VARIABILITY IN BACK SQUAT REPETITIONS PERFORMED BEFORE EXCEEDING DIFFERENT VELOCITY LOSS THRESHOLDS

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Abstract:

This study aimed to evaluate the intra-individual between-day variability in the number of repetitions performed before exceeding 10%, 20%, and 30% velocity loss thresholds (VLTs) during the back squat exercise. Thirty resistance-trained male wrestlers performed sets of repetitions to failure at 70% and 80% of their 1-repetition maximum (1RM) on two separate days. Velocity loss was calculated using as the reference either the first repetition of the set or the fastest repetition. The set termination criterion specified stopping the set after one or two consecutive repetitions exceeded the prescribed VLT. Variability in repetitions was expressed as the coefficient of variation (CV), calculated as the absolute difference between sessions divided by the average repetitions across sessions. All factors, including load (70%1RM vs. 80%1RM), reference repetition (first repetition vs. fastest repetition), and set termination criterion (one vs. two repetitions exceeding the VLT), significantly affected the number of repetitions performed for the 10%, 20%, and a 30% VLT conditions ($p<.01$). Regardless of these factors, intra-individual variability in the number of repetitions performed between sessions was consistently high ($CV > 10\%$). These findings highlight two key challenges when using VLTs in training prescription. First, specifying a VLT alone is insufficient, as the actual number of repetitions performed—which ultimately dictates adaptations—is influenced by multiple methodological factors. Second, even when methodological factors are standardized, the inherent variability in the number of repetitions performed across sessions remains high, which could impact acute fatigue responses and long-term training adaptations.

Keywords: *fatigue monitoring, linear position transducer, muscle strength, resistance training, training volume control, velocity-based training*

Introduction

Resistance training (RT) is widely accepted as an effective means of inducing neuromuscular adaptations that enhance sports performance and overall health (Deschenes & Kraemer, 2002; Kraemer, Ratamess, & French, 2014; Zhang, Li, Feng, & Su, 2022). Among the factors influencing its effectiveness, training volume and proximity to failure stand out as particularly significant (Colquhoun, et al. 2018; Grgic, Schoenfeld, Orazem, & Sabol, 2022). Traditional RT often emphasizes performing sets to failure to maximize muscle hypertrophy (Vieira, et al., 2022; Willardson, Norton, & Wilson, 2010). However, there is growing consensus that training to failure should be limited in most contexts, as less fatiguing strategies can achieve comparable or even superior outcomes (Grgic, et al., 2022). In recent years, velocity-based training (VBT) has emerged as a popular and precise method for regulating training volume and proximity to failure, offering a less fatiguing alternative to traditional approaches (Guppy, Kendall, & Haff, 2024; Weakley, et al., 2021a). VBT should be performed with maximal intended velocity to optimize neuromuscular adaptations, while maintaining technical proficiency to ensure exercise safety (González-Badillo, Rodríguez-Rosell, Sánchez-Medina, Gorostiaga, & Pareja-Blanco, 2014; Weakley, et al., 2021a). Three primary velocity-based approaches have been used for this purpose: (i) velocity loss thresholds (VLTs) (Jukic, et al., 2022), (ii) the relationship between lifting velocity and repetitions left in reserve (García-Ramos, et al., 2018), and (iii) the relationship between the maximum repetitions performed to failure and the fastest set velocity (Miras-Moreno, Pérez-Castilla, & García-Ramos, 2022). Of these, VLTs have been the most extensively studied in scientific research (Galiano, Pareja-Blanco, de Mora & de Villarreal, 2022; García-Ramos, Weakley, Janicijevic, & Jukic, 2021; Rodiles-Guerrero, et al., 2022; Rodríguez-Rosell, et al., 2021). By applying different VLTs, practitioners can target specific training adaptations and effectively manage acute fatigue (Jukic, et al., 2022). However, despite its widespread use, limited research has investigated the methodological factors that influence the practical application of VLTs.

