring high loading and rapid force transfer through the lower limbs include skiing, weightlifting, diving, and team sports such as basketball, football, and volleyball [13].

Agility may be described as a rapid whole-body action that involves changes in velocity or movement direction in response to an external stimulus. It integrates trainable physical qualities such as strength, power, and technical execution with cognitive processes including anticipation, decision-making, and visual scanning strategies. In practice, assessment of agility often focuses either on physical components, such as change-of-direction speed, or on cognitive elements such as anticipation and pattern recognition [14, 15]. Agility development has been associated with improvements in movement efficiency, balance control, and reactive decision-making during high-intensity sport situations [16]. This movement quality is relevant across a broad spectrum of sports, including individual disciplines such as tennis and combat sports, and team games such as basketball [17].

Given the role of agility and explosive movement capabilities in performance, regional evidence is relevant when considering how training responses may differ across athletic environments. Research involving athletes from South Asia reports the use of structured strength-oriented preparation at competitive and university levels. Comparative findings in cricket, football, and volleyball indicate differences in strength, explosive power, speed, endurance, and agility between rural and urban athlete groups, with several studies noting higher test outcomes among rural participants in pull-ups, abdominal strength, shuttle runs, and standing broad jumps [18, 19, 20, 21]. Experimental work also shows that interval-based, resistance-based, and core-strength interventions can improve neuromuscular output, anaerobic performance, movement speed, and body-composition parameters in regional sport contexts [22, 23, 24].

These observations suggest that strength-development strategies are already applied within South Asian athletic populations and can lead to measurable adaptation. However, most of this evidence relates to general resistance training, whereas methods involving accentuated eccentric work have been examined less frequently in relation to agility and explosive force expression in basketball. This indicates the value of evaluating eccentric-focused training models in environments that differ in equipment access, coaching provision, and training load.

Research comparing rural and urban athletes under eccentric-based interventions remains limited, even though training infrastructure and resource availability can differ considerably. Comparable performance responses to Accentuated Eccentric Loading (AEL) under varying training conditions may indicate how preparation models can be adapted for different collegiate settings.

It was hypothesized that explosive strength and agility would increase following AEL intervention, without large differences between rural and urban training environments. This study aimed to determine the effectiveness of Accentuated Eccentric Loading training in enhancing explosive strength and agility among collegiate basketball players.

Materials and Methods

Participants

The study involved 32 state-level male collegiate basketball players aged 18–25 years, all actively engaged in competitive play. Participants were selected using a non-probability convenience sampling procedure and represented both urban (n = 16) and rural (n = 16) training environments. They were allocated to four groups: Urban Control (UCON), Urban Accentuated Eccentric Loading (UAEL), Rural Control (RCON), and Rural Accentuated Eccentric Loading (RAEL). Athletes from different on-court positions, including guards, forwards, and centers, were included to represent varied performance characteristics.

A priori sample estimation was performed using G*Power 3.1 to determine the minimum number required to detect a training effect. The calculation was based on an F-test for group comparison with covariate adjustment (ANCOVA, fixed effects), with $\alpha = 0.05$, statistical power $(1 - \beta) = 0.80$, four groups, and one covariate. An effect size of $f = 0.35$ was selected from prior eccentric-loaded and plyometric research. The estimated minimum sample was 28 participants; 32 players were recruited to allow for dropouts and to maintain equal group size.

All athletes received study information and provided written informed consent prior to participation. Ethical approval was granted by the Institutional Human Ethics Committee, and study procedures followed the principles of the Declaration of Helsinki [25].

Study Design

The research employed a quasi-experimental design within a quantitative framework using non-probability convenience sampling. Accentuated Eccentric Loading (AEL) was the intervention condition, whereas explosive strength and agility served as outcome variables. Participants allocated to the UAEL and RAEL groups completed a six-week AEL program delivered three times per week on alternate days, with eccentric overload set at 30–35% of body mass via weight releasers or external loading during the eccentric phase. Each session included a standardized warm-up, progressive plyometric drills, and eccentric-emphasis jump variations. The control groups (UCON and RCON) continued regular basketball training that involved warm-up routines, technical-tactical practice, scrimmage play, and basic strength work without eccentric overload. Plyometric exercises with added resistance were not incorporated into control training.

