

Effect of the front squat as a pre-activation exercise on clean performance in well-trained weightlifters

ZAFEIRIOS BAMPOS¹, NIKOLAOS ZARAS², ANGELIKI KAVVOURA³, PANAGIOTIS FOTEINAKIS⁴,
ALEXANDRA AVLONITI⁵, THEODOROS STAMBOULIS⁶, ILIAS SMILIOS⁷, GERASIMOS TERZIS⁸,
MARIOS HADJICHARALAMBOUS⁹, ATHANASIOS CHATZINIKOLAOU¹⁰

^{1,2,3,4,5,6,7,10} Department of Physical Education and Sport Science, School of Physical Education, Sport Science and Occupational Therapy, Democritus University of Thrace, Komotini, GREECE.

⁸ Sports Performance Laboratory, School of Physical Education and Sport Science, National and Kapodistrian University of Athens, Athens, GREECE.

⁹ Department of Life Sciences, School of Life and Health Sciences, University of Nicosia, Nicosia, CYPRUS.

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Abstract

Problem statement: The front squat is a multi-joint exercise frequently used by weightlifters to improve weightlifting performance. A common training strategy is to perform the front squat at the beginning of a session as an effective whole-body warm-up and potential pre-activation exercise to increase athletes' readiness. However, it is unclear whether clean performance can be enhanced following front squats performed with light or heavy loads. **Purpose:** This study aimed to investigate the effects of the front squat, performed with either light or heavy loads as a pre-activation exercise, on one-repetition maximum (1RM) clean performance in well-trained weightlifters. **Approach:** Twelve well-trained weightlifters participated in the study, including nine males (age: 28.9 ± 2.5 years; body mass: 87.7 ± 7.2 kg; height: 179.3 ± 4.1 cm) and three females (age: 25.0 ± 3.6 years; body mass: 65.0 ± 8.5 kg; height: 158.0 ± 6.1 cm). A randomized, counterbalanced crossover design was used in which athletes completed three different pre-activation conditions: (i) a control condition with no front squat performed, (ii) a light squat condition consisting of 3 sets of 3 repetitions at 75% of 1RM, and (iii) a heavy squat condition consisting of 2 sets of 1 repetition at 95% of 1RM. Eight minutes after each pre-activation condition, athletes performed a 1RM clean assessment. In addition, barbell kinematics at 85%, 95%, and 100% of 1RM were measured using the Weightlifting Analysis Bar Path Tracker application. Peak and mean velocities during both the first and second pulls were recorded. The rate of perceived exertion was also assessed. **Results:** Clean performance remained unchanged across the three pre-activation conditions ($p = 0.142$). However, the light squat condition resulted in a significantly greater percentage increase in clean performance compared to the heavy squat condition ($0.61\% \pm 3.3\%$ vs. $-3.0\% \pm 5.6\%$; $p = 0.032$). The rate of perceived exertion was significantly lower following the light squat compared to the heavy squat condition ($p = 0.001$). No significant differences were observed in peak velocity during the first pull at 85% and 95% of 1RM; however, a statistical trend was noted at 100% of 1RM ($p = 0.056$) during the first pull. **Conclusions:** The light squat condition tended to enhance peak velocity during the maximal clean, which may influence pull technique and overall pull velocity. Percentage change analysis indicated that the light squat may elicit a greater pre-activation effect on clean performance compared to the heavy squat. Therefore, when the front squat is used as a pre-activation exercise, light loads performed with high movement velocity are recommended.

