Comparison of velocity-based and traditional 1RM-percent-based prescription on acute kinetic and kinematic variables

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Original Article

Comparison of Velocity-Based Training Methods and Traditional 1RM-Percent-Based Training Prescription on Acute Kinetic and Kinematic Variables

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Running Title: VBT and Traditional Strength Training Methods

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ABSTRACT

Purpose: This study compared kinetic and kinematic data from three different velocity-based training (VBT) sessions and a 1-repetition maximum (1RM) percent-based training (PBT) session using full-depth, free-weight back squats with maximal concentric effort. **Methods:** Fifteen strength-trained men performed four randomized resistance-training sessions 96-hours apart: PBT session involved five sets of five repetitions using 80%1RM; load-velocity profile (LVP) session contained five sets of five repetitions with a load that could be adjusted to achieve a target velocity established from an individualized LVP equation at 80%1RM; fixed sets 20% velocity loss threshold (FS_{VL20}) session that consisted of five sets at 80%1RM but sets were terminated once the mean velocity (MV) dropped below 20% of the threshold velocity or when five repetitions were completed per set; variable sets 20% velocity loss threshold (VS_{VL20}) session comprised 25-repetitions in total, but participants performed as many repetitions in a set as possible until the 20% velocity loss threshold was exceeded. **Results:** When averaged across all repetitions, MV and peak velocity (PV) were significantly ($p<0.05$) faster during the LVP (MV: ES=1.05; PV: ES=1.12) and FS_{VL20} (MV: ES=0.81; PV: ES=0.98) sessions compared to PBT. Mean time under tension (TUT) and concentric TUT were significantly less during the LVP session compared to PBT. FS_{VL20} session had significantly less repetitions, total TUT and concentric TUT than PBT. No significant differences were found for all other measurements between any of the sessions. **Conclusions:** VBT permits faster velocities, avoids additional unnecessary mechanical stress but maintains similar measures of force and power output compared to strength-oriented PBT.

Key Words: Load-Velocity Relationship, Back Squat, Load Monitoring, Training Volume, Resistance Training

INTRODUCTION

Determining training loads within a periodized programme allows strength coaches to target specific attributes, optimize adaptation and allow for recovery.[1] A common method to determine resistance-training loads known as percent-based training (PBT), prescribes relative submaximal loads from a one-repetition maximum (1RM). Even though 1RMs are valid, reliable and require no monitoring equipment, they are time consuming when conducted with large groups. Moreover, maximal strength can fluctuate daily when fatigued or significantly increase within a few weeks due to training adaptation.[2] Consequently, training when fatigued, or continued training based on an outdated 1RM may not optimize the neuromuscular stimuli required to maximize adaptation. For these reasons, alternative methods for prescribing training loads have been established.

For example, repetition maximum training (RM) requires an athlete to perform a prescribed number of repetitions in a set (e.g. 8-10RM) until concentric muscular failure (RM training). Although this method accounts for sessional adjustment of training load, it may require an athlete to perform multiple sets to reach the target RM load. Furthermore, research suggests that RM training sets can reduce the force generating capacity in subsequent training sets and may diminish maximal strength development in well-trained athletes.[3-5] More recently, adjusting training loads based on an athlete's rating of perceived exertion (RPE) has become an alternative to PBT, since it allows for the modification of sessional loads based on an athlete's perceptual readiness to train.[6,7] Although RPE-based methods are valid and reliable, they can be problematic since they are subjective and also require a prescribed number of repetitions in a set to be completed until adjustments can be made. Therefore, an approach that uses instantaneous repetition feedback to objectively prescribe training loads could optimize adaptation and avoid training to failure.

Due to advancements in commercially available kinetic and kinematic measuring devices, it is now possible to provide instantaneous feedback during training for numerous variables such as movement velocity. Accordingly, recent literature has explored the use of immediate feedback employing velocity-based training (VBT) methods to objectively manipulate resistance-training loads within a training session.[8-11] If an exercise is performed with maximal concentric effort and fatigue ensues, the barbell velocity of the movement will decrease within a set.[3,5] As greater movement velocities with a given load increase the neuromuscular stimuli and adaptations to strength training,[8] decreases in movement velocity can be detrimental. Therefore, VBT can be used to monitor barbell velocity and avoid performing repetitions to concentric muscular failure if the training target is to optimize maximal strength and power development, particularly in well-trained athletes.[4]

One VBT approach is characterized by the cessation of a working set if mean concentric velocity (MV) of a repetition falls below a pre-determined velocity loss threshold.[12] For example, Padulo et al.[2] implemented a 20% velocity loss threshold and showed that maintaining at least 80% of MV during training results in greater increases in bench press 1RM compared to RM training. Similarly, Pareja-Blanco et al.[9] also showed that using a 20% velocity loss threshold resulted in similar increases in strength but greater increases in power output compared to a 40% velocity loss threshold. To further elaborate, two variations of the velocity loss threshold method have been introduced.[12] The variable sets velocity loss threshold (VS_{VL}) method includes a fixed training load and total number of repetitions, but allows for an indefinite number of sets, each finishing when a repetition drops below a pre-determined maximum percent velocity loss.[11] This method allows an athlete to spread the total number of repetitions across multiple sets, allowing for greater recovery time, enabling an athlete to perform all of the prescribed repetitions with faster movement velocities. Comparatively, the fixed sets velocity loss threshold (FS_{VL}) method includes a pre-determined training load and number of sets, but does not have a prescribed number of repetitions. This method requires an athlete to perform repetitions in a set until they are no longer able to produce the required velocity.

