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Exploring the validity of perceived velocity in lower-limb resistance exercises with a cluster-set configuration

Explorando la validez de la velocidad percibida en ejercicios de fuerza en extremidades inferiores con una configuración de cluster-set

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Abstract. This feasibility study aimed to explore the relationship between mean propulsive velocity (MPV) and a scale of perceived velocity (SPV) in back-squat and deadlift exercises performed with heavy loads during a cluster-sets resistance training (CS-RT). Twelve resistance trained males (24.1[2.94] years; 80.7[9.05] kg; 172[4.7] cm; 19.1[6.17] %BF; 4.71[2.72] years of training experience) participated. Participants visited the laboratory three times, spaced 72 to 96 hours. Load-velocity profiles for each exercise were measured in first visit. During the second and third visits, participants engaged in CS-RT sessions with different intra-set rest period (20 vs 40 seconds, randomly), and consisted of three sets of squat and deadlift exercises at 80%1-RM. Each set concluded upon reaching a 10% velocity loss on two occasions. Bayesian Pearson correlation coefficients (r), 95% credible intervals (95%CrI) and Bayes factors (BF10) were computed to assess the relationship between variables. A low positive correlation was observed between MPV and SPV in deadlift (r=0.368, 95%CrI [0.144, 0.544]), with strong evidence supporting the alternative hypothesis (BF10=20.7). Interestingly, moderate correlation values were observed in the 40-second CS-RT configuration (r=0.47, 95%CrI [0.144, 0.544]) and in the first set of the deadlift (r=0.44, 95%CrI [0.118, 0.654]). Conversely, a negligible Bayesian correlation was identified for squat (r=0.101, 95%CrI [-0.132, 0.319]), with substantial evidence favoring the null hypothesis (BF10=0.208). In conclusion, a positive correlation between MPV and SPV in deadlift during a CS-RT configuration, indicating potential utility for perceived velocity. However, velocity feedback prior SPV use and validity for squatting warrants further investigation.
Keywords: Strength training, Perception, Powerlifting, Physical performance, Cluster training.

Resumen. El objetivo fue explorar la relación entre la velocidad media propulsiva (MPV) y una escala de percepción de velocidad (SPV) en ejercicios de sentadilla y peso muerto, en entrenamiento de cluster-sets (CS-RT). Participaron doce varones (24.1[2.94] años; 80.7[9.05] kg; 172[4.7] cm; 19.1[6.17] %GC; 4.71[2.72] años de experiencia de entrenamiento). Fueron citados en tres ocasiones. El perfil carga-velocidad para cada ejercicio fue evaluado en la primera sesión. Durante la segunda y tercera sesión, desarrollaron sesiones de CS-RT con diferentes períodos de descanso intra-serie (20 o 40 segundos), y consistieron en tres series de ejercicios de sentadilla y peso muerto realizados al 80%1-RM. Cada serie concluyó al alcanzar una pérdida de velocidad del 10%. Se calcularon los coeficientes de correlación Bayesiana de Pearson (r), los intervalos de credibilidad del 95% (95%CrI) y los factores de Bayes (BF10). Se observó una correlación positiva baja entre MPV y SPV en peso muerto (r=0.368, 95%CrI [0.144, 0.544]), con fuerte evidencia que respalda la hipótesis nula (BF10=20.7). Hubo correlaciones moderadas en la configuración CS-RT de 40 segundos (r=0.47, 95%CrI [0.144, 0.544]) y en la primera serie de peso muerto (r=0.44, 95%CrI [0.118, 0.654]). Asimismo, se identificó una correlación Bayesiana insignificante en sentadilla (r=0.101, 95%CrI [-0.132, 0.319]), con evidencia sustancial a favor de la hipótesis nula (BF10=0.208). En conclusión, se encontró correlaciones positivas entre MPV y SPV en peso muerto durante una configuración CS-RT, lo que indica una utilidad potencial para la percepción de velocidad. Sin embargo, la retroalimentación de la velocidad antes del uso de la SPV y su validez en sentadilla justifican una mayor investigación.
Palabras clave: Entrenamiento de fuerza, Percepción, Powerlifting, Rendimiento físico, Entrenamiento en grupo.

