Effects of Augmented Eccentric Load Bench Press Training on One Repetition Maximum Performance and Electromyographic Activity in Trained Powerlifters

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Abstract

Montalvo, S, Gruber, LD, Gonzalez, MP, Dietze-Hermosa, MS, and Dorgo, S. Effects of augmented eccentric load bench press training on one repetition maximum performance and electromyographic activity in trained powerlifters. J Strength Cond Res 35(6):1512–1519, 2021—Augmented eccentric load (AEL) training has been shown to elicit greater lower-body muscular strength improvements compared with traditional strength training. However, it is unknown whether AEL training could provide similar improvements in upper-body muscular strength. Therefore, this study investigated the effects of a 4-week AEL training program on bench press one repetition maximum (1RM) strength, bar kinetics and kinematics, and surface electromyography (EMG) activity. Eight competitive powerlifters completed 5 training sessions consisting of 7 sets of a single repetition with up to 5 minutes rest between sets. Each session was completed at a predetermined AEL percentage consisting of 90% 1RM for concentric and supramaximal loads ranging from 105 to 125% 1RM during the eccentric phase with the use of eccentric hooks. After 4 weeks of AEL training, 1RM performance significantly increased from pretest to posttest (116.62 ± 27.48–124.28 ± 26.96 kg, p = 0.001). In addition, EMG amplitude of the pectoralis major decreased during the 125% AEL session to 69.86 ± 15.36% of pretest 1RM EMG values (p = 0.049, effect sizes [ESs] = 0.69). Furthermore, peak power of 1RM increased by 36.67% from pretest to posttest (p = 0.036, ES = 0.58). These study findings suggest that incorporating AEL bench press training into a 4-week training cycle may be a novel strategy to improve 1RM performance in competitive powerlifters in a short period.

Key Words: powerlifting, eccentric overload, muscle activation, bar velocity

Introduction

The bench press plays a vital role in the sport of powerlifting, where points are accumulated across 3 lifts: the bench press, deadlift, and back squat (23). Consequently, training to improve the bench press is a large part of powerlifting training programs. During the traditional bench press exercise, the load remains equal between eccentric and concentric phases of the movement. However, for training and adaptation purposes there is evidence that eccentric muscle actions play a larger role in hypertrophy and muscular strength improvements when compared with concentric muscle actions (7,21,31). For example, a meta-analysis of 15 studies reported that eccentric movement-based training led to 10% mean improvement in muscular hypertrophy compared with the 6.8% mean improvement achieved by the concentric muscle contraction-based interventions (35). In addition, another meta-analysis found that greater improvements in muscle strength can be achieved by using greater eccentric load compared to the concentric load (33).

The strength improvements achieved through eccentric training can be further enhanced by adding an additional mechanical load during the eccentric phase, a training approach known as augmented eccentric loading (AEL) (2,8,10,20,31). Augmented eccentric load training occurs when the load being lifted through the eccentric phase is greater than the load being lifted through the concentric phase (32). Because maximal eccentric strength is generally greater than maximal concentric strength, it can be inferred that during a 1RM attempt the athlete experiences less than 100% relative load eccentrically (10). Therefore, to effectively train both concentric and eccentric strength, 2 different loads may need to be applied during the lift. Augmented eccentric load presents a method to successfully implement 2 distinct loads during the eccentric and concentric phases of the lift with the aim of maximizing both eccentric and concentric relative efforts.

Several studies have found significantly greater gains in strength, rate of force development, and hypertrophy when incorporating AEL into a lower-body training program compared with traditional concentric-eccentric strength training (11,14,31,34). Another study found that a 10-week lower-body AEL program led to greater increases in isokinetic and isometric strength and greater changes in muscle architecture than traditional resistance training (38). Given that increased strength and muscular hypertrophy results in higher capacity to overcome loads, the use of AEL may provide powerlifters the capacity to achieve greater scores in competition because of greater loads lifted across the 3 lifts. However, to date, no studies have examined the chronic effects of an AEL program on upper-body strength and muscle activation in powerlifters. Two studies are available in the current literature that examined the acute effects of bench press AELs, and these 2 studies reported conflicting findings (6,32). Doan et al. (6) found that an AEL of 105% one
repetition maximum (1RM) acutely increased the subjects’ subsequent concentric 1RM performance from 97.44 to 100.57 kg. The increase was attributed to increases in neural stimulation, recovery of stored elastic energy, contractile machinery alterations, and an increased preload (6). On the contrary, Ojasto and Häkkinen (32) reported that AEL ranging from 105 to 120% 1RM did not improve the subsequent concentric strength performance. In fact, these authors found reduced concentric forces in all their AEL conditions compared with the traditional constant (100%) eccentric or concentric load 1RM bench press (32). These contradicting findings could be a result of differences in experimental design, equipment, range of loads, the velocity of lift, the training status of subjects, and muscular activation of the eccentric and concentric movements.

