

# The Effect of Accentuated Eccentric Loading on Concentric Performance Characteristics of the Jump Shrug Exercise

Original Research

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## Abstract

**Introduction:** Resistance training loads are often derived from concentric 1RM, despite higher force production capabilities during eccentrics. Accentuated eccentric loading (AEL) allows heavier eccentric loading and may potentiate concentric performance. This study examined the effect of AEL on jump shrug (JS) performance.

**Methods:** Recreationally trained males ( $n=15$ ,  $\bar{X}\pm SD$ ; age= $22.5\pm 2.8$  yrs, height= $177.0\pm 7.5$  cm, body mass= $87.6\pm 14.2$  kg) performed the JS at varying percentages of body mass (20-120%) with and without AEL. Weight releasers added an additional 20% body mass during the eccentric phase of the AEL condition. All repetitions were performed on a force platform. Peak force, rate of force development (RFD), impulse, and impulse duration were compared between AEL conditions.

**Results:** Peak force, RFD, and impulse were not different between AEL and non-AEL ( $p=0.052-0.77$ ,  $\eta_p^2=0.03-0.24$ ). Observed differences were primarily driven by load, with lower peak force during the 20% load, when compared to 60-80% ( $p=0.004-0.007$ ,  $g=1.14-1.20$ ). Greater RFD was observed in lighter loads, with 20% greater than 60-120% ( $p<0.001-0.003$ ,  $g=1.28-2.29$ ), 40% greater than 80-120% ( $p<0.001$ ,  $g=1.95-3.22$ ), and 60-80% greater than 100-120% ( $p<0.001-0.007$ ,  $g=1.14-1.87$ ). Impulse during 20% was lower than 40-80% ( $p<0.001-0.001$ ,  $g=1.37-1.66$ ), with 80% being greater than 120% ( $p=0.041$ ,  $g=0.91$ ). When collapsing across loads, impulse duration was shorter during AEL ( $p=0.007$ ,  $g=0.80$ ).

**Conclusions:** In the current study, AEL minimally influenced JS performance. While shorter impulse duration was observed with AEL, it is unclear if AEL potentiated JS performance or if AEL influenced eccentric displacement. Observed differences were primarily driven by load. Practitioners should understand how load influences JS kinetics.

**Key Words:** eccentric overload, weightlifting derivatives, resistance training.

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## Introduction

Resistance training is often implemented to improve strength and power,<sup>1</sup> with these variables relating to measures of athletic performance,<sup>2,3</sup> discerning playing time and competitive sport level,<sup>4</sup> and correlating with performance of activities of daily living.<sup>5</sup> Resistance training loads are often based on percentages of concentric one repetition maximum (1RM). However, eccentric muscle actions are capable of producing greater forces than concentric muscle actions and may be underloaded during traditional resistance training when training loads are prescribed from concentric 1RM values,<sup>6</sup> with previous work suggesting that eccentric force production exceeds concentric by 20-60%

or more.<sup>7</sup> In addition, when performed at the same absolute load, eccentric muscle actions display lower motor unit recruitment than concentric muscle actions, indicating that greater loads are necessary for similar levels of recruitment.<sup>6</sup> Accentuated eccentric loading (AEL) is a training strategy that allows for greater loads during the eccentric phase and lighter loads during the concentric phase. This training style may allow for appropriately loaded eccentrics, recruitment of higher threshold motor units, and may serve as means to potentiate concentric force and power performance.<sup>8</sup> The AEL stimulus can be applied in a variety of ways, including through the use of weight releasers, manual adjustments by a coach/spotter, and manual adjustment by the lifter (e.g., dropping dumbbells at the bottom of a countermovement jump, before the initiation of the concentric phase).<sup>8</sup> Furthermore, AEL allows for the inclusion of the stretch-shortening cycle (SSC), which serves to enhance concentric performance in paired lengthening-shortening muscle actions.<sup>9-11</sup> Eccentric-only training may have limited carryover to sport due to elimination of the SSC.