When implementing VLTs, athletes are instructed to stop repetitions once a predetermined velocity loss (e.g., 10% or 40%) has been reached. However, the number of repetitions performed before exceeding a specific VLT can be affected by factors including gender (Rissanen, Walker, Pareja-Blanco, & Häkkinen, 2022) fatigue (Janicijevic, Cuevas-Aburto, Li, & García-Ramos, 2024a), exercise (Rodríguez-Rosell, et al., 2020), and other related states such as personality traits (Jukic, Prnjak, McGuigan, & Helms, 2023c). For instance, at a given load and VLT, male athletes performed repetitions with higher velocity, whereas female athletes completed a greater number of repetitions before reaching the same VLT (Jukic, et al., 2023c; Rissanen, et al., 2022). As fatigue accumulates, both the reference velocity and the number of repetitions performed within a given VLT decrease progressively (Janicijevic, et al., 2024a), which may alter the relationship between the VLT and the percentage of repetitions completed within a training session (Pérez-Castilla, Şentürk, Akyildiz, Jukic, & García-Ramos, 2024). Additionally, for a given individual, the number of repetitions performed before exceeding a specific VLT can vary significantly based on methodological factors, such as the selected velocity variable (e.g., mean velocity [MV] vs. peak velocity [PV]) and the reference repetition used to calculate velocity loss (e.g., the first repetition or the fastest repetition in the set). For example, García-Ramos et al. (2021) demonstrated in the bench press that participants occasionally reached failure before exceeding 15% or 30% VLT when using PV—a scenario that did not occur with MV. Additionally, when VLTs were calculated using the fastest repetition as the reference point, fewer repetitions were performed compared to using the first repetition, a discrepancy observed across exercises such as the bench press (García-Ramos, et al., 2021) and deadlift (Jukic, García-Ramos, & Tufano, 2023a). This phenomenon occurred because the fastest repetition within a set did not always occur in the first repetition, but sometimes in a subsequent repetition, such as the second or third. Consequently, the stop velocity calculated relative to the first repetition was consistently lower than that calculated relative to the fastest repetition (García-Ramos, et al., 2021). Furthermore, participants have occasionally been able to perform additional repetitions beyond a VLT when encountering these thresholds for the first time (García-Ramos, et al., 2021), prompting the question of whether sets should instead be terminated after two consecutive repetitions exceeding the threshold (Martos-Arregui, et al., 2025). These findings highlight the importance of accounting for methodological factors when prescribing training volume and proximity to failure using VLTs, as these factors can greatly influence the actual number of repetitions performed and their variability for individual athletes.

Advocates of VLT argue that adjusting the number of repetitions to terminate a set at a specific velocity loss leads to more consistent fatigue levels between individuals, compared to prescribing a fixed number of repetitions (Pareja-Blanco, Villalba-Fernández, Cornejo-Daza, Sánchez-Valdepeñas, & González-Badillo, 2019; Weakley, et al., 2019, 2020). This claim is primarily supported by the close relationship observed between velocity loss and the percentage of repetitions completed relative to the maximum possible in a set (González-Badillo, Yañez-García, Mora-Custodio, & Rodríguez-Rosell, 2017; Sánchez-Moreno, Rendeiro-Pinho, Mil-Homens, & Pareja-Blanco, 2021). However, recent research has raised concerns about the reproducibility of not only the absolute number of repetitions but also the proportion of repetitions performed relative to the maximum possible when identical VLTs are applied across different sessions (Jukic, Prnjak, King, McGuigan, & Helms, 2023b; Pearson, et al., 2020; Pérez-Castilla, Miras-Moreno, Janicijevic, & García-Ramos, 2023). Previous research has reported that the number of repetitions performed exhibits poor reliability across sessions in the real-time termination (Pearson, et al., 2020), as well as limited predictive accuracy regarding the percentage of completed repetitions under training to failure conditions at different loads (Jukic, et al., 2023b). However, to our knowledge, no study has yet investigated whether methodological factors influence the reliability of these outcomes. This suggests that, when prescribing a fixed VLT for a given relative load (e.g., 70% of the one-repetition maximum; 1RM), individuals may exhibit variability in training volume and terminate sets at differing proximities to failure, potentially leading to inconsistent training effects. Consequently, it is essential to establish robust criteria for defining VLTs to reduce between-sessions variability and ensure consistent training outcomes for the same participants.