Further contradiction in the current literature is in regards to muscle activation. Compared with concentric muscle actions, eccentric muscle actions have been shown to display an inverted pattern of motor unit activation, faster neural adaptations to resistance training, and a reduced EMG amplitude at similar force levels, but greater EMG preactivation before movement (3,12,22). However, Ojasto and Häkkinen reported no differences in EMG amplitude of the pectoralis major (PM), anterior deltoid (AD), and triceps brachii (TB) at 105, 110, and 120% AEL of 1RM bench press when compared with the 100% of 1RM concentric phase of the lift (32). In addition to the contradicting findings regarding the acute effects of AEL and the lack of available data on possible chronic adaptations, previous studies used recreationally trained men (6,32). Accordingly, further research is warranted to elucidate conflicting findings of previous research AEL studies and implement longitudinal training of highly trained subjects with less variability to training stimulus response. Given the absence of literature exploring the impact of a longitudinal upper-body AEL program in highly trained athletes, the purpose of this study was to determine the effects of a 4-week AEL intervention on bench press 1RM, surface EMG activity, and various bar kinetics and kinematics in competitive powerlifters. It was hypothesized that this 4-week mesocycle would improve 1RM bench press performance and accompanying bar kinetics and kinematics as well as muscle activation levels in the participating competitive powerlifter subjects.

**Methods**

**Experimental Approach to the Problem**

A within-subjects single-group experimental design was used in this study to determine the impact of a 4-week AEL program. Eight competitive powerlifters attended a total of 7 sessions during a 4-week period. The baseline session consisted of a 1RM bench press testing and familiarization of the eccentric hooks used during the bench press training sessions. This was followed by 5 AEL bench press training sessions with 90% 1RM used during the concentric phase and varying intensities used during the eccentric phase ranging from 105 to 125% 1RM (Figure 1). After the 4 weeks of AEL training, subjects completed a postintervention 1RM bench press assessment. All assessment and AEL training sessions took place during the same time of day for each of the subjects. During the baseline and posttest, 1RM weight, bar kinetics, bar kinematics, and EMG activity of the PM, TB, and AD were measured to determine the effects of the 4-week AEL program. The same variables were also measured during every AEL session to determine differences across AELs.

**Subjects**

Twelve competitive powerlifters (n = 12; men = 6; women = 6) between the ages of 18–38 years were initially recruited for this study. Descriptive statistics are shown in Table 1 for all subjects. A priori power analysis was conducted using G*Power (version 3.1, Universität Kiel, Germany), using previously published data with AEL training (5) indicated that a total of 5 subjects were needed to find a large effect (d = 1.52) with power (1 - β) set at 0.87 and α of 0.05. All recruited subjects had been actively competing in powerlifting regional, state, and national competitions for at least 2 years. Actively participating in powerlifting was defined as having competed in at least 2 powerlifting competitions in each of the last 2 years, as well as training specifically for a powerlifting competition. Following previously established criteria (30), subjects had to meet a minimum strength criterion as follows: being able to bench press a minimum of 1.0× their body mass for women and a minimum of 1.5× their body mass for men. In addition, the subjects reported to be free of injuries for the past 2 years before study participation. Given our injury-free criterion for inclusion, 4 potential powerlifters were not eligible to participate in this intervention. Hence, our sample size was reduced to 8 powerlifters (n = 8; men = 5; women = 3).

Before the initiation of the study, subjects just finished their strength-focused mesocycle within their individualized daily undulating periodization model. All experimental sessions took place between March and April 2019 because subjects were entering their competitive phase preparing for the 2019 Open National Championship held in mid-May. During the 4-week intervention, subjects were asked to maintain their normal nutritional intake and hydration levels. Subjects were not allowed to introduce new supplements that may alter their performance during the intervention and were asked to refrain from alcohol use during the 4-week intervention. Subjects who would begin cutting body mass in preparation for competition were not recruited for this study. Before study commencement, all recruited subjects were informed of the risks and benefits associated with study participation. All subjects signed an institutionally approved written informed consent form. The study was approved by the University of Texas at El Paso institutional review board (approval ID #1330943).