Keywords: Olympic weightlifting, peak velocity, front squat, clean, athletes, PAPE

Introduction

Weightlifting is consisted by two multi-joint power movements: the snatch and the clean and jerk. Both weightlifting movements have high technical demands since athletes need to activate several muscle groups while at the same time perform fast-shortening muscle contractions against high resistance loads (Storey and Smith, 2012). Performance in weightlifting depends on three major factors including biological, biomechanical and psychological elements. From a biological perspective, athletes with higher lean mass, greater percentage of type IIa muscle fiber composition and high neural activation appear to have a significant advantage in lifting higher loads (Häkkinen et al., 1982; Fry et al., 2003; Serrano et al., 2019; Zaras et al., 2021). On the other hand, biomechanical factors like the velocity movement, the vertical and horizontal displacement of the barbell (Gourgoulis et al., 2004) and the triple extension of ankles, knees and hips (Kipp et al., 2012) are selected biomechanical factors for success. However, during both snatch and clean the pull is considered being a major determinant for success (Enoka, 1979; De Weese et al., 2012). The pull is separated into three phases: the first pull, the transition and the second pull (Isaka et al., 2006; Chavda et al., 2021; Schilling et al., 2002). From a biomechanical perspective, the force application during the first pull (Gourgoulis et al., 2009) and the fast force

production during the second pull (i.e. rate of force development) seems to be major factors for a successful lift (Campos et al., 2006; Storey and Smith, 2012). Lastly, psychological factors like training stress, competitive anxiety and low self-confidence (do Nascimento et al., 2022) may also affect performance. Hence, the ideal combination of these factors may lead to an enhanced weightlifting performance.

Weightlifting training is designed according to the principles of periodization (De Weese et al., 2015). Weightlifting training programs are designed following different periodization forms including linear, block and non-linear models (Stone et al., 2021). In addition, training is separated into different periods with different goals (Anousaki et al., 2021). For example, the preparation phase is focused on increasing the training volume while pre-competition and competition phases are focused on increasing the training intensity (Häkkinen et al., 1982; Hornsby et al. 2017; Zaras et al., 2021). A common training strategy especially during the preparation phase is the initiation of training with a multi-joint resistance exercise like the back squat or the front squat. Anecdotal data and communication with coaches and athletes reveal that performing a back or a front squat prior entering the competitive exercises (snatch and clean and jerk) may enhance the warm-up procedure (Bishop, 2003; Fradkin et al., 2010), partially enhance the perceived feeling of athletes during the following exercise (feeling lighter) and probably acutely enhance weightlifting performance. In addition, the inclusion of a pre-activation exercise may enhance the warm-up routine, increase joint mobility while at the same time enhance lower body strength which is a major goal during the preparation training phase. Performing a high intensity exercise with maximum intentional movement velocity (Blazevich et al., 2020) may acutely increase performance. This phenomenon known as post-activation potentiation enhancement (PAPE) effect (Blazevich et al., 2019; Boullousa et al., 2021) may acutely increase power performance through the higher activation of type II motor units and the phosphorylation of myosin light chain (Tillin et al., 2003). A review study has shown that performing multiple repetitions and sets may lead to 320% higher increase in power performance (Wilson et al., 2012). Although the theory suggests that a high to moderate pre-activation condition may increase performance, the effect on weightlifting performance has been less studied.

According to the authors knowledge, only a handful of studies have investigated the effects of PAPE on weightlifting performance. A study on 8 well-trained female weightlifters investigated the acute effect of performing clean pulls with either 85% or 120% of 1 repetition maximum (1RM), on subsequent clean performance. The study showed that clean performance increased by $6.1 \pm 3.6\%$ ($p = 0.002$) after the 85% of 1RM and $4.7 \pm 3.1\%$ ($p = 0.004$) after 120% of 1RM although, the rate of perceived exertion (RPE) was lower following the 85% of 1RM condition. Therefore, in female well-trained weightlifters, pre-activation with either 85% or 120% of 1RM is an effective strategy for acute increase of 1RM clean performance (Kelekian et al., 2022), even though no barbell kinematics were measured during the experimental procedure. Hence, it would be interesting to investigate whether barbell kinematics during clean may change following PAPE pre-activation conditioning. Two more relative studies investigated the effects of pre-activation conditioning prior to 1RM weightlifting performance. Fry et al. (1995) showed that performing snatch and clean pulls at 85% of 1RM, 5.5 hours prior to 1RM snatch and clean and jerk maintained 1RM performance although, when athletes were separated into responders ($n = 6$) and non-responders ($n = 13$) the study showed that responders regulated their anxiety levels, and as a consequence, increased their weightlifting performance. Moreover, in the study of Stavropoulos et al., (2025) it was found that pre-activation conditioning with pull derivatives 24 hours prior to 1RM weightlifting measurement led to a significant increase in clean and jerk by 3.1% and almost in total (2.21%, $P = 0.077$). Moreover, in the latter study barbell kinematics including peak and mean velocity were measured but remained unchanged following both heavy and light conditions. Therefore, it remains uncertain whether a PAPE pre-activation condition may change weightlifting performance and whether these changes may be detectable through barbell kinematics.