Previous work has demonstrated AEL's efficacy in potentiating strength and power performance acutely. Doan and colleagues used supramaximal eccentric loads to elicit acute increases in 1RM performance, with all participants improving 1RM by ~2.3-6.8 kg.<sup>12</sup> Other areas where AEL has been shown to acutely benefit resistance training performance include force production,<sup>11,13</sup> lifting velocity,<sup>11,14,15</sup> and power output.<sup>11,15</sup> Furthermore, Ojasto and Häkkinen demonstrated that individualized eccentric loads led to improvements in power output during the concentric phase when compared to traditional loading during explosive resistance training.<sup>16</sup> Other instances of AEL improving explosive or high velocity performance in the concentric phase include volleyball block jumps and bench press throws.<sup>17,18</sup> In addition, AEL has been demonstrated to potentiate the performance of subsequent repetitions that are not under the influence of AEL. Comparing a set of five repetitions of the back squat between traditional loading and AEL loading, where only the first repetition was under AEL using weight releasers, eccentric rate of force development (RFD) remained elevated during subsequent repetitions without the weight releasers in the AEL condition when compared to traditional loading.<sup>19</sup> Various work also suggests that AEL may enhance chronic performance adaptations to a greater degree when compared to traditional loading.<sup>20-23</sup>

However, not all instances of AEL have been demonstrated to improve performance. Though AEL was found to potentiate block jump performance,<sup>17</sup> Moore and colleagues found that squat jump performance was not improved with AEL in resistance-trained males.<sup>24</sup> Though the exercises share some similarities, the substantially larger eccentric displacement observed in the squat jump may have limited potentiation from AEL.<sup>25</sup> Though not specifically measured, it was mentioned by Moore and colleagues that the eccentric portion of the squat jump was performed at a relatively slow velocity.<sup>24</sup> This may have impaired the potentiating ability of AEL, as it has been suggested that activities with a fast SSC component must use stored elastic energy in a rapid manner (under 250 ms) before it is dissipated as heat.<sup>26</sup> In addition, despite the finding that AEL potentiated eccentric RFD, concentric performance in the back squat was not improved with AEL.<sup>19</sup> Improvements in back squat performance were largely attributed to the use of cluster sets and inter-repetition rest, with both traditional loading and AEL loading on the first repetition showing reduced power and concentric RFD performance. Similar findings regarding cluster sets were observed by Lates et al.<sup>27</sup> Merrigan and colleagues also found that concentric velocity performance was not improved under various AEL conditions in the bench press.<sup>28</sup> However, when stratifying by strength, individuals with higher relative strength levels were able to realize improved concentric velocity under AEL conditions. This suggests that AEL may be a training strategy best reserved for individuals of a higher training status.<sup>29</sup>

The jump shrug (JS) is a weightlifting-derivative exercise that may allow lifters to exhibit unique force, velocity, and power characteristics in comparison to other weightlifting and weightlifting-derivative exercises. Previous work has demonstrated larger magnitudes of force, velocity, power, and work in the JS when compared to the hang power clean at similar loads.<sup>30,31</sup> Implementing weightlifting-derivatives like the JS may be attractive to practitioners because of the potential for greater force, velocity, and power characteristics, as well as added benefits like decreased complexity and time efficiency from eliminating the catch phase.<sup>32</sup> Producing greater force during training could influence strength adaptations, with strength underpinning power, velocity, and other measures of strength/power sport performance.<sup>3</sup> The JS appears to be a means for lifters to experience greater force, velocity, and power during training, which may influence adaptation. As AEL may also positively influence these variables, how AEL influences JS performance is of interest. The purpose of this study was to investigate the influence of AEL on parameters of JS performance (peak force, RFD, impulse, impulse duration) in recreationally trained males. It was hypothesized that the greater load provided during the eccentric phase through AEL would potentiate the JS and lead to improved acute performance.