Given the direct impact of the number of repetitions performed on acute fatigue and long-term training adaptations, it is essential to examine the number of repetitions performed and their between-day variability across different VLT methodological conditions, particularly in the Smith machine back squat. Overlooking this variability may result in substantial discrepancies between prescribed training stimuli and intended outcomes. In order to address this critical gap, the primary aim of this study was to evaluate the intra-individual between-day variability in the number of repetitions performed before set termination, which was triggered once the velocity of one or two consecutive repetitions exceeded a predetermined VLT during the back squat exercise performed in a Smith machine. Specifically, we investigated whether the number of repetitions completed and its variability across sessions were influenced by factors such as the magnitude of velocity loss (10%VLT vs. 20%VLT vs. 30%VLT), relative load (70%1RM vs. 80%1RM), the reference repetition used to calculate the VLT (the first repetition vs. fastest repetition), and the criterion for terminating the set (one vs. two consecutive repetitions exceeding the VLT). We hypothesized that both the actual number of repetitions performed and their variability would be significantly influenced by the analyzed methodological factors. Specifically, we hypothesized that using the fastest repetition as the reference would reduce the total repetitions performed, whereas the threshold requiring two consecutive repetitions would increase them relative to that of one repetition criterion. Refining these methodological criteria could help standardize training prescriptions using VLTs, minimizing variability in training volume and ensuring more consistent proximity to failure across sessions, thereby improving the reliability and effectiveness of VBT programs.

Method

Participants

The required sample size was estimated using G*Power 3.1. A repeated-measures three-way ANOVA (ANOVA: repeated measures, within factors) was specified with an assumed medium effect size (f = 0.25), significance level (α=0.05), and statistical power of 0.90 (Pearson, et al., 2020). The study design was a fully within-subjects 2 × 2 × 2 factorial design, with each participant providing data under eight conditions. The analysis indicated that a minimum of 20 participants would be required. In the present study, 30 resistance-trained male wrestlers (mean ± standard deviation [SD]; age: 22.6 ± 2.2 years; body mass: 79.9 ± 7.9 kg; height: 1.79 ± 0.05 m; parallel back squat 1RM: 164.8 ± 25.5 kg) participated in the study. The inclusion criteria required participants to be: (i) males aged 18 to 35 years, (ii) experienced in performing the parallel back squat to failure with maximal intended velocity, and (iii) free from any physical injuries or limitations that could impact their performance of the parallel back squat. These criteria were assessed and verified by a qualified researcher during the initial testing session. Throughout the study, participants were prohibited from engaging in any other form of lower-body RT. Prior to commencing, all participants were informed of potential risks and provided written informed consent. The study adhered to the principles of the Declaration of Helsinki and received approval from the Institutional Review Board.

Study design

A repeated-measures design was utilized to evaluate intra-individual variability in the number of repetitions performed before exceeding various VLTs. Participants attended the laboratory on three occasions, with a minimum of 48 hours of rest and a maximum of one week of rest between each visit. None of the participants reported delayed onset muscle soreness. The first session involved determining the parallel back squat 1RM through an incremental loading test. The second and third sessions followed the same protocol, comprising three sets of repetitions to failure with 5-minute rest intervals between sets, using sequential loads of 90%, 80%, and 70% of 1RM. Due to the low number of repetitions completed with the 90% 1RM load (4.1 ± 0.8 repetitions), it was excluded from statistical analyses due to the difficulties to use VLTs to prescribe repetitions volume. All sessions were conducted at consistent times for each participant (± 1 hour).

One-repetition maximum assessment (session 1)

After measuring body mass and height using a Seca 654 scale (Seca®, Hamburg, Germany), participants completed a standardized warm-up consisting of five minutes of jogging, lower-body joint mobilization exercises, and five, three, and two repetitions of the parallel back squat with loads equivalent to 20%, 50%, and 80% of each participant's self-perceived 1RM, respectively. Following the warm-up, participants performed 2-5 single attempts to determine their actual 1RM load, with a 5-minute rest interval between each attempt. Load increments were determined collaboratively by an experienced researcher and the participants.

The squat exercise was always performed in a Smith machine. Participants positioned their feet shoulder-width apart, ensuring the barbell was maintained in contact with the upper back in a high-bar position. They were instructed to descend smoothly until their thighs were parallel to the floor, followed by an upward phase executed with maximal intended velocity, without jumping.