Pre-intervention testing was conducted before the program commenced, and post-testing followed completion of Week 6. A visual outline of participant flow, subgroup allocation, and final sample retention is presented in Figure 1.

Weekly Progressive AEL Training Protocol

Training sessions were held three times per week on alternate days for six consecutive weeks. Performance testing included the Vertical Jump Test and the Agility T-Test before the intervention and repeated at the end of Week 6. The AEL protocol was developed with reference to previously documented methods [3, 26]. Eccentric loading was applied using weight releasers during back-squat movements and weighted vests (5–12 kg) for drop-jump and broad-jump variations. All eccentric repetitions were executed with a controlled lowering phase of approximately 3 seconds, followed by an explosive concentric action. Tempo monitoring was maintained through verbal cues and metronome pacing when required. All sessions were supervised by two certified strength and conditioning professionals with at least five years of applied training experience.

A weekly breakdown of training progression is summarized in Table 1, and the load progression across six weeks is shown graphically in Figure 2.

Outcome Measurements

All performance assessments were conducted under standardized conditions. Each testing session was preceded by a warm-up that included 5 minutes of jogging, dynamic stretching, and submaximal jump attempts. Testing was scheduled at the same time of day (±1 hour) to reduce diurnal variation. Assessors conducting the vertical jump and agility tests were blinded to group allocation. Inter-

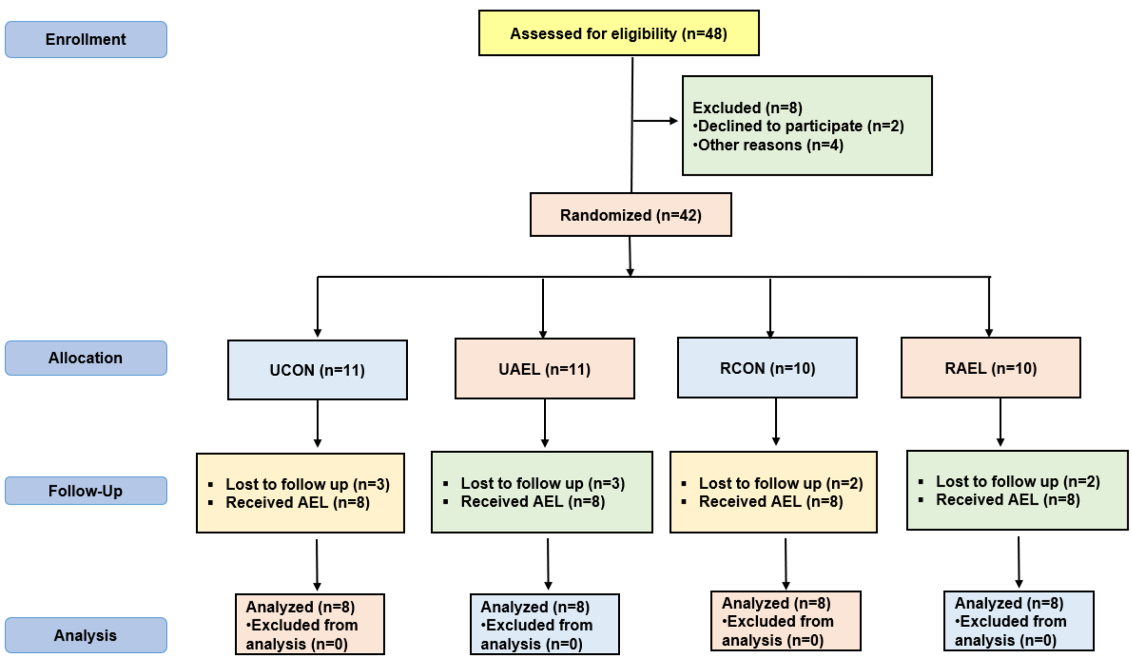

Figure 1. Flowchart of participant recruitment, inclusion and exclusion criteria, and final sample selection.

