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The Acute Effects of Velocity Loss During Half Squat Exercise on Jump Performance

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ABSTRACT

The velocity loss (VL) approach during squat exercise may increase the post-activation potentiation enhancement effect on squat jump performance. If this method succeeds, then different conditions of VL should be researched before its implementation to the field. This study hypothesized that squat jump performance would be increased after different volumed VL conditions during half-squat exercise. Eighteen resistance-trained men (mean [M] ± standard deviation [SD]; age: 24.00±3.53 years; body mass: 78.37±5.53 kg; height: 179.35±7.04 cm; one-repetition maximum (1RM) half squat: 110.85±11.92 kg) voluntarily performed squat jump under unloaded and four different VL conditions (R_6: six repetitions, R_{uf}: repetitions until failure, VL_{10}: velocity loss thresholds 10%, VL_{20}: velocity loss thresholds 20%) after a set of half-squat exercises at 80% of one-repetition maximum separated by at least 72 hours. The results revealed that subjects demonstrated significantly better squat jump performance in VL_{10}, $VL_{20,}$ and R_6 conditions than the unloaded and R_{uf} conditions ($p<0.05$). According to these findings, if coaches and sports scientists desire to increase the post-activation potentiation enhancement effect, following heavy resistance training with a VL approach, VL_{10} and VL_{20} conditions instead of the traditional repetition method for squat jump performances are recommended.

INTRODUCTION

Explosive power is a key and the most distinctive component of performance in many sports activities (Dobbs et al., 2019; Sinovas et al., 2015; Yilmaz et al., 2021), such as sprinting and vertical jumping. While vertical jump (VJ) is a crucial component of sports performance, it is also the most valid and reliable field test for the determination of explosive power of the lower limbs (Dobbs et al., 2019; Markovic et al., 2004). The high correlation of VJ with other sports components, such as weightlifting performance and sprinting speed, makes it widely used by both trainers and researchers (Boullosa et al., 2013; Dobbs et al., 2019). Even minor improvements in the explosive performances of players can cause significant differences, especially at high levels. Therefore, coaches and sports scientists examine those components' chronic and acute effects to develop effective training programs (Blazevich & Babault, 2019; Prieske et al., 2020). For example, using post-activation potentiation enhancement (PAPE) in the warm-up is one of the most preferred tools in sports science. PAPE refers to the acute positive effects of a pre-load stimulus on muscular performance, such as maximal strength, power, and speed (Atalag et al., 2021; Blazevich & Babault, 2019; Prieske et al., 2020; Zimmermann et al., 2020).

Two main factors that acutely affect sports performance are fatigue and potentiation. In contrast to potentiation, which enhances performance, fatigue has the most obvious negative effect on it (Dobbs et al., 2019; Nibali et al., 2015; Rassier & MacIntosh, 2000; Sale, 2002; Zimmermann et al., 2020). The balance between potentiation and fatigue determines muscle performance. If fatigue exists more, muscle performance may decrease (Rassier & MacIntosh, 2000; Seitz & Haff, 2016). Previous potentiation studies reported inconsistent results (Dobbs et al., 2019). One possible reason for that could be the volume strategies of those studies. There are two main approaches for adjusting the volume of pre-load. The first is the fixed number of repetitions per set with a given percentage of one-repetition maximum (% of 1RM), a daily changeable value. Coaches cannot be sure if the athletes are training with the appropriate loads in each session (Pareja-Blanco et al., 2017b). The other approach is the number of repetitions until failure (Galiano et al., 2020; González-Badillo et al., 2011; Pareja-Blanco et al., 2017b) however, it is thought that this method could not be optimal for some athletes (Davies et al., 2016; Pareja-Blanco et al., 2017b). Therefore, coaches should use new strategies that guarantee low-level fatigue and high-level potentiation to PAPE (Boullosa et al., 2013).