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Introduction

Resistance training (RT) is an exercise modality known for its efficacy in enhancing both health and performance (Cannataro et al., 2022; Fernández-Ozcorta, Ramos-Véliz, & Nour-Frías, 2024; Kraemer, Ratamess, & French, 2002). Numerous approaches exist for prescribing its intensity, ranging from objective methods such as percentages of the one repetition maximum (%1-RM), mean propulsive velocity (MPV), to subjective indicators like the rate of perceived exertion (RPE) and repetitions in reserve (RIR) (Dewangga, Faozi, Wilger, & Medistianto, 2024; Lagally, Robertson, & Research, 2006; Suchomel, Nimphius, Bellon, Hornsby, & Stone, 2021). RT prescription methods, such as %1-RM and MPV, have demonstrated effectiveness in achieving favorable outcomes (Baena-Marin et al., 2022). However, a common referred issue in prescribing RT using %1-RM is its daily variability (Williams, Esco, Fedewa, Bishop, & Research, 2020)Therefore, velocity-based resistance training (VBRT) has emerged as a potential alternative for training load monitoring. By using MPV, VBRT offers the advantage of optimizing adaptations through real-time feedback during the sets (Suchomel et al., 2021) and preventing excessive accumulation of fatigue (Romagnoli, Civitella, Minganti, Piacentini, & Health, 2022). Assessing the movement velocity of each lift throughout the set is essential for coaches, as it enables immediate adjustments and facilitate personalized training for athletes, a capability often unattainable with other prescription methods (Bautista et al., 2016).

The applicability of VRBT has also raised the interest among researchers in the analysis of perceived velocity (Lazarus, Halperin, Vaknin, & Dello Iacono, 2021; Sindiani, Lazarus, Iacono, & Halperin, 2020). In this sense, a scale of perceived velocity (SPV) was originally developed for the bench press exercise in physically active men (Bautista et al., 2014). It is worth noting that maximum intended concentric velocity is a key requirement to optimize muscle strength and power adaptations in high-speed actions using the VBRT methodology (Baena-Marin et al., 2022; Cormie, McGuigan, & Newton, 2011). While RPE and RIR can be used to quantify perceived effort and proximity to muscular failure, as well as strongly associated to MPV (Zourdos et al., 2016), both do not account for intention to move at certain velocity. A SPV could address this limitation while also overcomes the cost barrier associated with the use of a linear position transducer when prescribing or monitoring exercises based on movement velocity.

Bautista et al. (Bautista et al., 2016) conducted a concurrent validation study involving young elite skiers at the international level, reporting the validity of the SPV during back squat exercise. In 2022, Romagnoli et al. (Romagnoli, Piacentini, & Kinesiology, 2022) demonstrated the validity of SPV in resistance-trained individuals during free-weight back squat and bench press exercises. Furthermore, this researcher group also validated a specific SVP for the back squat exercise, establishing its reliability in accurately quantifying exercise intensity, particularly at high workloads (Romagnoli, Civitella, et al., 2022). Given this SPV has been tested in traditional-sets RT, the aim of this feasibility study was to explore the relationship between MPV and SPV during lower-limb exercises (deadlift and back squat) using a cluster-set configuration and heavy loads.

Material y methods

Study design

A cross-sectional study was conducted to analyze two-point measurements of MPV and SPV data. The measurements were taken across three visits, separated by 72 to 96 hours. The first visit involved 1-RM testing and construction of load-velocity (L-V) profiles for both the back squat and deadlift exercises. The second and third visits were administered in a randomized sequence, differing only on the duration of the intra-set rest period, which was either 20 or 40 seconds. The study was designed/reported following the Consolidated Standards of Reporting Trials (CONSORT) extension to pilot and feasibility trials (Eldridge et al., 2016).

Setting

This study was carried out from November 2021 to June 2023 with the assistance of the 'Facultad de Deportes - Campus Tijuana' at the Universidad Autónoma de Baja California, Mexico. The experimental design received approval as a bachelor's thesis project from the Research Evaluation Committee (UABC-CA-341-20211021-01).

Participants

Subjects were suitable for eligibility if: i) between 18 and 35 years old; ii) physical education majors at Universidad Autónoma de Baja California; iii) residing in Tijuana (Baja California, Mexico); iv) with at least one year of experience in RT and regularly incorporate squat and deadlift exercises into their training regimen; and v) available to visit the laboratory in three separate occasions. Exclusion criteria included self-reported injuries that impeded performance of the RT exercises or use of performance- and image enhancing drugs.

All participants provided informed consent and received detailed information regarding the study's objectives, potential risks, and protection of their rights, in adherence to the latest iteration of the Declaration of Helsinki (da Silva Telles et al., 2023; Jama, 2013). Individual appointments were scheduled for participants, who were instructed to arrive dressed in appropriate sportswear for both training and measurement visits.

