1. **Delayed potentiation effects on neuromuscular performance after optimal load and high load resistance priming sessions using velocity loss.**
2. **Submission Type:** Original investigation
3. **Authors:** Jaime González-García[1-3], Verónica Giráldez-Costas[1-3], Carlos Ruiz-Moreno[1], Jorge Gutiérrez-Hellín[2], Blanca Romero-Moraleda[3]

[1] Education and Health Faculty. Camilo José Cela University, Madrid, Spain

[2] Exercise and Sport Sciences, Education and Humanities Faculty, Francisco de Vitoria University, UFV, Bulding E, Ctra. M-515 Pozuelo-Majadahonda Km 1,800, 28223, Pozuelo de Alarcón, Madrid.

[3] Department of Physical Education, Sport and Human Movement, Autonomous University of Madrid, Madrid, Spain
4. **Contact details:**

Name: Jaime González García

Institution: Healthy Sciences Faculty. Camilo José Cela University, Madrid, Spain

Mail address: Urb. Villafranca del Castillo, Calle Castillo de Alarcón, 49, 28692 Villanueva de la Cañada, Madrid, Spain

Telephone: 699686379

e-mail address: jaime33gonzalez@gmail.com

Preferred running head: Priming session Optimal Load and High load

Abstract word count: 250 words

Text-only word count: 3801 words

Number of figures and tables: 2 figures, 2 tables

Delayed potentiation effects on neuromuscular performance after optimal and high load resistance priming sessions using velocity loss.

Abstract

Aim: (i) to compare the effects of two different low-volume resistance priming sessions, where the external load is modified on neuromuscular performance after 6 hours of rest; and (ii) to identify the effects on psychological readiness in participants with resistance training experience. **Methods:** Eleven participants (Body mass: 77.0±8.9 kg; Body height: 1.76±0.08 m; Half squat repetition maximum: 139.8±22.4 kg) performed the priming session under three experimental conditions in a randomized and cross-over design during the morning. The control (CON) condition: no resistance training, "optimal load" (OL) condition: two half-squat sets with a velocity loss of around 20% were performed with the "optimal load", and 80% of repetition maximum (80% RM) condition: 2 half-squat sets with a velocity loss of around 20% were performed with the 80% RM. Countermovement jump (CMJ), mean power with OL (MP_{OL}) and 80% RM (MP_{80RM}), and mean velocity with OL (MV_{OL}) and 80% RM (MV_{80RM}) were assessed six hours after the intervention. Subjective readiness was also recorded prior to resistance training and evaluation. Significance was set at $p<0.05$. **Results:** CMJ was higher after the 80% RM intervention than CON ($p<0.001$; $\Delta=6.5\%$ [3.4-9.5]). MP_{OL} and MV_{OL} seemed to be unaffected by both morning sessions. Higher MP_{80RM} ($p=0.044$; $\Delta=9.7\%$ [4.0-15.6]; $d=0.24$[0.10-0.37]) and MV_{80RM} ($p=0.004$; $\Delta=8.1\%$ [3.2-13.3]; $d=0.32$[0.13-0.52]) after 80% RM than after CON were observed. No effect was observed on psychological readiness. **Conclusions:** 80% RM priming session increased CMJ height and the capacity to generate power and velocity under a high-load condition without any effect on psychological readiness.

Keywords: velocity-based training, squat, precompetition, readiness, power.

INTRODUCTION

One of the main goals of strength and conditioning coaches is to manage different strength training and recovery strategies in order to optimize force and power production during competitive actions, such as jumping, sprinting or changing direction[1]. The importance of optimal load (i.e., the external load that maximizes power production) and strength oriented prescription strategies in resistance training have previously been investigated in the long term[2,3]. However, the available research has also observed an increase in different performance outcomes after a priming session[4]. This type of session is defined as being carried out in the hours prior to a competition with the aim of acutely maximizing performance[5]. Some investigations suggested that a low-volume priming resistance training intervention may enhance sport performance when implemented 2 to 48 hours before[4,6–8]. Specifically, this delayed potentiation was observed for different performance markers, such as the countermovement jump (CMJ) height, 3 repetition maximum (RM) bench press, 3RM back squat[9], height in drop jump (DJ) [8], reactive strength index (RSI) and rate of force development (RFD) in the leg press [10] after different priming exercises performed up to 48h beforehand.

While the benefits of performing a priming session have been documented[4,8], the underlying mechanisms have not yet been clarified[6]. Different resistance training influences the α- amylase[11], creatine kinase, ammonia and growth hormone concentrations[12]. Moreover, other authors suggested that improved kinematic outcomes may be produced due to higher motor unit activation[8], improved neural peripheral excitability[13], higher muscle temperature and/or variations after a resistance session in the circadian cycle hormone decline[9]. Previously, a link between athlete readiness and testosterone and cortisol concentrations have been suggested in athletic populations[11]. These two biomarkers follow a circadian rhythmicity which may be altered by a priming exercise [4,9] and this, in turn, may change the athlete's readiness state and performance outcomes. In fact, only one investigation has observed the psychological and hormonal responses together after a priming exercise, and it revealed a favorable psycho-physiological context, but some performance markers were diminished[11].

