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Acute Potentiation on Propulsive-Only Jump (POJ) Performance Following Supramaximal Accentuated Eccentric Loading in High School Basketball Players

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ABSTRACT

The purpose of this study was to investigate the acute responses of accentuated eccentric loaded (AEL) back squats to induce a post activation performance enhancement (PAPE) effect in youth athletes across three jump conditions: countermovement jump (CMJ), squat jump (SJ), and novel propulsive-only jump (POJ). Fifteen participants (age: 15.6 ± 1.1 years; RT experience: 1.3 ± 0.9 years; relative strength (back squat 1RM: body mass; 1.32 ± 0.3) completed three sessions (one familiarization, two experimental). AEL interventions were performed on each experimental session (3 sets x 3 repetitions, with only the initial repetition of each set was overloaded during the eccentric phase followed by 2 full repetitions of nonvarying loads) (ECC: 95%, 105%, 115%; CON: 60% 1RM) with pre- and post-testing (3 min, 6 min, 9 min, 12 min). Random assignment to either (a) CMJ, (b1) SJ+POJ, or (b2) POJ+SJ, where jump height (JH), net propulsive impulse (NPI) and peak relative propulsive power (PrPP) were assessed for each jump. Three 3x5 repeated measures ANOVAs were used to analyze each dependent variable across jump conditions and time with a level of significance of $p \leq 0.05$. Results revealed a significant increase in POJ JH performance at 9 min (+12.26% ± 13.65%, $p < 0.05$), while CMJ and SJ performance did not show statistically differences from pre-testing. JH performances peaked at 12 min for CMJ (+2.22% ± 7.71%) and SJ (+5.03% ± 12.77%) but did not reach statistical significance. These findings suggest that male high school basketball players may realize superior or unaffected jump performances at 9-12 min post-supramaximal AEL back squats. In addition, no significant deficits in performance outcomes were found for any condition from pre- to post-testing.

Keywords: accentuated eccentric, propulsive-only jump, PAPE, jump performance

INTRODUCTION

Accentuated eccentric loading (AEL) is a training modality involving a movement or exercise performed through the stretch-shortening cycle (SSC) without interruption, while inducing greater eccentric loading during the eccentric phase only (Wagle et al., 2017). This ability to incorporate greater eccentric loading is designed to account for the greater strength capabilities (up to 50% greater) seen during eccentric contractions compared to either concentric or isometric counterparts

(Schoenfeld et al., 2017). AEL is the only training modality that allows for supramaximal eccentric loading (>1RM loads) without compromising the natural stretch-shortening cycle mechanics that would otherwise be limited by eccentric-only movements. Consequently, most eccentric-focused research on youth athletes has been limited to flywheel inertial training (FIT) (Coutinho et al., 2022; de Hoyo et al., 2014) and plyometric-AEL variants (Aboodarda et al., 2013 & 2014; Lloyd et al., 2022), with intent of inducing positive acute performance enhancements.

Evidence of FIT as a conditioning activity (CA) to stimulate the phenomenon known as post activation performance enhancement (PAPE) has been inconclusive in its efficacy with youth athletic populations (Coutinho et al., 2022; de Hoyo et al., 2014). De Hoyo and colleagues revealed significant acute enhancements in countermovement jump (CMJ) performance following a session of FIT when compared to a control group (5 min of stationary cycling), although pre- and post-testing windows to identify potentiation durations are unclear. In contrast, Cutinho and researchers (Coutinho et al., 2022) did not find statistically significant differences in CMJ performance following a FIT (half-squat) intervention at the post-testing intervals (30 sec & 10 min). Both studies used high school-aged male participants of 17.0 ± 1.0 yrs. (de Hoyo et al., 2014). and 16.2 ± 0.6 yrs. (Coutinho et al., 2022), respectively. Although the use of FIT as a CA to stimulate a PAPE has been identified, no prior studies have investigated the use of supramaximal eccentric loading through means of AEL on high school-aged athletes for either acute or chronic adaptations. Additionally, the use of plyometric-AEL has shown increased performances during the drop jump (DJ) exercise with an additional 15% of one's body mass held during the eccentric action compared to a body mass-only control group (Lloyd et al., 2022). Lloyd and colleagues (2022) found significant increases in jump heights (r = 0.47, $p < 0.05$) in the AEL DJ group at the expense of increased ground contact durations (r = 0.45, $p < 0.05$) and a decrease in spring-like correlations (g = 0.94, $p < 0.05$). These findings suggest that increased (submaximal) eccentric phase loading can positively enhance the subsequent propulsive phase of the movement, although post-movement analysis of potentiation has yet to be uncovered. Moreover, only one study has investigated the use of supramaximal AEL as a conditioning activity to induce acute performance enhancement observed following the conclusion of the exercise (Tseng et al., 2021). Prior evidence of youth populations and AEL has been limited to submaximal loading procedures, primarily due to a greater likelihood of lower resistance training experience, lower relative strength, and higher likelihood of engaging a slower lowering strategy to deter the effects of inter-repetition concentric phase enhancement (Merrigan et al., 2022). Therefore, this investigation aimed to uncover the acute vertical jump outcomes following supramaximal AEL loading to further elucidate the practical applications of this method for high-school aged athletes and the use of AEL.

This investigation concurrently explored a novel vertical jump assessment, with intent to assess propulsive-only qualities in comparison to the standardized squat jump (SJ) assessment. The SJ assessment is performed with a 3-second isometric hold during the amortization phase prior to the propulsive action. This isometric action is intended to negate SSC contribution to assess and compare one's ability to utilize eccentric loading in relation to the CMJ (Bosco & Komi, 1979). Although the SJ is commonly used in tandem with the CMJ to analyze eccentric utilization ratio (EUR: CMJ/SJ jump heights), conflicting evidence of residual SSC contribution may indicate greater variability and the potential need for a seated variant to diminish pre-propulsive activity (Kozinc et al., 2021). Kozinc and colleagues (2022) evaluated 45 volleyball players and found no significant correlations between EUR and performance outcomes, with analyses spanning over COD tasks, sprint, and jump performances (Kozinc et al., 2021). Interestingly, only the CMJ jump height resulted in a statistically significant predictor of other performance outcomes stated.