Both front and back squats are significant contributors for 1RM in snatch and clean and jerk. This is evident from a review study which showed that 1RM squat had the highest correlations with weightlifting performance (r ranged from 0.93 to 0.94 for both snatch and clean and jerk) compared to vertical jumps, rate of force development and isometric peak force (Joffee et al., 2023). Considering this, it would be interesting to investigate the effects of front squat as a pre-activation condition during the same training session in clean performance. Also, since weightlifters often utilize heavy loads in training and especially in squats, it would also be interesting to investigate the effects of light vs. heavy loads front squats on clean performance. The hypothesis of the study was that front squats with heavy loads will induce greater increases in clean performance and barbell kinematics.

Materials and Methods

Participants

Twelve well trained weightlifters ($N = 9$ males: 28.9 ± 2.5 years; body mass: 87.7 ± 7.2 kg; body height: 179.3 ± 4.1 cm; 1RM performance in clean 123.3 ± 15.6 kg; and $N = 3$ females: 25.0 ± 3.6 years; body mass: 65.0 ± 8.5 kg; body height: 158.0 ± 6.1 cm; 1RM performance in clean 86.7 ± 5.8 kg) with 9.4 ± 3.5 years of training experience, participated in the study. Athletes were recruited from three different weightlifting clubs

while all of them participated in local and national competitions during the period of the study. For being eligible to participate in the study, athletes should meet the following criteria: absence of any illegal substances, regular participation in weightlifting training (at least 3 training sessions per week), participate in weightlifting competitions during the past two years, and free from any cardiovascular diseases and musculoskeletal injuries. Athletes were fully informed about the experimental procedures and signed an informed consent. All procedures were in accordance with the 1975 Declaration of Helsinki as revised in 2000 and were approved by the University ethics committee of the Democritus University of Thrace (project number A.Π.Δ.Π.Θ./Ε.Η.Δ.Ε./48170/352).

Experimental Design

A crossover counterbalanced study design was used to investigate the effects of front squat with heavy and light loads as a pre-activation condition on clean performance in well-trained weightlifters. All athletes followed three different pre-activation conditions including a control condition where no front squat was performed prior to clean (control, C), the heavy front squat condition (HS) and the light front squat condition (LS). All pre-activation conditions were randomly performed during a 20-day experimental period with at least 5 days of rest between interventions. All measurements were performed during the preparation phase. Athletes visited the training facilities on five different occasions. During the first visit, anthropometric characteristics were measured while a 1RM strength test in front squat was performed. During the second experimental day, athletes performed their individualized warm-up and the 1RM strength in clean was performed. Then, during the next three experimental days, athletes were randomly assigned into the three different pre-activation conditions and performed the C, HS and LS pre-activation interventions. Thus, all athletes performed all experimental conditions. Following the interventions, athletes performed the evaluation of 1RM clean. The time of rest between the pre-activation condition and the initiation of the 1RM evaluation in clean was determined at 8 minutes (Wilson et al., 2012; Ioannides et al., 2024). Twenty minutes after the end of each pre-activation condition athletes provided their RPE in a scale of 1-10 (Kelekian et al., 2022; Stavropoulos et al., 2025)