However, several factors may influence the recovery patterns (i.e. training volume, rest time between sets and repetitions and external load) and therefore, the acute responses to a priming resistance training session[6]. Additionally, the level of effort prescribed (defined as the % of velocity loss in subsequent repetitions according to the fastest repetition) can be a determining factor due to its implication for the time-course of recovery after resistance training[14]. While moderate and high loads increased different performance outcomes [15] it is relevant to consider the effect of external loads against total volume and different levels of effort [16]. Higher training volumes with high levels of effort [16] and high external loads [13,17] need more time for recovery (i.e., up to two days) which would prevent the potential of a priming session. However, low-volume priming resistance training sessions with low to moderate loads involving lower-limb exercises (30-65% 1RM) increased vertical jump height up to 48 hours later[10,13]. Cook et al.,[9] demonstrated that a higher training volume (3 x 50% 3RM; 3 x 80% 3RM; 3 x 90% 3RM and 3 x 100% 3RM bench press and back squat) also increased CMJ peak power output, 3RM bench press and 3RM back squat 6 hours after completion. Nevertheless, when velocity-based training is used as a priming session the effects on neuromuscular performance remain unclear. Different set configurations of the bench press exercises using external loads from 40 to 80% 1RM and velocity drops of 10 and 30% suggest increases in bench press throw performance up to 12 minutes after the end of the session[18,19]. In contrast, when lower-limb neuromuscular performance is evaluated after more time to rest (6-48h), [16] no significant increases over baseline squat movement velocity with a moderate load (about

1m/s) and CMJ were observed after two 80% 1RM resistance training sets with different levels of effort (i.e., leading to failure vs. doing half of the possible repetitions). The low effort training recovered movement velocity and CMJ in 6 hours while the high effort training needed more than 24h to recover the baseline values. Similarly, 3 sets of 70% 1RM half squat with around 20% of velocity loss increased the velocity against the load that elicited 1m/s by 1.3% without an increase in CMJ height after 6 hours rest[14].

Despite this research background, the effects of a resistance-based priming exercise on neuromuscular and psychological performance outcomes remain unclear due to the differences in the prescribed exercise typology, training volume, level of effort [4,9] and different neuromuscular recovery patterns after a low or a high load between training sessions [13,17]. Therefore, the main aim of this study was to compare the effects of two different low-volume resistance priming sessions, where the external load is modified, on neuromuscular performance; and secondly, to identify the effects on psychological readiness after 6 hours in healthy active participants with resistance training experience. The hypotheses of this study predict that a morning squat-based priming session may enhance neuromuscular performance and psychological readiness 6 hours after the end of the session.

METHODS

Participants

Eleven participants, ten men and one woman, were recruited for this study (Mean±SD: Body mass: 77.0±8.9 kg; Body height: 1.76±0.08 m; Body mass index (BMI): 24.9±1.8; Age: 24.6±4.1 years; Half squat repetition maximum: 139.8±22.4 kg; Half squat optimal load: 60.9±5.8 %1RM). Participants were informed about the experimental procedures and the possible risks and benefits associated with their participation. Additionally, they signed the written informed consent to participate in this research. The study and informed consent procedures were approved by the Camilo José Cela Ethics Committee in accordance with the latest version of the Declaration of Helsinki.

Experimental Design

The participants visited the laboratory on five different occasions throughout a 10-day period. Two familiarization and three experimental (control, optimal load and 80% RM) trials were performed. Experimental conditions were completed in a randomized cross-over design separated by 48 hours. In order to evaluate the effects of delayed potentiation on performance, experimental training interventions were carried out in the morning followed by around 6 hours of rest. After this period, 3 evaluations of CMJ, mean velocity with the optimal load (MV_{OL}), mean velocity with the 80% RM (MV_{80RM}), mean power with the optimal load (MP_{OL}) and mean power with the 80% RM (MP_{80RM}) during the half-squat were assessed. A readiness questionnaire was also collected before priming resistance training (a.m.) and before evaluation (p.m.). Participants were required to refrain from physical activity, to replicate sleep patterns and eating habits 48 hours prior to the start of the research and during the 10-day research period. Caffeine ingestion and nutritional supplementation were also avoided from the week before familiarization and during the research period.

<u>Familiarization sessions</u>

During the first session, participants signed the informed consent. Their 1RM and optimal load (OL) were determined on a Smith Machine (Technogym, Barcelona, Spain) using a rotatory encoder[20]. OL was defined as the load that maximized power production in a 7-load incremental test (i.e., 30, 40, 50, 60, 70, 80, and 90% 1RM). The determination of the load that maximized power output was carried out without the combination of the encoder with the force platform. Each participant performed 2 repetitions with each load. The mean value was used as power output. To facilitate accessibility, this session was held in the morning. Prior to 1RM and OL determination, participants performed a standardized warm-up which consisted of 5 minutes cycling on a cycle ergometer with a rate of perceived effort (RPE) of 5/10, followed by 3 minutes of hip and ankle mobility. Then, ten bodyweight squats and two approximation sets of 6 and 4 repetitions with 30 and 40 kg were performed[12]. This warm-up routine was the same during the whole study. During the second session, participants visited the laboratory in the afternoon (14:00 – 16:00 p.m. This time was consistent throughout the experimental conditions) to carry out the p.m. assessment. The objectives of this second familiarization session were to minimize the learning effect during evaluation and to obtain data for reliability analysis. In addition, due to the influence of circadian rhythmicity on force-velocity relationship[21], OL and 80% RM loads were reevaluated.

Experimental conditions

Subjective readiness was assessed using an adaptation of the Short Recovery Stress Scale (SRSS)[11] between 08:00 and 10:00 a.m. Physical performance capability (PPC), mental performance capability (MPC), activation balance (AB) and overall stress (OS), were assessed using a seven-point scale from 0 (not at all) to 6 (extreme). Three different conditions were implemented throughout the study (Table 1): a control condition (CON), where no exercise was performed, and two experimental conditions: optimal load (OL) and 80% RM (80% RM). For the OL intervention, 2 sets with a velocity loss of around 20% regarding best repetition of half-squat were performed with the optimal load. For the 80% RM intervention, 2 sets with a velocity loss of around 20% regarding best repetition of half-squat were performed with 80% RM load. This velocity loss threshold was selected because greater losses of velocity lead to an increase in biochemical markers of fatigue[12]. Descriptive characteristics of the priming interventions are shown in Table 1. When priming exercises were performed, the RPE was measured using the Borg CR-10 Scale[22].