Assessment of sets of repetitions to failure (sessions 2 and 3)

The second and third sessions were identical. A standardized warm-up was performed at the beginning of each session consisting of jogging and, lower-body joint mobilization exercises. Participants then completed one set of 10, three, and one repetitions of the parallel back-squat exercise performed against 30% 1RM, 70% 1RM, and 90% 1RM, respectively. After warming up, subjects rested for three minutes and then performed single sets of repetitions to failure. Momentary concentric failure was explicitly defined as the point at which participants could no longer complete a full repetition with proper technique (e.g., failure to achieve parallel depth, excessive forward trunk flexion, or a prolonged barbell stall ≥2 s) despite maximal voluntary effort. Participants were instructed to perform all repetitions with maximal intended velocity. The MV of each repetition was measured by GymAware linear position transducer (GymAware PowerTool, Kinetic Performance Technologies, Canberra, Australia), affixed perpendicular to the barbell of the Smith machine. The MV was calculated as the average velocity from the initial positive movement until it reached 0 $m \cdot s^{-1}$. Subjects received MV feedback immediately after performing each repetition to motivate them to give maximal effort. Subjects were not informed of the specific VLTs and received no cues or instructions regarding set termination criteria at any point during the experiment. Two trained spotters were present on each side of the barbell to ensure safety and encourage subjects to complete the maximum possible number of repetitions.

Data analysis

This study focused on two dependent variables: (i) the actual number of repetitions performed, and (ii) the variability in repetitions across sessions. Both variables were analyzed separately for each combination of load (70% and 80% 1RM) and velocity loss threshold (10%, 20%, and 30% VLT). Two additional methodological factors were considered. First, the reference repetition used to calculate velocity loss was either the first repetition of the set or the fastest repetition of the set. Second, the set termination criterion specified stopping the set after one or two consecutive repetitions exceeded the prescribed VLT. Variability in the number of repetitions was expressed as two-session coefficient of variation (CV), calculated for each individual as the absolute difference in repetitions performed between session 1 and session 2, divided by the average number of repetitions performed across the two sessions, and multiplied by 100 to express as a percentage. This approach is appropriate for quantifying between-day variability with only two testing sessions and has been widely used in sport science reliability research (Srinivasan, Rudolfsson, & Mathiassen, 2015).

Statistical analyses

Descriptive data are presented as means (SD). The Shapiro-Wilk test revealed that most variables violated the normality assumption ($p<.05$). To address this issue, Box-Cox transformations were applied to all variables separately for each VLT condition before conducting statistical analyses. A three-way repeated measures ANOVA was conducted separately for each VLT (10% VLT, 20 %VLT, and 30% VLT) to compare the actual number of repetitions performed across different conditions: load (70% 1RM vs. 80% 1RM), reference repetition (first repetition vs. fastest repetition), and set termination criterion (one vs. two repetitions), and the Bonferroni correction was applied for multiple comparisons. The analysis considered the average number of repetitions performed across both sessions. Additionally, three separate three-way repeated measures ANOVAs were performed to analyze the variability (CV%) in repetitions between the two sessions for each VLT (10%, 20%, and 30%) under the same conditions (load, reference repetition, and set termination criterion), and the Bonferroni correction was applied for multiple comparisons. This analytical approach was chosen for two reasons: (1) VLTs represent distinct training fatigue and adaptations, and combining them may violate assumptions of variance homogeneity and obscure condition-specific effects; (2) analyzing each threshold independently aligns with applied practice, as practitioners typically prescribe a single VLT per training phase rather than comparing multiple thresholds within the same session. Variability was classified as low if the CV was < 10% (Hopkins, Marshall, Batterham, & Hanin, 2009)

All statistical analyses were conducted using SPSS (version 25.0; IBM Corp, Chicago), with statistical significance set at p<.05.

Results

The fastest repetition velocity was almost always achieved during the first or second repetition of the set (Table 1).

The ANOVAs conducted on the actual number of repetitions performed revealed significant main effects of load (greater values at 70%1RM compared to 80%1RM), reference repetition (greater values for the first repetition compared to the fastest repetition), and set termination criterion (greater values for two repetitions compared to one repetition exceeding the threshold) for the three VLTs (10%, 20%, and 30% VLT) (Table 2). Significant interaction effects were found for load × set termination criterion at 10% and 30% VLT (differences between 70%1RM and 80%1RM were larger using the one-exceeding set termination criterion than the two-exceeding set termination criterion) and reference repetition × set termination criterion at 10% and 20% VLT (differences between the one-exceeding and two-exceeding set termination criteria were more pronounced when the fastest repetition was used as the reference point compared to using the first repetition).