Furthermore, no prior studies have directly evaluated acute or chronic exposure of supramaximal AEL loading with high-school aged athletes. Therefore, the purpose of this study is to (a) determine the efficacy of AEL back squats, using near-maximal and supramaximal loading, to induce an acute PAPE effect, (b) investigate a specified duration of PAPE occurrences, and (c) to compare performance outcome between the SJ and the novel propulsive-only jump (POJ) in high school-aged basketball players. It was hypothesized that AEL could increase jump height performance to a greater degree in the CMJ than that of the SJ and the POJ, at a specified window of potentiation. Furthermore, it was also hypothesized the SJ and POJ would respond differently (evaluated by jump height, peak relative propulsive power, and net relative impulse) due to the residual contributions of the SSC in the SJ.

METHODS

Experimental Approach to the Problem

The aim of this present study was to investigate the acute responses of supramaximal accentuated eccentric loaded back squats on subsequent jump performances in high school male athletes. A within-subject, crossover study design was used to determine potentiation effects of each jump condition across various time intervals. 3 meeting dates were separated by 72 hours, one familiarization session followed by two experimental sessions. A counterbalanced design was utilized to randomly assign participants into the following testing groups (A: CMJ, B: POJ+SJ or SJ+POJ). In the second experimental session, assignments were counterbalanced, ensuring participants served as their own controls (Figure 1).

Subjects

Fifteen male high school basketball players were recruited and completed a sports-physical examination by their physician and provided written informed consent (parental and standard) with prior approval from Liberty University Institutional Review Board. Anthropometric information was attained in the familiarization session (mean ± SD: age: 15.6 ± 1.1 years; body mass: 78.3 ± 19.6 kg; height: 182 ± 7.13 cm) as well as maximal (1RM) back squat values (99.3 ± 23.8 kgs), relative strength ratio (back squat 1RM: body mass;1.32 ± 0.3), and resistance training experience (3/week) of (1.3 ± 0.9 years). All participants in the sample revealed no prior experience with AEL training (submaximal, maximal, or supramaximal), SJ (jumps with a pause), or the POJ (or any seated jump derivatives).

Procedures

Testing Procedures

Participants reported to the testing location on 3 separate dates. On each occasion, participants completed a standardized warmup, consisting of 10-minutes of cycling at a constant power of 1 W per kg of body weight, aligned with FIT and PAPE protocols with this population (Beato et al., 2019; De Keijzer et al., 2020). The first session (familiarization) was used to acclimatize participants to jump conditions, retrieve individual settings for the POJ and SJ monitoring tool, and assess maximal (1RM) back squat values to be used for AEL intervention prescription over the following two experimental sessions. Participants were asked to maintain their normal dietary, hydration and sleep schedules throughout the study. Countermovement, squat, and propulsive-only jumps were performed on a portable HD force plate system (Hawkin Dynamics Inc™., Maine, USA) to collect vertical ground reaction forces at a sampling rate of 1000 hertz, as stated to be a high reliability when compared

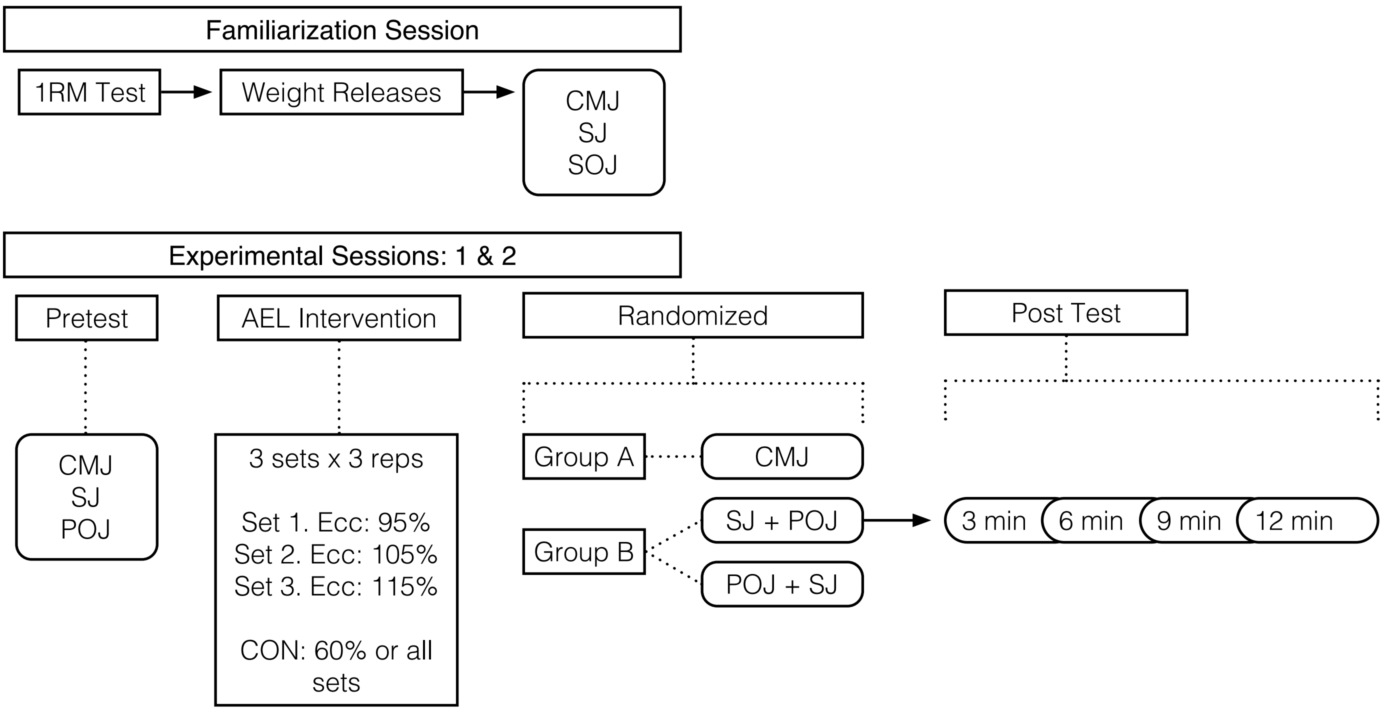

Figure 1. Study Design 1RM = one repetition maximum; CMJ = countermovement jump; SJ = squat jump; POJ = propulsive-only jump; ECC = eccentric loading of 1RM; CON =

to gold-standard in-ground force platforms (Badby et al., 2023). Likewise, a combination of HD™ hardware and software were utilized in the current study with less than a 3% error of error across all tests in previously analyzed literature (Merrigan et al., 2022).