## Methods

### Participants

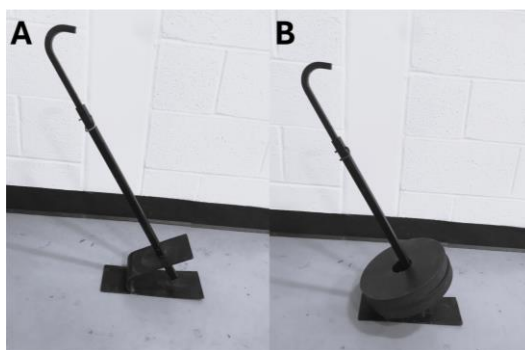
Recreationally trained males ( $n = 15$ ,  $\bar{X} \pm SD$ ; age =  $22.5 \pm 2.8$  yrs, height =  $177.0 \pm 7.5$  cm, body mass =  $87.6 \pm 14.2$  kg) participated in this study. To be eligible for participation, participants were required to have at least one year of prior resistance training experience and be free from lower extremity injury. All participants provided written informed consent prior to participation. This study was approved by the University of Kansas Institutional Review Board.

### Procedures

Participants visited the laboratory on three separate occasions. The first visit familiarized participants with the jump shrug exercise and AEL. On the two subsequent visits, participants performed single repetitions of the JS across a spectrum of loads (20, 40, 60, 80, 100, & 120% of participant body mass) with or without the presence of AEL. Percentages of body mass were used for the JS loads due to limited participant experience with weightlifting derivative exercises. Using varying percentages of body mass for the loads allowed for the inclusion of light and heavy loads without limitation due to participant technique. Visits were separated by a minimum of 48 hours.

### Visit 1: Familiarization

After obtaining consent, participants completed familiarization with the jump shrug exercise and AEL. Prior to familiarization, participants completed a standardized warm up that consisted of five minutes on a cycle ergometer at a self-selected intensity and a dynamic warm up. Participants performed 2 sets of 3 repetitions each of the JS with an unloaded barbell, and bars loaded to 20% body mass, and 40% body mass. Participants then performed the JS with the same loads on the barbell with the addition of AEL. AEL added an additional 20% body mass for the eccentric phase only and was accomplished by using weight releasers (Power Recruit Inc., Houtzdale, PA) (Figure 1). Participants were instructed to hold the barbell near the top of the thigh with a grip width just outside the hips. To perform the JS, participants hinged at the hips and lowered the barbell to just above the patella. Subjects then rapidly changed the direction of the barbell, pushing their feet into the floor and generating upward movement. Participants were instructed to jump as high as possible and shrug the shoulders. The weight releasers were adjusted so they disengaged when the barbell was just above the patella. Figure 2 illustrates the JS performed during the AEL condition.



**Figure 1.** Weight releasers used during the AEL condition shown (A) unloaded and (B) with added resistance.

### Visits 2 and 3: AEL and non-AEL experimental sessions

A minimum of 48 hours after familiarization, participants returned to complete the first of two experimental sessions. Participants were randomly assigned to perform either the AEL or non-AEL condition first, with the condition not performed during visit 2 performed during visit 3. A minimum of 48 hours separated the two experimental visits. The only difference between the two sessions was the use of weight releasers to provide an AEL stimulus during the AEL visit. When participants reported to the lab, the same standardized warmup used during familiarization was performed. Following the warmup, participants completed a JS warmup that consisted of 4 single JS with an empty barbell, each separated by 1 minute. During the AEL condition, the JS warmup included the weight releasers and added an additional 20% of body mass on the bar for the eccentric portion of the exercise. Following warmup, participants completed single repetitions of the JS at varying percentages of body mass (20, 40, 60, 80, 100, & 120%) in a randomized order. Kinetic data was collected using a uniaxial force platform (Rice Lake Weighing Systems, Rice Lake, WI) and analyzed through a data acquisition system (Biopac MP 150 System, Goleta, CA) sampling at 1000 Hz. Each JS was separated by 2 minutes of rest. Dependent variables measured include peak force, rate of force development (RFD), impulse,

and impulse duration. Peak force is the point on force-time curve where the greatest force value was observed. RFD values were obtained from the slope of the line beginning at participant system mass and ending at peak force. Impulse values were obtained from the area under the curve corresponding with the points on the force-time curve where system mass was reached prior to and after peak force, with impulse duration simply being the duration of the window for impulse. All values are for system mass (body mass + bar mass). Other measures of interest were not included due to an inability to detect the exact time point on the force-time curve the weight releasers were removed from the bar.