None of the conditions showed low between-day variability in the number of repetitions performed at the group level (CV > 10%) (Table 3). The ANOVA for the 10% VLT condition revealed statistical significance for the main effect of the reference repetition (p=.007; lower variability for the fastest repetition compared to the first repetition) and for the interaction between the reference repetition and the set termination criterion (p=.003; the lower variability for the fastest repetition was more pronounced when using the two-exceeding set termination criterion). The ANOVA for the 20% VLT condition did not reach statistical significance

Table 1. Repetition number at which the fastest velocity output was achieved

Session	Repetition	70%1RM	80%1RM
Session 1	1	13 (43.3%)	23 (76.7%)
	2	14 (46.7%)	5 (16.7%)
	3	1 (3.3%)	2 (6.7%)
	4	1 (3.3%)	0 (0.0%)
	5	1 (3.3%)	0 (0.0%)
Session 2	1	21 (70.0%)	21 (70.0%)
	2	5 (16.7%)	6 (20.0%)
	3	1 (3.3%)	2 (6.7%)
	4	2 (6.7%)	1 (3.3%)
	5	1 (3.3%)	0 (0.0%)

Table 2. Number of repetitions performed for the 10%, 20%, and 30% velocity loss threshold (VLT) conditions

VLT	Load (%1RM)	Reference repetition	Set termination criterion		ANOVA	
			1-exceeding	2-exceeding	Main effect	Interaction
10%	70%	First	6.5 ± 2.2	7.8 ± 2.2	**L: F = 60.8, p < 0.001**	L×R: F = 0.2, p = 0.693
		Fastest	5.9 ± 1.3	7.3 ± 1.5	**R: F = 15.6, p < 0.001**	**L×S: F = 29.9, p < 0.001**
	80%	First	4.0 ± 1.1	5.1 ± 1.2	**S: F =159.7, p < 0.001**	**R×S: F = 7.4, p = 0.011**
		Fastest	3.8 ± 0.9	5.0 ± 1.1		L×R×S: F = 0.3, p = 0.562
20%	70%	First	9.8 ± 2.2	11.2 ± 2.1	**L: F = 126.0, p < 0.001**	L×R: F = 3.7, p = 0.065
		Fastest	9.4 ± 2.1	11.1 ± 2.0	**R: F = 16.6, p < 0.001**	L×S: F < 0.1, p = 0.968
	80%	First	5.8 ± 1.3	6.8 ± 1.1	**S: F = 207.9, p < 0.001**	**R×S: F = 5.4, p = 0.028**
		Fastest	5.8 ± 1.3	6.8 ± 1.1		L×R×S: F = 3.5, p = 0.073
30%	70%	First	12.2 ± 2.1	13.5 ± 1.7	**L: F = 369.9, p < 0.001**	L×R: F = 2.4, p = 0.132
		Fastest	12.0 ± 2.1	13.4 ± 1.7	**R: F = 8.2, p = 0.008**	**L×S: F = 11.2, p = 0.002**
	80%	First	7.2 ± 1.2	7.9 ± 1.0	**S: F = 87.9 p < 0.001**	R×S: F = 1.6, p = 0.222
		Fastest	7.2 ± 1.2	7.9 ± 1.0		L×R×S: F = 0.4, p = 0.530

Note. L – load; R – reference repetition; S – set termination criterion. Significant differences (p<.05) are emphasized in bold.

Table 3. Between-days variability in the number of repetitions performed for the 10%, 20%, and 30% velocity loss threshold (VLT) conditions