Familiarization Session

Each participant underwent an evaluation for squat depth (knee flexion) using a Hopkins Medical goniometer, with measurements being monitored by a modified Range of Motion (ROM) Detection tool during the 1RM back squat tests (90°) and squat jump evaluations (70°) (Figure 2). The seat height of the POJ was also gained to match the 70° of knee flexion in the SJ. Back squat 1RM followed angle measurements and executed within NSCA (National Strength & Conditioning Association) guidelines stated in McMaster and colleagues (McMaster et al., 2014).

Experimental Sessions

Participants were paired by strength levels and completed three standardized sets of traditional (bar only x 10 reps, 25% x 6 reps, and 50% x 3 reps) sets of back squats prior to jump condition pretesting (CMJ, SJ + POJ or SJ + POJ). Rest times for each participant allowed a minimum of 3 min and maximum of 5 min between all traditional (warmup) and AEL (intervention) sets. Three AEL loading sets were completed with 3 repetitions each set, whereby only the first eccentric phase of the first repetition was eccentrically overloaded using weight releasers, with the 2nd and 3rd repetitions being constant at 60% 1RM through both the eccentric and concentric phases. The loading scheme of only inducing eccentric overload during the initial repetition had been completed with Wagle and colleagues (2018), which had been identified as "AEL1" and had shown positive indications for potentiating subsequent repetitions without having

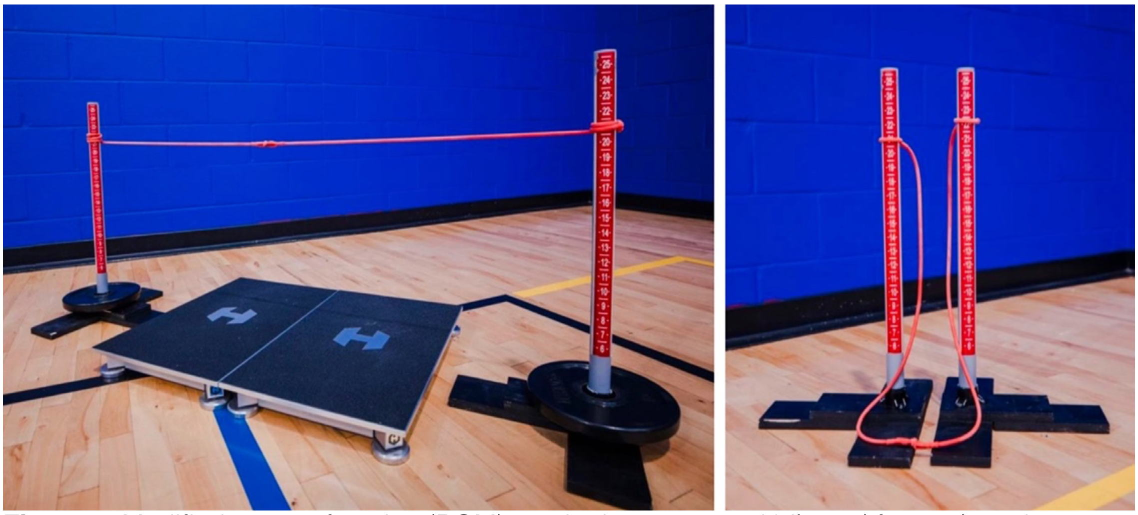

Figure 2. Modified range of motion (ROM) monitoring setup and bilateral force plates by Hawkin Dynamics™, USA.

Figure 3. Adjustable weight releasers (also known as eccentric hooks) used during AEL protocols during the first, initial repetition of each set (Rogue Fitness™, USA).

Table 1. AEL Loading Scheme: Percentage (%) of Back Squat 1-Repetition Maximum (1RM).

Set #	Eccentric Load: Repetition 1	Eccentric Loads: Repetitions 2 & 3	Concentric Loads: All Repetitions
1	95%	60%	60%
2	105%	60%	60%
3	115%	60%	60%

to reload the weight releaser following the first repetition. Concentric loading was held constant at 60% of concentric 1RM over all AEL sets with an increase of eccentric loading at 95%, 105%, and 115% 1RM for each of the sets. Post-test timing began the instant the individual re-racked the barbell.

Testing Protocols

Participants were randomly assigned to either CMJ or a combination of SJ and POJ for pre- and post-testing. A total of 3 jumps (CMJ condition) or 4 jumps (SJ & POJ combination, 2 attempts each condition) were completed at every 3 min increment following the AEL intervention, up to 12 min.

Propulsive-Only Jump (POJ)

POJ Set Up

Also known as the "rocker jump", "seated jump" or concentric-only jump," the propulsive-only jump (POJ) aims to evaluate vertical jump performance without SSC contribution, similar to that of the squat jump (SJ). The use of an adjustable bench with incline adjustment to an 85°incline was used to limit anteroposterior "rocking" prior to the start of the jump. Custom seat risers enabled height increases to meet the anthropometric starting positions of each individual (Figure 4). Seat heights per individual were determined by a knee flexion starting position of 70° while the subjects maintained complete foot contact with the force platforms in maximal dorsiflexion (active range of motion). The knee flexion starting angle of 70° was determined to be the most advantageous starting positions in similar jumps (Gheller et al., 2015; Hecksteden et al., 2018).