**Procedures**

**Baseline Testing and Familiarization.** A baseline testing and equipment familiarization session was conducted to determine the subject’s 1RM bench press and allow familiarization with the eccentric hooks. Recruited subjects reported to the training facility where anthropometric measurements (height and body mass) and 1RM bench press results were obtained. Bench press form and performance were completed in compliance with the International Powerlifting Federation competition rules (23). For 1RM, subjects performed a general warm-up, followed by a standardized 1RM protocol (37). As part of their warm-up, subjects assumed a supine position on the bench, grasped the barbell and performed 10 repetitions with no weight added for 2 sets. After these sets, subjects added a comfortable weight to perform 5–10 repetitions. After the warm-up sets, the load was increased by 20% of the weight used on the first set, and the subjects completed 2–3 repetitions. After this set, subjects attempted their first 1RM trial by increasing the load in the warm-up set by 10% to perform a single repetition. If the subject was able to successfully lift the weight, the subject was asked if another repetition can be performed with weight increments of 5–10 lbs.
To ensure the safety of the subjects, 3 spotters were monitoring the attempts and provided support when necessary during a failed attempt. Subjects had a 3–5-minute rest period between 1RM attempts (37). For each of the attempts, subjects were instructed to lower the bar at a comfortable speed to their chest or upper-abdominal area. On contact with the body, the bar had to remain motionless for at least one second. Thereafter, subjects were given a “press” signal to lift the bar and complete the trial. The same protocol was followed for all repetitions during the experimental sessions, as well as for posttesting. A closed grip with the thumb – abdominal area. On contact with the body, the bar had to remain motionless for at least one second. Thereafter, subjects were given a “press” signal to lift the bar and complete the trial. The same protocol was followed for all repetitions during the experimental sessions, as well as for posttesting. A closed grip with the thumb around the bar with width not exceeding 81 cm was enforced for each trial (23). Subjects were instructed to perform each repetition with their best effort, while also being verbally motivated by the research team. The technique of each lift was supervised by the athlete’s Certified Strength and Conditioning Specialist (CSCS) coach, as well as the research team members also with CSCS certifications. All subjects had previous experience using the eccentric hooks and working with AELs. However, subjects never participated in a systematic AEL program, and therefore, the familiarization session emphasized the proper form and safety measures when using the AEL approach.

Experimental Sessions. Before each of the experimental sessions, subjects performed a standardized warm-up, consisting 10–15 minutes of self-paced jogging and dynamic stretching of the upper body consisting of arm circles and arm hugs, followed by exercise band work (external/internal rotation of the shoulder and shoulder dislocation). After this, subjects performed barbell only bench press for 5–10 repetitions, followed by a set of 5–10 repetitions of an arbitrary load of 60 kg for men and 45 kg for women. Subjects then completed one repetition with 90% of their pretest 1RM load without the eccentric hooks.

During the experimental sessions, subjects performed 7 sets of a single repetition bench press with a minimum of 3 minutes and up to 5 minutes of rest in between sets. The barbell was loaded with a load equivalent to 90% of each subject’s pretest 1RM. Additional weight was added through the eccentric hooks to achieve supramaximal load for the eccentric phase of the movement. Although the barbell load of 90% of 1RM was constant, the load placed on the eccentric hooks increased for each session, representing 105, 110, 115, 120, and 125% of subject’s baseline 1RM performance. Subjects were instructed to lower the bar with a controlled speed during the descending phase and lift the bar as explosively as possible during the concentric phase. During the AEL bench press attempts, subjects were verbally encouraged to perform with maximal effort. A recovery period of minimum 48 hours was provided to subjects between experimental sessions as per previous recommendations for high-intensity strength training (15,18). After the completion of all 5 experimental sessions, another 48–72 hours of rest took place before the post-intervention assessment, as shown in Figure 1.