Pre-activation conditions

Prior to each pre-activation condition athletes refrained from vigorous exercise for at least 48 hours, while a 24-hour rest was preceded prior to each condition. Pre-activation conditions included the front squat exercise either with light or with heavy loads. Athletes were fully familiar with the front squat exercise since they regularly used it during training. Following the first experimental day, athletes completed the 1RM strength test in front squat to determine the percentage load of light and heavy condition. Prior to each pre-activation condition athletes performed the same warm-up routine including 2-3 minutes of low intensity running, foam roller exercises, static stretching and dynamic stretching. In addition, exercises with an empty barbell were allowed including good-mornings, Romanian dead lifts, barbell pulls, shoulder presses and various mobility and core exercises. For the C condition, athletes performed the warm-up routine, remained seated for 8 minutes and then begun the 1RM clean strength test. For the LS condition, athletes performed the warm-up condition and then added 3 sets of 3 repetitions at the 75% of 1RM in front squat. On the contrary, for the HS condition, athletes performed the warm-up routine and 2 sets of 1 repetition at the 95% of 1RM in front squat. During the LS and HS conditions athletes had the instruction to perform each repetition with maximum intentional movement velocity (Blazevich et al., 2020). Eight minutes following the LS and HS the 1RM strength measurement in clean was performed.

1RM clean measurement

Eight minutes after the squat pre-activation condition athletes performed the clean 1RM strength measurement. Specifically, athletes performed the clean with full competitive technique. The loading of the barbell during the measurement was the same during all measurements. Athletes performed several sets and repetitions with an empty barbell, then 2 sets of 3 repetitions at 50% of 1RM, 2 sets of 2 repetitions at 60% of 1RM, 2 sets of 1 repetition at 70% of 1RM, 2 sets of 1 repetition at 75% of 1RM, 1 set of 1 repetition at 85% of 1RM and 1 set of 1 repetition at 95% of 1RM. Athletes were allowed three maximum attempts at the 100% of 1RM and if they succeeded, they performed a single repetition at 103% of 1RM. A successful attempt was considered one where the athlete could stand upright with the barbell racked on the shoulders. During all clean attempts a certified weightlifting coach, member of the research team, was present to evaluate the validity of all attempts.

Weightlifting analysis bar path tracker application

For the evaluation of barbell kinematics during the pull, the weightlifting analysis bar path tracker application was used through an iPhone 15 Pro Max with a 48MP, 24mm camera (Lemus et al., 2024). The self-phone was placed at the side of the barbell and from a predetermined distance of 3 meters while it was attached to a tripod and placed approximately 1 meter above the ground. The background during the video recording was a dark colored wall while additional lights were placed at the sides of the plateau in an attempt to minimize the shadows on the barbell. During all experimental conditions the same settings were applied. All videos were recorded at 1080p slow motion with 240fps which enhanced sampling frequency and therefore were more likely to capture higher velocity points (Lemus et al., 2024). Video analysis was performed with the highest video

quality processed by the app at the time of data collection. Analysis from the app included only the pulling phase of the clean at 85%, 95% and 100% of 1RM. Athletes had the instruction to attempt all loading conditions regardless of the success of the attempt during the 100% of 1RM. Video analysis of the pull was separated into the first pull and the second pull. First pull was determined from the detachment of the barbell from the floor to the height of the knee of each athlete. Following the transition phase, the second pull was measured from the mid-thigh (start of the second knee bend) to the highest point of the hips (Isaka et al., 2006; Chavda et al., 2021; Schilling et al., 2002). Measurement included the peak velocity (PV) and the mean velocity (MV) of the barbell for both first and second pull.

Statistical Analysis

All variables are presented as mean $\pm$ SD. Following the Shapiro–Wilk test, all data were normally distributed. An analysis of variance for repeated measures was used to examine differences between control, HS and LS pre-activation conditions. Effect size eta squared (η^2) was also calculated. T-Test was used for detecting differences between LS and HS for RPE and between the percentage change differences of LS vs. C with the HS vs. C. Hedges g effect size was also calculated. Significance was set at $p \leq 0.05$.