Importantly, MV and individualized load-velocity profiles (LVP) have been shown to be reliable,[13-15] yet no research has explored the use of the LVP as a method to adjust training load. It is proposed that if velocity targets are not met according to the individualized LVP during a training session then training load can be adjusted to meet these targets.[14] For example if the velocity is lower than the velocity from the individualized LVP, the training load can be reduced. Alternatively, if the velocity output during a training session is faster than the target velocity then the training load can be increased. Previous VBT research has individualized training volume prescription (number of repetitions per set)[9-11] but notably, no research has used velocity to individualize training load prescription (load-velocity relationship). Additionally, participants within these studies have used a Smith machine and not a large mass free-weight barbell exercise. This is important to discern since free-weight exercises are extensively utilized in practice with most athletes and often require movements in both the vertical and horizontal planes, which may produce different velocity, force and power outputs. Furthermore, no studies have compared VBT to more traditional PBT methods.

Therefore, the objective of this study was to compare the effects of the LVP, FS_{VL}, VS_{VL} and PBT methods on the mechanical capacities of the lower body during a typical strength-oriented training session in a free-weight exercise. Based on the results of previous research,[9-11] we hypothesized all three VBT training methods would result in greater movement velocities and power outputs, but the LVP and FS_{VL} methods would result in the completion of less work and time under tension compared to a PBT session since it is conceivable that lighter loads (LVP method) or fewer repetitions (FS_{VL} method) would be completed.

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METHODS

Participants

Fifteen resistance-trained male volunteers participated in this study (age: 25.1±3.9y, height: 179.7±6.7cm, body mass: 83.9±10.6kg) and performed the full depth back squat with a mean knee flexion angle of 121.8±9.4° as measured by a handheld plastic goniometer. Their mean 1RM was 151.3±22.2 kg which was normalized to 1.83±0.29 per kg of body mass (range = 1.55 to 2.43 per kg of body mass). The participants had 6.7±2.2 years of resistance training experience ranging from one to three sessions per week and were free from musculoskeletal injuries. Each participant gave written informed consent prior to volunteering, which was in accordance with the ethical requirements of the Institutional Human Research Ethics Board. The protocols for this study also adhered to The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Experimental Design

A randomized crossover design was chosen where volunteers completed all four conditions. Participants visited the laboratory for a 1RM session, load-velocity profile (LVP) assessment and four randomized strength-oriented training sessions. Participants were afforded 48h rest following the 1RM and LVP assessments, but 96h rest between the four testing sessions to allow for sufficient recovery. Experimental sessions included: 1RM-percent-based training (PBT); load-velocity profile (LVP); fixed sets 20% velocity loss threshold (FS_{VL20}); variable sets 20% velocity loss threshold (VS_{VL20}) (Table 1).

Session One: One-Repetition Maximum (1RM) Assessment

Participants performed all repetitions in a power cage (Fitness Technology, Adelaide, Australia) using a 20kg barbell (Eleiko®; Halmstad, Sweden). Prior to the 1RM assessment, participants performed warm-up procedures consisting of five minutes pedaling on a cycle ergometer (Monark 828E cycle ergometer; Vansbro, Dalarna, Sweden) at 60-revolutions per minute and 60W, three minutes of dynamic stretching and 10 full depth bodyweight squats. Participants then commenced the 1RM assessment, comprising sets estimated at 20%1RM (3-repetitions), 40%1RM (3-repetitions), 60%1RM (3-repetitions), 80%1RM (1-repetition), and 90%1RM (1-repetition).[16] This was then followed by the first 1RM attempt with five 1RM attempts permitted. After successful 1RM attempts, barbell load was increased in consultation with the participant between 0.5 and 2.5kg. The last successful lift with correct technique and full depth was classified as the 1RM load. Two minutes passive rest was allocated between all warm-up sets, but three minutes between 1RM attempts. Participants were required to keep the barbell in constant contact with the superior aspect of the trapezius muscle and their feet with ground contact at all times. The eccentric phase of the squat was performed in a controlled manner but once full knee flexion was achieved, the concentric phase was completed as fast as possible.

Session Two: Load-Velocity Profile (LVP) Assessment

Recent research has reported that MV of the free-weight back squat is reliable at 20%1RM, 40%1RM, 60%1RM, 80%1RM and 90%1RM but not 100%1RM.[14] Therefore, it was recommended that individualized LVPs should be developed using MV from 20%1RM to 90%1RM. Consequently, participants came to the laboratory and performed the same cycling and dynamic warm-up protocols as session one, followed by back squat sets using 20%1RM (3-repetitions), 40%1RM (3-repetitions), 60%1RM (3-repetitions), 80%1RM (1-repetition) and 90%1RM (1-repetition) with two minutes passive recovery given between sets. The 1RM assessment (session one) allowed for accurate relative 1RM loads to be lifted for the LVP assessment. For sets that included more than one repetition (i.e. 20%1RM, 40%1RM, and 60%1RM), the repetition with the fastest MV was utilized for the LVP.[17] The individualized

LVP's were constructed by plotting MV against relative load and then applying a line of best fit to the data (Microsoft Excel 2016, Microsoft, Redmond, Washington, USA). A linear regression equation was then calculated and used to modify the training load in the LVP experimental session.