Instrumentation: Surface Electromyography. Surface electromyography (EMG) pregelled Ag/AgCl dual electrodes (Noraxon, Inc., Scottsdale, AZ) were placed on the PM, AD, and TB at an interelectrode distance of 20 mm. Moreover, in efforts to maintain identical placement during subsequent visits, electrode placement was marked with permanent marker. Electrodes were oriented parallel to the respective muscle fibers. Before electrode placement, the skin was prepared according to SENIAM guidelines (17). Electrode placement was the same for both male and female subjects. The electrode for the PM was placed at the most superior part of the muscle on the medial sternum lateral to the suprasternal notch, one-third of the distance from the sternal notch and anterior axillary line. Electrodes for the TB and AD were placed at the belly of the muscle, at roughly 50% of between the insert and origin of the muscle (24). Electrodes were connected to wireless EMG sensors. The signal was captured at a sampling frequency of 1,000 Hz, with a band pass of 20–450 Hz. Figure 2 illustrates the electrode placement on the PM, AD, and TB.

Table 1

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age (y)</th>
<th>Height (m)</th>
<th>Body mass (kg)</th>
<th>BMI (kg m⁻²)</th>
<th>Baseline 1RM relative to BW</th>
<th>Wilks coefficient</th>
<th>IPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>8</td>
<td>26.25 ± 4.13</td>
<td>1.66 ± 0.06</td>
<td>79.09 ± 6.38</td>
<td>25.58 ± 1.26</td>
<td>1.46 ± 0.28</td>
<td>366.07 ± 137.24</td>
<td>86.11 ± 9.06</td>
</tr>
<tr>
<td>Male</td>
<td>5</td>
<td>25.00 ± 4.10</td>
<td>1.68 ± 0.05</td>
<td>82.54 ± 4.11</td>
<td>29.26 ± 1.13</td>
<td>1.63 ± 0.32</td>
<td>328.62 ± 137.24</td>
<td>84.46 ± 10.49</td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>28.67 ± 3.51</td>
<td>1.63 ± 0.06</td>
<td>73.33 ± 5.38</td>
<td>27.42 ± 0.1</td>
<td>1.17 ± 0.28</td>
<td>428.16 ± 137.24</td>
<td>88.86 ± 6.99</td>
</tr>
</tbody>
</table>

*1RM = one repetition maximum; BMI = body mass index; IPF = International Powerlifting Federation; BW = bodyweight; GL = International Powerlifting Federation “Good Lift” Points.
rate of 1,000 Hz, preamplified at the source at a gain of 500 Hz, converted by 16-bit analog to digital converter, and transmitted telemetrically to a PC interface receiver (Telemyo DTS, Noraxon, Scottsdale, AZ) and was recorded by a data acquisition system (MyoResearch, version 3.14, Noraxon, Scottsdale, AZ). Data were then rectified and filtered using a band-pass filter set at 20–450 Hz (24,26). Amplitude was expressed as root mean square over an epoch of 150 ms (26) during the concentric phase of the bench press. All data were expressed as a percentage of EMG amplitude obtained during the initial 1RM testing session (baseline EMG).

**Instrumentation: Eccentric Hooks.** Weight releasers, also known as eccentric hooks (Monster Grips, Inc., Columbus, OH) were hung from the ends of the barbell and used to increase the load during the eccentric phase of the bench press. The unloaded weight of the 2 eccentric hooks was 9.5 kg. The hooks were designed to support extra eccentric loading and detach from the bar at the lowest point of the eccentric phase, which allowed a lighter concentric phase to be performed. Hooks were adjustable to accommodate an individual’s stature and to ensure the full eccentric range of motion before the hook detachment. The weight placed on the barbell was equal to that of 90% of a subject’s pretest 1RM with additional load placed onto the hooks (Figure 2).

**Instrumentation: Bar Kinetics and Kinematics.** The PUSH Band 2.0 accelerometer (Push, Inc., Toronto, ON, Canada) was used to accurately capture specific barbell kinetic and kinematic variables to include peak force, peak power, peak velocity, peak acceleration, and concentric and eccentric phase duration. Data were captured at a sampling rate of 200 Hz and transmitted wireless to the PUSH Band 2.0 acquisition software previously downloaded onto an iPad (fourth generation; Apple, Inc., Cupertino, CA). Data were synced automatically from iPad to the Push Portal desktop version, which allowed to obtain all the barbell kinetic and kinematic variables previously indicated. The PUSH Band 2.0 has previously been identified as a valid and reliable tool during bench press to measure peak and mean velocity and power compared with motion capture at moderate to heavy loads (28). The PUSH Band 2.0 was placed on the end of the left side of the bar to avoid any contact with the subject or the eccentric hooks during the bench press.