POJ Protocols

The following verbal instructions (VIs) were provided prior to each of the sessions:
VI1: Once seated on the box, slightly rock backward (until contact is made with the bench) while maintaining the same degree of hip and knee flexion with dorsiflexion at the ankles. Hands placed on the hips throughout the duration of the movement.
VI2: While maintaining a rigid position, allow the momentum to bring you back to the starting position until the feet reconnect with the ground.
VI3: At the instant of ground contact, explode upwards into a jump by moving off the ground as fast as possible.
Supplementary: Instruct the participants to maintain hip flexion position to deter from eccentric loading at the initial contact, by "pressing or punching the ground away." See Figure 5 for visual representation of the POJ in action.

CMJ & SJ Protocols

All jump conditions (CMJ, SJ, & POJ) were performed with hands-on-hips to diminish contribution of arm-swing and to increase reliability between and within jump conditions (15). The modified ROM detection tool was used during squat jump testing to ensure proper depth (70° of knee flexion) was attained, with the participant lowering into the

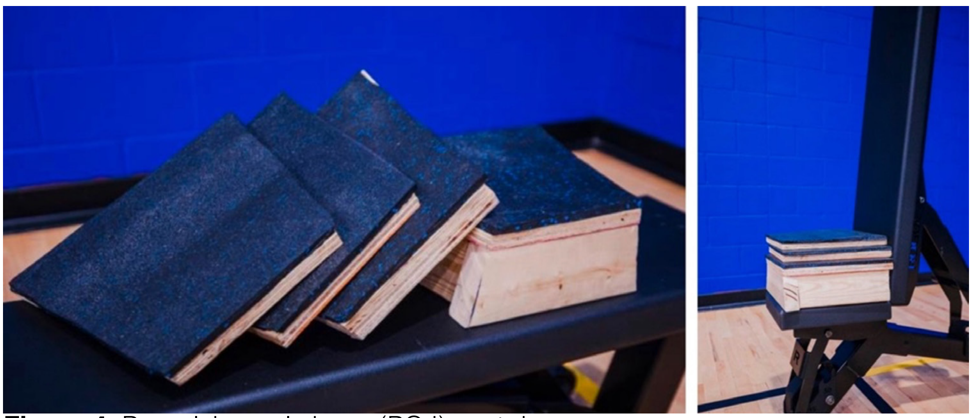

Figure 4. Propulsive-only jump (POJ) seat risers.

Figure 5. Propulsive-only jump (POJ) in action (beginning left to right).

eccentric phase until contacting the red band near their proximal hamstring region. Once the contact and resultant depth was attained, a subsequent 3-second amortization period (isometric squat) was held before the propulsive phase of the jump with monitoring of countermovement throughout all attempts. Pretesting of all conditions occurred 30 sec prior to the first set of training intervention and between 5-6 min following the standardized warmup stated prior. Post testing occurred at 3, 6, 9, and 12 min post-AEL intervention and included 3 attempts for the CMJ condition and 2 attempts each for the POJ and SJ conditions at each time interval. Attempts with the greatest jump height were retained from each participant at each of the testing intervals for statistical analyses.

Statistical Analyses

Attempts with the greatest jump height values were retained for analysis (one per jump type at each testing interval). Statistical analysis software (IBM SPSS v28.0™) was used to investigate the contributions of PAPE by jump condition x time interactions, three 3x5 ([CMJ, SJ, POJ]) x [pre-intervention, post 3 min, 6 min, 9 min, and 12 min]) repeated measures analysis of variances (ANOVA) were utilized (Hecksteden et al., 2018). Qualification of statistical significance was indicated with a priori alpha level of $p \leq 0.05$. Significant interactions of time and jump performance were followed by post-hoc analysis (Bonferroni) to analyze jump performance outcomes for each dependent variable addressed. GPower version 3.1.9.6 software (Heinrich Heine University, Düsseldorf, Germany) revealed a sample size of fifteen participants, with a 3x5 crossover design, alpha level of 0.05, and power level of 0.8 would require a minimum effect size of 0.70. Effect sizes (ES) were interpreted using partial eta squared whereby the magnitude of the variances found were defined by a small effect size ($0.01 < \eta_p^2 < 0.06$), moderate effect size ($0.06 < \eta_p^2 < 0.14$), or large effect size ($0.14 < \eta_p^2$) (Rhea, 2004). Post hoc analyses were further analyzed in respect to the resistance training experience of the sample population (1.3 ± 0.93 years), categorized as "recreationally trained" (Richardson, 2011). Furthermore, the ES were identified within the following threshold of trivial (< 0.35), small (0.35 – 0.80), moderate (0.80-1.50) or large (> 1.5) (Richardson, 2011).

RESULTS

Jump Height

Mean ± SD were used for each of the dependent variables assessed for each jump over time. Jump height (JH) revealed a significant main effect for time with a large effect size ($F(4, 56) = 5.19$, $p = 0.001$, $\eta_p^2 = 0.270$), and a significant main effect for condition with a large effect size ($F(2, 28) = 24.34$, $p < 0.001$, $\eta_p^2 = 0.635$). No significant interaction effects for condition and time were found ($p = 0.188$), a moderate effect size was apparent ($\eta_p^2 = 0.105$) which may have been influenced by the lack of power from the limited sample size (n = 15).