Sessions Three, Four, Five, and Six: Experimental Sessions

At the commencement of the randomized sessions, participants performed the identical cycling, dynamic stretching and bodyweight squat warm-up protocols to sessions one and two. Participants then performed warm-up squat sets with maximal concentric effort using 20%1RM (3-repetitions), 40%1RM (3-repetitions), 60%1RM (3-repetitions), and 80%1RM (1-repetition) prior to all experimental testing sessions. Following these squat sets, two minutes rest was given before the commencement of an experimental session. The rest period between each training set was two minutes and the time between repetitions within a set was approximately two seconds for the VBT sessions as well as the PBT session. All squat repetitions in every session were performed with a self-selected, controlled eccentric velocity to full depth (knee angle = 122.5 ± 8.3º, squat depth = 707 ± 57mm), which did not differ between sets or sessions ($p>0.05$). The concentric phase for every repetition in all sessions was performed with maximal effort immediately after the eccentric phase. In addition, all participants were verbally encouraged to perform each repetition with maximal effort but no participant was provided or able to observe any velocity feedback in any session. However, participants were instructed to terminate a set if velocity targets were not met (FS_{VL20} or VS_{VL20} session) and the load was adjusted if velocity targets were not met (LVP session), and the load was adjusted if velocity targets were not met (LVP session), indicating that the subjects could figure out whether their velocity of the previous set was above or below the threshold.

The PBT session involved five sets of five repetitions (25-repetitions) using 80%1RM. During this protocol, MV was measured, but did not dictate changes in the external load, number of sets, or number of repetitions.

For the LVP training session, participants performed five sets of five repetitions, but with a load that (when performed with maximal intent) achieved an individualized target velocity that was established from the individual's LVP regression equation at 80%1RM (established in session two). If the difference in MV during the warm-up at 80%1RM was $\pm 0.06 m \cdot s^{-1}$ compared to the target velocity at 80%1RM according to the individualized LVP (as reported by Banyard et al.[14]), the first set's training load was adjusted by ±5%1RM. Otherwise, the relative load for the initial training set was kept at 80%1RM. Once a set of five repetitions was completed, the load for the subsequent set could be adjusted by ±5%1RM if the average of the MV for the five repetitions of the previous set was $\pm 0.06 m \cdot s^{-1}$ the target velocity at 80%1RM according to the LVP. In this manner, all participants completed 25-repetitions, but the load of subsequent sets could be adjusted according to the MV of the preceding set's repetitions.

The FS_{VL20} session was similar to the PBT session where individuals completed five sets using 80%1RM. However, sets were terminated once the MV of a repetition dropped below 20% of the threshold velocity or when five repetitions in the set were completed at or above the threshold velocity. When a set was terminated the participant was instructed to cease from squatting and rack the barbell. In this manner, it was possible for participants to complete all 25-repetitions, or fewer.

In the VS_{VL20} session, participants completed 25-repetitions in total, but they performed as many repetitions in a row as possible until the threshold velocity loss (20%) was exceeded. In this manner, participants completed 25-repetitions in as few sets as possible. The 20%

velocity loss threshold for the FS_{VL20} and VS_{VL20} sessions was determined from the MV of the single repetition performed at 80%1RM in the experimental protocol warm-up.

Data Acquisition

All kinetic and kinematic data were collected during the concentric phase of the squat unless noted otherwise using similar methodology to previous research.[18-20] This included MV and peak velocity (PV) measures that were captured from four linear position transducers (LPTs) (Celesco PT5A-250; Chatsworth, California, USA) mounted to the top of the power cage with two positioned in an anterior and posterior location on both the left and right side of the barbell. The eccentric phase of each repetition commenced at zero displacement (standing) and was completed at maximal displacement (greatest descent) whereas the concentric phase began at maximal displacement and terminated at zero displacement. Time under tension (TUT) was calculated by adding the time spent during the eccentric (ETUT) and concentric (CTUT) phases of each repetition. The sum of the time under tension for the respective phases was also calculated for the session (sETUT, sCTUT and sTUT) (Figure 5). Mean force (MF) and peak force (PF) were acquired from the quantification of ground reaction forces with the use of a force plate (AMTI-BP6001200, Watertown, Massachusetts, USA). Mean power (MP) was calculated as the average and peak power (PP) measures were calculated from the product of force and bar velocity. Mean total work (MW) and total session work (TW) were calculated by integrating the area under the force-displacement curve during the eccentric and concentric phases of each repetition.[21] The sum of the total session load (TL) and mean session load (ML) were also established. The LPT and force plate data were collected through a BNC-2090 interface box with an analogue-to-digital card (NI-6014; National Instruments, Austin, Texas, USA) and sampled at 1000Hz. All data were collected and analyzed using a customized LabVIEW program (National Instruments, Version 14.0). All signals were filtered with a 4^{th}

