Advancing Strength Training: A Review of Velocity-Based Training for Performance Optimisation

Fan Yi
Imperial College London, London, U.K.

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Abstract: Velocity-based training (VBT) has been introduced as a data-driven approach to resistance training, providing a precise and adaptable method for monitoring and optimising athletic performance. Unlike conventional percentage-based training, VBT leverages movement velocity to estimate daily readiness, prescribe individualised loads, and manage fatigue accumulations. This review explores two key aspects of VBT: (1) the development of personalized velocity-load profiles (VLP) and their role in estimating one-repetition maximum (1RM), and (2) the implementation of percentage velocity loss thresholds (VLT) to regulate training volume and adaptation. While VBT presents advantages in some respects over traditional regimes, challenges remain in its practical application, including variability in load-velocity relationships, biomechanical constraints, and technological limitations. Future research should focus on refining measurement techniques and integrating VBT with traditional periodization models to maximize its effectiveness in strength and conditioning programs.

1 INTRODUCTION

Resistance training (RT) has been programmed by strength and conditioning professionals to achieve muscle growth (hypertrophy) and subsequent improvements of strength and power (González-Badillo & Sánchez-Medina, 2010; Cunanan et al., 2018a; Suchomel et al., 2018). The rationale of sports performance training is to efficaciously approximate maximum power output by amplifying contraction force and movement velocity by suing relatively light loads in RT. In terms of athletic performance, the force-generating capability (FGC) and relevant rate of force development (RFD) in sport-specific movements are considered more important than simply absolute strength, both of which are determined by the velocity (Maffiuletti et al., 2016). The combination of RT and plyometric training highlighted significantly better enhancement on FGC and RFD due to increasing improved intermuscular and intramuscular coordination (Young, 2006; Sáez-Sáez de Villarreal, Requena & Newton, 2010; Guerriero, Varalda & Piacentini, 2018). Maximal velocity accomplished in plyometric training under low/moderate loads is emphasized as an essential role in increasing the reflexed motor units and facilitating other neuromuscular adaptions. Moreover, when comparing performance gains between a maximal velocity group and a deliberately controlled half-velocity group, only the maximal velocity group showed a significant increase in countermovement jump height, along with twice the improvement in 1RM back squat (Pareja-Blanco et al., 2014). As such, an increasing amount of science research is shedding light on the potential role of velocity as an indicator of strength gaining and even a quality marker of RTs.

Conventional RT programs refer to training intensity and volume as two pivotal factors boosting athletic performances. Percentage-based training (PBT) has been prevalently exploited by coaches and trainers owing to their load prescriptions based on generalised 1 repetition maximum (RM) data (Tan, 1999; Rhea & and Alderman, 2004). However, a previously recorded 1RM does not account for the daily oscillations in athletic strength caused by factors such as life stress, training fatigue, sleep quality and recovery status (Mann, Ivey & Sayers, 2015). Furthermore, progressive strength gains cannot be examined gradually and aligned with the real-time 1RM, which furthers the erroneousness of later load prescriptions and deviations from an athlete's real-time performance readiness(Guppy, Kendall & Haff, 2024). Another approach is supervising the maximum repetitions of certain exercises an individual can

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perform under specific loads (nRM) during RT, where subjects have to complete as many repetitions as possible (Guerriero, Varalda & Piacentini, 2018). An inappropriate training volume (repetitions × sets) in a training regime, as one factor of exercise intensity, also results in fatigue and non-functional overreaching in the presence of training goals combined with the effect of prescribed loads. Many autoregulatory methods, including the rating of perceived exertion (RPE) and adjustable progressive resistance exercise (APRE), have been introduced to adjust training volume instead of setting fixed numbers (Knight, 1985; Mann, Ivey & Sayers, 2015). Following more autoregulation being integrated into modern RTs, disadvantages have been discovered and reflected on. The use of RPE is restricted by its nature of rating fatigue level depending on subjective feelings, which has shown weak correlation with exercise intensities and even variations among different training methods (power training, super slow training and traditional training) and training experience (Egan et al., 2006; Ormsbee et al., 2019). Compared to RPE, APRE replaces the subjective ratings used in RPE with the number of completed nRMs, involving set 3 and set 4, where subjects perform as many consecutive repetitions as possible until reaching failure (Mann et al., 2010). The resulting fatigue, on the other hand, makes APRE less effective in explosive training via slowing down the muscle contraction speed, prolonged recovery time and ineffective FGC (Sánchez-Medina & González-Badillo, 2011). Moreover, with both RPE and APRE, set-to-set adjustments on the training volume have to be made after a training set has been completed. It is, thus, of utmost importance to develop safer and simpler methods for measuring accurate 1RM values and monitoring an athlete's fatigue level, preventing them from overloading and unnecessary fatigue.