Studies have shown that velocity-based training (VBT) has been a good alternative to traditional repetition training in the last decades (Galiano et al., 2020; Pareja-Blanco et al., 2017a; Pareja-Blanco et al., 2017b; Sánchez-Medina & González-Badillo, 2011; Weakley et al., 2020). The repetition with velocity loss can be an objective tool to monitor the degree of fatigue (Pareja-Blanco et al., 2017a; Pareja-Blanco et al., 2017b; Weakley et al., 2020). So, it can be used to keep the balance between fatigue and potentiation. Velocity loss (VL) training ensures more remarkable power development due to reduced neuromuscular fatigue and preferential hypertrophy of type II fibers (Galiano et al., 2020; Pareja-Blanco et al., 2017a; Pareja-Blanco et al., 2017b; Sánchez-Medina & González-Badillo, 2011; Weakley et al., 2020). Thus, this method seems to be a useful and practical approach for PAPE. Not many studies examined the acute effects of VL on PAPE (Tsoukos et al., 2019, 2021). In these studies, only upper body exercises were used. Additionally, in these studies, only two different VL methods were compared. At the same time, there is no comparison of VL with traditional load strategies or any information regarding the effects of lower limb exercise. Therefore, this study aimed to evaluate the acute effect of different velocity loss (VL) thresholds as 10% (VL_{10}) and 20% (VL_{20}) with six repetitions (R_6) and repetitions until failure (R_{uf}) of half-squat (HSQ) exercises. HSQ is one of the most used exercises for PAPE on squat jump performance. It is also sport-specific because it consists of closed kinetic chain activities (Boullosa et al., 2013). The hypothesis of this current study was squat jump performance of subjects would be more significant after the VL conditions through the less volume due to lower development of fatigue than traditional repetition methods (Galiano et al., 2020; Pareja-Blanco et al., 2017a; Pareja-Blanco et al., 2017b; Weakley et al., 2020).

METHODS

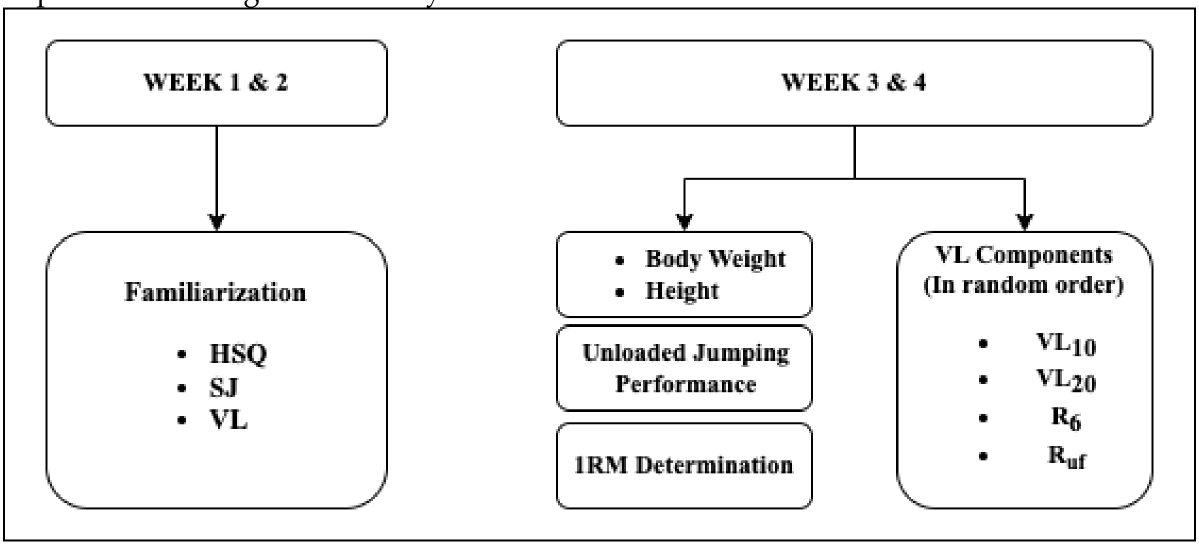
Study Group

G-Power analysis was conducted to determine the sample size for this study. According to the results of this analysis, eighteen resistance-trained men (mean ± standard deviation [SD]; age: 24.00±3.53 years; body mass: 78.37±5.53 kg; height: 179.35±7.04cm; 1RM half squat: 110.85±11.92 kg) voluntarily participated in this study. Seventeen subjects completed the entire experimental protocol, with one subject withdrawing due to performing less repetition than six in the R_{uf} condition. Subjects were required to have experience in resistance training for more than two years and were familiar with the technique involved with HSQ. They have no health problems or other injuries that would limit their participation in the study. All participants were informed about the procedures, rules, advantages, and risks of the research before providing their informed consent. The study was approved by the local University Ethics Committee of Non-Invasive Clinical Research (E.23467 - 2020) and conducted by institutional ethical requirements on human experiments consistent with the Declaration of Helsinki.