VLT	Load (%1RM)	Reference repetition	Set termination criterion		ANOVA	
			1-exceeding	2-exceeding	Main effect	Interaction
10%	70%	First	24.3 ± 21.4%	30.8 ± 25.6%	L: F= 0.3, p = 0.572	L×R: F = 1.5, p = 0.231
		Fastest	24.8 ± 21.6%	23.0 ± 15.6%	**R: F = 8.4, p = 0.007**	L×S: F = 0.2, p = 0.623
	80%	First	28.3 ± 24.1%	30.6 ± 24.6%	S: F = 0.9, p = 0.343	**R×S: F = 10.7, p = 0.003**
		Fastest	22.6 ± 22.8%	20.0 ± 17.5%		L×R×S: F = 0.5, p = 0.472
20%	70%	First	19.8 ± 17.5%	24.6 ± 20.4%	L: F < 0.1, p = 0.826	L×R: F = 0.3, p = 0.573
		Fastest	19.0 ± 16.8%	23.1 ± 16.1%	R: F = 0.1, p = 0.786	L×S: F = 3.3, p = 0.078
	80%	First	22.0 ± 19.5%	22.5 ± 23.3%	S: F = 1.8, p = 0.188	R×S: F = 0.3, p = 0.573
		Fastest	21.3 ± 19.2%	20.0 ± 20.7%		L×R×S: F = 1.3, p = 0.267
30%	70%	First	15.3 ± 11.8%	14.8 ± 13.5%	L: F < 0.1, p = 0.875	L×R: F = 0.9, p = 0.338
		Fastest	16.4 ± 11.6%	14.6 ± 11.7%	R: F = 0.3, p = 0.594	L×S: F = 3.8, p = 0.062
	80%	First	19.1 ± 12.1%	11.2 ± 9.2%	**S: F = 7.7, p = 0.010**	R×S: F < 0.1, p = 0.980
		Fastest	18.3 ± 11.8%	11.1 ± 8.5%		L×R×S: F = 0.8, p = 0.367

Note. L – load; R – reference repetition; S – set termination criterion. Significant differences (p<.05) are emphasized in bold.

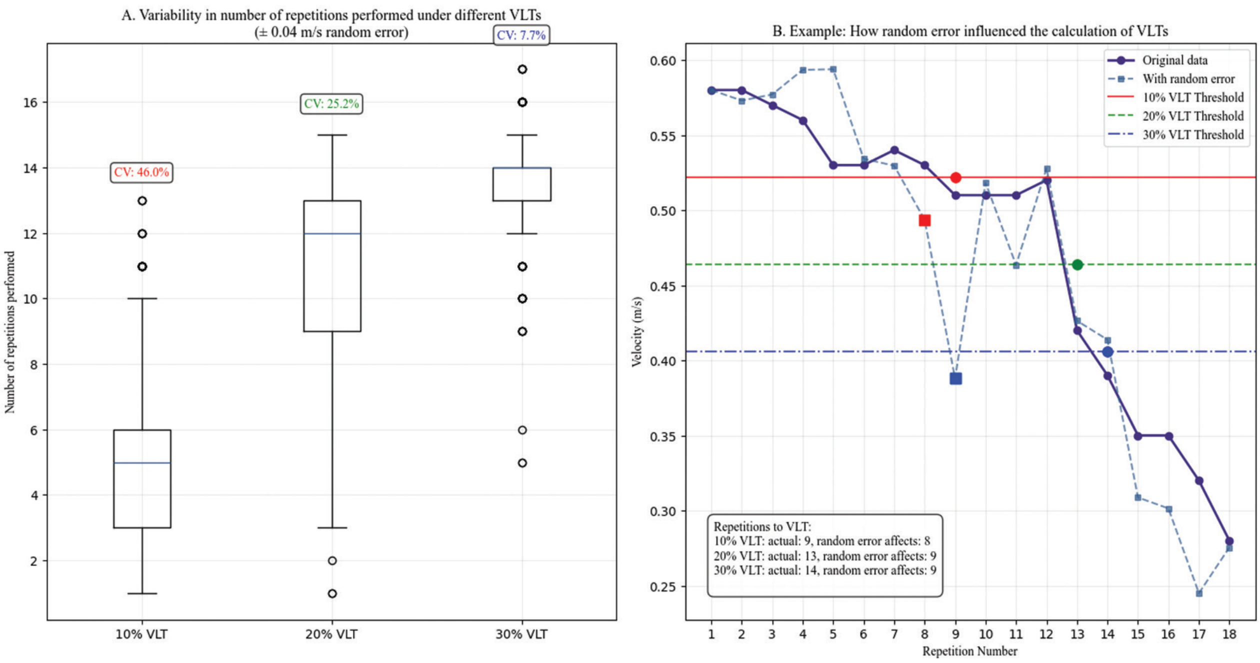

Figure 1. Effects of velocity loss thresholds (VLT) on the number of repetitions performed and related variability: (A) Box plot summarizing the distribution of total repetitions completed across all simulations; (B) Velocity-repetition series from a representative single simulation trial (ε = 0.04 m/s).

(p≥.078). Finally, the ANOVA for the 30% VLT condition revealed a main effect for the set termination criterion (p=.010; lower variability for the two-exceeding set termination criterion).