Velocity-based training (VBT) is an RT method that utilizes movement velocity to optimize athletic force development and inform improved performance through measuring velocity during the concentric phase of major strength exercises (squat, bench press and power clean) with linear position transducers (LPT) and then velocity-load profiles (VLP). The robust relationships of velocity with several strength and conditioning measurements, such as training intensity, relative loads and fatigue, have laid down the foundation for the advent of VBT (Weakley et al., 2021). In the study carried out by Dorrell, Smith & Gee, the VBT intervention was found to improve maximal strength and jump height in trained men more effectively than traditional PBT, accompanied with a significantly lower training volume, pointing out its benefits for fatigue management in RT. While VBT is often promoted for its continuously and precisely updated training prescription, research suggests no between-group difference in neuromuscular fatigue and perceived soreness between VBT, RPE and APRE (Cowley et al., 2022). Despite debates regarding VBT's functionality and real-life applications in strength training, its ability to use velocity as a quantitative measure to assess training effort while simultaneously monitoring the athletes' physiological condition daily makes it a promising metric for RT prescriptions.

In this paper, I will discuss the advantages and limitations of current VBT from two key aspects: (1) the development of personalised LVP and 1RM predictions and (2) the use of velocity loss threshold (VLT) to manage fatigue and achieve specific adaptations.

2 RESULTS

2.1 Individual LVP and 1RM Prediction

The highly linear pattern observed in polynomial and regression models between load and velocity provides LVP with reliability and feasibility (Weakley et al., 2021). Furthermore, velocity will maintain the declining trend until 1RM is reached, which indicates the arrival of terminal velocity threshold (V1RM) and allows sports scientists to estimate 1RM (Izquierdo et al., 2006). The two characteristics of VBT suggest its novel means of load prescriptions and monitoring training intensities.

The two-point method was proposed by Garcia-Ramos & Jaric in 2018, where two submaximal (< 1RM) could be used to construct the linear regression model to estimate 1RM. Regarding only two load samples used in the LVP construction, the two-point method is much less time-consuming compared to the direct (conventional) 1RM measurement talked about in the introduction. Undoubtedly, the two-point method offers the availability of periodically and tailored updated 1RM and removes the need for a time-consuming and potentially fatiguing maximal strength testing.

However, with deeper investigations into the original load-velocity mathematical models and application of LVP, the underlying downsides start to be excavated. The biggest problem, in my opinion, is the choice of proper velocity variables. There are three different velocity metrics: mean velocity (MV), mean concentric velocity (MCV) and peak velocity

(PV). MV is interpreted as the mean velocity during a complete concentric phase, while MCV and PV mean the mean velocity before the phase when the acceleration is less than gravity and the instantaneous greatest velocity during the concentric stage, respectively. To discriminate MCV from MV, MCV does not include the braking phase or stick point encountered in specific exercises like bench press and overhead push, in which voluntary decelerations avoiding the body off the ground or solid surface are likely to disobey the linear load-velocity relationship. In a study of the LVP applied in the free-weigh prone bench pull exercise, the absence of a braking phase provided a similar velocity corresponding with each 1%RM for the MV and MPV sessions (García-Ramos et al., 2019). This study also noted that between-subject velocities always have a larger difference than within-subject velocities, especially at lower relative loads (faster velocity), implying a meaningful view of utilizing individual LVPs in personal training. Future studies should endeavour to fill the gap of variability of general load-velocity relationship equations among exercise intensities and types (ballistic, concentric-only and concentric-eccentric). Ultimately, the public should be aware of a possible 1RM overestimation, exposing athletes to loads beyond their ability and restraining the beneficial incorporation of autoregulatory (Macarilla et al., 2022). Even though some innovative versions of the two-point method (Thompson's and LVP with a final submaximal load close to the 1RM) have been introduced to improve the reliability of produced LVPs, VBT is still an underexplored area in the demand for a more precise L-V model evolving with phase-specific velocity and force-velocity meta-analysis (Guppy, Kendall & Haff, 2024).