Table 1. AEL training schedule

Week	Session	Duration	Exercises (AEL)	Load (% BM)	Repetitions	Sets	Recovery (min)	Notes / Tests
Week 1	1–3	60 min	Warm-up (jogging, stretching, leg swings, bodyweight squats); AEL Jump Squats; Weighted Drop Jumps	30	6	3	3–5	Pre-test: Vertical Jump & Agility T-Test
Week 2	4–6	60 min	AEL Jump Squats; Weighted Drop Jumps; Countermovement Jump onto Box	30	6–7	3	3–5	Focus on controlled eccentric movement
Week 3	7–9	60 min	AEL Jump Squats; Weighted Drop Jumps; Weight Release Broad Jump	32	7	3	3–4	Progressive load increase
Week 4	10–12	60 min	AEL Jump Squats; Countermovement Jump onto Box; Single-leg Weight Release Jumps	33	7–8	3	3–4	Integration of unilateral variations
Week 5	13–15	60 min	AEL Jump Squats; Weighted Drop Jumps; Countermovement Jump onto Box; Weight Release Broad Jump	34	8	3	3–4	Higher peak loading phase
Week 6	16–18	60 min	AEL Jump Squats; Weighted Drop Jumps; Single-leg Weight Release Jumps; Countermovement Jump onto Box	35	8	3	3–4	Post-test: Vertical Jump & Agility T-Test

Note. Each session began with a standardized warm-up and concluded with recovery stretching. Training progression was achieved by gradually increasing weekly load and repetitions while maintaining correct form.

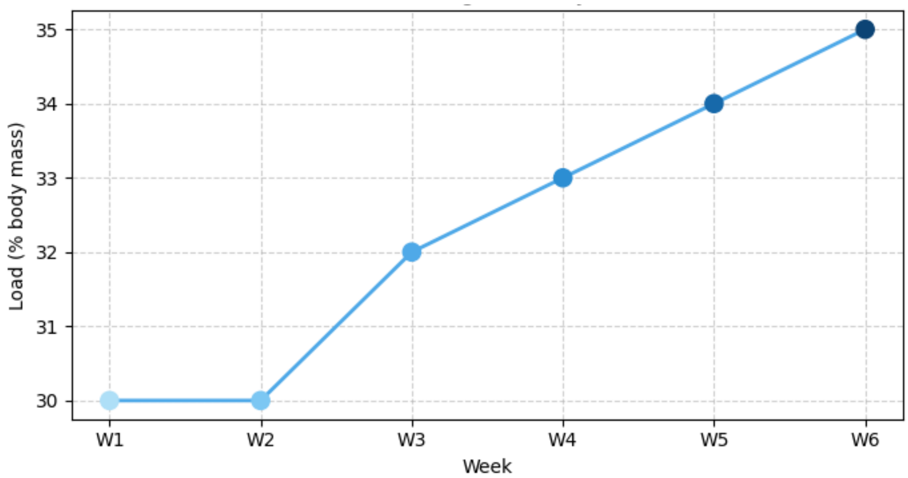

Figure 2. Week-by-week progression of Accentuated Eccentric Loading (% body mass).

rater consistency was maintained by assigning a single experienced examiner to each test across all sessions. Participants were asked to avoid strenuous physical activity during the 24 hours prior to testing.

Explosive Strength. Lower-body explosive strength was assessed using the Vertical Jump Test. Standing reach height and jump reach height were recorded with a standard vertical-jump apparatus, and vertical jump height (cm) was calculated as the difference between the two values. The test is widely applied in sport science and provides reliable indicators of lower-limb power in athletic populations [27].