Post-hoc analysis using Bonferroni Corrections found significant increases in the POJ condition from pre- to post-intervention, the statistical outcomes are further defined by Mean Differences (MD) and Standard Error (SE) with Cohen's *d* effect sizes. Significant findings of potentiated performance for POJ were indicated from pre-intervention at 9 min (MD) = 3.60, SE = 0.83, $p < 0.001$, $d = 0.48$), as well as 3 min to 9 min (MD = 4.81, SE = 1.03, $p < 0.001$, $d = 0.64$) and 3 min to 12 min (MD = 2.68, SE = 1.25, $p = .035$, $d = .52$). All significant findings

Table 2. Reliability Statistics: Baseline Jump Outcome (single jump per individual, per jump type, n=15)

Variable	Jump Condition	Mean ± SD	Min.	Max.	CV %	ICC (95% CI)
Jump Height (cm)	CMJ	32.9 ± 5.69	21.8	43.6	17.3	0.85 (0.78-0.92)
	SJ	26.2 ± 7.02	15.7	39	26.8	0.75 (0.67–0.83)
	POJ	31.6 ± 8.63	14	45.8	27.3	0.73 (0.65–0.81)
Net Propulsive Impulse (Ns)	CMJ	199.7 ± 42.1	148.2	284.7	21.1	0.80 (0.72–0.88)
	SJ	175.8 ± 39.45	131.2	244	22.4	0.78 (0.71–0.86)
	POJ	190.9 ± 38.4	141.1	283	20.1	0.79 (0.71–0.87)
Peak Relative Propulsive Power (W)	CMJ	51.3 ± 5.98	38.3	67.1	13.6	0.90 (0.85-0.94)
	SJ	46.7 ± 8.88	29.9	60.4	19	0.81 (0.74–0.89)
	POJ	47.7 ± 9.78	26.2	66.8	20.7	0.76 (0.69–0.84)

resulted in effect size magnitudes categorized as small. In similar terms, the propulsive only jump revealed a mean increase of +12.26% (± 13.65%) change from baseline to 9 min. Inferential analysis did not find statistically significant differences between 12 min and pre-testing values for POJ, although an increase of +9.37% (± 17.83%) indicated potentiation may have been realized for only some of the participants. Nonsignificant statistical changes of jump height performance were found for both CMJ and SJ conditions. Post hoc analysis for time, with adjustments for multiple comparisons (Bonferroni) revealed a significant increase in jump height with all conditions combined from pre-intervention testing at 9 min (MD = 1.68, SE = 0.50, p = 0.047, d = 0.22), displaying a trivial effect. Differences from pre-intervention to 12 min were close to meeting statistical significance (MD = 1.56, SE = 0.58, p = 0.10) and revealed an effect size similar to that of shown at 9 min (d = 0.21) Significant differences from 3 min to 9 min (MD = 2.16, SE = 0.58, p = 0.022, d = 0.28) and 3 min to 12 min (MD = 2.03, SE = 0.58, p = 0.01, d = 0.27), were likely associated with the acute onset of fatigue directly following the conditioning activity compared to the later testing intervals. Although, no significant deviations in performance from pre-intervention testing were revealed at 3 min (MD = - 0.47, SE = 0.49, p = 1.0, d = 0.06), 6 min (MD = 0.72, SE = 0.68, p = 1.0, d = 0.09). See Figure 6 for visual representation.

Net Propulsive Impulse

Net propulsive impulse (NPI) revealed a significant main effect for time (F (4, 56) = 3.79, p = 0.008, η_p^2 = 0.213) and condition (F (2, 28) = 14.65, p < 0.001, η_p^2 = 0.511) with a large effect size for each. No significant interaction effects between condition and time were observed (F (8, 112) = 1.58, p = 0.140, η_p^2 = 0.101). Post-hoc comparisons revealed significant mean differences in net propulsive impulse outcomes for the averages of all conditions between time intervals with a trivial effect size: 3 min to 9 min (MD = 5.92, SE = 1.24, p = 0.003, d = 0.15). No significant deviations from pre-intervention outcomes were found at 3 min (MD = -2.27, SE = 1.45, p = 1.0), 6 min (MD = 0.79, SE = 2.53, p = 1.0), 9 min (MD = 3.79, SE = 1.58, p = 0.31), or 12 min (MD = 3.39, SE = 1.60, p = 1.0).

Although no significant differences were revealed from pre-intervention testing in the inferential analysis, all jump conditions revealed their greatest values at either 9 min or 12 min following the intervention, such as CMJ at 12 min (200.46 ± 38.38), SJ at 12 min (178.99 ± 40.39), and POJ at 9 min (200.53 ± 32.85). These values are also identified by their percentage of mean change (and SD) from pre-testing values, as shown for CMJ at 12 min (+0.65% ± 3.85%), SJ at 12 min (+1.79% ± 6.81%), and POJ at 9 min (+5.69% ± 6.24%) and 12 min (+4.05% ± 8.39%).

Peak Relative Propulsive Power

Peak relative Propulsive Power (PrPP) revealed no significant main effects for time (F (4, 56) – 1.236, p = 0.306, η_p^2 = 0.081), condition (F (2, 28) – 2.91, p = 0.071, η_p^2 = 0.172), or interaction effects (F (4, 56) – 1.236, p = 0.306, η_p^2 = 0.081). Although no significant differences were revealed from pre-intervention testing in the inferential analysis, the greatest propulsive power values (Mean ± SD) were found at 9 min for POJ (49.92 ± 8.86 W/kg), and at 12 min for SJ (47.14 ± 9.11 W/kg), whereas CMJ revealed its best outcomes during pre-testing (51.29 ± 6.7 W/kg). These values can also be identified by their percentage of mean change (and standard deviation) from pre-testing values, as shown for SJ at 12 min (+0.94% ± 6.35%) and POJ at 9 min (+5.97% ± 8.52%).

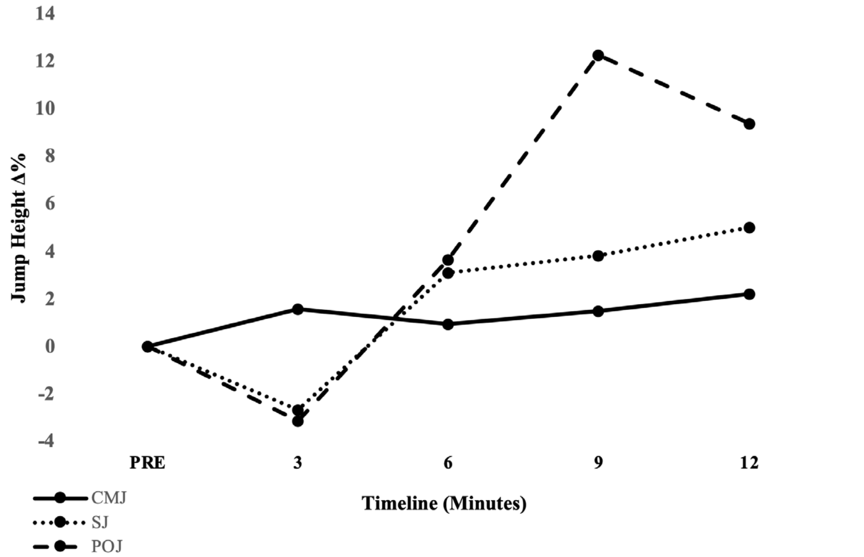

Figure 6. Jump Height (cm) percent change from pre-testing.