Discussion and conclusions

This study was designed to explore the number of repetitions performed and their between-day variability when reaching 10%, 20%, and 30% VLTs during the back squat exercise on a Smith machine. Load, reference repetition, and set termination criterion all impacted the number of repetitions performed at the given VLTs. Lower loads, with the first repetition as the reference and the two-repetition set termination criterion, allowed for a greater number of repetitions to be performed at the given VLTs. Although the mentioned methodological factors slightly affected the intra-individual between-day variability of the number of repetitions performed at the given VLTs, the variability always exceeded the acceptable criterion (CV > 10%).

Aligning with common knowledge and previous research, our study found that the number of repetitions performed at a given VLT decreased with increasing load (Pareja-Blanco, et al., 2019; Rodríguez-Rosell, et al., 2020; Sánchez-Medina & González-Badillo, 2011). Additionally, given that the fastest velocity did not always occur in the first repetition (Table 1) (García-Ramos, et al., 2021; Jukic, et al., 2023a), using the velocity of the first repetition as the reference consistently led to a lower stopping velocity and a higher number of repetitions performed. In our study, using the first repetition as the reference resulted in a lower stopping velocity, with an average difference of around 0.01 m s^{-1} compared to the fastest repetition criterion. Individual differences in magnitude ranged up to 0.03 m s^{-1}. This caused an average difference of up to half a repetition between the two conditions. Unsurprisingly, athletes complete more repetitions using the two-exceeding set termination criterion. However, the differences often exceeded one repetition because, as seen in the bench press exercise (García-Ramos, et al., 2021), athletes sometimes performed additional repetitions beyond a VLT when encountering these thresholds for the first time. In summary, the number of repetitions performed at fixed VLTs is significantly affected by methodological factors, including the load lifted, the reference repetition, and the set termination criterion.

All significant interaction effects on the number of repetitions performed at a given VLT were related to the set termination criterion. Specifically, changing the set termination criterion from one to two repetitions exceeding the threshold led to significantly greater differences in the number of repetitions completed at 70% 1RM compared to 80% 1RM under both the 10% and 30% VLT conditions. The cause of this interaction effect differed between the 10% and 30% VLTs. For the 10% VLT, athletes at 70% 1RM were able to complete additional repetitions with velocities above the stopping velocity after initially exceeding it, leading to more repetitions being counted below the stopping velocity. This was less likely at 80% 1RM, where athletes struggled to regain velocity once the threshold had been exceeded. In contrast, for the 30% VLT, athletes sometimes reached failure before encountering the VLT at 80% 1RM, which was less common at 70% 1RM, as their failure velocity was typically below the velocity corresponding to the 30% VLT.

Another significant interaction effect was observed between reference repetition and set termination criterion at 10% and 20% VLTs. Specifically, using the first repetition as the reference resulted in a lower stopping velocity, leading to a greater increase in the number of repetitions performed when the set termination criterion was changed from one to two, compared to using the fastest repetition as the reference. However, this difference was less pronounced at 30% VLT. One possible explanation for the non-significant interaction effect at 30% VLT was its proximity to failure. Previous study by Jukic et al. (2023c) have reported that, as approaching failure, athletes often experienced a rapid decline in velocity, which frequently terminated following only a few slow repetitions. At lower VLTs (10% and 20%), reference repetition choice exerted a stronger influence, as athletes remained further from failure and could often complete additional repetitions above the VLT even after the velocity of the repetition exceeded the threshold for the first time. In contrast, at 30% VLT, athletes were already near exhaustion. Consequently, regardless of the reference repetition used, their capacity to perform further repetitions exceeding the VLT was severely limited. Building on previous research showing that the effect of reference repetition velocity is more pronounced in low-repetition sets (<12RM) compared to high-repetition sets (>12RM) (García-Ramos, et al., 2021), our findings further revealed that changing the set termination criterion from one to two also led to a greater increase in repetitions performed for low-repetition VLTs (10% and 20%) compared to high-repetition VLTs (30%).