Results

All athletes completed all conditions and measurements without injuries. Figure 1 presents the changes in clean performance following the pre-activation protocols. Specifically, no significant difference was found between conditions ($F_{(2,10)} = 2.390$; $\eta^2 = 0.323$; $p = 0.142$). Athletes lifted 113.2 ± 22.6 kg in control, 113.8 ± 22.1 kg following the LS and 109.7 ± 22.0 kg following the HS. Nine athletes lifted their 100% of 1RM following the LS pre-activation condition, while 2 males managed to lift the 103% of 1RM. On the contrary, only 4 athletes lifted their 100% of 1RM after the HS pre-activation condition and 1 male athlete lifted the 103% of his 1RM. In addition, significant difference was found for RPE between LS and HS pre-activation ($t = 8.684$; $g = 2.331$; $p = 0.001$) with LS pre-activation inducing lower RPE (4.95 ± 1.09 AU) compared to HS pre-activation (7.58 ± 0.97 AU).

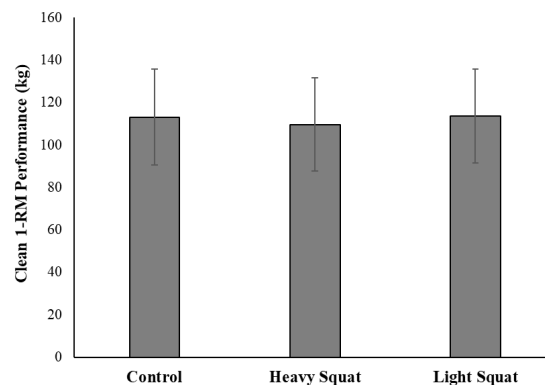


Fig. 1 No significant changes were observed for clean performance between the three pre-activation conditions.

Table 1 presents the changes in PV following the three pre-activation conditions. Although no significant differences were found for all 1RM loads, both for the first and second pull, a statistical trend was observed during the first pull for the 100% of 1RM where PV tended to be higher following LS compared to HS. Specifically, 6 athletes (4 males and 2 females) increased their 1RM PV following the LS, while only 3 male athletes increased their 1RM PV following the HS.

Table 1. Changes in peak velocity during the first and second pull in clean, following the three pre-activation conditions.

	Control	Heavy Squat	Light Squat	$F_{(2,10)}$	η^2	P
First Pull						
PV at 85% of 1RM	1.18 ± 0.15	1.19 ± 0.15	1.18 ± 0.10	0.075	0.015	0.928
PV at 95% of 1RM	1.13 ± 0.13	1.13 ± 0.14	1.14 ± 0.12	1.528	0.234	0.264
PV at 100% of 1RM	1.09 ± 0.16	1.06 ± 0.17	1.13 ± 0.14	3.894	0.438	0.056
Second Pull						
PV at 85% of 1RM	1.58 ± 0.12	1.56 ± 0.15	1.62 ± 0.16	1.773	0.262	0.219
PV at 95% of 1RM	1.48 ± 0.15	1.49 ± 0.17	1.51 ± 0.13	1.096	0.180	0.371
PV at 100% of 1RM	1.42 ± 0.15	1.35 ± 0.20	1.44 ± 0.13	1.483	0.229	0.273

PV = peak velocity, 1RM = one repetition maximum

Table 2 presents the changes in MV following the three pre-activation conditions. Similar to PV, no significant differences were found between conditions for MV, for both first and second pull. However, a statistical trend was observed for MV at 100% of 1RM during the first pull between control and LS pre-activation.

Table 2. Changes in mean velocity during the first and second pull in clean, following the three pre-activation conditions.

	Control	Heavy Squat	Light Squat	$F_{(2,10)}$	η^2	P
First Pull						
MV at 85% of 1RM	0.44±0.17	0.42±0.15	0.46±0.13	0.385	0.071	0.690
MV at 95% of 1RM	0.40±0.12	0.41±0.16	0.40±0.14	0.147	0.029	0.865
MV at 100% of 1RM	0.36±0.12	0.42±0.13	0.50±0.21	4.522	0.442	0.053
Second Pull						
MV at 85% of 1RM	1.07±0.19	1.07±0.10	1.09±0.07	0.146	0.028	0.866
MV at 95% of 1RM	1.01±0.11	1.02±0.11	1.02±0.08	0.084	0.017	0.920
MV at 100% of 1RM	0.91±0.12	0.89±0.17	0.99±0.08	2.867	0.364	0.104