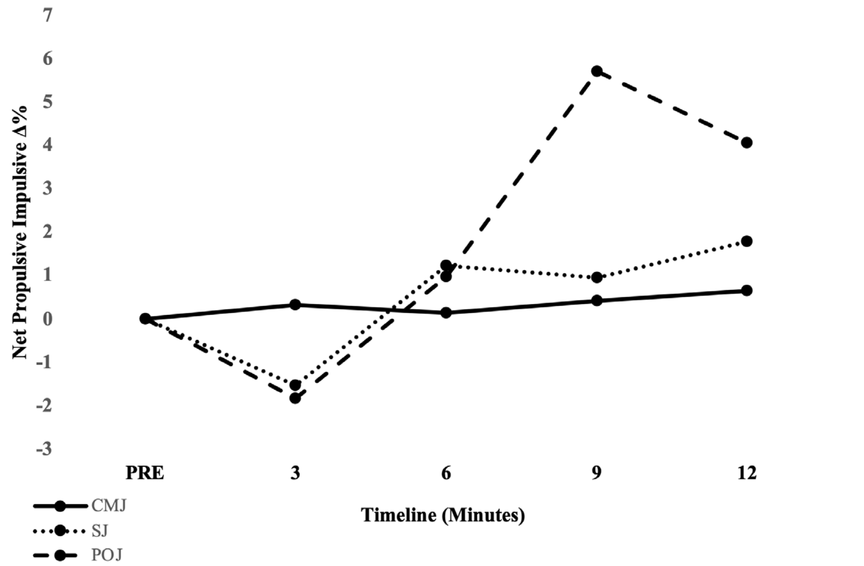

Figure 7. Net Propulsive Impulse (N.s) percent change from pre-testing.

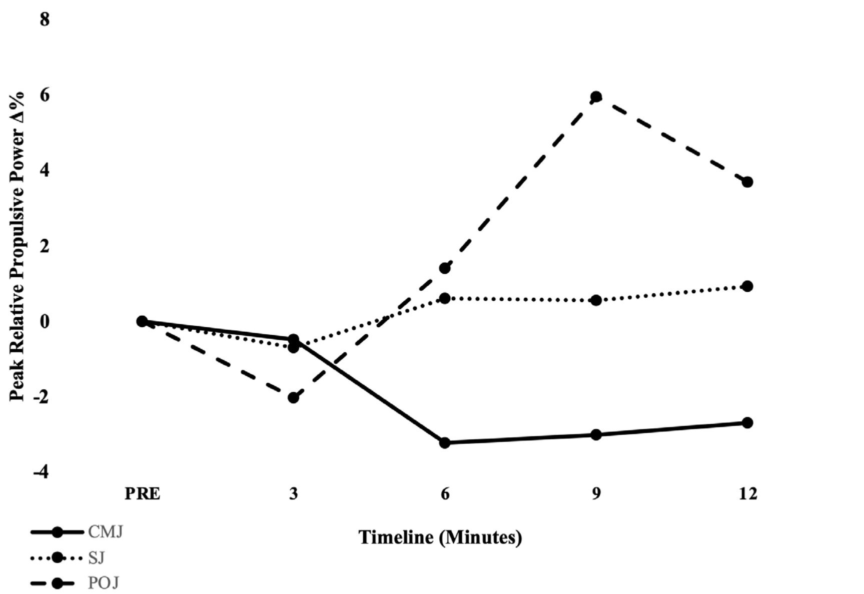

Figure 8. Peak Relative Propulsive Power (W/kg) percent change from pre-testing.

Table 3. Descriptives (M ± SD): Jump conditions for each variable over time.

Condition	Pre-Testing	Post-Testing 3 min	6 min	9 min	12 min
		Jump Height (cm)			
CMJ	33.07 ±5.44	33.67 ± 6.23	33.44 ±6.08	33.56 ± 5.84	33.86 ± 6.16
SJ	26.21 ± 7.02	25.40 ± 7.28	26.85 ± 6.93	27.18 ± 7.73	27.43 ± 7.66
POJ	31.59 ± 8.64	30.38 ± 8.47	32.75 ± 10.02	35.19 ± 8.75	34.27 ± 8.68
		Net Propulsive Impulse (N.s)			
CMJ	199.68 ± 40.66	200.21 ± 40.26	199.68 ± 39.47	200.19 ± 39.22	200.46 ± 38.38
SJ	175.84 ± 38.12	172.54 ± 35.68	177.32 ± 37.05	177.13 ± 38.0	178.99 ± 40.39
POJ	190.95 ± 40.39	187.34 ± 38.29	191.83 ± 38.89	200.53 ± 32.85	196.79 ± 29.25
		Peak Relative Propulsive Power (W/kg)			
CMJ	51.29 ± 6.74	50.45 ± 6.5	49.64 ± 6.98	49.65 ± 6.62	49.87 ± 6.41
SJ	46.68 ± 8.60	46.42 ± 8.97	46.92 ± 8.6	47.02 ± 9.23	47.14 ± 9.11
POJ	47.36 ± 9.45	46.22 ± 9.41	47.99 ± 10.39	49.92 ± 8.86	48.96 ± 9.19

Table 4. Table 4: Percent-changes (Δ% ± SD) for each variable and condition from pre-testing.