Table 1 about here

Testing and measurements

Participants rested for six hours following the end of the priming session. During this time frame they were requested to avoid any physical exertion and to replicate caloric ingestion. Neuromuscular performance assessment started between 14:00-16:00 p.m. As load influences the force-power-velocity relationship, the neuromuscular performance against low, medium and high loads was evaluated to provide information about the possible changes along the whole profile[23]. CMJ height was selected as a low-force-high-velocity performance marker [24], power and velocity (about 1m/s) with OL were selected as a moderate-force-moderate-velocity marker, and power and velocity with 80% RM were used as a high-force-low-velocity performance marker[25].

Low load measurements

All of the participants performed three maximal CMJ attempts (separated by 1 minute) with arms akimbo [9]. Subjects were requested to maintain their hands on their hips during the jump. Knee flexion was not allowed during the flight phase. If any of these parameters were not followed, the trial was repeated. All the attempts were performed on a portable force platform (Type 92866AA, Kistler, Germany). Jump height was calculated using the instantaneous velocity and displacement of the center of gravity, which was derived from the vertical component of the ground reaction force and the participant's body mass (Countermovement Jump Height = (Take off velocity^2) / (2 x gravity)) using a previously published Excel (2013; Microsoft Corporation, Albuquerque, NM) spreadsheet[26].

Moderate and high load measurements

Following CMJ assessment, participants performed three different repetitions with OL and 80% RM. Two minutes of passive rest were allocated between attempts. Mean velocity and mean power were measured in the concentric phase of the movement using a rotatory encoder (Isocontrol, EV-Pro, Spain) with a frequency of 500 Hz. The complete range of motion (ROM) consisted of lowering the body by bending the knees to a 90º angle until touching a bench, in addition ROM was controlled through vertical displacement of the barbell in cm with visual instant feedback. The bench height was modified for every participant. Execution technique and verbal encouragement were standardized and monitored by 2 experienced researchers for greater safety of the participants and reliability of the experimental conditions. Participants were requested to perform the eccentric phase in a controlled manner and to displace the bar in the concentric phase with the maximal intended velocity. Jumping was not allowed. The mean of the three attempts were used for statistical analyses.

Statistical Analysis

Statistical significance tests were carried out using IBM SPSS Statistics for Macintosh, Version 26.0 (IBM Corp., Armonk, NY, U.S.) Sample size was estimated using free software (G*Power v3.1). Sample size estimation revealed that 8 participants were sufficient for a within-factors repeated measures ANOVA assuming a partial eta-squared

(η^2) of 0.573 for CMJ as reported in previous research [4], with a Pearson correlation of 0.94 (data obtained during familiarization) and values of 5% and 1% for type I and type II errors, respectively. Data reported during familiarization were normally distributed as determined by the Shapiro-Wilk test of normality ($p>0.05$ for all variables). Additionally, the variance and sphericity assumptions were checked with the Levene and Mauchly tests. Intraclass Correlation Coefficient (ICC), Pearson's Correlation *r*, Standard Error of the Measurement (SEM) and minimum detectable change (MDC) at 90% confidence interval (90%CI)[27] were calculated using an Excel (2013; Microsoft Corporation, Albuquerque, NM) spreadsheet[28]. ICC values were analyzed based on the following criteria: poor reliability, <0.5; moderate reliability, 0.5-0.75; good reliability, 0.75- 0.90; and excellent reliability, >0.90 [29]. The interpretation for Pearson's r values were large: greater than 0.5, moderate: between 0.5-0.3, small: between 0.3-0.1, and trivial: smaller than 0.1. The overall acceptable value for this study was 0.90 [30]. In order to identify the effects of the priming interventions on single time-point data (neuromuscular outcomes and % of change) a repeated measures ANOVA was performed. For two-time point data (psychological readiness) a two-way (3x2) repeated measures ANOVA (within participants: intervention x time) was used. Partial eta-squared (η_p^2) values (classified as follows: small: 0.01, medium: 0.06 and large: 0.14 [31]) were calculated and Bonferroni's *post-hoc* test was used to check pairwise comparisons. Additionally, estimated magnitudes (Cohen's *d* [CI 90%]) were calculated between pairs. These estimated magnitudes were classified in standardized units as follows: ≤0.2 trivial, ≥0.2-0.6 small, ≥0.6-1.2 moderate, ≥1.2-2.0 large, and ≥2 very large [32]. Results are expressed as mean ± standard deviation (SD). The significance level was set at $p<0.05$.

RESULTS

Within-subject reliability analysis showed that all outcomes presented a high ICC and Pearson's correlation coefficient: CMJ (ICC=0.95[0.83-0.98]; r=0.94[0.79-0.98]; SEM = 1.3 cm; MDC = 3.06 cm), MP_{OL} (ICC=0.94[0.81-0.98]; r=0.93[0.79-0.98]; SEM = 35.6 W; MDC = 82.79 W), MV_{OL} (ICC=0.95[0.82-0.99]; r=0.95[0.81-0.99]; SEM = 0.04 m/s; MDC = 0.09 m/s), MP_{80RM} (ICC=0.99[0.98-1.00]; r=0.99[0.97-1.00]; SEM = 38.7 W; MDC = 89.92 W) and MV_{80RM} (ICC=0.95[0.84-0.98]; r=0.94[0.74-0.98]; SEM = 0.03m/s; MDC = 0.06 m/s).