MV = mean velocity, 1RM = one repetition maximum

The comparison between the percentage change of LS vs. C compared to the percentage change of HS vs. C is presented in figure 2. Interestingly, clean performance almost maintained following LS ($0.61 \pm 3.3\%$), in contrast to HS where a reduction of $-3.0 \pm 5.6\%$ occurred ($t = -2.460$; $g = 0.660$; $p = 0.032$). Although no significant differences were observed for PV at 85% and 95% of 1RM during the first and second pull, at 100% of 1RM, percentage change for PV was significantly higher for the LS compared to HS (LS: $4.63 \pm 9.5\%$ vs. HS: $-1.8 \pm 12.5\%$; $t = -2.597$; $g = 0.697$; $p = 0.025$).

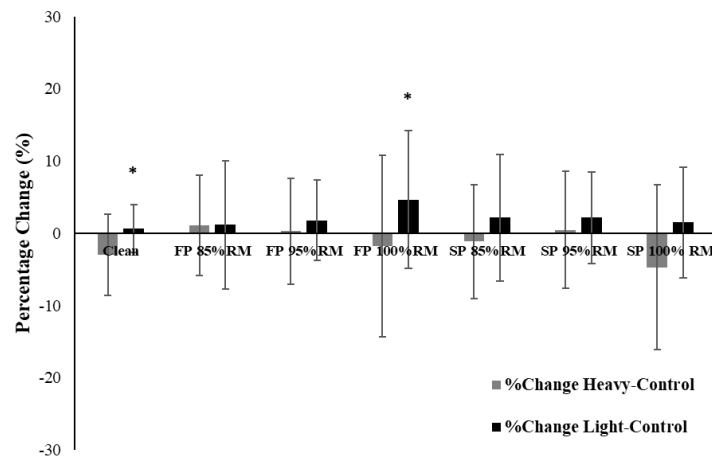


Fig. 2 Comparison between the percentage change of light squat vs. control with the percentage change of heavy squat vs. control for clean 1RM, peak and mean velocity. * = significant difference between percentage change conditions. FP = first pull, SP = second pull, RM = repetition maximum

Discussion

The purpose of the study was to investigate the effects of performing either light or heavy front squats as a pre-activation exercise on clean performance in well-trained weightlifters. The hypothesis of the study was that HS would induce greater increases in 1RM clean and enhance barbell kinematics. The main finding of the study was that both LS and HS conditions induced small non-significant changes in 1RM clean performance, although when percentage comparisons to C were made, LS induced significantly higher increases in 1RM clean compared to HS. In addition, RPE was significantly lower following LS compared to HS. Moreover, PV at the 100% of 1RM during the first pull tended to be higher following LS compared to HS ($p = 0.055$), while MV at the 100% of 1RM during the first pull tended to be higher following LS compared to C ($p = 0.053$). In line with these results, most athletes ($N = 9$) achieved their 1RM clean following the LS condition whilst only 4 managed to lift their 1RM clean following the HS. These results suggest that performing LS prior to 1RM clean may possibly lead to an enhanced 1RM clean performance and PV compared to HS. Consequently, our initial hypothesis and the expectation that performing front squats with high loads will acutely increase clean performance seems to be rejected. Lighter loads with faster movement velocity and lower RPE seem to favour the PV of the first pull and therefore probably enhance clean performance.