Agility. Agility was evaluated using the Agility T-Test, which consists of forward sprinting, lateral shuffles, and backward running to measure multidirectional change-of-direction speed. Time was recorded with timing gates or a stopwatch, and the best result of three valid attempts was used for analysis. The test shows high test–retest reliability (ICC ≈ 0.98) and acceptable validity for agility/change-of-direction measurement [28].

Statistical Analysis

Pre-test and post-test scores for vertical jump and agility performance were analyzed using parametric procedures. Descriptive statistics (mean ± standard deviation) were calculated to summarize group data. Within-group change was evaluated using paired sample t-tests. Between-group comparison of post-test scores was performed using Analysis of Covariance (ANCOVA), with pre-test values entered as covariates for group adjustment. Post-hoc pairwise comparisons based on estimated marginal means were conducted to identify differences between RAEL, RCON, UAEL, and UCON. Effect size was expressed as partial eta squared (ηp^2), with 0.01, 0.06, and 0.14 interpreted as small, medium, and large magnitudes [29]. Statistical significance was accepted at $p < 0.05$. All analyses were completed using standard statistical software.

Results

Table 2 presents the pre- and post-intervention values for vertical jump height and agility time obtained from the paired t-test analysis.

Table 2. Pre- and post-test comparison of vertical jump and agility (paired t-test)

Variable	Test phase	Mean ± SD	t	p-value
Vertical Jump (cm)	Before	41.59 ± 12.09	8.69	0.00
	After	44.18 ± 12.02		
Agility (s)	Before	11.12 ± 0.71	5.59	0.00
	After	10.55 ± 0.68		

The table summarizes the changes in performance following the six-week AEL training program. After the training period, vertical jump performance improved, indicating increased explosive lower-limb output, and agility times were reduced, reflecting faster change-of-direction performance. Both outcomes showed statistically significant within-group change, supporting the presence of positive adaptation to the AEL intervention.

Table 3 summarizes the ANCOVA results for vertical jump and agility performance following the intervention. Following adjustment for pre-test values, statistically significant between-group effects were observed for both performance variables ($p < 0.05$). Vertical jump analysis indicated a large effect size, reflecting a considerable proportion of explained variance. Similarly, agility outcomes showed a large effect magnitude, suggesting that the intervention meaningfully influenced change-of-direction performance.

Table 3. Results of ANCOVA for Vertical Jump and Agility Performance

Variable	SS	F value	p-value	η^2
Vertical Jump	56.63	19.80	0.000	0.68
Agility	3.34	10.37	0.000	0.53

Note: SS – Sum of Squares; η^2 – Partial Eta Squared.

Table 4 reports the post-hoc pairwise comparisons among the four treatment groups based on estimated marginal means for vertical jump and agility performance. Post-hoc comparison results show clear differences between eccentric-loaded and control groups. Rural AEL (RAEL) demonstrated greater vertical jump gains than its rural control counterpart, while Urban AEL (UAEL) outperformed the urban control group. Differences between UAEL and RAEL were smaller, indicating comparable training responses across environments. For agility, RAEL showed faster completion time than RCON, and UAEL performed better than UCON. The contrast between UAEL and RAEL was not statistically distinct, suggesting similar directional improvement in both settings. Overall, AEL interventions produced superior outcomes relative to control groups, with UAEL showing the strongest relative advantage within its environment, while RAEL also achieved meaningful performance enhancement.

Table 4. Post-hoc pairwise comparisons of treatment groups

Variable	Group (I)	Group (J)	Mean Diff. (I–J)	Std. Error	Sig.
Vertical Jump	RAEL	RCON	2.132*	.55	.001
		UAEL	-1.176*	.50	.027
	UAEL	UCON	3.299*	.49	.000
		RAEL	1.176	.50	.027
Agility	RAEL	RCON	-.501*	.17	.009
		UAEL	.266	.15	.107
	UAEL	UCON	-.753*	.17	.000
		RAEL	-.266	.15	.107

Note. Estimated marginal means used for vertical jump and agility outcomes. Mean differences marked * indicate significance at $p < 0.05$.

