Velocity-Based Training: From Theory to Application

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Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (http://journals.lww.com/nsca-scj).

ABSTRACT

Velocity-based training (VBT) is a contemporary method of resistance training that enables accurate and objective prescription of resistance training intensities and volumes. This review provides an applied framework for the theory and application of VBT. Specifically, this review gives detail on how to: use velocity to provide objective feedback, estimate strength, develop load-velocity profiles for accurate load prescription, and how to use statistics to monitor velocity. Furthermore, a discussion on the use of velocity loss thresholds, different methods of VBT prescription, and how VBT can be implemented within traditional programming models and microcycles is provided.

INTRODUCTION

Athletes perform resistance training to develop strength, power, and lean body mass (81,82). To achieve this, coaches typically prescribe specific resistance training loads relative to an individual's maximal ability (e.g., 70% of one repetition maximum [1RM]) (35,95). In addition, athletes are commonly assigned a specified number of sets and repetitions to complete (e.g., 5 sets of 10 repetitions) based on the desired training goal (9). However, using an athlete's previous maximal ability to prescribe training loads can be problematic if the athlete's 1RM changes as a consequence of training because the prescribed load may not match the % of 1RM intended for the particular session. In addition, it is known that the number of repetitions that can be performed with a given % of 1RM differs between athletes and, therefore, assigning the same number of sets and repetitions for all athletes may induce different levels of effort and fatigue (72,88). Therefore, alternative methods such as velocity-based training (VBT) have been developed to provide accurate and objective data to support the prescription of resistance training (7–9).

WHAT IS VELOCITY-BASED TRAINING?

VBT is a term that covers a wide array of training topics and approaches. The integration of VBT lies on a continuum and can be used with varying emphasis (Figure 1). At its most basic level, velocity can be used as an accessory to traditional percentage-based training. For example, visual or verbal feedback of velocity can be provided to athletes to enhance performance and improve motivation and competitiveness (1,90,91,93,96). Alternatively, VBT can be implemented across all facets of a resistance training programming and support the prescription of load, sets, number of repetitions, and the programming method applied (9,20,49,95). For this reason, VBT should be defined as a method that "uses velocity to inform or enhance training practice." This definition accounts for the broad implementation of training methods that use velocity and assist the practitioner in achieving their training goals.

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KEY WORDS:
VBT; 1RM prediction; load-velocity profile; periodization; fatigue; statistics

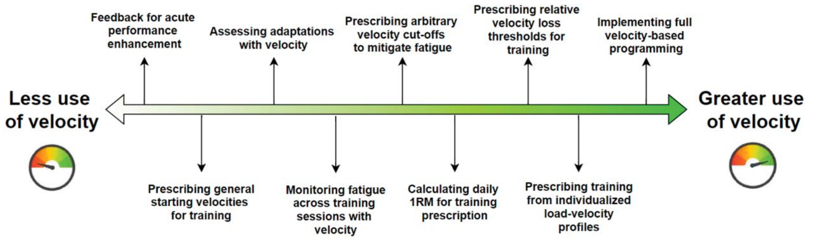

Figure 1. Velocity-based training continuum highlighting the varying emphasis on velocity within a training program.

WHY VELOCITY?

Velocity is commonly used over other kinetic or kinematic outputs (e.g., power) when resistance training for 3 reasons. First, it is well established that as an external mass is increased, reductions in lifting velocity occur (45,87). This loss of velocity continues until a 1RM load is achieved which corresponds with the minimum/terminal velocity threshold (V1RM) (45). Second, there is a nearly perfect linear relationship between velocity and intensity as a percentage of maximum ability (i.e., % of 1RM). This has been demonstrated consistently across a range of exercises and submaximal loads (13,27). Third, a common element to many definitions of exercise-induced fatigue is that as fatigue increases, there is a transient decline in muscle fiber shortening speeds, relaxation times, and force-generating capacity that cause subsequent reductions in voluntary exercise velocity (33,74). Put simply, as fatigue accrues, exercise velocity decreases. By acknowledging these fundamental concepts, practitioners can use velocity outputs to accurately and objectively prescribe external loads and training volumes for each session, irrespective of fluctuations in fatigue and athlete readiness.

USING VELOCITY TO PROVIDE FEEDBACK AND ENHANCE PERFORMANCE

The use of feedback during resistance training is a powerful tool for acute performance enhancement and adaptation. Although feedback can occur in many forms, visual and verbal feedback of barbell velocities have received the most investigation (1,50,59,92,93,96,98). It has been demonstrated that these forms of feedback can cause improvements in performance in male (96) and female (93), adults (92) and adolescents (93,96), and professional (1,59) and nonprofessional (50) athletes. Not only do these improvements occur instantaneously during training (93,96) but also when feedback is supplied and then removed, performance returns to baseline levels (50). These changes in performance have been found to occur alongside improvements in psychological characteristics, with increases in motivation and competitiveness being demonstrated when feedback of velocity performance is provided (92,93,96–98).