Data Collection

This study used a randomized, crossover research design to compare the acute effects of unloaded and four different velocity loss conditions (R_6: six repetitions, R_{uf}: until failure, VL_{10}: velocity loss thresholds 10%, VL_{20}: velocity loss thresholds 20%) of half-squat (HSQ) exercises at 80% of 1RM on squat jump (SJ) performance. Figure 1 shows the experimental design of this study. The subjects were asked to maintain their daily habits and avoid non-routine physical activities, alcohol, and caffeine before the all-testing sessions. Subjects participated in 4 sessions of familiarization with the HSQ and SJ for two weeks. In the first session, followed by the familiarization week, height, body mass, and one repetition maximum (1RM) HSQ were determined for each subject. During the third and fourth weeks, subjects were asked to perform SJ tests 4 minutes after the unloaded and VL_{10}, VL_{20}, R_6, and R_{uf} of HSQ. The subjects performed all the conditions randomly after a standardized warm-up, which comprised unloaded cycling for five minutes at a slow pace, five minutes series of dynamic stretches, and ten unloaded half squats. The tests of the conditions were separated by at least 72 hours. During the VL_{10}, VL_{20} conditions, and 1RM test, the bar was fitted with a Push™ accelerometer (PUSH Inc., Toronto, Canada) device.

Figure 1
Experimental Design of the Study



Note. HSQ = Half Squat; SJ = Squat jump; VL_{10} = velocity loss 10 %; VL_{20} = velocity loss 20 %; R_{uf} = repetitions until failure; R_6 = six repetitions

Data Collection Tools

One Repetition Maximum Protocol

After the standardized warm-up, the 1RM of subjects practiced in the familiarization period of this study were defined to the PUSH application (Version 7.18.0) via mobile phone. Subjects were asked to perform the movement's concentric phase with the maximum achievable speed (Balsalobre-Fernández et al., 2016). All lifts were recorded with 200 Hz (Balsalobre-Fernández et al., 2016) and automatically detected by the software (Hughes et al., 2019). Subjects performed HSQ on smith-machine equipment (Esjim, Eskişehir, Turkey - the barbell only moves along the vertical axis) with five sets of 3 repetitions at 40%, 50%, 60%, 70%, and finally 80% of the 1RM, which were defined to the software before. The rest periods between trials were 3 minutes. After determining the 1RM, subjects were asked to perform velocity-based 1RM for adapting them to the test conditions. According to their performance responses within three attempts with five minutes rest periods between trials (Bogdanis et al., 2011), the resistances were set for each subject, if needed. The push device was placed parallel to the ground, inside the barbell's left collar, on the bar's upper side (Balsalobre-Fernández et al., 2016).

Half Squat Exercise (HSQ)

At the beginning position of HSQ, subjects stand on their feet fully extended. They kept their feet roughly shoulder-width apart while holding the barbell across the top of the shoulders and upper back. Each subject was instructed to perform a countermovement to 90º of knee flexion and then return to an upright position while keeping their toes grounded (Pérez-Castilla et al., 2020). They were required to perform each repetition of the half squat exercise as fast as possible, from the first repetition until reaching muscle failure (R_{uf}), six repetitions (R_6) or 10% (VL_{10}) and 20% (VL_{20}) velocity loss. During VL_{10} and VL_{20}, the most important value was the target mean concentric velocity (MCV), which was usually the fastest and achieved on the first repetition in each session (Pareja-Blanco et al., 2017a). The set was terminated when the velocity loss limit (10% or 20% of MCV) was exceeded. Trained spotters gave subjects visual and verbal real-time velocity performance feedback and encouraged them to provide maximal effort for each repetition (Pérez-Castilla et al., 2020; Weakley et al., 2019).