Warm-up is a major component of every-day training routine for all sports (Bishop et al., 2003). Warm-up is aiming at increasing body temperature, blood flow, flexibility and mobility. In weightlifting, whole-body mobility is a crucial factor not only for an enhanced performance but also for injury prevention (Bousquet et al., 2018). Therefore, performing squat exercise (back or front) prior to a power-based exercise like the clean may enhance whole-body warm-up and mobility conditioning. In addition, the presence of the PAPE phenomenon (Blazevich et al., 2019) may lead to significant neuromuscular enhancement during the following exercise. Therefore, it would be logical to assume that the front squat would have a positive impact on clean performance, although the load that would be used to induce these positive adaptations remained unclear. Anecdotal communications with coaches revealed the use of a low volume high intensity pre-conditioning exercise prior to clean performance as a tool to acutely enhance performance. However, 1RM performance in clean remained unchanged following both pre-activation conditions. A previous study on well-trained female weightlifters investigated the effects of clean pulls with light (85% of clean 1RM) vs. heavy loads (120% of clean 1RM) on competitive clean performance. The study showed that clean performance increased significantly by $6.1 \pm 3.6\%$ and $4.7 \pm 3.1\%$, following the light and heavy pulls, respectively (Kelekian et al., 2022). However, the latter study included the clean pulling derivative as a pre-activation exercise, with a small rest period between pre-activation and performance evaluation (approximately 2 minutes) and a lower training volume including only 1 repetition with maximum intentional velocity of movement. On the contrary, in the present study a structural multi-joint exercise was implemented (front squats) which has been shown to have a strong positive correlation with weightlifting performance (Joffe et al., 2023), with a higher rest period between pre-activation and performance evaluation (approximately 8 minutes) while a higher training volume was applied during the activation exercise. A previous study has shown that utilizing moderate rest periods lengths (7–10 minutes) with multiple sets during the pre-activation exercise with moderate intensities (60–84%) may result to enhanced athletic performance (Wilson et al., 2013). Weightlifters often use high loads during training ($> 90\%$ of 1RM) therefore, it would be logical to hypothesize that HS would enhance 1RM clean performance. However, this was not proven by the results of the study.

Two more related studies showed conflicting results of the effects of a priming training session prior to weightlifting performance. Specifically, when a priming session was performed 5.5-6h prior to weightlifting 1RM performance, snatch and clean and jerk remained unchanged, although athletes with higher levels of anxiety increase their 1RM performance (Fry et al., 1995). On the contrary, when the priming session was performed 24h prior to 1RM snatch and clean and jerk then performance in clean was significantly increase while a statistical trend was also found for total (Stavropoulos et al., 2025). In the current study, when a comparison was made between the percentage differences with C, changes following HS seemed to be negative on 1RM clean performance ($-3.0 \pm 5.6\%$) compared to LS which maintained 1RM clean performance ($0.61 \pm 3.3\%$). Although these percentage differences were small, a significant difference was also found in RPE with LS inducing lower RPE responses compared to HS. Similarly, results from previous studies showed that a lighter load pre-activation condition induce lower RPE values compared to a heavier (Kelekian et al., 2022; Stavropoulos et al., 2025). Taking together these results suggest that performing a LS session prior to 1RM clean performance may induce lower RPE and perhaps lead to a positive enhancement of maximum clean performance.

The pull phase during both snatch and clean consider being a major determinant for success in weightlifting (Enoka, 1979; De Weese et al., 2012). Studies have shown that the pull is separated into three phases: the first pull which includes the detachment of the barbell from the floor until the knee height, the transition phase where the second knee bend is occurred and the second pull where the velocity of barbell is increased drastically until the highest point of the hips (Isaka et al., 2006; Chavda et al., 2021; Schilling et al., 2002) while the triple extension of ankles, knees and hips occurred (Kipp et al., 2012). During the pull, athlete's main objective is keeping the barbell close to them, increase the vertical barbell pulling height and reduce any horizontal displacement (Chavda et al., 2021; Schilling et al., 2002; Campos et al., 2006). In addition, barbell accelerates abruptly especially during the second pull leading to a whole-body-barbell system vertical displacement (Stone et al., 1998). Therefore, a progressive application of force and velocity is applied during the pull in an attempt to achieve the optimal mechanics of the movement and maximize pull velocity during the second pull. Although no significant differences were observed for 85% and 95% of 1RM during the first pull, a statistical trend was found for 100% of 1RM with the LS tending to induce higher PV compared to HS. The significant difference between the percentage differences of LS vs. C and HS vs. C on PV at 100% of 1RM further reinforces the positive effect of LS on first pull PV. This finding may partially be explained by the lower RPE induced by LS while at the same time by the higher velocity of the pre-activation movement during the LS (75% of 1RM) compared to the HS (95% or 1RM) (Haff and Nimphius, 2012). Overcoming the inertial of the barbell from the floor with proper mechanics and technique is a challenging part of the whole technique during the pull (Campos et al., 2006; Ben-Zeev et al., 2023). Moreover, a study in elite weightlifters showed that proper direction of the force applied during the first pull is crucial for a successful performance in weightlifting (Gourgoulis et al., 2009). Although several other biomechanical factors affect performance in weightlifting the