**Figure 2.** Sequential positions of the jump shrug during the AEL condition. (A) Starting position with weight releasers attached to the barbell. (B) End of the eccentric phase, with the barbell at approximately the top of the patella and weight releasers fully disengaged. (C) Peak jump height achieved during the jump shrug.

#### *Statistical Analysis*

Separate 2x6 (condition x load) repeated measure analyses of variance (ANOVAs) with Bonferroni adjustments were used to assess the effect of AEL and load on JS peak force, RFD, impulse, and impulse duration. A Greenhouse-Geisser correction was used when sphericity was violated. Partial-eta squared ( $\eta_p^2$ ) effect sizes were calculated using the following cutoff magnitudes (small = 0.01-0.06, medium = 0.06-0.14, large =  $\geq 0.14$ ). Where appropriate, Hedges' g effect sizes were calculated to compare the magnitude of effect using the following cutoff values (trivial =  $< 0.20$ , moderate = 0.21-0.60, large = 0.61-1.20, very large =  $> 1.20$ ). The alpha level indicating statistical significance was set at 0.05 for all analyses. Statistical analyses were carried out in SPSS (SPSS v. 27, IBM Corp., Armonk, NY, USA).

## **Results**

### *Peak Force*

Data for peak force are displayed in Table 1. For peak force, the two-way interaction ( $p = 0.56$ ,  $\eta_p^2 = 0.04$ ) and main effect for condition ( $p = 0.48$ ,  $\eta_p^2 = 0.04$ ) were not significant. However, there was a significant main effect for load ( $p = 0.009$ ,  $\eta_p^2 = 0.24$ ). When collapsing across condition, peak force during 20% was significantly lower than the 60% ( $p = 0.004$ ,  $g = 1.20$ ) and 80% conditions ( $p = 0.007$ ,  $g = 1.14$ ). No other differences between loads were noted.

### *Rate of Force Development*

Data for RFD are displayed in Table 1. The condition by load interaction ( $p = 0.21$ ,  $\eta_p^2 = 0.10$ ) and main effect for condition ( $p = 0.12$ ,  $\eta_p^2 = 0.16$ ) were not significant. However, a main effect for load was found ( $p < 0.001$ ,  $\eta_p^2 = 0.75$ ), indicating differences in RFD between loads. When collapsing across condition, RFD for the 20% load was significantly greater than the 60-120% loads ( $p < 0.001-0.003$ ,  $g = 1.28-2.29$ ), the 40% load was greater than the 80-120% loads ( $p < 0.001$ ,  $g = 1.95-3.22$ ), and the 60% and 80% loads were both greater than the 100-120% loads ( $p < 0.001-0.007$ ,  $g = 1.14-1.87$ ). The 20% and 40% ( $p = 0.11$ ,  $g = 0.78$ ), 40% and 60% ( $p = 0.43$ ,  $g = 0.61$ ), 60% and 80% ( $p = 0.32$ ,  $g = 0.65$ ), 100% and 120% ( $p = 0.35$ ,  $g = 0.64$ ) loads were not different from each other.

### *Impulse*

Data for impulse are displayed in Table 1. The condition by load interaction was not significant ( $p = 0.77$ ,  $\eta_p^2 = 0.03$ ). When collapsing across loads, no differences between AEL and non-AEL were noted ( $p = 0.052$ ,  $\eta_p^2 = 0.24$ ). However, a main effect for load was found ( $p = 0.002$ ,  $\eta_p^2 = 0.36$ ). When collapsing across conditions, impulse in the 20% condition was significantly lower than the 40-80% conditions ( $p < 0.001-0.001$ ,  $g = 1.37-1.66$ ) and the 80% condition was greater than the 120% condition ( $p = 0.041$ ,  $g = 0.91$ ). No other differences between loads were noted.