Vertical Jump Test

Squat jump (SJ) is one of the most valid and reliable field tests for the determination of explosive power of the lower limbs (Tsoukos et al., 2019). Each subject executed two maximal SJs on a compact pressure-sensitive mat (Smart Speed; Fusion Sport, Brisbane, Australia) followed by a 30-second rest period. The subjects were instructed to perform maximum effort on jumping, and the highest value was recorded in centimeters. The subject was asked to keep the hands on hips throughout the test.

Velocity Measurement

The PUSH™ band is one of the devices designed to measure the velocity of body or bar movement in body weight and resistance exercise using a smartphone. PUSH provides sampling with 200 Hz via a 3-axis accelerometer and a gyroscope, which provides six degrees of freedom (6DOF; van den Tillaar & Ball, 2019). The PUSH™ calculates vertical mean concentric velocity by integrating vertical acceleration values regarding time. To calculate the mean velocity of the movement, the software takes the average of all instantaneous velocities registered (González-García et al., 2019). Balsalobre-Fernández et al. (2016) reported that PUSH™ showed a very high association (mean velocity, $r = 0.85$, $SEE = 0.08\ m \cdot s^{-1}$) and agreement (mean velocity $ICC = 0.907$) with linear position transducer. PUSH™ was found to be a highly reliable device ($ICC = 0.981$); ($CV = 5.0\%$) also showed high individual load-velocity correlation ($R^2 = 0.94$; Balsalobre-Fernández et al., 2016).

Data Analysis

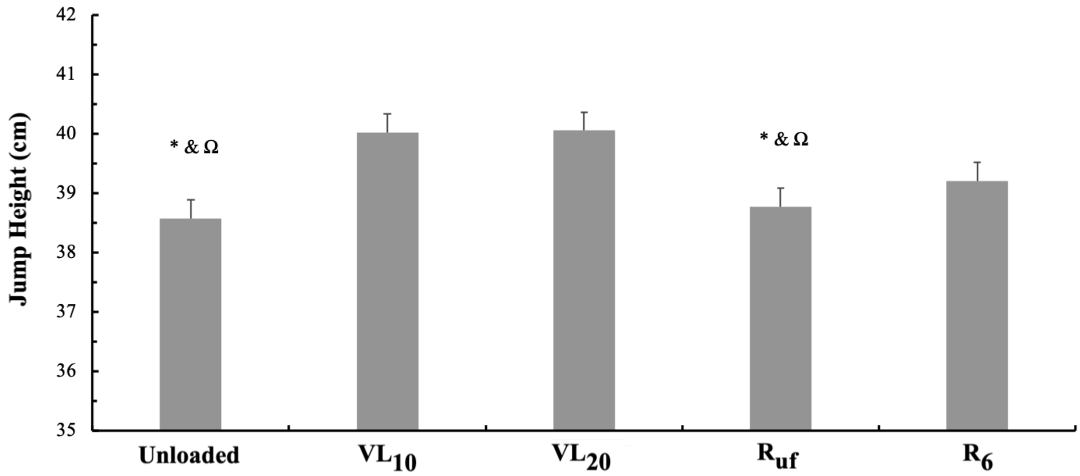
The data were reported as means and standard deviations. Before using parametric tests, skewness and kurtosis were calculated to determine the normality of the values (between -2 and +2). The differences between the five conditions (unloaded, VL_{10}, VL_{20}, R_6, R_{uf}) on SJ height were determined using a one-way analysis of variance for repeated measurements. Effect sizes (η^2) for the practical differences between conditions were calculated with descriptors of "small" for 0.01, "medium" for 0.06, and "large" for 0.14 and above (Cohen, 1988). A pairwise comparison between the five conditions was determined using the paired-t-test. Cohen's d (*d*) values were also calculated by dividing the mean differences by the standard deviation of the differences. The results were considered small = 0.20-0.49, medium = 0.50-0.79, and large = 0.8 and above (Cohen, 1988). Additionally, the reliability of measurements was determined using intraclass correlation coefficients (ICC). The dispersion of sample means was measured using the standard error of mean (SEM). The statistical significance level was set at $p < 0.05$.