**Statistical Analyses**

All data collected were exported to Microsoft Excel to create a comprehensive spreadsheet. Data were then exported to SPSS IBM 26 (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, version 26.0, Armonk, NY: IBM Corp.) for statistical analysis; figures were created using R in the open-source RStudio (version 1.3.959) with ggpubr (publication ready) library. Normality tests...
were conducted; Shapiro-Wilk test, skewness, and kurtosis levels were obtained. A paired t-test was used to show changes in 1RM bench press performance from pretest to posttest across all subjects. A repeated measures Friedman’s test was conducted to find differences in percentage of baseline EMG amplitude during the AEL conditions for the PM, AD, and triceps muscle with a Wilcoxon signed-rank test post hoc to test for pairwise differences. Individual Friedman’s tests with post hoc Wilcoxon signed-rank tests were also used to find differences in bar kinetic and kinematic variables between eccentric loads. Effect sizes (ESs) are expressed as Cohen’s $d$ values and calculated according to previous literature (4,9,29). The ESs were interpreted as follows: trivial = $\leq 0.20$; small = $0.20–0.60$; moderate = $0.60–1.2$; large = $1.2–2.0$; very large = $2.0–4.0$; and nearly perfect $>4.0$ (4,19). Reliability was obtained using a two-way mixed-effects model intraclass correlation (ICC2,k) and interpreted as follows: $<0.5$ as poor, $0.5–0.7$ as moderate, $0.7–0.9$ as good, and $>0.9$ as excellent reliability (25). Minimum detectable change (MDC) was calculated to obtain a minimum change threshold in 1RM from baseline to posttest. The standard error of the mean (SEM) was obtained from the SD of the mean difference of 1RM by the square root of the mean difference. Then MDC was obtained by the z-score ($1.96$) and interpreted as follows: $0.5$ as poor, $0.5–0.7$ as moderate, $0.7–0.9$ as good, and $>0.9$ as excellent reliability (25). Minimum detectable change (MDC) was calculated to obtain a minimum change threshold in 1RM from baseline to posttest. The standard error of the mean (SEM) was obtained from the SD of the mean difference of 1RM by the square root of the mean difference. Then MDC was obtained by the z-score ($1.96 \times SEM \times \sqrt{2}$) (13). A significance alpha level of $\leq 0.05$ was used for all analyses.

### Results

#### One Repetition Maximum Performance

Paired t-test showed significant changes in 1RM bench press performance from baseline to posttest from $116.62 \pm 27.48$ kg to

### Table 2

Muscular activation for all conditions as a percentage of baseline EMG values, 95% confidence intervals (95% CI), and ICC for each measure.*†

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pectoralis major 95% CI</th>
<th>ICC</th>
<th>Anterior deltoid 95% CI</th>
<th>ICC</th>
<th>Triceps brachii 95% CI</th>
<th>ICC</th>
<th>Effect sizes</th>
<th>Pectoralis major</th>
<th>Anterior deltoid</th>
<th>Triceps brachii</th>
</tr>
</thead>
<tbody>
<tr>
<td>105% 1RM</td>
<td>89.37 ± 20.23</td>
<td>0.53</td>
<td>89.31 ± 77.07</td>
<td>0.90</td>
<td>74.72 ± 17.07</td>
<td>0.96</td>
<td>0.10 (trivial)</td>
<td>0.59 (small)</td>
<td>0.09 (trivial)</td>
<td></td>
</tr>
<tr>
<td>110% 1RM</td>
<td>76.35 ± 25.06</td>
<td>0.28</td>
<td>89.63 ± 51.12</td>
<td>0.96</td>
<td>68.22 ± 28.76</td>
<td>0.57</td>
<td>0.25 (small)</td>
<td>0.45 (small)</td>
<td>0.29 (small)</td>
<td></td>
</tr>
<tr>
<td>115% 1RM</td>
<td>78.91 ± 25.96</td>
<td>0.28</td>
<td>88.41 ± 98.30</td>
<td>0.96</td>
<td>65.76 ± 15.68</td>
<td>0.91</td>
<td>0.54 (small)</td>
<td>0.89 (small)</td>
<td>0.35 (small)</td>
<td></td>
</tr>
<tr>
<td>120% 1RM</td>
<td>82.23 ± 20.10</td>
<td>0.29</td>
<td>81.48 ± 58.21</td>
<td>0.96</td>
<td>60.57 ± 25.54</td>
<td>0.92</td>
<td>0.25 (small)</td>
<td>0.69 (moderate)</td>
<td>0.49 (small)</td>
<td></td>
</tr>
<tr>
<td>125% 1RM</td>
<td>59.86 ± 15.36‡</td>
<td>0.92</td>
<td>90.31 ± 89.52</td>
<td>0.96</td>
<td>62.43 ± 20.94</td>
<td>0.96</td>
<td>0.69 (moderate)</td>
<td>0.22 (small)</td>
<td>0.64 (small)</td>
<td></td>
</tr>
<tr>
<td>Posttest 1RM</td>
<td>96.73 ± 58.48</td>
<td>0.74</td>
<td>70.40 ± 164.85</td>
<td>—</td>
<td>51.79–108.46</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