Cluster-sets resistance training

We followed procedures based on previous studies carried out by our research group (Bonilla et al., 2021; Vargas-Molina et al., 2020), which are described in detail as follows. A 10-minute treadmill warm up at a 4/10 intensity in the OMNI-Walk/Run scale, which corresponded to being somewhat easy (Utter et al., 2004). After this warm-up and five minutes rest, the squat specific warm up begin, by performing three sets of three repetitions with 20, 40 and 60% of their 1-RM, followed by two sets of one repetition with their 80 and 90% respectively, with three minutes inter-set rest interval. After the warmup, 1-RM was calculated based on their individual L-V profile, and five minutes rest was provided.

Cluster-sets resistance training (CS-RT) is characterized by consecutive repetitions with intra-set rest periods resulting in a total of 3–4 blocks per set (Vargas-Molina et al., 2021). In this study, participants completed three sets of back squats at 80% of their 1-RM, with instructions to stop the exercise upon experiencing a 10% velocity reduction from the highest MPV attained within the set. Subsequently, participants had an intra-set rest period of either 20 or 40 seconds (during second and third sessions based on randomization). Immediately after, participants progressed to the subsequent cluster, repeating the aforementioned process. Then, a five-minute inter-set rest interval was given. The criteria outlined in the International Powerlifting Federation Rules (2020) (Federation) were employed to determine the validity of each lift. If a lift was deemed invalid, it was repeated. After finishing each set (made of two clusters), participants were presented with the SPV and asked to indicate their perceived velocity for the completed set, with their responses duly recorded. The participants received verbal instructions and encouragement to move the barbell as fast as possible during the concentric phase. Following the completion of three sets for the squat exercise, a 10-minute rest interval was provided, and the identical procedure was replicated for the deadlift. The tempo for the squat was 2-0-X-0 and 2-2-X-1 for the deadlift.

Variables

The following variables were measured: body mass (kg), stature (cm), estimated body fat percentage (%BF), 1-RM (kg), MPV ($m \cdot s^{-1}$), and perceived movement velocity.

Data sources / measurement

Body composition

Body mass was measured in underwear to the nearest 0.1 kg using digital scale. Stature was measured to the nearest 0.1 cm with a fixed adult stadiometer BSM® 170 (InBody, Cerritos, CA, USA). The %BF was estimated through bioelectrical impedance analysis using a tetra-polar multi-frequency analyzer (InBody 770, Cerritos, CA, USA), which has shown high agreement for %BF estimation (TE = 2.5%, SEE = 2.2%) compared to the 4 compartment model in young male adults (Brewer et al., 2021).

One Repetition Maximum

The 1-RM testing was performed following previous procedures reported by our research group (Bonilla et al., 2021; Vargas-Molina et al., 2020). In brief, participants performed 12 to 15 repetitions at ~40%1-RM, followed by sets of three repetitions with progressive increases of ~10% of their 1-RM until the MPV reached 0.5 $m \cdot s^{-1}$. Upon reaching this value, participants performed sets of one repetition with additional weight increments ranging from five to 20 pounds. If a participant failed to complete a lift, the weight was reduced by 5 to 15 pounds, depending on their perception and researchers' feedback. The highest MPV attained during each rep and the corresponding relative load were used to create individual L-V profiles for each exercise. These profiles were used to predict 1-RM in the experimental visits as it has been reported previously (Benavides-Ubric, Díez-Fernández, Rodríguez-Pérez, Ortega-Becerra, & Pareja-Blanco, 2020; Fernandez Ortega, Mendoza Romero, Sarmento, & Prieto Mondragón, 2022).

Mean Propulsive Velocity

A validated linear position transducer (Speed4Lift, Madrid, Spain) (Callaghan, Guy, Elsworthy, & Kean, 2022; Perez-Castilla et al., 2019) was placed on the right side of the subjects for both exercises, with the cable positioned vertically before commencing the lifts. Data was recorded using the manufacturer's app.

Perceived Movement Velocity

The perceived movement velocity was recorded using the scale developed originally by Bautista et al. (2014) (Bautista et al., 2014). Although participants possessed a high level of RT experience, a brief familiarization with the scale was provided.