order-low pass Butterworth filter with a cut-off frequency of 50Hz. The total tension on the barbell as a result of the transducer attachments (23.0N) was accounted for in all calculations. Mean values of velocity, force and power were determined as the average data collected during the concentric phase of the repetition. Contrastingly, peak values of velocity, force and power were determined as the maximum value during the concentric phase of the lift. MV, PV, MF, PF, MP, PP, ML, MW, ML, ETUT, CTUT, and TUT were calculated as the average of all repetitions for each individual within a session (Figure 1-5), whereas TL, TW, sETUT, sCTUT and sTUT were calculated by totaling the respective data from all repetitions for each individual in a session (Figure 4 and 5).

Statistical Analyses

For all dependent variables a repeated measures ANOVA was used to identify any differences between the four experimental protocols with a type-I error rate set at $\alpha \leq 0.05$. Holm's Sequential Bonferoni post hoc comparisons were used when appropriate.[22] Effect sizes (ES) (±95% confidence intervals) were calculated using Cohen's *d* which was interpreted as trivial (≤0.2), small (0.21-0.59), moderate (0.60-1.19), large (1.2-1.99) or very large (≥2.0).[23] Data analyses were performed using a statistical software package (SPSS version 22.0, IBM, Armonk, NY, USA). Data are reported as mean ±SD unless stated otherwise.

RESULTS

The load, number of sets, number of repetitions per set, and total session repetitions for each experimental session is shown in Table 2. There was no adjustment of training load for the first set of the LVP session for any participants, indicating the MV at 80%1RM in the warm-up was within the smallest detectable difference range (±0.06 $m \cdot s^{-1}$ at 80%1RM). Significantly fewer repetitions were performed during FS_{VL20} (23.6 ± 2.0 repetitions) compared to all other sessions (25-repetitions) (Table 2). During VS_{VL20}, participants completed the 25-repetitions in 4.3±0.9 sets (range = 3 to 6 sets) (Table 2). Session time was significantly shorter during VS_{VL20} (9:02 ± 1:55 min) than PBT (10:36 ± 0:19min), LVP (10:34 ± 0:22 min), and FS_{VL20} (10:21 ± 0:55 min). Compared to PBT (MV: 0.53 ± 0.06 $m \cdot s^{-1}$; PV: 1.04 ± 0.04 $m \cdot s^{-1}$), MV and PV were significantly faster during LVP (MV: 0.60 ± 0.06 $m \cdot s^{-1}$, ES = 1.05; PV: 1.09 ± 0.04 $m \cdot s^{-1}$, ES = 1.12) and FS_{VL20} (MV: 0.58 ± 0.05 $m \cdot s^{-1}$, ES = 0.81; PV: 1.10 ± 0.06 $m \cdot s^{-1}$, ES = 0.98) (Figure 1). TUT and CTUT was significantly less during LVP compared to PBT (Figure 5). Significant differences were also observed between PBT and FS_{VL20} for sTUT and sCTUT (Figure 5). There were no significant differences between any of the sessions for all other variables.

DISCUSSION

The major findings from the present study were that participants could sustain significantly faster MV and PV for repetitions performed during LVP and FS_{VL20} compared to PBT. In addition, the same two VBT methods allowed participants to perform repetitions with significantly less mechanical stress (CTUT, TUT, sCTUT, sTUT) while still completing similar amounts of work (MW, TW) to PBT. The FS_{VL20} session also resulted in significantly fewer repetitions than all other methods. Furthermore, no significant differences were observed for measurements of force (MF, PF), power (MP, PP) and training load lifted (ML, TL) between any of the experimental sessions. Consequently, the LVP and FS_{VL20} methods appear to be more favorable than PBT for athletes performing strength-oriented training sessions due to faster movement velocities, less mechanical stress but still enduring similar measures of force, power, work and training load.

The significantly higher MV (ES = 1.05) and PV (ES = 1.12) observed during the LVP session compared to the PBT session can be attributed to subtle decreases in load (~5%1RM) between sets, yet the total load lifted was not significantly less. By comparison, the significantly higher movement velocity observed during FS_{VL20} compared to PBT (MV: ES = 0.81; PV: ES = 0.98) were due to the strict 20% velocity loss threshold which resulted in the completion of significantly fewer repetitions (23.6 ± 2.0 vs 25). It is difficult to determine the "optimal" resistance-training dose to maximise strength and power development since there are so many factors that influence adaptation. However, research investigating this phenomenon in the back squat and weightlifting exercises have established that performing a moderate volume of repetitions could be more beneficial than performing an unnecessarily high number of repetitions (high volume).[24,25] For example, Pareja-Blanco et al.[10] had 16 resistance trained professional male soccer players perform six weeks (18 sessions, ranging from ~50 to ~70%1RM) of back squat training and were evenly assigned into two groups, which differed by a 15% or 30% velocity loss threshold in each training set. Subsequently, the 15% velocity loss group trained with significantly fewer repetitions (total repetitions: 251.2 ± 55.4 vs 414.6 ± 124.9; mean repetitions/set: 6.0 ± 0.9 vs 10.5 ± 1.9) and at faster movement velocities (AV: 0.91 ± 0.01 $m \cdot s^{-1}$ vs 0.84 ± 0.02 $m \cdot s^{-1}$), yet had significantly greater increases in maximal strength (estimated 1RM squat) and power output (CMJ height) compared to the 30% velocity loss group. In light of these findings, coaches can monitor velocity and employ velocity loss thresholds so that immediate feedback can help inform accurate training volume decisions where limiting repetitions performed at slower movement velocities and maximizing the number of repetitions performed at faster velocities may produce greater increases in strength and power adaptations over time.