*1RM = one repetition maximum; ICC = intraclass correlation.
†Presented as mean ± SD.
‡Significantly different from posttest 1RM ($p < 0.05$).

### Table 3

Mean, SD, 95% CI, ICC, and effect sizes (ESs) of peak force, peak power, and peak velocity values obtained from PUSH Band 2.0 for Each testing condition.*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Peak force (N) 95% CI</th>
<th>ICC</th>
<th>Effect size</th>
<th>Peak power (W) 95% CI</th>
<th>ICC</th>
<th>Effect size</th>
<th>Peak velocity (m/s) 95% CI</th>
<th>ICC</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest 1RM</td>
<td>2,522.64 ± 647.17</td>
<td>1981.58–3,063.68</td>
<td>—</td>
<td>—</td>
<td>511.35 ± 237.46</td>
<td>312.82–709.86</td>
<td>—</td>
<td>0.36 ± 0.10</td>
<td>0.27–0.44</td>
</tr>
<tr>
<td>105</td>
<td>2,348.00 ± 548.81</td>
<td>1899.17–2,806.81</td>
<td>0.75</td>
<td>0.29 (small)</td>
<td>565.67 ± 212.00</td>
<td>388.42–742.90</td>
<td>0.84</td>
<td>0.24 (small)</td>
<td>0.40 ± 0.08</td>
</tr>
<tr>
<td>110</td>
<td>2,757.37 ± 793.61</td>
<td>2093.90–3,420.84</td>
<td>0.64</td>
<td>0.33 (small)</td>
<td>702.02 ± 268.14</td>
<td>477.85–926.19</td>
<td>0.74</td>
<td>0.75 (mode rate)</td>
<td>0.43 ± 0.08</td>
</tr>
<tr>
<td>115</td>
<td>2,422.46 ± 350.83</td>
<td>2,129.15–2,715.75</td>
<td>0.56</td>
<td>0.20 (small)</td>
<td>568.52 ± 165.68</td>
<td>430.01–707.02</td>
<td>0.91</td>
<td>0.28 (small)</td>
<td>0.40 ± 0.06</td>
</tr>
<tr>
<td>120</td>
<td>2,680.29 ± 583.92</td>
<td>2,192.11–3,168.46</td>
<td>0.55</td>
<td>0.26 (small)</td>
<td>644.16 ± 216.30</td>
<td>463.32–824.99</td>
<td>0.74</td>
<td>0.59 (small)</td>
<td>0.41 ± 0.06</td>
</tr>
<tr>
<td>125</td>
<td>2,457.24 ± 409.11</td>
<td>2,115.21–2,799.26</td>
<td>0.82</td>
<td>0.12 (trivial)</td>
<td>584.10 ± 178.62</td>
<td>434.76–733.43</td>
<td>0.84</td>
<td>0.35 (small)</td>
<td>0.40 ± 0.06</td>
</tr>
<tr>
<td>Posttest 1RM</td>
<td>3,411.03 ± 1715.67</td>
<td>1976.69–4,845.35</td>
<td>—</td>
<td>0.75 (mode rate)</td>
<td>698.88 ± 317.34‡</td>
<td>433.58–964.18</td>
<td>—</td>
<td>0.58 (small)</td>
<td>0.38 ± 0.08</td>
</tr>
</tbody>
</table>

*95% CI = confidence intervals; 1RM = one repetition maximum; ICC = intraclass correlation.
†Significantly different from pretest 1RM ($p < 0.05$).
Discussion