Study Size

Non-probability sampling (convenience sampling) was implemented as we have previously used in pilot studies (Bonilla et al., 2021). After the call to participate in the study at the university (e-mailing and social media), 12 subjects volunteered to participate in the study and were suitable for eligibility.

Statistical methods

The descriptive statistics are expressed as mean and standard deviation (SD). A Bayesian correlation analysis (Nuzzo, 2017) was performed to evaluate the relationship between MPV and SPV for the back squat and deadlift exercises by using all data measurements through the sets. The prior was set as all possible values of the correlation were equally likely. The Pearson correlation values were interpreted according to Mukaka (2012) (Mukaka, 2012). Following current recommendations in sport science (Bernards, Sato, Haff, & Bazyler, 2017), we report the likelihood ratio (also known as Bayes Factor [BF]) and the corresponding 95% credible intervals (95% CrI), which is the most widely accepted measure to quantify how much evidence a data set provides for a hypothesis. In our case, the BF was expressed as BF_{10} to grade the intensity of the evidence that the data provide for H_1 versus H_0 (where H_0 is the null hypothesis and H_1 is the alternative hypothesis that assumes an effect is present). All the statistical analyses were performed in Jamovi v2.3.28.0 (Jamovi Project, Sydney, Australia).

Results

A sample comprising 12 resistance-trained males with 4.7 (2.7) years of RT experience participated in this pilot study. Data collection was effectively carried out over the course of three visits. Table 1 provides the descriptive statistics pertaining to the participants in the study, while

Table 2 shows the descriptive information for the MPV and the SPV for all the sets performed by the participants.

For the back squat exercise, a negligible correlation (r = 0.101, 95% CrI [-0.132, 0.319]) was observed between MPV and SPV, with anecdotal evidence supporting the null hypothesis (BF_{10} = 0.208). Figure 1 illustrates the distribution and correlation plot between MPV and SPV after back squat with heavy loads.

Table 1.
Descriptive information of participants

Variable	n = 12 Mean (SD)	95% CI (LL, UL)
Age (years)	24.1 (2.9)	22.2, 25.9
Body Mass (kg)	80.7 (9.1)	74.9, 86.4
Stature (cm)	172.0 (4.7)	169.0, 175.0
Training experience (years)	4.7 (2.7)	2.9, 6.4
Body fat (%)	19.1 (6.2)	15.2, 23.1
Squat 1-RM (kg)	140.0 (24.9)	125.0, 156.0
Deadlift 1-RM (kg)	162.0 (22.3)	148.0, 176.0
Squat relative 1-RM ($kg \cdot kg^{-1}$)	1.7 (0.3)	1.5, 1.9
Deadlift relative 1-RM ($kg \cdot kg^{-1}$)	2.0 (0.3)	1.8, 2.2

Data are expressed as mean (SD, standard deviation). The lower limits (LL) and upper limits (UL) of the 95% confidence interval (CI) are shown.

Table 2.
Descriptive statistics of MPV and SPV

Variable	Exercise	Condition	n = 36 Mean (SD)	95% CI (LL, UL)
MPV	SQ	CL20	0.47 (0.09)	0.44, 0.50
		CL40	0.50 (0.11)	0.46, 0.54
	DL	CL20	0.46 (0.06)	0.44, 0.48
		CL40	0.46 (0.08)	0.43, 0.49
SPV	SQ	CL20	0.66 (0.27)	0.57, 0.75
		CL40	0.65 (0.28)	0.56, 0.75
	DL	CL20	0.72 (0.28)	0.62, 0.81
		CL40	0.68 (0.32)	0.57, 0.79

Data are expressed as mean (SD, standard deviation). The lower limits (LL) and upper limits (UL) of the 95% confidence interval (CI) are shown. DL, deadlift; MPV, mean propulsive velocity; SQ, back squat; SPV, scale of perceived velocity.