### Impulse Duration

Data for impulse duration are displayed on table 1. The condition by load interaction was not significant ( $p = 0.08$ ,  $\eta_p^2 = 0.15$ ). However, when collapsing across load, a significant main effect for condition was found, with a faster impulse duration found for the AEL condition ( $p = 0.007$ ,  $g = 0.80$ ). There was also a main effect for load when collapsing across conditions, with the 20% load having a shorter impulse duration than all other loads ( $p = <0.001-0.029$ ,  $g = 0.96-2.32$ ) and the 40% loads having a shorter impulse duration than the 100 and 120% loads ( $p <0.001$ ,  $g = 1.59-1.61$ ). No other differences between loads were noted.

**Table 1.** Comparisons of performance variables across loads and AEL conditions.

Peak Force (N)			RFD (N·s <sup>-1</sup> )			Impulse (N·s)			Impulse Duration (s)		
Load	AEL	Non-AEL	Load	AEL	Non-AEL	Load	AEL	Non-AEL	Load	AEL <sup>e</sup>	Non-AEL
20%	2966.3 ±	3038.9 ±	20%	8711.1 ±	7951.4 ±	20%	245.0 ±	283.6 ±	20%	0.3 ±	0.4 ±
	556.6	497.3		4406.9	3805.8		51.9	61.9		0.1	0.1
40%	3042.8 ±	3021.1 ±	40%	6971.8 ±	6409.4 ±	40% <sup>a</sup>	267.0 ±	306.1 ±	40% <sup>a</sup>	0.3 ±	0.4 ±
	558.5	490.6		2101.9	2845.5		63.6	62.1		0.1	0.1
60% <sup>a</sup>	3123.1 ±	3167.1 ±	60% <sup>a</sup>	6603.0 ±	5144.5 ±	60% <sup>a</sup>	283.4 ±	317.8 ±	60% <sup>a</sup>	0.4 ±	0.5 ±
	558.9	499.0		3572.5	2667.8		68.5	57.2		0.1	0.2
80% <sup>a</sup>	3138.8 ±	3193.6 ±	80% <sup>ab</sup>	4781.6 ±	4326.3 ±	80% <sup>a</sup>	292.8 ±	327.0 ±	80% <sup>a</sup>	0.4 ±	0.5 ±
	562.7	491.3		1545.4	1371.5		79.3	62.5		0.2	0.1
100%	3123.9 ±	3146.9 ±	100% <sup>abcd</sup>	3706.9 ±	2956.3 ±	100%	268.4 ±	310.5 ±	100% <sup>ab</sup>	0.4 ±	0.6 ±
	495.9	417.8		1675.1	844.8		91.6	52.3		0.1	0.1
120%	3067.5 ±	3062.9 ±	120% <sup>abcd</sup>	2623.6 ±	2768.0 ±	120% <sup>d</sup>	256.7 ±	281.1 ±	120% <sup>ab</sup>	0.5 ±	0.6 ±
	481.7	456.5		1352.8	2128.6		87.0	79.6		0.1	0.2

Data are presented as mean ± SD. Load indicates the percentage of body mass of the barbell. AEL = accentuated eccentric loading. RFD = rate of force development. <sup>a</sup> indicates significant main effect difference from the 20% load. <sup>b</sup> indicates significant main effect difference from the 40% load. <sup>c</sup> indicates significant main effect difference from the 60% load. <sup>d</sup> indicates significant main effect difference from the 80% load. <sup>e</sup> indicates significant main effect difference from non-AEL condition ( $p < 0.05$ ).