The LVP and FS_{VL20} sessions also resulted in significantly less mechanical stress compared to PBT session, evidenced by less CTUT (Figure 5). In accordance with the load-velocity relationship, the lower mechanical stress observed during the LVP session was a consequence of the subtle training load reduction (ML and TL) which was not statistically different to the PBT session (ES = 0.00 – 0.34). Contrastingly, the significantly lower mechanical stress (sCTUT and sTUT) during FS_{VL20} compared to PBT was due to the completion of fewer repetitions (ES=1.01). A potential limitation of reduced mechanical stress associated with the LVP and FS_{VL20} sessions is the reduced training stimulus required to maximize muscle hypertrophy.[26] For example, Pareja-Blanco et al. (2017) had 22-resistance-trained males perform eight weeks (16-sessions, ranging from ~68 to ~85%1RM) of the back squat exercise on a Smith machine (back squat 1RM: 106.2 ± 13.0kg, 1RM to body mass ratio: 1.41 ± 0.19) with the training groups only differing by the allowed velocity loss threshold in each set (20% vs 40%). The 40% velocity loss-training group performed significantly more repetitions (total repetitions: 310.5 ± 42.0 vs 185.9 ± 22.2; mean repetitions/set: 6.5 ± 0.9 vs 3.9 ± 0.5) and had significantly greater hypertrophy of Vastus Lateralis and Intermedius muscles (9.0% increase in muscle volume) compared to the 20% velocity loss group (3.4% increase) which was not surprising since they completed significantly more work by performing 40% more repetitions.[26] These findings indicate that completing fewer repetitions or reducing mechanical stress would likely result in less muscular development, suggesting that the FS_{VL20} method and parameters employed in the present study may not be beneficial for hypertrophic-oriented training. However, Pareja-Blanco et al.[9] also found that the 20% velocity loss training group maintained significantly faster movement velocities (MV: $0.69 \pm 0.02 m\cdot s^{-1}$ vs $0.58 \pm 0.03 m\cdot s^{-1}$), had similar increases in maximal strength (18.0% vs 13.4%) and had significantly greater improvements in CMJ height (9.5% vs 3.5%) compared to the 40% velocity loss group. Therefore, although more repetitions maximized muscle hypertrophy, more repetitions did not lead to additional strength gains and may not be advantageous for adaptations associated with explosive, powerful movements.

Although the present study did not investigate the chronic effects of these protocols, it is possible to hypothesize the rationale for adopting the LVP, FS_{VL20} and VS_{VL20} training sessions for strength and power development in a strength-oriented training cycle. The phosphagen system in the human body is the predominant energy system responsible for explosive movements desired to maximize increases in strength and power output.[1,27] This energy system typically lasts for up to 10 seconds of maximal effort and when depleted, coincides with rapid decreases in movement velocity.[27] If energy stores are depleted without sufficient recovery, it is speculated that training under energy depletion and excessive velocity loss could induce adaptations towards slower, more fatigue resistant fibre types. This is particularly important for athletes whose training goal is primarily focused on explosive force production associated with strength and power training and not on maximizing muscle hypertrophy. In addition, increased muscular development could be problematic for athletes required to maintain a specific body mass and furthermore, the greater mechanical stress which does not lead to greater increases in strength may cause unnecessary fatigue and prolong recovery time. Therefore, in order to optimize strength and power development, a coach can employ PBT and prescribe a lower number of repetitions per set, or VBT (e.g. LVP, FS_{VL20} and VS_{VL20}) with objective repetition velocity feedback to reduce the amount of velocity loss in a training session so that the required energy system and preferential targeting of Type IIX fibers can be utilized to maximize strength and power development.[9,12]

Importantly, participants completed the VS_{VL20} session in a significantly shorter amount of time (~90 seconds shorter) compared to the other sessions, yet there were no significant differences in MV, PV, MF, PF, MP, PP, ML, TL, MW, TW, ETUT, CTUT, or TUT between VS_{VL20} and all other sessions. This additional 90seconds per exercise (e.g. ~9minutes for 6 exercises) could potentially be reallocated to another training modality or an additional exercise: something that could be valuable during time-restricted strength sessions. Although some may argue that it takes more time to implement VBT compared to PBT due to setting up the devices, these steps can be done by the strength and conditioning staff before training, which does not increase an athlete's training time. However, in the present study there were two participants who took longer (6-sets) than the five sets prescribed in the other experimental sessions. Even though VS_{VL20} required participants to complete as many quality (highest possible velocity output against a given load) repetitions in as few sets as possible, the VS_{VL20} training method can allow for flexibility in determining the optimal repetition scheme to accommodate daily fluctuations in performance.[28] As such, the VS_{VL20} method allowed these two participants to complete fewer repetitions per set, allowing for more recovery time to complete the prescribed total number of repetitions with higher velocity outputs. By contrast, VS_{VL20} also allowed the other 13-participants to complete 25-repetitions in fewer sets than the other experimental methods. Therefore, VS_{VL20} could be preferred over PBT since it integrates a more objective, individualized approach based upon an athlete's readiness to train.