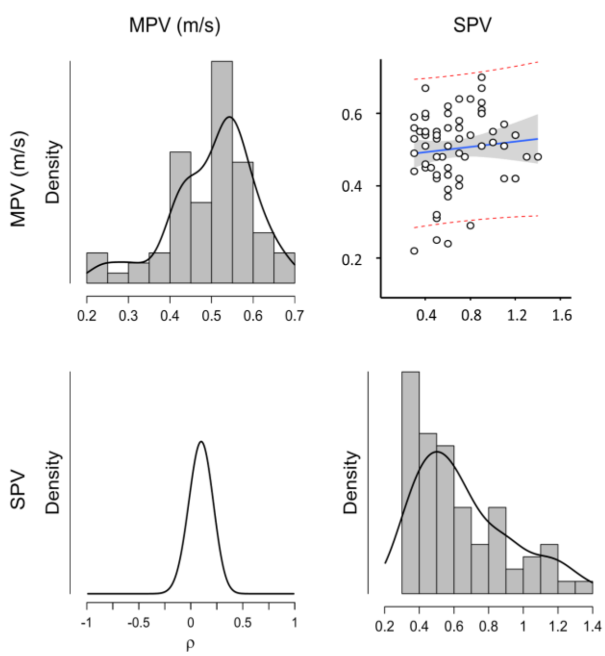

Figure 1. Correlation plots between MPV and SPV in back squat with heavy loads. Upper left and lower right show histograms with density plots of MPV and SPV respectively. Upper right shows a scatterplot with SPV in the X axis and MPV in the Y axis, including the regression line (blue line), standard deviation (grey area), and 95% confidence intervals (red dashed line). The lower left shows the posterior probability distribution of the population correlation between SPV and MPV.

For the deadlift exercise, a low positive relationship between MPV and SPV was found (r = 0.368, 95% CrI [0.144, 0.544]), with strong evidence supporting the alternative hypothesis (BF_{10} = 20.7). Figure 2 presents the distribution of the variables and the scatterplot correlation plot after the deadlift exercise with heavy loads.

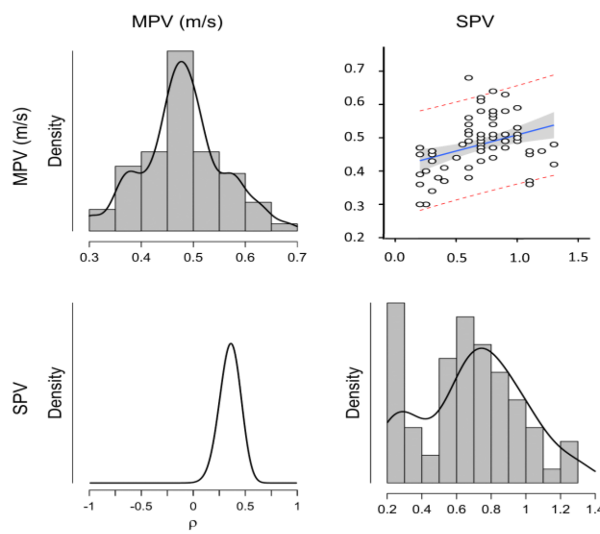

Figure 2. Correlation plot between MPV and SPV in deadlift with heavy loads. Upper left and lower right show histograms with density plots of MPV and SPV respectively. Upper right shows a scatterplot with SPV in the X axis and MPV in the Y axis, including the regression line (blue line), standard deviation (grey area), and 95% confidence intervals (red dashed line). The lower left shows the posterior probability distribution of the population correlation between SPV and MPV.

Interestingly, significantly higher correlation coefficients were observed during the first set of the deadlift (r = 0.47, 95%CrI [0.07, 0.712], BF_{10} = 3.23) and when comparing the CS-RT with a 40-second intra-set rest period to the 20-second protocol (r = 0.44, 95%CrI [0.118, 0.654], BF_{10} = 6.38 versus 0.27, 95%CrI [-0.062, 0.534], BF_{10} = 0.71, respectively) (Figure 3).

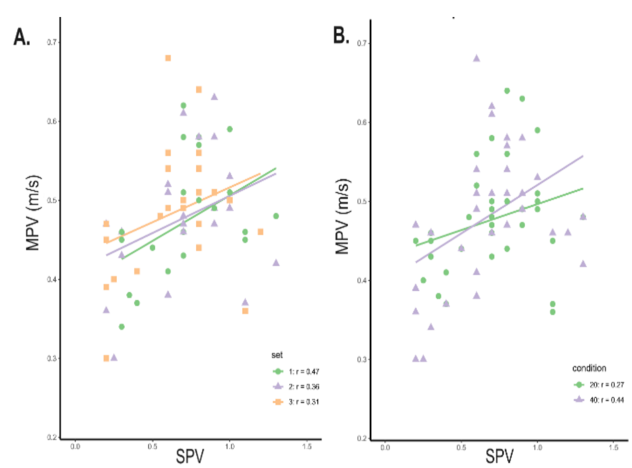

Figure 3. Correlation plots between MPV and SPV in deadlift by set (A) and by cluster-set resistance training protocol (B).