Results from one-way ANOVA showed a main effect of the priming session on CMJ height ($F_{2,20}$=11.58; p<0.001; η_p^2=0.537). 80% RM priming session increased CMJ height compared to CON (p=0.006; Δ=6.5% [3.4-9.5]; *d*=0.35[0.19-0.51]) (see Table 2). As depicted in Figure 1, the percentage of change in CMJ was greater after the 80% RM intervention than CON (p<0.001) and OL (p=0.030), with no differences between the last two groups (p=0.228).

Table 2 about here

Figure 1 about here

No main effect of the intervention was observed on MP_{OL} ($F_{1,20}$=2.55; p=0.132; η_p^2=0.203) or MV_{OL} ($F_{2,20}$=2.87; p=0.080; η_p^2=0.223) (see Table 2). Similarly, the percentage of change analysis did not show significant differences in mean power ($F_{2,20}$=2.31; p=0.125; η_p^2=0.188) or mean velocity ($F_{2,20}$=2.57; p=0.102; η_p^2=0.204) (see Figure 2).

Figure 2 about here

There was a main effect of the intervention in MV_{80RM} ($F_{2,20}$=4.18; p=0.030; η_p^2=0.295). After the 80% RM priming session, MV_{80RM} (p=0.004; Δ=8.1% [3.2-13.3]; *d*=0.32[0.13-0.52]) and MP_{80RM} (p=0.044; Δ=9.7% [4.0-15.6]; *d*=0.24[0.10-0.37]) were higher than in the CON protocol. Besides, the OL priming session did not increase MP_{80RM} (p=1.00; Δ=3.7% [-3.4-11.3]; *d*=0.09 [-0.09-0.28] or MV_{80RM} (p=1.00; Δ=1.6% [-4.2-7.7]; *d*=0.06 [-0.18-0.31] compared to CON. In addition, a main effect was observed in the percentage of change of MP_{80RM} ($F_{2,20}$=4.30; p=0.028; η_p^2=0.301) and MV_{80RM} ($F_{2,20}$=4.98; p=0.018; η_p^2=0.332) (see Figure 2). After the 80% RM priming session the change in MP_{80RM} (p=0.025) and MV_{80RM} (p=0.020) were higher than in the CON. No significant differences were identified in the percentage of change between OL and CON (p>0.05).

For the readiness assessment, there was only a time-effect on Activation Balance ($F_{1,9}$=12.69; p=0.006; η_p^2=0.585), which was higher on p.m. (p=0.006), without any effect of the intervention or the interaction on any other psychological variable (p>0.05).

DISCUSSION

This study aimed to compare the effects of two different low-volume resistance priming sessions on neuromuscular performance and psychological readiness after 6 hours of rest. As was argued, the available research is still unclear about the possible effects of a resistance-based priming exercise on neuromuscular and psychological performance outcomes [4,9,11]. In fact, the results of the current study showed increases in CMJ height with the 80% RM training intervention, displaying a different inter-individual response among participants. The development of power and velocity with the optimal load seemed to be unaffected by any of the morning priming sessions performed. Alternatively, mean power and velocity with the 80% RM showed that only the priming training with 80% RM improved their outcomes, suggesting that the increases in neuromuscular performance may be specific to the load trained during a.m.[33]. However, despite the specificity of the OL condition, squat mean velocity and power output with the optimal load did not show significant increases after 6 hours of rest. The OL group performed more repetitions than 80%1RM with a lower external load (Table 1). This set configuration may require longer recovery times to return to baseline performance than a high-load low-volume set when performed near to failure[34]. However, velocity drops about 20% in comparison to the best repetition suggests that upper and lower limb neuromuscular fatigue is minimized even at the end of the training session[12]. Therefore, it seems that non-ballistically back squat priming session with optimal load (60.9±5.8 %1RM) is not a sufficient stimulus to improve performance after 6 hours of rest.

Resistance training produces immediate changes in neural peripheral excitability that are accompanied by a decrease in force production, which is not totally recovered after several hours[35]. This increase in fatigue, has meant that resistance training sessions have been avoided[5] in the hours prior to a competition, as sport performance could be impaired. For this reason, since lower training volumes may follow a shorter time-course of fatigue [34], recovery and supercompensation[35], several investigations have aimed to identify if different training set configurations may acutely improve different markers of sport performance. [4,7–11]. Our results from the priming session with the OL showed a non-statistically significant increase in CMJ height (Table 2) compared to CON, but 45% (5/11) of the participants increased their CMJ height more than the SEM (1.3 cm). Nevertheless, when we compared the effect of different priming interventions, with low-to moderate loads, we could observe different responses to low-force high-velocity markers[10,14]. Pareja-Blanco et al., [14] did not observe increases in vertical jump after 6 to 48 hours following different half-squat set configurations, whereas ballistic training (5 sets x 4 repetitions with 40% 1RM in the jump squat exercise) increased CMJ height (Δ=5.1±1.0%; Δ=+2.1 cm, 95%CI: 1.3-3.0 cm, p=0.0001, *d*=0.48) and RSI (Δ=10.7±2.1%; Δ=+0.18 m-s-1, 95%CI: 0.12-0.24 m-s-1, p=0.0003, *d*=0.42) after 24 hours of rest [10]. This higher potentiation after a ballistic exercise may be explained by the larger neural drive and longer portions of positive acceleration phase associated with this type of movements, which may lead to an increase in muscle activation[36] and force output [37]. This notion is also supported by previous research that showed a higher post-activation potentiation effect on squat jump height after a ballistic intervention than a non-ballistic and control conditions [38].