### Discussion

The aim of the current study was to explore AEL's influence on performance characteristics of the JS exercise. In this investigation, AEL appeared to have minimal influence on JS performance, with most of the observed differences independent of AEL condition and primarily driven by barbell load. This finding was observed for peak force, RFD, and impulse, which is consistent with previous work on the JS.<sup>33-35</sup> Reductions in peak velocity have been observed as JS load increased.<sup>33</sup> Though velocity was not measured in the current study, lower velocity may lead to longer duration during the JS,<sup>35</sup> which may explain the reductions in RFD as load increased in the current study. Furthermore, reductions in jump height have been observed as JS load increases.<sup>34</sup> Although jump height was not a measurement in the current study, impulse has been identified as a strong predictor of jump height,<sup>36</sup> with a lower impulse observed in the heaviest JS loading condition in the current study. When considering the inverse relationship observed between load and velocity,<sup>37</sup> load being the primary factor in differences observed makes sense. When collapsing across AEL conditions, the highest peak force values were found in the 60-80% loads, with these loads being greater than peak force during 20%. Considering Newton's Second Law ( $F = ma = m\Delta v/\Delta t$ ), the lighter mass of the 20% condition likely contributed to the lower force. However, peak force in the 20% load was not different than the 40%, 100%, or 120% loads, demonstrating that both mass and acceleration can influence force. Although the specific contributions of mass and acceleration to force were not investigated in the current study, force may be maintained during lighter loads due to greater velocity and acceleration, with a greater mass contributing to peak force to a greater degree during the heavier loads.<sup>38</sup> Suchomel and colleagues have reported similar peak force across a spectrum of loads during the JS,<sup>33</sup> despite reductions in velocity<sup>33</sup> and increases in propulsive duration observed as JS load increases,<sup>35</sup> which would yield lower accelerations. Though mass and acceleration may differ across a load spectrum, their combination may yield similar peak force values. Additionally, the JS is typically placed near the high-velocity end of the force-velocity curve for weightlifting derivatives and may be preferred to other weightlifting derivative exercises in the development of speed-strength characteristics due to the higher velocities that may be achieved during the JS.<sup>39</sup> This may indicate limitations in very high peak force capabilities in this exercise, which may be why no differences were observed in peak force between the heaviest and lightest loads. Furthermore, the inverse relationship between force and velocity may explain why the greatest RFD was observed with the lightest load. It is likely the greatest velocities were observed during the 20% load,<sup>33</sup> despite similar peak force to heavier loads. Furthermore, a greater impulse in the 40-80% loads was observed when compared to 20%. As impulse is the product of force and time, it is likely these differences were

primarily driven by barbell load. Previous work supports that moving from 30-80% of hang power clean maximum, increases in relative impulse are observed.<sup>40</sup> Impulse duration in the 20% load was lower than all other loads. The ability to achieve a similar peak force in a shorter time may have contributed to the higher RFDs in lighter loads.

Of interest is that AEL appeared to influence impulse duration. Across all loads, impulse duration was lower in AEL, indicating the ability to achieve similar force characteristics in a shorter time. As impulse is the product of force and time, a shorter duration would require a greater force to achieve the same impulse.<sup>41</sup> However, differences in peak force and impulse were not observed between AEL conditions. Impulse is generally determined using mean force, which was not measured in the current study. Additionally, it is unclear if the shorter impulse duration for AEL was due to a potentiated movement velocity or if differences in the range of motion used during the countermovement between conditions was employed. While limited work assessing the reliability of the countermovement depth of the JS exists, previous research has assessed reliability of countermovement depth during vertical jumping. Poor intersession reliability was observed in countermovement depth among NCAA Division I volleyball players when athletes were free to self-select depth.<sup>42</sup> Further, differences in countermovement depth were observed between professional and semi-professional rugby league athletes, with a smaller countermovement depth observed in professionals.<sup>43</sup> Though participants were instructed to lower the barbell to the patella and weight releaser height was adjusted to allow for disengagement from the barbell at this position, depth of the countermovement was not assessed in the current study. It is possible that the mechanical aspects of AEL influenced the eccentric displacement, possibly accounting for the observed differences in impulse duration. While this finding is novel and may warrant further investigation, it appears that AEL minimally influenced JS performance within the context of the present investigation.