2.2 Relative Velocity Loss Threshold (VLT) and Fatigue and Adaptation Management

Theoretically and mathematically, fatigue positively correlates with velocity loss because of acute metabolic stress and stressful FPC (González-Badillo et al., 2017). When programming variables are not suitably organized, the resulting fatigue has a counterproductive effect on athletes' sport form (physical, psychic, technical and tactical readiness) (Bowen et al., 2017). However, fatigue is not entirely harmful for RTs. According to the well-known general adaptation syndrome (GAS), the central dogma of biological adaptation is a training stimulus (fatigue) that can disturb the normal state (homeostasis) of an organism (Cunanan et al., 2018b). The understanding of GAS inspired sports scientists with an idea of periodized training (PT) where decisions on programming variables are fluid and identifiable depending on distinctive training aims (Cunanan et al., 2018b). To clarify, strength-power trainings require high velocities to stimulate more motor units and synchronizations (i.e. neural factors), while strength exercises can be completed in a more controlled way, resembling more muscle stimulus for the desired hypertrophy (Mann, Ivey & Sayers, 2015). The combination of VLP and VLT estimates daily 1RM and tracks velocity decline within each set to effectively manage fatigue accumulation. It further treats adaptational and pathological (excessive) fatigue separately with distinct velocity loss zones and avoiding interference phenomenon. Additionally, Unique flexible or fixed set and repetition schemes facilitate the transition from a set-to-set basis in RPE and APRE to a rep-to-rep basis in VBT. Therefore, VBT comes into play as a practically measurable parameter to monitor ongoing athletic responses to training, followed by scientifically driven and evidence-based periodisation.

More limitations have been found through the real-life integration of autoregulation with VBT. Firstly, it's very hard for strength and conditioning practitioners to make sure that athletes satisfy the assumption of maximal voluntary efforts (strength). Secondly, fatigue management may not be implemented throughout a periodization cycle. Accordingly, pre-season and in-season periods may temporarily involve VBT as an approach to reduce training volume while maintaining — or even increasing — training intensity, thereby enhancing preparedness by minimizing fatigue. Thirdly, biomechanical restrictions of certain movements might attenuate the correlation between exercise fatigue accumulations and velocity loss. With the standardized efforts and absolute strength, the MV of squat and bench press is expected to be lower than that of power clean owing to a larger amplitude of motion, reinforcing the importance of analysing specificity of training with similar exercise physique and velocity variables (Mann, Ivey & Sayers, 2015). Lastly, the accuracy of measuring devices also matters. LVP has been proven to be superior to most accelerometer-based equipment and as precise as 3D motion capture in slow conditions (< 1m/s) (Weakley et al., 2021). Alternatively, LVP offers vibrating data influenced by the position of the displacement detector on barbells or subjects (Appleby et al., 2020). Moreover, all measuring technologies share a limitation in that they are unable to automatically disaggregate acceleration and deceleration, or in the case of ballistic exercise, take off phase and flight phase (Guppy, Kendall & Haff, 2024). Until now, LVP is still the best choice considering commercial and practical factors.

3 CONCLUSION

The two major elements, individual LVP and percentage velocity loss threshold, propose the advantages of VBT over conventional RT approaches, namely rapid quantitative and objective measurements on reflecting athletic performance and fatigue. Nonetheless, I want to emphasize that there are still many practical obstacles for VBT to achieve its maximum capacity on monitoring RTs. Before getting more reliable experimental evidence supporting the advantages of VBT, sports science professionals should exploit VBT more as a complementary tool to catalyse training outcomes with traditional RT models in the previous sections, in case athletes shift focus away from the intended physical quality and trigger unintended fatigue accumulation at inappropriate stages of the periodization. Furthermore, the intra-set motivation feedback ought to be given for advancing competitiveness and consciousness, in the premise of optimal movements of the training exercises. In conclusion, VBT is currently a grey area, encouraging practitioners to try more synthesis with conventional training strategies built upon their experiences and expert knowledge.

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