On the other hand, our 80% RM priming session enhanced CMJ height (Δ=6.5% [3.4-9.5]; *d*=0.35 [0.19-0.51]), mean velocity with the 80% RM (Δ=8.1% [3.2-13.3]; *d*=0.32 [0.13-0.52]) and mean power with the 80% RM (Δ=9.7%[4.0-15.6]; *d*=0.24[0.10-0.37]) after 6 hours of rest (Figure 2). Similar recovery patterns were observed on knee extensor voluntary isometric contraction (MVIC) after only 6 hours of rest following maximum strength (5x3RM) oriented resistance sessions[35,39]. Furthermore, a supercompensation effect on biceps brachii MVIC (Δ=5.6%; *d*= 0.89; 95% CI [0.36, 1.16]) was observed following the maximum strength training in the biceps curl exercise[39]. Similar results were observed by Cook et al.[9] which showed a primer effect on back squat 3RM (95%CI=4-8kg) and maximum power in CMJ (95%CI=110-182W). In this case, the potentiation effects were accompanied by an attenuation of the circadian decrease in salivary testosterone concentration (95%CI=12.9-30.4 pg ml^{-1}) in comparison to a control group. However, this morning training consisted of 12 sets of increasing loads up to 3RM of bench press and back squat carried out 6 h prior to competition, which was a much higher training load than ours. Thus, it seems that higher training volumes of heavy weight resistance training, that attenuate the circadian decline in the testosterone concentration, could be another strategy to induce a delayed potentiation in performance outcomes. Additionally, some authors have attempted to associate athletes' readiness levels with changes in testosterone concentration after resistance training, however their relationship remains unclear[15]. In fact, our results suggest an increase in performance without any change in readiness levels after a priming protocol with high load, low volume and low level of effort As previously shown, there is a moderate to strong relationship between maximum bar power output in the half squat and different performance markers, such as squat jump, CMJ height and 5-60m sprint time in track & field, bobsled, rugby and soccer athletes [40]. However, no research has directly measured the changes in power output with the optimal or high load after a priming session. Just a few studies have examined the time-course of bar mean propulsive velocity against different loads [12,14]. These studies consistently observed that the mean propulsive velocity displayed at moderate loads (around 1 m/s) and at high loads (75%1RM) returned to baseline performance levels after 6 hours of recovery following different training sets far from muscle failure. However, no increases in mean propulsive velocity were observed. In contrast, our data show that both MV_{80RM} and MP_{80RM} increased by 8.1% [3.2-13.3] and 9.7% [4.0-15.] respectively, after the 80% 1RM protocol. This specificity can be explained by the fact that force and velocity adaptations along the whole profile are independent of each other[23]. We therefore hypothesize that there could be a transient increase in force or velocity capacities at high loads which translates into greater power outputs.

The current study has some limitations that need to be addressed in future studies. Firstly, the lack of neurophysiological and hormonal variables limits the understanding of the observed enhancing performance effects. Secondly, only a single rest period was investigated which limits the understanding of the time-course recovery and delayed potentiation at different time points. Additionally, participants performed different numbers of repetitions due to the nature of the velocity loss-based training which complicates the identification of the load effect as the two interventions do not have the same training volume.

Although priming sessions has not been commonly used on the day of competition, our data revealed that low volume training, particularly at 80% RM loads, appears to be an appropriate stimulus for improving CMJ performance and mean velocity and power at high loads without affecting the psychological readiness of the participants. However, different individual responses were observed after the different priming sessions. Finally, and despite the statistically significant differences observed between groups, it is necessary to interpret with caution the results of the CMJ, power and velocity against the 80% 1RM. We cannot categorically conclude that the observed changes are only produced by the priming session since the calculated minimum detectable change is greater than the observed differences in the mean.

From a practical perspective our results present an opportunity to increase performance in sports where power is developed at low and high loads when the competition is carried out in the afternoon, allowing a resistance session 6 hours prior to competition-time. Practitioners could prescribe a high-load, low-volume and low level of effort squat-based priming session during the morning if they look for increased vertical jump and high-load squat performance in the afternoon.

REFERENCES

1. Suchomel TJ, Nimphius S, Stone MH. The Importance of Muscular Strength in Athletic Performance. *Sport Med*. 2016;46(10):1419-1449. doi:10.1007/s40279-016-0486-0
2. Loturco I, Nakamura FY, Kobal R, et al. Traditional Periodization versus Optimum Training Load Applied to Soccer Players: Effects on Neuromuscular Abilities. *Int J Sports Med*. 2016;37(13):1051-1059. doi:10.1055/s-0042-107249
3. Chelly MS, Fathloun M, Cherif N, Ben Amar M, Tabka Z, Van Praagh E. Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. *J strength Cond Res*. 2009;23(8):2241-2249. doi:10.1519/JSC.0b013e3181b86c40
4. Russell M, King A, Bracken RM, Cook CJ, Giroud T, Kilduff LP. A comparison of different modes of morning priming exercise on afternoon performance. *Int J Sports Physiol Perform*. 2016;11(6):763-767. doi:10.1123/ijspp.2015-0508
5. Harrison PW, James LP, McGuigan MR, Jenkins DG, Kelly VG. Prevalence and application of priming exercise in high performance sport. *J Sci Med Sport*. September 2019. doi:10.1016/j.jsams.2019.09.010
6. Harrison PW, James LP, McGuigan MR, Jenkins DG, Kelly VG. Resistance Priming to Enhance Neuromuscular Performance in Sport: Evidence, Potential Mechanisms and Directions for Future Research. *Sport Med*. 2019;49(10):1499-1514. doi:10.1007/s40279-019-01136-3
7. Fry A, Stone M, Thrus J, Fleck S. Precompetition training sessions enhance competitive performance of high anxiety junior weightlifters. *J Strength Cond Res*. 1995;9(1):37-42.
8. Saez Saez de Villarreal E, González-Badillo JJ, Izquierdo M. Optimal warm-up

stimuli of muscle activation to enhance short and long-term acute jumping performance. *Eur J Appl Physiol*. 2007;100(4):393-401. doi:10.1007/s00421-007-0440-9