Previous work has shown that AEL can potentiate performance of high-velocity movements, such as volleyball block jumps. Sheppard et al. demonstrated that peak force, velocity, power, and jump height were improved with the addition of a 20 kg AEL load during countermovement block jumps.<sup>17</sup> The load used (20 kg) and mean participant body mass (91.4 kg) lead to a similar percent body mass AEL stimulus (~21.9%) as the AEL stimulus in the current study. However, differences between the movements may help explain the limited potentiation in the JS. Eccentric movement velocity can influence concentric performance, with faster eccentric velocities positively influencing concentric performance.<sup>44</sup> As eccentric velocity was not measured in the current study, it is unknown how eccentric velocity may have influenced concentric performance in the JS or potentiation from AEL. As mentioned previously, Moore and colleagues noted AEL did not potentiate jump squat performance.<sup>24</sup> However, it was noted that the eccentric phase was performed with a “relatively slow velocity.” The eccentric phase of the JS is recommended to be performed in a controlled, but not slow, manner to maximally benefit from the SSC.<sup>45</sup> Eccentric velocity was not measured or standardized in the current study, so it is not known how this may have influenced concentric performance and the potentiating effects of AEL. Further, the interaction between eccentric and concentric loads may influence performance, with larger discrepancies between eccentric and concentric loads positively influencing potentiation.<sup>11,28</sup> Though the current study used a spectrum of concentric loads, the AEL stimulus was always an additional 20% body mass. On the low end of the load spectrum, the eccentric load may not have been heavy enough to elicit potentiation, with supramaximal eccentric loads often shown to potentiate concentric performance.<sup>11,12,15</sup> On the higher end, despite a heavier system mass, the small discrepancy between eccentric and concentric loads may not have been enough for potentiation, as previous work has shown the same supramaximal eccentric load potentiates concentric performance when there is a greater discrepancy between the eccentric and concentric loads.<sup>28</sup>

This study was not without limitations. As discussed previously, eccentric phase velocity was not measured or standardized. Though eccentric muscle actions are part of the SSC and can positively influence concentric performance,<sup>10</sup> greater eccentric velocities improve concentric performance when compared to deliberately slow velocities,<sup>44</sup> with stored elastic energy dissipated as heat if the eccentric phase is too long.<sup>26</sup> Though not explicitly measured, Moore and colleagues noted that the eccentric phase of the jump squat was performed at a relatively slow velocity in their investigation, with no improvements in concentric performance provided by AEL.<sup>24</sup> As eccentric velocity was not measured in the current study, it is unknown how it may have influenced concentric performance or the potentiating effect of AEL. In addition, participants only performed a single repetition for each loading condition. As such, with the potential for limited experience with the JS or AEL, this may have influenced data reliability. Future work should ensure multiple repetitions and an assessment for reliability. In addition, the use percentages of body mass as a loading parameter may be viewed as a limitation. However, previous work supports the use of body mass for loading the JS, as limited criteria exist to determine JS 1RM.<sup>35</sup> While relative strength or body composition could influence the efficacy of using body mass for loading, it is suggested that body mass loads could be converted to

percentages of 1RMs for lifts like the squat or clean for comparison. Further, the use of body mass was used due to limited JS experience among the participants.

### Conclusions

Overall, the results of this study indicate that AEL had minimal influence on concentric JS performance in recreationally trained lifters. Observed differences were primarily driven by load, with lower RFD and greater impulse duration observed as load increased. Further, peak force values were similar between low and high loads, with moderate (60-80%) loads displaying slightly greater peak force than the 20% load. Though mass was substantially different, the similar peak force values across loads are likely influenced by varying masses and accelerations. Though AEL has previously been used to acutely potentiate lifting performance, it had minimal influence on performance in the current study. This may have been influenced by the relatively limited experience in weightlifting exercises by the participants. As load appears to be the primary influence in differences observed, coaches and practitioners should understand the influence of load on kinetic characteristics of the JS. While peak force characteristics may be similar across a spectrum of loads, RFD is clearly influenced by load. Further, changes in duration and velocity may influence power characteristics, as both force and velocity are contributors. While load influences JS performance, the presence of AEL had minimal influence in the current investigation.

### Conflict of Interest

The authors declare no conflicts of interest.

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