None of the conditions (VLT, load, reference repetition, or set termination criterion) contributed to achieve acceptable intra-individual variability in the number of repetitions performed across sessions. This high intra-individual variability aligns with previous findings in exercises such as free-weight squat (Jukic, et al., 2023c) and Smith bench pull (Pérez-Castilla, et al., 2022). However, variability was somewhat reduced when using the fastest repetition as the reference and a two-exceeding set termination criterion at 10% VLT. This improved consistency with the fastest repetition is expected, as the fastest velocity does not always occur in the first repetition, particularly with lighter loads (García-Ramos, et al., 2021). Additionally, the two-exceeding set termination criterion showed lower variability, especially at 30% VLT. This can be attributed to the fact that many athletes reached failure (100% of completed repetitions) before completing two repetitions exceeding the 30% VLT, particularly when using 80% of 1RM. For example, our study found that using the first repetition as the reference point meant that four participants reached failure before reaching 30% VLT in session 1. These findings suggest that while some strategies slightly reduce variability, none consistently achieve an acceptable level of reliability in repetition performance across sessions.

Between-day variability in the number of repetitions performed at a given VLT might result from measurement errors or inherent fluctuations in strength performance. Relative to the load-specific reference velocity (e.g., ~0.6 m s^{-1} at 70% 1RM and ~0.5 m s^{-1} at 80% 1RM), the absolute decrease in mean velocity required to reach the VLTs ranged from approximately 0.05 to 0.20 m s^{-1}. However, previous research reported that the velocity measurement devices used in this study had a standard error of measurement of 0.04 m s^{-1} when compared to gold-standard motion capture systems (Orange, et al., 2020). Additionally, the smallest detectable change (SDC) for back squats ranged from 0.02 m s^{-1} to 0.06 m s^{-1} (Banyard, Nosaka, Vernon, & Haff, 2018; Orange, et al., 2020). These errors might compromise the precision required for effective regulating repetition volume through VLTs. To better illustrate the influence of measurement device error on variability, a simulation is presented in Figure 1. However, many of the devices currently used in experiments and training exhibit comparable or greater measurement errors (Weakley, et al., 2021b). In addition, we maintained the same load across sessions instead of ensuring consistent barbell velocity at the beginning of the set. Considering the variability in athletes' daily readiness, this approach led to variability in the velocity of the fastest repetition for some load (Janicijevic, Şentürk, Akyildiz, Weakley, & García-Ramos, 2024b). This fluctuation in velocity might be reflected in changes in maximal strength capacity, making it challenging to maintain stable repetition output for a given VLT across varying %1RM conditions. Utilizing velocity anchors may provide a more consistent and reliable approach. Only one study compared the repetitions performed under the same VLTs for the fixed velocity. However, Pearson et al. (2020) also found poor reliability in the number of repetitions performed at a given starting velocity (0.7 m s^{-1}) concluding the sets when reaching the 10%, 20%, and 30% VLT over a four-week mesocycle.

Hence, practitioners should interpret session-to-session fluctuations in repetition performance with caution, as they may reflect inherent measurement noise rather than true changes in muscular endurance or fatigue resistance. Furthermore, inconsistencies in the applied training stimulus across sessions may further contribute to these variations, underscoring the need for careful contextualization before making programmatic adjustments.

Finally, some limitations and directions for future research should be addressed. This study utilized fixed loads to evaluate the between-day variability in repetitions performed under different VLTs. However, daily fluctuations in strength performance exist, being possible that the relative load was not identical in both sessions. Therefore, future research should consider using a given velocity as the basis for comparison rather than fixed loads. Additionally, this study only examined the variability in repetitions performed within three sets consisting of training to failure in the given session, which might cause fatigue in the following set. Considering that training sessions typically involve multiple sets, further research should investigate the variability as the number of sets increases. Lastly, the findings of this study are limited in their applicability to male athletes, lower-body movements, and machine-based exercises. To enhance generalizability, future research should include female athletes, upper-body movements, and free-weight exercises.

In conclusion, the number of repetitions performed at 10%, 20%, and 30% VLTs was influenced by several methodological factors, including load (70% 1RM vs. 80% 1RM), reference repetition (the first vs. the fastest), and set termination criterion (one vs. two repetitions exceeding the VLT). These findings indicate that specifying a VLT alone is insufficient, as the actual number of repetitions performed is significantly impacted by these variables. Moreover, high intra-individual variability (CV > 10%) in the number of repetitions performed across sessions was observed regardless of the methodological conditions. This inherent variability could influence acute fatigue responses across sessions and potentially affect long-term training adaptations. Given these findings, using VLT to prescribe RT volume may not ensure a consistent number of repetitions performed and volume control across training sessions. While these findings offer practical insights for VLT-based prescription, they should be interpreted within the context of the studied population and exercise modality.

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