9. Cook CJ, Kilduff LP, Crewther BT, Beaven M, West DJ. Morning based strength training improves afternoon physical performance in rugby union players. *J Sci Med Sport*. 2014;17(3):317-321. doi:10.1016/j.jsams.2013.04.016

10. Tsoukos A, Veligekas P, Brown LE, Terzis G, Bogdanis GC. Delayed effects of a low-volume, power-type resistance exercise session on explosive performance. *J Strength Cond Res*. 2018;32(3):643-650. doi:10.1519/jsc.0000000000001812

11. Marrier B, Durguerian A, Robineau J, et al. Preconditioning Strategy in Rugby-7s Players: Beneficial or Detrimental? *Int J Sports Physiol Perform*. 2018;14(7):918-926. doi:10.1123/ijspp.2018-0505

12. Morán-Navarro R, Pérez CE, Mora-Rodríguez R, et al. Time course of recovery following resistance training leading or not to failure. *Eur J Appl Physiol*. 2017;117(12):2387-2399. doi:10.1007/s00421-017-3725-7

13. Raastad T, Hallén J. Recovery of skeletal muscle contractility after high- and moderate-intensity strength exercise. *Eur J Appl Physiol*. 2000;82(3):206-214. doi:10.1007/s004210050673

14. Pareja-Blanco F, Rodríguez-Rosell D, Aagaard P, et al. Time Course of Recovery From Resistance Exercise With Different Set Configurations. *J Strength Cond Res*. July 2018:1. doi:10.1519/jsc.0000000000002756

15. Mason B, McKune A, Pumpa K, Ball N. The Use of Acute Exercise Interventions as Game Day Priming Strategies to Improve Physical Performance and Athlete Readiness in Team-Sport Athletes: A Systematic Review. *Sport Med*. August 2020:1-20. doi:10.1007/s40279-020-01329-1

16. González-Badillo JJ, Rodríguez-Rosell D, Sánchez-Medina L, et al. Short-term Recovery Following Resistance Exercise Leading or not to Failure. *Int J Sports Med*. 2016;37(4):295-304. doi:10.1055/s-0035-1564254

17. Linnamo V, Häkkinen K, Komi P V. Neuromuscular fatigue and recovery in maximal compared to explosive strength loading. *Eur J Appl Physiol Occup Physiol*. 1998;77(1-2):176-181. doi:10.1007/s004210050317

18. Tsoukos A, Brown LE, Terzis G, Veligekas P, Bogdanis GC. Potentiation of Bench Press Throw Performance Using a Heavy Load and Velocity-Based Repetition Control. *J Strength Cond Res*. 2020;Publish Ah.

19. Tsoukos A, Brown LE, Veligekas P, Terzis G, Bogdanis GC. Postactivation potentiation of bench press throw performance using velocity-based conditioning protocols with low and moderate loads. *J Hum Kinet*. 2019;68(1):81-98. doi:10.2478/hukin-2019-0058

20. Askow AT, Merrigan JJ, Neddo JM, et al. Effect of Strength on Velocity and Power During Back Squat Exercise in Resistance-Trained Men and Women. *J strength Cond Res*. 2019;33(1):1-7. doi:10.1519/JSC.0000000000002968

21. Teo W, McGuigan MR, Newton MJ. The effects of circadian rhythmicity of salivary cortisol and testosterone on maximal isometric force, maximal dynamic force, and power output. *J Strength Cond Res*. 2011;25(6):1538-1545. doi:10.1519/JSC.0b013e3181da77b0

22. Borg G. Psychophysical scaling with applications in physical work and the perception of exertion. In: *Scandinavian Journal of Work, Environment and Health*. Vol 16. Scand J Work Environ Health; 1990:55-58. doi:10.5271/sjweh.1815

23. Cormie P, McGuigan MR, Newton RU. Developing maximal neuromuscular

power: Part 2 training considerations for improving maximal power production. *Sport Med*. 2011;41(2):125-146. doi:10.2165/11538500-000000000-00000

24. Cormie P, McBride JM, McCaulley GO. Power-Time, Force-Time, and Velocity-Time Curve Analysis of the Countermovement Jump: Impact of Training. *J Strength Cond Res*. 2009;23(1):177-186. doi:10.1519/JSC.0b013e3181889324
25. Rahmani A, Viale F, Dalleau G, Lacour JR. Force/velocity and power/velocity relationships in squat exercise. *Eur J Appl Physiol*. 2001;84(3):227-232. doi:10.1007/PL00007956
26. Chavda S, Bromley T, Jarvis P, et al. Force-time characteristics of the countermovement jump: Analyzing the curve in excel. *Strength Cond J*. 2018;40(2):67-77. doi:10.1519/SSC.0000000000000353
27. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res*. 2005;19(1):231-240. doi:10.1519/15184.1
28. Hopkins W. Spreadsheets for analysis of validity and reliability. *Sportscience*. 2015;19:36-42.
29. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice, 3rd Edition | Pearson*. New Jersey; 2008. https://www.pearson.com/us/higher-education/program/Portney-Foundations-of-Clinical-Research-Applications-to-Practice-3rd-Edition/PGM274308.html. Accessed April 29, 2020.
30. Hopkins WG. Measures of reliability in sports medicine and science. *Sport Med*. 2000;30(1):1-15. doi:10.2165/00007256-200030010-00001
31. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. L. Erlbaum Associates; 1988.

32. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009;41(1):3-12. doi:10.1249/MSS.0b013e31818cb278

33. Behm DG, Sale DG. Velocity Specificity of Resistance Training. *Sport Med*. 1993;15(6):374-388. doi:10.2165/00007256-199315060-00003

34. Bartolomei S, Sadres E, Church DD, et al. Comparison of the recovery response from high-intensity and high-volume resistance exercise in trained men. *Eur J Appl Physiol*. 2017;117(7):1287-1298. doi:10.1007/s00421-017-3598-9

35. Latella C, Teo WP, Harris D, Major B, VanderWesthuizen D, Hendy AM. Effects of acute resistance training modality on corticospinal excitability, intra-cortical and neuromuscular responses. *Eur J Appl Physiol*. 2017;117(11):2211-2224. doi:10.1007/s00421-017-3709-7

36. Newton RU, Kraemer WJ, Häkkinen K, Humphries BJ, Murphy AJ. Kinematics, kinetics, and muscle activation during explosive upper body movements. *J Appl Biomech*. 1996;12(1):31-43. doi:10.1123/jab.12.1.31

37. Suchomel T, Taber C, Sole C, Stone M. Force-Time Differences between Ballistic and Non-Ballistic Half-Squats. *Sports*. 2018;6(3):79. doi:10.3390/sports6030079

38. Suchomel TJ, Sato K, Deweese BH, Ebben WP, Stone MH. Potentiation Effects of Half-Squats Performed in a Ballistic or Nonballistic Manner. *J Strength Cond Res*. 2016;30(6):1652-1660. doi:10.1519/JSC.0000000000001251

39. Latella C, Hendy AM, Pearce AJ, VanderWesthuizen D, Teo WP. The time-course of acute changes in corticospinal excitability, intra-cortical inhibition and facilitation following a single-session heavy strength training of the biceps brachii. *Front Hum Neurosci*. 2016;10(DEC2016).

doi:10.3389/fnhum.2016.00607

40. Loturco I, Suchomel T, Bishop C, Kobal R, Pereira LA, McGuigan M. One-repetition-maximum measures or maximum bar-power output: Which is more related to sport performance? *Int J Sports Physiol Perform*. 2019;14(1):33-37. doi:10.1123/ijspp.2018-0255

Table 1. Descriptive characteristics of training interventions

	OL		80% RM	
	Mean	SD	Mean	SD
Load that maximizes power output (%RM)	60.9	5.8	-	-
Reps Set 1	10.4	4.1	4.4	1.5
Reps Set 2	8.9	3.3	4.7	1.6
TL (AU)	2111.0	617.0	1352.0	658.0
Fastest Velocity Set 1 (m/s)	0.61	0.10	0.46	0.08
Slowest Velocity Set 1 (m/s)	0.49	0.11	0.35	0.06
Velocity Loss Set 1 (%)	20.6	4.8	25.2	6.1
Fastest Velocity Set 2(m/s)	0.61	0.10	0.45	0.10
Slowest Velocity Set 2(m/s)	0.48	0.09	0.34	0.08
Velocity Loss Set 2 (%)	22.3	3.5	24.3	4.9
RPE	7.1	1.8	7.9	2.2

Reps=Repetitions performed in each set; TL=Training Load (sets x reps x RPE), Velocity Loss=Mean percent loss in velocity from the fastest to the slowest repetition in each set; RPE=Rating of Perceived Exertion

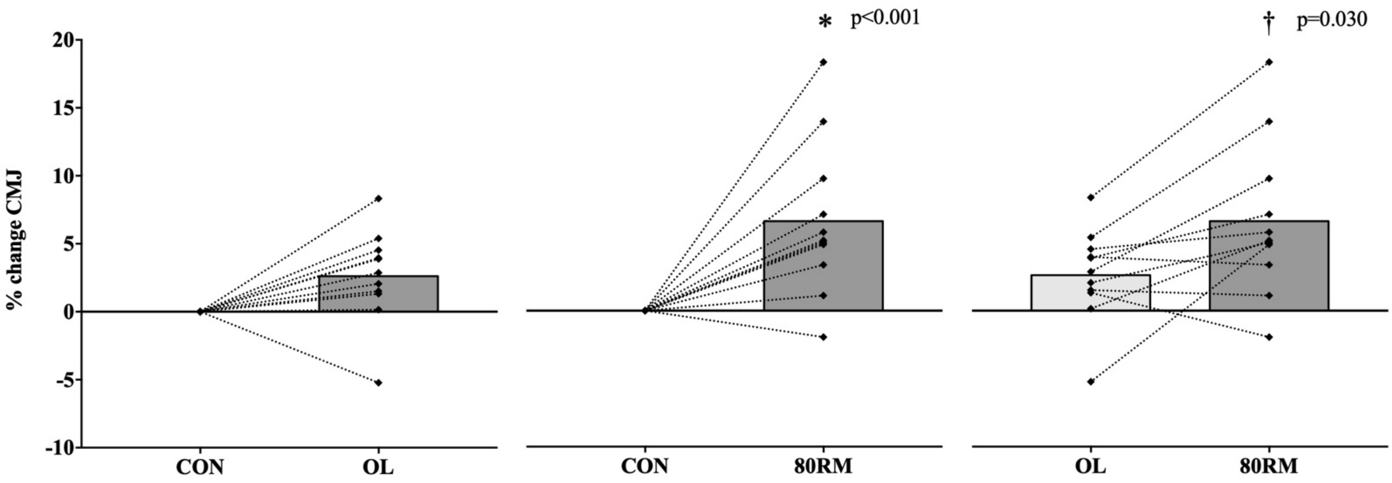
Table 2. Mechanical values after the different priming resistance sessions.