RESULTS

VL_{10} and VL_{20} conditions were found to be the most effective conditions on SJ performance, whereas the lowest SJ heights were found in the unloaded and R_{uf} conditions

(Figure 2). One-way repeated analysis of variance findings indicated statistically significant differences among the five conditions regarding SJ performance (F = 9.125, p = 0.000, η^2 = 0.363, large effect; ICC = 0.995). According to paired-t comparisons, there were significant differences between SJ performance of subjects following unloaded conditions and VL_{10} (t = -5.120; p = 0.000; 95%CI = -2.045, -0.847; SEM = 1.438; *d* = 1.242, large effect), VL_{20} (t = -4.284; p = 0.001; 95%CI = -2.206, -0.745; SEM = 1.593; *d* = 1.038, large effect) and R_6 (t = -3.093; p = 0.007; 95%CI = -1.902, -0.355; SEM = 1.533; *d* = 0.750, medium effect) in exception of R_{uf} (t = -0.575; p = 0.573; 95%CI = -0.935, 0.536; SEM = 1.514; *d* = 0,139). Additionally, subjects performed significantly lower jump height in R_{uf} condition than VL_{10} (t = 4.094; p = 0.001; 95%CI = 0.601, 1.892; SEM = 1.438; *d* = 0.993, large effect); VL_{20} (t = 4.286; p = 0.001; 95%CI = 0.645, 1.907; SEM = 1.593; *d* = 1.039, large effect) and R_6 (t = -3.446; p = 0.003; 9%5CI = -1.497, -0.361; SEM = 1.533; *d* = 0.841, large effect).

Figure 2
Squat Jump Performance Following Different Pre-Load Protocols



Note. VL_{10} = velocity loss 10 %; VL_{20} = velocity loss 20 %; R_{uf} = repetitions until failure; R_6 = six repetitions; *Significantly different from VL_{10}; &Significantly different from VL_{20}; Ω Significantly different from R_6

Table 1
Average Squat Jump Height and Repetition Number of Half Squat Exercise Following Different Pre-Load Protocols

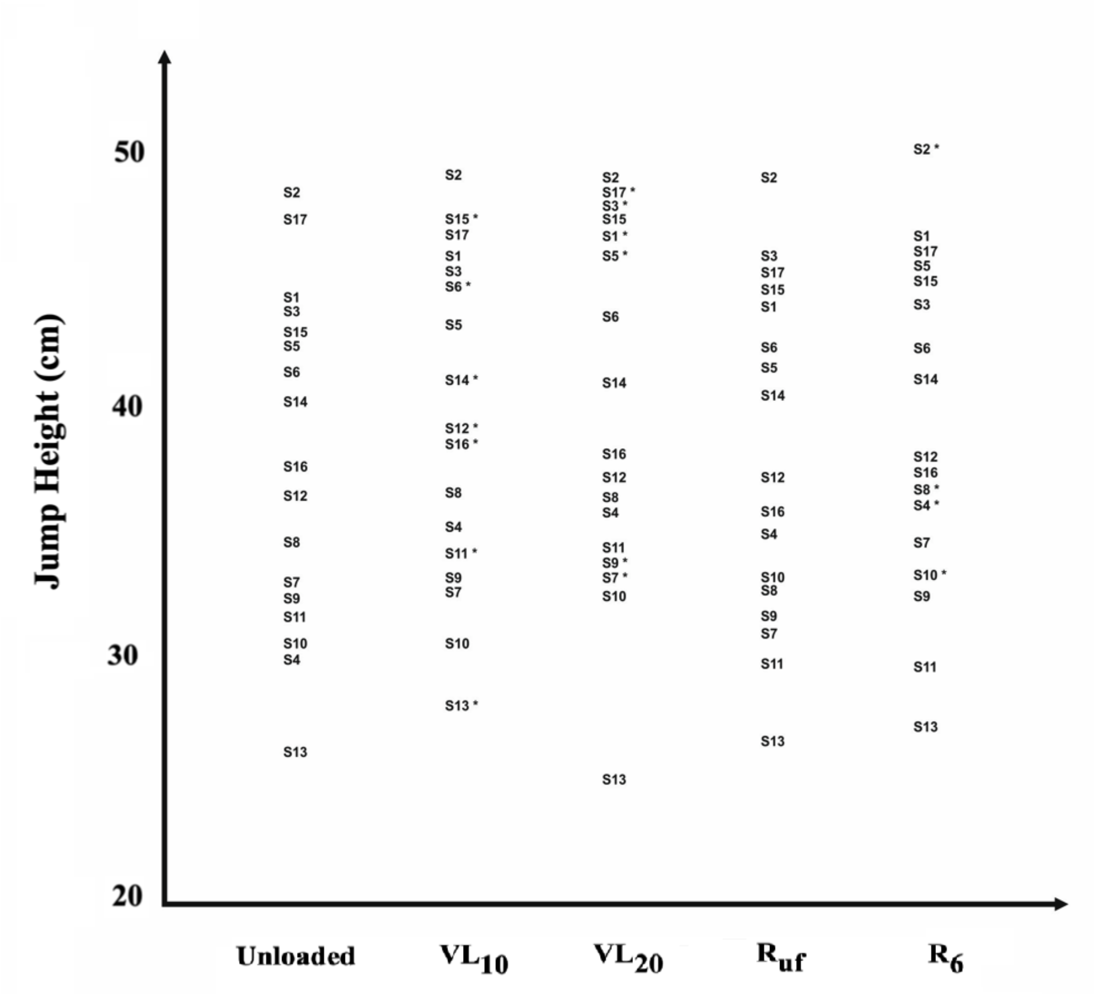
Variables	Unloaded		VL_{10}		VL_{20}		R_{uf}		R_6		ES	
	M±SD	CV (%)	M±SD	CV (%)	M±SD	CV (%)	M±SD	CV (%)	M±SD	CV (%)		
SJ (cm)	38.58±5.98	15	40.03±5.9	14	40.06±6.57	16	38.78±6.24	16	39.71±6.32	15	0.363	large
Repetition (number)			4.11±0.78	18	5.05±0.74	14	6.8±0.95	13			0.899	large