The inclusion of VBT methods over PBT may raise some potential limitations with its use in large groups. For example, all VBT methods require specialized equipment to accurately monitor movement velocity, and an athlete or coach must modify the training load or repetition volume based on the velocity outputs. Additionally, the LVP method requires individualized mathematical calculations, but these are no more difficult than the calculations required for PBT load prescription. Nevertheless, monitoring devices are becoming more affordable and the latest devices now provide instantaneous feedback making it simple to employ the VBT methods from the present study. For instance, velocity-monitoring tools can report the average MV of a set, making it easy to compare with a prescribed target velocity (LVP method). Furthermore, some devices even allow for a specified velocity loss threshold to be set prior to training (e.g. FS_{VL20} and VS_{VL20}), expediting their use during training.

PRACTICAL APPLICATIONS

The present study shows that the VBT methods employed in the present study may serve as an alternative to more traditional strength-oriented PBT sessions. Specifically, the

LVP and FS_{VL20} methods permitted individuals to perform repetitions with faster velocities across the entire training session compared to PBT, while performing repetitions with less mechanical stress but maintaining similar measures of force and power output. Alternatively, the VS_{VL20} method had similar kinetic and kinematic data compared to PBT and the other VBT methods but could be completed in a significantly shorter time period which could benefit individuals with time constraints. However, it must also be acknowledged that the use of VBT methods requires time to set up the equipment prior to training which is not required for PBT sessions.

CONCLUSIONS

The present study revealed that individuals employing the LVP and FS_{VL20} VBT methods could reduce mechanical stress and maintain significantly faster movement velocities during a training session compared to PBT. In addition, VS_{VL20} elicited similar training responses to the other experimental sessions, yet was completed in a significantly shorter time. Therefore, VS_{VL20} could be viewed as a viable training method for athletes who are pressured for time. As a consequence, the use of VBT allows one to modify training, accounting for the current state of the neuromuscular system. Results from the present study show that LVP and FS_{VL20} VBT methods can be employed in a strength-oriented training phase to diminish fatigue-induced decreases in movement velocity that can occur in training based on 1RM percentages.

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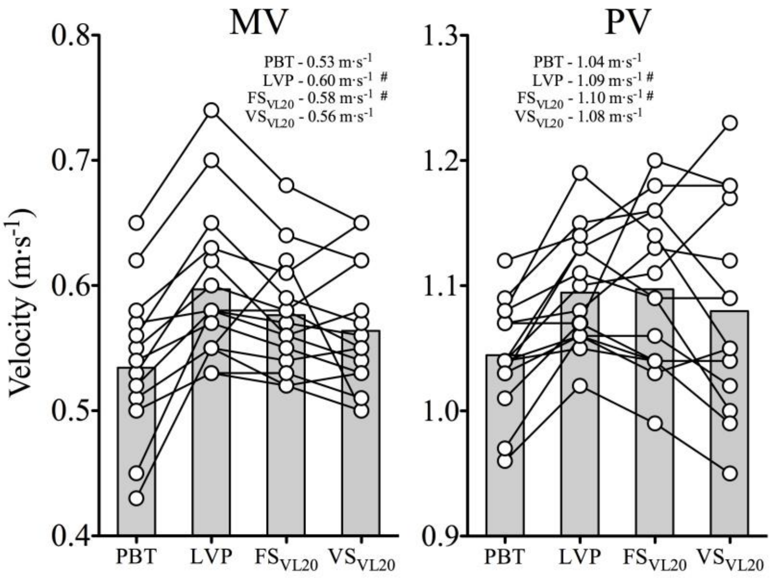

Figure 1: Individual variation of mean repetition values of mean velocity (MV) and peak velocity (PV) for the 1RM-percent-based training (PBT), load-velocity profile (LVP), fixed sets 20% velocity loss threshold (FSVL20), and variable sets 20% velocity loss threshold (VSVL20) sessions. The shaded bars indicate the group mean, and the figure legend contains the numerical group velocities for the experimental sessions.

#Denotes a significant difference between an experimental session and PBT.