	CON		OL			80% RM			
	Mean	SD	Mean	SD	*p* vs CON	Mean	SD	*p* vs CON	*p* vs OL
CMJ (cm)	33.0	5.3	33.8	5.0	0.102	35.0	4.4	**0.006***	0.062
MP OL (W)	636.4	146.8	677.8	199.7	0.316	660.4	154.2	0.075	1.000
MV OL (m/s)	0.61	0.08	0.64	0.11	0.293	0.63	0.09	0.058	1.000
MP 80%RM (W)	569.6	182.0	590.6	197.6	1.000	618.1	180.1	**0.044***	0.436
MV 80%RM (m/s)	0.44	0.09	0.44	0.09	1.000	0.47	0.09	**0.040***	0.061

CMJ=Countermovement jump height; MP =Mean Power; MV=Mean Velocity; OL=Optimal load.

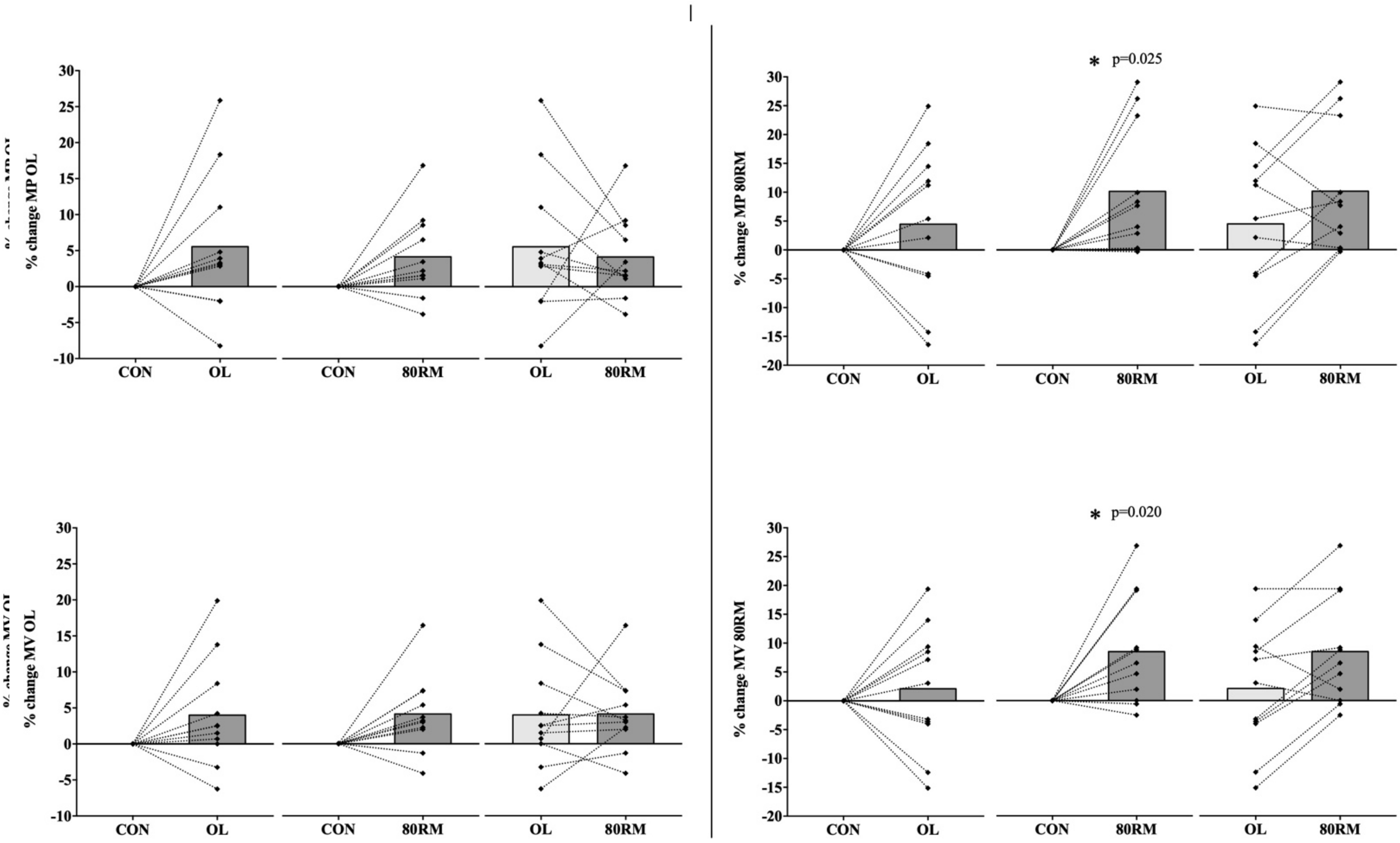
* Differences with CON ($p<0.05$)

Figure 1. Individual (lines) and mean (bar) values of percentage of change in CMJ height after different priming protocols.



* Significant differences with CON; † significant differences with OL

Figure 2. Individual (lines) and mean (bar) percentage of change of Mean Velocity and Mean Power with the OL and 80% RM after priming sessions.



* Significant differences with CON