Discussion

The aim of this feasibility study was to explore the applicability of the SPV in monitoring movement velocity during lower-limb RT exercises within a CS-RT protocol using heavy loads. Results indicated a low positive Bayesian correlation between SPV and MPV in the deadlift exercise (r = 0.368, 95%CrI [0.144, 0.544], BF_{10} = 20.7). Conversely, for the back squat exercise, a negligible Bayesian correlation was observed (r = 0.101, 95%CrI [-0.132, 0.319], BF_{10}=0.208). This data will inform the experimental design of a forthcoming project focusing on CS-RT and VBRT, which will involve a larger sample size.

This study marks the first investigation into the potential utility of perceived velocity compared to actual movement velocity in a CS-RT configuration, especially during the deadlift exercise. Notably, the correlation between MPV and SPV during deadlift was observed to be higher in the initial set when contrasted with subsequent sets. Similarly, the CS-RT employing 40 seconds of intra-set rest exhibited a stronger correlation when compared to the 20-seconds CS-RT protocol. This observation suggests that fatigue levels may influence the accuracy of subjects' perception of movement velocity. To our knowledge, this aspect has not been investigated in deadlifts within a CS-RT program. This notion is reinforced by studies indicating that RPE undergoes similar increments to muscle fatigue during elbow flexion, knee extension, and squats (Zhao, Nishioka, & Okada, 2022; Zhao, Seo, Okada, & Rehabilitation, 2023), implying that as fatigue intensifies, participants' capacity to determine their movement velocity via SPV may be impaired. While the total number of repetitions may vary depending on the intra-set rest period of CS-RT, employing a shorter intra-set rest duration could augment perceived motor fatigue in the perceptual-discriminatory dimension, thereby affecting the perception of effort (Behrens et al., 2023) and potentially constraining the ability to evaluate movement velocity. This phenomenon could also explain the higher correlation observed during the initial sets, as participants did not experience cumulative fatigue from preceding sets, thereby potentially diminishing perceived motor fatigue and facilitating a more accurate response.

In general, the correlation values observed in our study are different than the ones reported by previous studies. Bautista et al. (Bautista et al., 2014) reported correlation coefficients from 0.72 to 0.78 across five days, although for the bench press. In back squat in the smith machine, a Pearson correlation coefficient of 0.93 was also found for heavy loads (Bautista et al., 2016). Similarly, a SPV for the squat reported a Pearson correlation coefficient against MPV of 0.73 to 0.82 for light loads (≥1.0 m/s), 0.74 to 0.81 for medium loads (0.6 to 0.8 m/s), and 0.79 to 0.83 for heavy loads (≤0.4 m/s) (Romagnoli, Civitella, et al., 2022). Thus, the low relationship between MPV and SPV in our study is different to those values reported in the literature (Bautista et al., 2016), indicating not good in practice at least for our study population. The difference in the results could be due to the short time for familiarization when compared to the longer time dedicated to this in previous studies; for example, Shaw et al. (2022) inferred that the absence of velocity feedback or knowledge of movement velocities might preclude participants from engaging in any memory-anchoring process, potentially contributing to their reduced accuracy relative to findings in prior literature (Shaw et al., 2023). Furthermore, the higher years of experience of the participants in our study (4.71 [2.72], 95% CI: 2.98, 6.43) and the powerlifting-based rules might have influenced decision making and ratings of perceived velocity. These results will definitively guide the next research projects on this topic.

As a feasibility study, this trial has several limitations that should be mentioned. Firstly, we exclusively assessed heavy loads (80% 1-RM), thus the generalizability of the results to other load intensities remains uncertain. Secondly, the brief familiarization period even in highly trained participants may have possibly influenced the observed outcomes. Future investigation of our group will prioritize examining the impact of movement velocities knowledge or visual feedback to potentially enhance the accuracy of the SPV. Lastly, the findings presented pertain to male participants with RT experience undergoing an intervention targeting power and maximal strength improvement. Consequently, caution should be exercised when extrapolating these findings to females or individuals seeking improvements in body composition (e.g., increases in fat-free mass).

Conclusions

The results of this feasibility study showed low positive correlations between MPV and SPV in the deadlift during a CS-RT configuration, suggesting potential utility, although with some limitations, for perceived velocity, especially in longer intra-set rest periods. However, additional investigation is required to examine the impact of velocity feedback before SPV use within a larger sample and its applicability to back squat exercise in a cluster-sets configuration.

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