velocity at which the force is applied during the pull seems to be a major contributor of success (Suchomel et al., 2020). However, coaches should be aware that a faster first pull may negatively affect the technical elements during the first pull and perhaps reduce the overall velocity of movement due to technical mistakes. Therefore, the possible increase in PV during the first pull should be interpreted with caution.

In line with the results of the current study, a previous study in well-trained weightlifters showed that a priming training session either with light or heavy load pulls, maintained the PV and MV during the next day 1RM in snatch and clean and jerk (Stavropoulos et al., 2025). Therefore, changes in barbell kinematics may not be detected following short-term training strategies. One possible explanation for the absence of differences in barbell PV and MV may be partly caused by the competitive technique used by athletes (including the transition phase) and the possible effort of the athletes to concentrate on lifting the load at 100% of their 1RM, and not on maximizing the velocity of movement (Suchomel et al., 2025; Stavropoulos et al., 2025). In addition, evaluation of barbell PV was performed via the weightlifting analysis bar path tracker application which has previously showed to underestimate peak velocity with a mean difference of 6.23% and 10.55% (0.14 and 0.21 m/s) for the 40% and 70% clean trials (Lemus et al., 2024). However, in the current study videos were recorded at 1080p slow motion with 240fps which probably enhance sampling frequency and more likely capture higher velocity points. In addition, higher loads were measured during the pull, including 100% of 1RM even if the athletes failed the attempt. Although the easy-to-use nature of the app is an advantage during everyday training, more studies are needed with linear position transducers, force plates or motion capture systems to examine changes in barbell kinematics during weightlifting exercises. Consequently, coaches may use the app during training, but errors and bias should be considered.

This study has some limitations. Athletes participating in the study were well-trained athletes participating in National competitions; therefore, the results may not be generalized to elite athletes with greater training experience. The number of athletes (N=12) was relatively small; however, recruiting athletes and minimizing the interference with their daily training programs can be challenging. Also, the weightlifting analysis bar path tracker application used in the study may underestimate PV for loads from 40% to 70% of 1RM (Lemus et al., 2024). Moreover, the use of linear position transducers or force platforms was not possible for the current study, while no EMG data were collected which might have provided greater insights into the underlying mechanisms of the observed results. Future studies may be focused on the investigation of other weightlifting derivatives (i.e. pulls, back squat, muscle clean etc.) as pre-activation exercises on weightlifting performance. Moreover, studies with linear position transducers and force platforms may investigate the kinematic and kinetic characteristics effectively and observe differences in the velocity of movement following different pre-activation training strategies.

Conclusions

The results of the study suggest that LS pre-activation condition performed 8 minutes prior to 1RM clean evaluation may enhance PV during the first pull, induce lower RPE and may yield greater percentage increase on 1RM clean performance and PV compared to HS. Specifically, LS prior to 1RM clean should be performed with maximum intentional movement velocity especially during the concentric phase of movement. Three sets of 3 maximum velocity repetitions are recommended. In addition, such training strategies should be implemented on well-trained athletes with high training experience. Moreover, coaches should keep in mind that although LS may partially enhance PV of the first pull, the force applied on the barbell should be technically correct and not alter the kinematic path of the pull. Furthermore, due to interindividual differences, coaches may choose to apply both light and heavy pre-activation conditions in an attempt to verify the best condition that may enhance 1RM clean performance in their athletes. All pre-activation conditions are strongly suggested to be performed during training conditions to examine their effectiveness in weightlifting performance.

Conflicts of interest: The authors declare no conflict of interest.

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