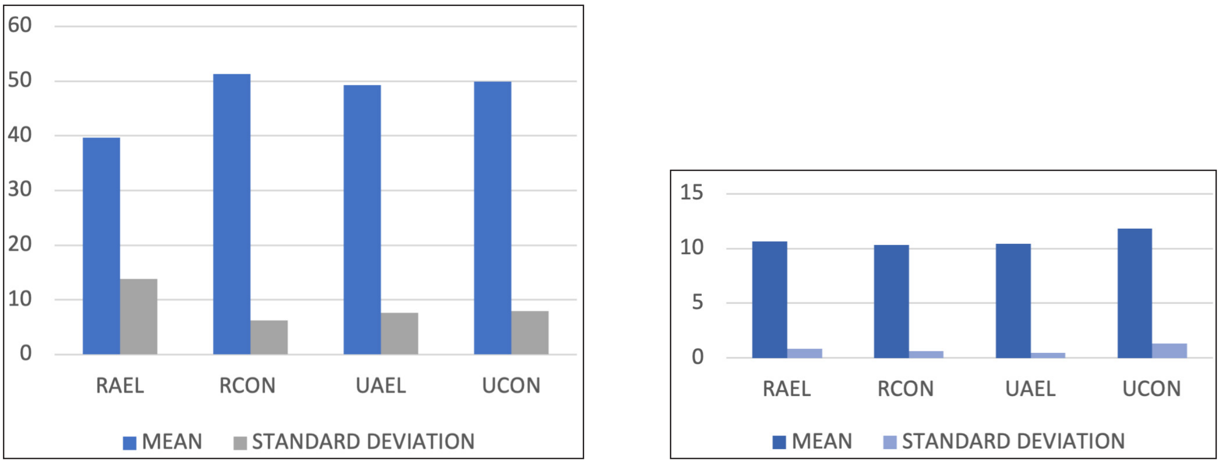

Figure 3. Comparison of Vertical Jump Performance Across Groups (RAEL, RCON, UAEL, UCON) Showing Mean and Standard Deviation

Figure 3 illustrates the comparison of vertical jump performance among the four groups (RAEL, RCON, UAEL, UCON), displaying mean values with associated standard deviations. Visual comparison indicates higher jump performance in the AEL-trained groups relative to their control counterparts. The separation between AEL and non-AEL conditions reflects the influence of eccentric loading on explosive strength, and the profiles of RAEL and UAEL appear broadly similar, suggesting comparable training response patterns across environments.

Discussion

This study examined the effects of AEL training on explosive strength and agility in collegiate basketball players. Significant improvement was observed in both variables following six weeks of progressive eccentric-based training. The findings support the hypothesis that AEL promotes greater adaptation in explosive strength and agility compared with conventional training, indicating that eccentric overload is an effective method for enhancing performance qualities relevant to basketball. A notable contribution of this work is the evaluation of AEL across rural and urban training settings, a dimension rarely addressed in previous literature. Many existing studies were conducted under controlled laboratory conditions or in high-performance environments that do not reflect the constraints faced by athletes training with limited equipment or infrastructure. The similar gains observed in both rural and urban groups suggest that AEL can be implemented successfully in settings with restricted resources. This is particularly relevant for South Asian athletes, where variability in training conditions is common and accessible intervention methods are required.

The improvement in vertical jump height reflects the established capacity of eccentric loading to enhance force production and mechanical efficiency. Eccentric contraction promotes structural and neural adaptations, including increased fascicle length, greater sarcomere number and hypertrophy of type II fibers, which allow muscles to tolerate higher external loads than during concentric actions [4, 6, 30]. These changes support the stretch–shortening cycle function and enable more effective transfer of stored elastic energy into concentric output [10, 28]. The present findings correspond with those reported by Aboodarda et al. [10], who observed enhanced jump performance when additional eccentric load was applied during drop jumps. Douglas et al. also demonstrated that eccentric-emphasized resistance training produced greater strength and power gains in comparison with traditional resistance methods when total work was matched [31]. Overall, the observed increase in vertical jump height suggests development in neuromuscular coordination, elastic energy utilization and concentric force expression following AEL exposure.