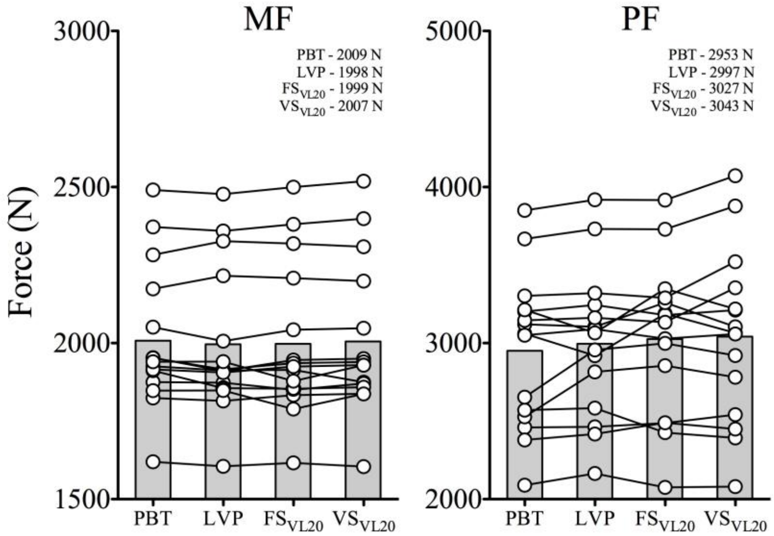

Figure 2: Individual variation of mean repetition values of mean force (MF) and peak force (PF) for the 1RM-percent-based training (PBT), load-velocity profile (LVP), fixed sets 20% velocity loss threshold (FSVL20), and variable sets 20% velocity loss threshold (VSVL20) sessions. The shaded bars indicate the group mean, and the figure legend contains the numerical group force values for the experimental sessions.

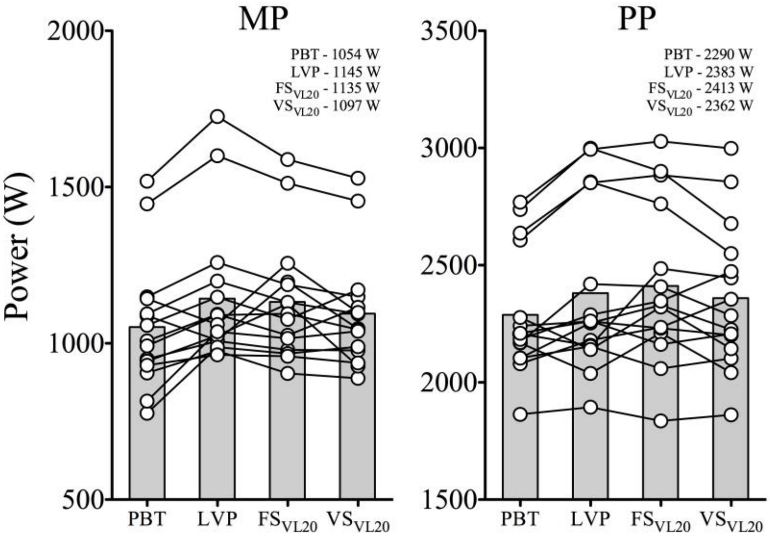

Figure 3: Individual variation of mean repetition values of mean power (MP) and peak power (PP) for the 1RM-percent-based training (PBT), load-velocity profile (LVP), fixed sets 20% velocity loss threshold (FSVL20), and variable sets 20% velocity loss threshold (VSVL20) sessions. The shaded bars indicate the group mean, and the figure legend contains the numerical group power values for the experimental sessions.