Note. SJ = Squat jump; VL_{10} = velocity loss 10 %; VL_{20} = velocity loss 20 %; R_{uf} = repetitions until failure; R_6 = six repetitions; CV = coefficient of variance; ES: Effect size

The statistically significant change in the number of repetitions across the three conditions (VL_{10}, VL_{20}, R_{uf}) is shown in Table 1 ($F = 143.038$, $p = 0.000$, $\eta^2 = 0.899$, large effect; ICC = 0.862). Obviously, subjects performed more repetitions during the R_{uf} (SEM = 0.230) condition which statistically different from both VL_{10} ($t = -13.143$; $p = 0.000$; 95%CI = -3.142, -2.269; SEM = 0.189) and VL_{20} ($t = -9.670$; $p = 0.000$; 95%CI = -2.151, -1.377; SEM = 0.181). There were also significant differences between VL_{10} and VL_{20} ($t = -16.000$; $p = 0.000$; 95%CI = -1.065, -0.816). Figure 3 displays the best SJ performance of each subject; while four subjects reached their best performances following R_6 conditions, the rest of the subjects performed the highest jump performance after the velocity loss approach (V_{10} = 7 subjects; V_{20} = 6 subjects, R_6 = 4 subjects).

Figure 3

Squat Jump Performance of Each Player in All Conditions



Note. S: Subject; VL_{10} = velocity loss 10 %; VL_{20} = velocity loss 20 %; R_{uf} = repetitions until failure; R_6 = six repetitions. *Best performance

DISCUSSION

The aim of the current study was to investigate the acute effect of velocity loss during half-squat (HSQ) exercise on squat jump performance (SJ). The main result was that the VL approach seems more appropriate than traditional repetition methods despite less volume. In addition, the fixed number repetition method is also an appropriate method to create the PAPE effect without the need for any technological devices. Finally, repetition until failure could affect the performance very little or negatively because of increased fatigue.