Improvement in agility performance following AEL training suggests enhanced capacity for movement control, deceleration and direction change during basketball-specific actions. Eccentric strength contributes to agility development due to its role in force absorption and redirection [32]. The reduction in agility T-test time observed in this study aligns with findings by Zhang et al. [33], who reported that eccentric-focused training improves movement speed through braking force control and motor unit coordination. Similar responses have been documented in relation to speed and agility outcomes under plyometric protocols with eccentric emphasis, supporting the concept that eccentric stimuli facilitate efficient force transition during directional changes [2].

The comparable outcomes observed in rural and urban AEL groups indicate similar physiological adaptations across settings with different resource levels. This suggests that agility improvements from AEL are influenced primarily by neuromuscular factors rather than training infrastructure, consistent with observations reported by Armstrong et al. [8]. Accordingly, AEL can be applied in various environments using basic external loading implements such as weight releasers or weighted vests.

AEL can produce measurable improvements in performance within a relatively short training period. In comparison with more complex or combined methods, AEL alone is capable of improving explosive ability without advanced equipment or long adaptation phases. Gu et al. [35] reported comparable gains in lower-body power and strength using AEL-based countermovement and drop-jump protocols, indicating that this method can be applied effectively across different plyometric formats. The present findings support this evidence within a collegiate basketball cohort. For applied practice, a six-week mesocycle of AEL may serve as a practical in-season option to enhance vertical and multidirectional explosiveness.

Further work incorporating electromyography, force-plate analysis or ultrasonography could clarify how AEL influences muscle activation, tendon stiffness and fascicle architecture [31, 36]. Maeo et al. [36] noted that contraction velocity affects the extent of neuromuscular adaptation during eccentric loading, although this aspect remains under-examined in basketball. The combination of AEL with complementary approaches, including plyometric, resistance or complex training, may produce additive effects, as suggested by Flórez Gil et al. [37]. Examination of such integrated models would help define the position of AEL within a broader performance-development structure.

The findings of this work indicate that eccentric-based loading can influence performance attributes relevant to basketball within a short training cycle. The response pattern observed across rural and urban groups suggests that adaptation depends more on neuromuscular mechanisms than on training infrastructure, which expands the scope for practical application in varied environments. AEL may therefore be incorporated into basketball preparation as a functional conditioning option, providing a basis for further refinement of prescription variables and integration within broader training models.

Limitations and Future Directions

Several limitations should be considered. The six-week duration restricts interpretation of long-term adaptation or retention effects, although it is sufficient for identifying initial performance changes. Longer studies are required to determine whether continued AEL exposure leads to sustained improvement or performance stabilization. The field-based measures used in this study, including vertical jump and the agility T-test, are practical and reflect sport-specific demands, yet they do not provide information on neuromuscular mechanisms. The sample size and inclusion of only male participants also limit generalization to other groups. Future work should incorporate female athletes and different performance levels to improve population coverage. Further research may also examine loading intensity, contraction velocity and exercise selection, as well as evaluate AEL use in other sports such as volleyball and handball.

Conclusions

This study indicates that Accentuated Eccentric Loading (AEL) improves explosive strength, agility and shooting-related performance in basketball players, with similar responses in rural and urban training environments. The six-week AEL protocol (30–35% body mass) likely enhanced stretch–shortening cycle function, eccentric force capacity and motor unit recruitment, which contributed to performance improvement relative to conventional training. While the findings are constrained by sample size and intervention duration, they suggest that AEL can be incorporated into basketball preparation using basic external loading implements.

Conflict of Interest

The authors report no conflict of interest.

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