Condition	Post-Testing 3 min	6 min	9 min	12 min
	Jump Height (cm)			
CMJ	1.59% (±6.74%)	0.95% (±7.29%)	1.49% (±7.62%)	2.22% (±7.71%)
SJ	-2.68% (±14.53%)	3.08% (±11.06%)	3.83% (±12.87%)	5.03% (±12.77%)
POJ	-3.12% (±13.16%)	3.65% (±22.78%)	12.26% (±13.65%)	9.37% (±17.83%)
	Net Propulsive Impulse (N.s)			
CMJ	0.32% (± 3.12%)	0.13% (± 3.48%)	0.42% (± 3.76%)	0.65% (± 3.85%)
SJ	-1.54% (± 5.76%)	1.22% (± 6.28%)	0.95% (± 5.25%)	1.79% (± 6.81%)
POJ	-1.84% (± 7.18%)	0.97% (± 11.14%)	5.69% (± 6.24%)	4.05% (± 8.39%)
	Peak Relative Propulsive Power (W/kg)			
CMJ	-0.49% (±5.92%)	-3.21% (±5.29%)	-3.01% (±7.28%)	-2.68% (±4.37%)
SJ	-0.68% (±4.04%)	0.61% (±6.82%)	0.57% (±7.14%)	0.94% (±6.35%)
POJ	-2.03% (±8.79%)	1.40% (±12.97%)	5.97% (±8.52%)	3.70% (±9.76%)

DISCUSSION

The purpose of this investigation was to measure the acute effects of supramaximal AEL back squats in male high school athletes and its effect on post-activation performance enhancement for different jump conditions. Additionally, this study aimed to assess a novel jump assessment (propulsive-only jump, POJ) to compare with the standardized SJ assessment.

The results of this study revealed modest changes in performance enhancement in the propulsive-only jump (POJ), whereas no statistically significant changes (positive or negative) were found for either the countermovement jump (CMJ) or the squat jump (SJ). Of the three variables assessed over each condition, jump height (JH) was the primary measurement eliciting a small, significant increase from pre-testing, occurring from pretesting to 9 min, as well as 3 min to 9 min for POJ condition only. No significant changes were found in net propulsive impulse or peak relative propulsive power across any of the jump conditions. Despite the lack of performance enhancements, no significant negative deviations from pre-testing values were indicated, suggesting the imposed stimuli may have under-stimulated the participants in this study.

Positive enhancements in subsequent concentric performances have been found with youth populations when utilizing submaximal loading (Aboodarda et al., 2013 & 14; Lloyd et al., 2022; Wagle et al., 2017, 2018a & 2018b), but had yet to be explored with supramaximal eccentric loading or the assessment of PAPE effects. This investigation provided the first positive indications for acute performance enhancements using supramaximal eccentric overloading with high school age athletes. Interestingly, the increased performances following the AEL intervention only occurred in the condition with the least amount of SSC contribution (POJ), whereas the CMJ and SJ did not reach statistical significances.

The current study progressed eccentric loads incrementally, where 115% of concentric 1RM values were used on the last working set (3 total) and revealed no negative deviations from pre-testing values, suggesting the loading magnitude (115% of 1RM) may be sufficient in this population without significant decline in acute performance but insufficient for inducing a PAPE effect. In contrast, some research has indicated that weaker individuals may benefit from using higher eccentric loading magnitudes (120-130%) and stronger individuals may see greater benefits when using lower eccentric magnitudes of up to 110% of their respective 1RM (Suchomel et al., 2019a & 2019b). However, these findings are consistent to outcomes of Tseng and colleagues (2021), where supramaximal AEL back squats did not enhance CMJ jump height performance in collegiate male volleyball players, although training experience and comparative testing interval timelines (10 min, 24 hr, and 48 hr) are not comparable to the youth athletes and testing intervals used in this study.

These findings raise interesting questions about the biomechanical and neuromuscular aspects of different jump types and their responses to AEL. The CMJ and SJ, while integral to athletic performance, did not show significant improvements post-AEL intervention in our study. Wallace et al. (2018) noted the complexity of neuromuscular coordination involved in these jumps, which may explain their differing response compared to the POJ. The CMJ, for instance, relies heavily on the stretch-shortening cycle (SSC), where both eccentric and concentric muscle actions are crucial for performance and the resultant increase in propulsive outcomes (Bosco et al., 1982, Bright et al., 2023). The SJ, similarly, involves a preloading phase that masks or dilutes the potentiation effects observed in a purely concentric movement like the POJ (Aura & Komi, 1986). Potential reasoning for the greater improvements found in the POJ condition could be explained by the developmental limitations of adolescent or youth athletes to utilize the stretch-shortening cycle (SSC) to their full potential when compared to adults (Radnor et al., 2018). Contribution of SSC is evident when comparing CMJ and SJ outcomes, where an implicit movement-phase segmentation to decrease the contribution of the SSC with lower relative outcomes seen in the SJ (Bosco & Komi, 1979).

Compelling evidence suggests that the development of musculature and neuromuscular abilities significantly influence young male athletes, particularly in tasks like maximal rebound jumping (Radnor et al., 2021). These physiological and neurophysiological elements are further developed through natural maturation, increased resistance training exposure, and sport-specific stressors. The absence of the SSC encountered in the propulsive-only jump may dispose the limitations of young athletes and help to display the potentiation qualities associated thereafter. It has been well-documented that plyometric training involving both the eccentric and concentric phases can produce enhanced performance outcomes in male, youth basketball athletes (Aztarain-Cardiel et al., 2024; King et al., 2010). Although acute and chronic adaptations to POJ within training has yet to be uncovered, it is speculated that the POJ may be useful as a supplementary exercise to increase training volume of jumps without the overloaded strain seen in high-volume plyometric programs. For instance, Aztarain-Cardiel and colleague (2024) investigated the effects of plyometric training volume (identified by number of jumps performed) on male, youth basketball athletes. Their findings indicated that their lower-volume plyometric training program induced similar in jump performance in the CMJ, SJ and horizontal jump (HJ) when compared to a higher-volume group. The non-linear relationship of volume and performance outcomes in this population may see the benefit of a supplementary vertical jump exercise (POJ) which may reduce the cumulative stress and fatigue for long-term performance outcomes.