The purpose of this study was to investigate the effects of a 4-week AEL bench press microcycle on IRM performance, EMG activity, and various bar kinetics and kinematics. A secondary purpose was to compare EMG muscle activity between several different AELs (105, 110, 115, 120, and 125%). It was hypothesized that IRM load and bar kinetics and kinematics will be improved at the end of 4-week AEL and there would be a greater normalized EMG amplitude during the AEL sessions than baseline 1RM. The findings of this study partially accept the hypothesis. Subjects demonstrated a mean increase of 7.06 ± 4.15% in their 1RM bench press performance. At the same time, there were no significant differences in AD and TB EMG amplitude during any of the overload conditions. However, a significant difference in EMG amplitude between conditions was found for the PM. Specifically, a decreased PM activity to 59.86 ± 15.36% of baseline EMG at the 125% 1RM condition, which differed significantly from posttesting EMG 1RM values. In addition, peak power and concentric duration were significantly altered between baseline and posttesting.

Earlier studies reported acute increases in 1RM after an AEL. For example, Doan et al. (6) observed immediate increases in 1RM bench press performance after a bench press repetition performed with an eccentric overload of 105% 1RM. This resulted in a 3.21% increase in the subsequent concentric 1RM bench press performance with authors attributing this increase to increases in neural stimulation, recovery of stored elastic energy, contractile machinery alterations, and an increased preload (1,6,39). However, a limitation of the study by Doan et al. (6) was the investigation using moderately trained subjects, who may have had a larger adaptational window for potential strength improvement between the 1RM testing sessions. In this study, it was hypothesized that highly trained competitive powerlifters with a much smaller adaptational window for chronic adaptation may allow a more critical assessment of the efficacy of the AEL method. The 4-week AEL resulted in a 7.06% mean strength improvement across the male and female competitive powerlifters with moderate ESs. The greater increase in 1RM bench press may be due to the longitudinal nature of this study compared with the cross-sectional design of the study by Doan et al. (6) Interestingly,

Electromyography

The nonrepeated measures Friedman test showed no significant difference (p > 0.05) between the 7 repetitions performed at the various eccentric loads (105, 110, 115, 120, and 125%). Thus, an average of the 7 repetitions was used to compare muscular activation between the different AEL conditions. Values were normalized by using percentage of the baseline 1RM measurements (Table 2). There were no significant differences in EMG amplitude of the AD (χ²(5) = 9.786, p = 0.082) and TB (χ²(5) = 6.643, p = 0.249) at any of the AEL conditions and posttest 1RM (Table 2). A significant difference between AEL conditions for the PM was found (χ²(5) = 11.286, p = 0.046); pairwise comparison indicated that PM activation was significantly decreased to 59.86 ± 15.36% of baseline concentric EMG at the 125% 1RM condition. This decrease was significantly different from the alteration in concentric PM EMG activity archived during 1RM posttesting (z = -1.959, p = 0.049, ES [moderate] = 0.69). No other pairwise comparisons were significant.

Bar Kinetics and Kinematics

The repeated measures Friedman test showed no statistical changes in peak force (χ²(6) = 11.464, p = 0.075), peak power (χ²(6) = 11.089, p = 0.086), peak velocity (χ²(6) = 8.357, p = 0.213), peak acceleration (χ²(6) = 3.321, p = 0.768), concentric phase duration (χ²(6) = 8.143, p = 0.228), or eccentric phase duration (χ²(6) = 1.982, p = 0.921) between the various AELs. The Wilcoxon signed-rank test between baseline and posttest revealed significant differences in peak power (z = -2.100, p = 0.036, ES [small] = 0.525) and concentric phase duration (z = -1.960, p = 0.050, ES [small] = 0.490); however, no other comparisons were statistically significant (Tables 3 and 4).
Ojasto and Häkkinen (32) concluded that incorporating eccentric loads greater than 100% of concentric 1RM significantly lowered 1RM force and power during the concentric phase of the bench press, with the greatest decrease seen with the 120% 1RM eccentric load condition. These findings contradict the conclusions by Doan et al. (6), as well as the findings of lower-body AEL studies that found immediate increases to 1RM squat performance (10,11). However, conflicting findings between studies may be accredited to discrepancies in study design and associated muscular fatigue from differing protocols. Although significant improvements to strength were observed, the underpinning mechanisms such as muscular hypertrophy, neuromuscular adaptations, or changes to the SSC remain to be elucidated.