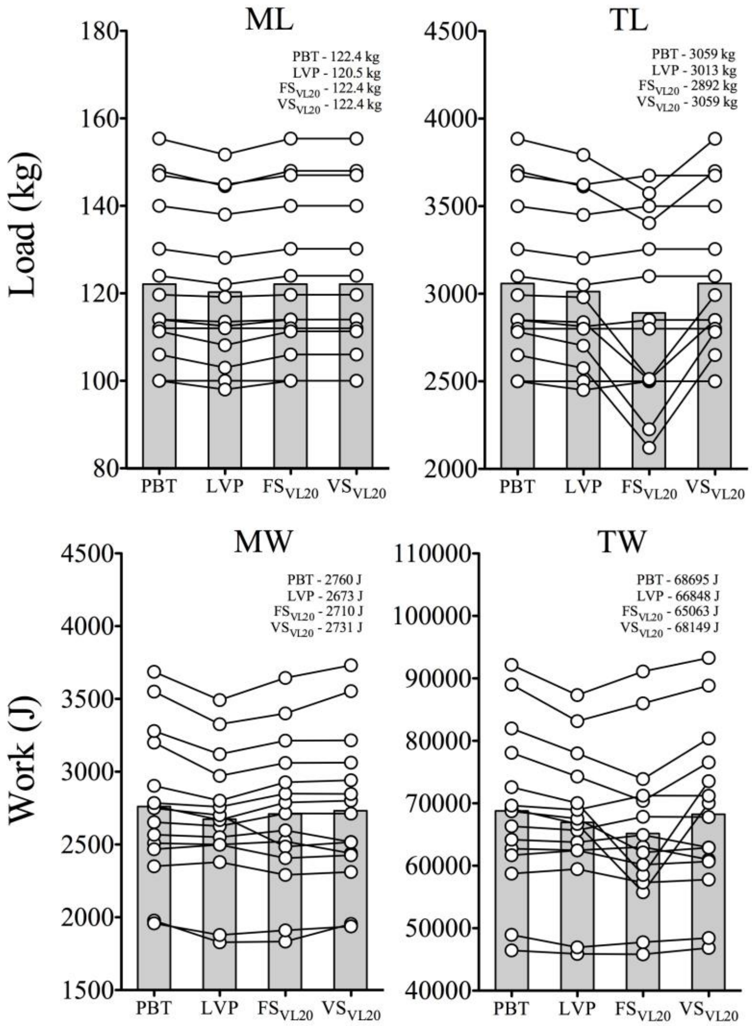

Figure 4: Individual variation during the 1RM-percent-based training (PBT), load-velocity profile (LVP), fixed sets 20% velocity loss threshold (FSVL20), and variable sets 20% velocity loss threshold (VSVL20) sessions for values of mean repetition load (ML), mean repetition work (MW), total session load (TL) and total session work (TW), The shaded bars indicate the group mean, and the figure legend contains the numerical mean group values for the experimental sessions.

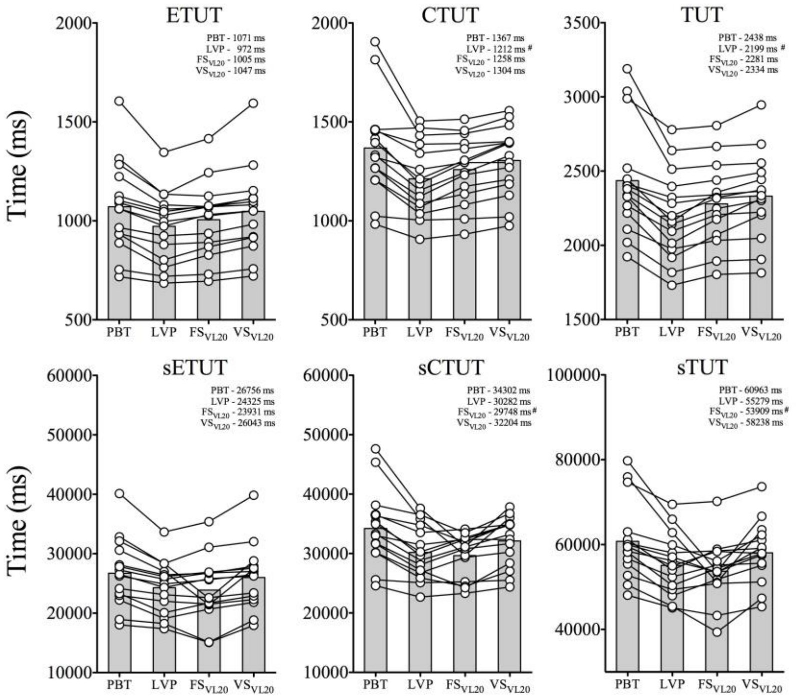

Figure 5: Individual variation during the 1RM-percent-based training (PBT), load-velocity profile (LVP), fixed sets 20% velocity loss threshold (FSVL20), and variable sets 20% velocity loss threshold (VSVL20) sessions for values of mean eccentric time under tension (ETUT), mean concentric time under tension (CTUT), mean total time under tension (TUT), total session eccentric time under tension (sETUT), total session concentric time under tension (sCTUT) and total session time under tension (sTUT). The shaded bars indicate the group mean, and the figure legend contains the numerical mean group values for the experimental sessions.

#Denotes a significant difference between and experimental session and PET.

Table 1: Description of the experimental sessions.

Group	Load (%1RM)	Sets	Reps	Total Reps	Set Completion
PBT	80%	5	5	25	Forced Completion
LVP	80%; Adjust Load by 5%1RM if set is ±0.06 $m \cdot s^{-1}$ LVP@80%	5	5	25	Forced Completion
FS_{VL20}	80%	5	?	?	20% Velocity Decline
VS_{VL20}	80%	?	?	25	20% Velocity Decline

Traditional 1RM-percent-based training (PBT), load-velocity profile (LVP); fixed sets 20% velocity loss threshold (FS_{VL20}), variable sets 20% velocity loss threshold (VS_{VL20}) sessions.

Table 2: Mean ± SD description of each experimental session.

Session	Load (kg)	Sets	Repetitions per Set						Total Repetitions
			1	2	3	4	5	6	
PBT	122.4 ± 17.8	5	5	5	5	5	5	-	25
LVP	120.5 ± 17.2	5	5	5	5	5	5	-	25
FS_{VL20}	122.4 ± 17.8	5	5	5	4.8 ± 0.4	4.5 ± 0.7	4.2 ± 0.9	-	23.6 ± 2.0
VS_{VL20}	122.4 ± 17.8	4.3 ± 0.9	7.9 ± 1.9	6.9 ± 1.7	5.5 ± 0.9	3.0 ± 1.8	1.2 ± 1.8	0.5 ± 1.8	25

Traditional 1RM-percent-based training (PBT), load-velocity profile (LVP); fixed sets 20% velocity loss threshold (FS_{VL20}); variable sets 20% velocity loss threshold (VS_{VL20}).