Squats are one of the most commonly and widely used exercises to improve performance in sports and to examine the acute effects of pre-load on jump performance in research (Crewther et al., 2011). However, previous potentiation studies examining the acute effects of squat exercise reported inconsistent results. One possible explanation is that different intensities (Fukutani et al., 2014; Lowery et al., 2012) and rest intervals (Crewther et al., 2011; Koklu et al., 2022; Lowery et al., 2012) have been used in the previous studies. On the other hand, the vertical jump could be increased if appropriate intensity (≥80% 1RM; Dobbs et al., 2019; Esformes & Bampouras, 2013; Evetovich et al., 2015; Fukutani et al., 2014; Koklu et al., 2022) and rest periods (3-7 min) are used (Bauer et al., 2019; Dobbs et al., 2019; Esformes & Bampouras, 2013; Evetovich et al., 2015; Koklu et al., 2022; Lowery et al., 2012) in pre-load squat exercise, just as the current study design. The reason for PAPE could be neuromuscular, mechanical, and biochemical factors (Beato et al., 2021). A greater rate of cross-bridge attachment due to phosphorylation of the myosin regulatory light chains occurring in type II muscle fibers during a muscle contraction, a Ca^{2+}-dependent process, could be underlying physiological mechanisms (Beato et al., 2021; Blazevich & Babault, 2019; Evetovich et al., 2015; Prieske et al., 2020; Rassier & MacIntosh, 2000; Seitz & Haff, 2016) and greater motor unit recruitment could be another reason (Beato et al., 2021; Evetovich et al., 2015; Prieske et al., 2020; Seitz & Haff, 2016). Additionally, changes in muscle temperature, muscle/cellular water content, and muscle activation could be a factor that creates PAPE (Blazevich & Babault, 2019).

While potentiation enhances performance, fatigue causes diminished performance owing to decreasing peak Ca^{2+} concentration in the myoplasm (Rassier & MacIntosh, 2000). Thus, the balance between potentiation and fatigue must be considered for PAPE (Dobbs et al., 2019). Coaches should select appropriate pre-load exercises, which may induce less fatigue and more potentiation. It is essential to monitor fatigue via velocity loss in order to quantify neuromuscular fatigue during resistance training objectively (Galiano et al., 2020; Pareja-Blanco et al., 2017a; Pareja-Blanco et al., 2017b; Sánchez-Medina & González-Badillo, 2011; Weakley et al., 2020). In a study where the acute effects of the bench press, with low and moderate loads on bench throw exercise, were examined, it is reported that V_{10} is a more effective method than V_{30} for PAPE (Tsoukos et al., 2019). Another study also reported that after heavy bench press V_{10} exercise, the bench throw performance of players improved

(Tsoukos et al., 2021). Our study results show similarities with previous studies. It could be stated that using the small velocity loss approach could be more effective than the failure rep approach due to the high lactate response and rising ammonia levels that could indicate an accelerated purine nucleotide degradation (Sánchez-Medina & González-Badillo, 2011). Moreover, there were moderate CVs in both SJ performance and number of repetitions ranging between 14 -16 and 13-18 % respectively in the current study. Figure 3 shows that appropriate approaches could be changeable for each individual. Therefore, sports scientists and coaches should consider individual differences, while configuring volume (Tsoukos et al., 2019, 2021), rest duration (Koklu et al., 2022; Lowery et al., 2012), intensity (Fukutani et al., 2014), and several sets configuration (Boullosa et al., 2013).

CONCLUSION

As this study is one of the early studies to provide knowledge of velocity-based training and the implementation of velocity loss thresholds, it has its limitations. The physiological aspects, which would explain the mechanism underlying fatigue and could have supported our results, were not measured in the current study. On the other hand, if the biomechanical analysis had also examined, the fatigue-related technical corruptions during half squat movement could have been evaluated. Additionally, the daily differentiation of 1RM was not considered, while the daily velocity loss threshold was used for the velocity loss approach.

PRACTICAL IMPLICATIONS

This study assessed how the velocity loss approach positively affects SJ performance in resistance-trained men. On the other hand, the requirements of technological devices or applications for the VL method should be taken into consideration while applying these methods. Additionally, coaches should account each player's daily first repetition’s velocity and optimum percent velocity loss. The fixed number repetition method could be a practical alternative to the VL method. Sports scientists and coaches should be careful while using the R_{uf} method; a longer rest period could be one solution to increase the effects of this method on PAPE and decrease fatigue.

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Authors' contributions

The first and second authors contributed to the study design, data collection and data analysis. The second, third and fourth authors contributed to data interpretation, drafting the manuscript and its critical revision. All authors have read and approved the final version of the manuscript.

Conflict of interest declaration

The authors declare that there is no conflict of interests.

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