To date, only the study by Ojasto and Häkkinen (32) sought to observe the acute effects of increased eccentric load during a 1RM bench press on muscular activation of the PM, AD, and TB. The authors concluded that there were no significant differences in EMG activity of the PM, AD, or TB during the various intensities of AEL (105, 110, and 120%). These conclusions were also suggested by Korak et al. (26) where EMG activity of the PM was found to have no significant differences when comparing traditional bench press and rest-pause bench press training (26). The current findings agree with these previous studies because no significant differences in AD and TB EMG amplitudes between any of the AEL conditions and posttest 1RM were found. However, a significant difference between the 125% 1RM overload condition and the posttesting 1RM EMG activity for the PM was found. This could potentially be due to differences in intensities for the eccentric and concentric phases. The current study maintained a 90% 1RM concentric load, whereas Ojasto and Häkkinen (32) examined the effects of various AEL intensities with 100% 1RM concentric load. Furthermore, differences could be observed because of the differences in eccentric overload levels with Ojasto and Häkkinen (32) using AELs up to 120% 1RM, whereas the current study used loads up to 125% 1RM. In addition to this, an increased—although not statistically significant—AD EMG activity was observed in the current study. A previous study showed that the PM and AD muscles are greatly activated at submaximal and maximal loads (90 and 100% of 1RM) when compared with lighter submaximal loads (70 and 80% of 1RM) (27). Accordingly, the strength increases observed in the current study may likely have been neuromuscular adaptations due to the AEL intervention.

The current study added to the scarce research that has explored the impact of AEL on bar velocity, force, power, and displacement. Ojasto and Häkkinen (32) reported no significant differences in velocity, eccentric duration, or concentric duration after participation in an acute bout of AEL. This concurs with the current study findings, where velocity and eccentric duration did not show any statistical changes from baseline to posttest, despite the longitudinal nature of the intervention. However, there was a significant increase in peak power and a simultaneous decrease in concentric duration at posttest compared with baseline. Because power is the product of force and velocity, lack of statistical significance for peak force and velocity was surprising. However, large SDs for peak power may explain some of the findings presented in the current study. Given the longitudinal design of the study, this may have enabled specific adaptations to the neuromuscular system resulting in increased rate coding and recruitment of higher-order motor units resulting in greater peak power (16,36).

There is clinical and practical relevance to the current study findings; however, these are statistically limited by a small sample size due to the lack of available competitive powerlifters. Therefore, a replication of this study with larger sample size or other athletic populations is recommended. Moreover, the study design did not use a control group for comparison because of the unavailability of sufficient number of trained subjects. Instead, a within-subject repeated measures design was used. Although improvements to 1RM performance were observed, this study is unable to attribute improvements to muscle hypertrophy, stretch-shortening cycle, or possible changes to body kinematics during the bench press (6,39). In addition, although subjects were highly trained, they were not accustomed to the AEL at the frequency at which the training was implemented. Given the novelty of the study, there were no previous research guidelines on proper training frequency for AEL or a previously tested range of eccentric loads that could ensure safe and effective training. Unfortunately, this study was unable to standardize exposure to previous training programs, which may have impacted the effectiveness of the AEL intervention. The nutritional intake and hydration levels of subjects were not controlled. Hence, alterations during the 4-week training program may have influenced reported findings. Finally, although efforts were made to ensure identical EMG electrode placement during all visits, it is acknowledged that identical placement during all visits could not be guaranteed.

Future research may desire to explore the mechanisms behind the apparent improvements in 1RM performance after AEL. Furthermore, training frequency, duration, and intensity variables, such as increasing the duration of the intervention to 8–12 weeks, could be explored. The duration of the effects after AEL was not identified in the study and can present an important avenue for future research. The current study used experienced powerlifters; future research could explore the impact of AEL on a different population or similar population with a larger sample size to corroborate current study findings.

### Practical Applications

The findings of this study suggest that AEL bench press training may serve as a novel short-term training strategy to further improve 1RM bench press performance that might be prudent for lifters who have experienced a plateau. On average, subjects experienced a 1RM increase of 6.5% after a brief 4-week training cycle. The training program was easily implemented with the addition of simple equipment with improvements representing a moderate ES. Therefore, coaches and athletes seeking to increase 1RM bench press performance and peak power may benefit from the application of an AEL mesocycle within the overall program design of the athlete.

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