It must be noted that the practicality of a propulsive-only assessment is inherently limited to the absence of the SSC that is rarely, if ever, found in real-world applications in sport. The utilization of this exercise has been programmed and implemented at all levels of sport-preparations without thorough evaluations for its potential as a suitable stimulus for specified adaptations. Implementation of the POJ findings may benefit as a training modality to improve the efficacy of stretch-shortening cycle movements in youth athletes.

Limitations of this study may include the singular familiarization session for the (youth) subjects in this study may not have been sufficient in providing time to fully acclimatize to eccentric overload training modalities. Current literature suggests a minimum of three familiarization sessions is needed for youth populations to acclimatize to similar eccentric-focused modalities such as FIT and plyo-AEL (Bobbert et al., 1996). In the current body of literature, the integration of AEL methods and youth athletes have been limited to the use of submaximal loading prescriptions (Bobbert et al., 1996; Lloyd et al., 2022), due to reasonable variables such as pacing strategies and potential muscle-activation abilities to ensure the safety of the athlete (Bobbert et al., 1996; Merrigan et al., 2022; Suchomel et al., 2019b; Wagle et al., 2017). The most common variables believed to contraindicate the use of supramaximal AEL with youth lifters is identified by having a low training age, with presumable low level of relative strength to properly perform said modalities due to physiological and neuromuscular development attained through increased resistance training exposure.

The sample population examined in this study had an average of 1.32 ± 0.93 years of resistance training experience with average relative strength values of 1.32 ± 0.3 (1RM back squat values / body mass). These relatively low training ages and relative strength values had not been evaluated with supramaximal accentuated eccentric loading, primarily due to the increased likelihood of (untrained) athletes assuming slower pacing strategies which diminishes the intended potentiation found in the higher eccentric phase velocities (Merrigan et al., 2020, 2021, 2022; Merrigan & Jones, 2021). This study did not evaluate the eccentric or concentric velocities analyzed in prior studies, with primary insights directed at PAPE effects which occur following the conditioning activities conclusion. Intended use of AEL as a conditioning activity was implemented as a stimulus to induce a potentiation effect shown in vertical jump variations up to 12 min post AEL activity, respectively.

Prescribed loads across all participants may or may not had invoked a sufficient stimulus to induce PAPE responses. This may have been due to limiting the eccentric-overload to only the first repetition of each set performed. The inclusion of multiple eccentric-overloaded repetitions within each set may have produced a more potent stimulus for inducing the phenomenon.

Lastly, the variances in the jump abilities (Table 1) and low sample size (*n=15*) may indicate noteworthy differences between participants in the study. Unique inter-individual differences are not uncommon among the ages of the male youth analyzed in this study (15.6 ± 1.1 years).

FUTURE RECOMMENDATIONS

Research incorporating AEL and youth populations should further address loading prescriptions, phase durations, chronic adaptations, and use of submaximal versus supramaximal eccentric loads. Future investigations are recommended to evaluate similar populations with greater training experiences with reference to the presence of acute potentiation in one of the three jump conditions found in the current study. Lastly, expansion of research pertaining to kinematic and kinetic differences of the propulsive-only jump (POJ) to current standardized jumps commonly found in literature, such as the CMJ, SJ, and/or the DJ.

PRACTICAL APPLICATIONS

It is suggested that the incorporation of AEL training with any population should first be introduced via submaximal loading to gain familiarity and comfort with the unique demands. Implementation of higher loading magnitudes also brings higher potential of delayed onset of muscle soreness (Ojasto & Häkkinen, 2009), practitioners are encouraged to introduce initial familiarization sessions during off-season training period(s) to ensure athletes can become accustomed to the novel stimulus without fear of in-season performance detriments. With evidence indicating greater concentric potentiation with larger differences between concentric and eccentric loading schemes (Merrigan et al., 2020), it is recommended that maximal and supramaximal AEL training should incorporate low to moderate loads in the concentric phase (50% - 70% of 1RM) in the quest for improvements in subsequent concentric power and velocity performance (Merrigan et al., 2021). Maximal and supramaximal eccentric loads may be introduced when the individual exhibit's consistent control of eccentric overloads without adopting pacing strategies that would diminish the resultant performance enhancements found in the subsequent concentric phase. Familiarization sessions for all EOL loading magnitudes (submaximal, maximal, and supramaximal) are stated to receive the best results (superior concentric performance) when a minimum of three familiarization sessions are implemented (Bobbert et al., 1996). To ensure the safety and health of our youth athletes, it is highly suggested that the use of AEL encompasses submaximal values in conjunction with plyometric-jumping activities such as the CMJ with the release of dumbbells at the termination of the eccentric phase. Lastly, the propulsive-only jump (POJ) is suggested for youth athletes in addition to standardized plyometric movements (CMJ, DJ, SJ) with the intent to improve jump performance through enhanced SSC utilization, which is commonly identified as a hinderance to younger populations (Radnor et al., 2018). Although the efficacy of the POJ to induce performance adaptations is unknown and still in the early stages of investigation, the POJ is assumed to be useful as a dynamic, high intensity movement that may provide jump volume without the comparable fatigue of known plyometric movements such as the CMJ or DJ. The combination or separate use of AEL training (eccentric-focused) and the POJ movement (concentric-focused) may provide a sufficient training stimulus to improve jump performance and other sport-related outcomes. Adaptations from greater training magnitudes identified through AEL training may supply a more efficient transfer to vertical jump capacity and skill that is commonly found in many sports (e.g., basketball, volleyball, soccer).

CONFLICTS OF INTEREST

Jon-Kyle Davis is an employee of the Gatorade Sports Science Institute, a division of PepsiCo. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of PepsiCo, Inc.

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ETHICAL APPROVAL

Ethics for this study were approved in line with University's ethics procedure.

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