Although feedback of velocity can easily be provided within the training routine, the frequency, method of delivery, and personality of the athlete should be considered (refer to Table 1). Recent research (59) has demonstrated that different modes of feedback delivery influence performance adaptations. Nagata et al. (59) has shown immediate improvements and greater long-term physical development of loaded jump ability when verbal feedback of barbell velocity is supplied after each repetition. This was compared with the provision of average set velocity or a visual recording of the set. Furthermore, it is acknowledged that athletes may have a preference of whether they are visually or verbally informed of their performance outcomes (92). These differences may be due to intrinsic or extrinsic motivating factors (i.e., competition within or between athletes) and levels of athlete conscientiousness (92). However, it should be noted that in athletes with low levels of conscientiousness, verbally encouraging statements after each repetition may provide the greatest benefit (92).

Finally, the chronic delivery of feedback during training is known to be of substantial benefit. Over a 6-week period, Randell et al. (71) provided either feedback or no-feedback at the completion of each repetition of the jump squat and observed small to moderately greater improvements in standing broad jump (effect size [ES] = 0.28) and 30 m sprint performance (ES = 0.46). In addition, recent research by Weakley et al. (90) has highlighted greater improvements in 10- and 20-m sprint performance (ES = 0.69 and 0.71, respectively), jump height (ES = 0.21), and 3RM squat and bench press strength (ES = 0.28 and 0.21, respectively) when feedback is provided after each repetition of each exercise across a 4-week mesocycle. Also, of interest for the strength and conditioning practitioner, was that this study emphasized the benefit of providing feedback of performance when performing sprint drills. Sprint times and average velocity across a known distance can easily be conveyed to athletes and are believed to promote similar improvements in motivation and feelings of competitiveness within and between athletes as feedback during resistance training (90).

THE DIFFERENT TYPE OF VELOCITY VARIABLES AND WHEN TO USE THEM

The 2 velocity variables most commonly used in practice and scientific research are mean velocity (MV) (i.e., the average velocity across the entire concentric phase) and peak velocity (PV) (i.e., the maximum instantaneous velocity reached during the concentric phase) (68,83). However, mean propulsive velocity (MPV) (i.e., the average velocity from the start of the concentric phase until the acceleration is less than gravity [$-9.81\ \mathrm{m \cdot s^{-2}}$]) has also been proposed as an alternative (77). The difference between the MPV and MV is that the latter does not account for the braking phase of the movement.

Table 1
Feedback variables and their effects on acute-training performance

Variable	
Frequency	Frequency after each repetition has been shown to have greater effects than after each set (59).
Quantitative vs. qualitative	Quantitative feedback of velocity enhances performance greater than observing video recording of previous exercise (59).
Conscientiousness	Athletes with low levels of conscientiousness have the greatest improvements in kinematic outputs when verbal encouragement is supplied (92).
Motivation and competitiveness	When visual feedback of kinematic outputs are supplied, improvements are observed in both males and females (92,93,96–98).
Intrinsically vs. extrinsically motivated athletes	Intrinsically motivated athletes may prefer visual feedback, while extrinsically motivated may prefer to hear feedback (92).
Encouragement	Verbally encouraging statements can enhance barbell velocity and power output (92).

However, it is our opinion that MV and PV provide more valuable information for strength and conditioning practitioners for both testing and training purposes.

MONITORING VELOCITY DURING TESTING

Neuromuscular function can be assessed by measuring the velocity value achieved against a given load using traditional (e.g., bench press or squat) or ballistic (e.g., bench press throw or vertical jump) exercises (15,66). When testing with light/moderate loads (≤70% 1RM), it is recommended that ballistic exercises are used (e.g., bench press throw rather than the traditional bench press variant). This removes the braking portion of the concentric movement and can provide greater reliability of velocity outcomes (61,66). However, using MV and MPV to measure ballistic performance is problematic because these metrics include the flight phase. Furthermore, MPV values could be even more problematic due to difficulties in detecting the exact moment take-off occurs. This issue may explain counterintuitive findings reported in the scientific literature such as the power developed in a traditional exercise (e.g., bench press) being greater than its ballistic variant (e.g., bench press throw) (46). Consequently, we recommend the use of PV for the testing of ballistic exercises. On the other hand, nonballistic variants of exercises are advised for testing heavier loads (>70% 1RM), with MV and MPV providing virtually the same information (28,32,76). Therefore, when testing "heavy" (>70% 1RM), nonballistic exercises, all velocity variables could be equally valid.

MONITORING VELOCITY DURING TRAINING

Although velocity can be used in many ways during training, 3 important applications are (I) estimating the 1RM, (II) prescribing the volume and relative intensity of the training session based off the magnitude of velocity loss, and (III) increasing motivation and competitiveness through the provision of real-time velocity feedback. Presumably, all 3 velocity variables could be equally valid to fulfill the applications of points II and III. However, we recommend the use of MV to estimate the 1RM because of its greater reliability (when compared with MPV) when lifting light relative loads (23,67). The advantage of MV over PV is that the former varies less between different devices designed to measure movement velocity (22,30), the relationship between load and velocity is more linear using MV (31), and that between-subject variability in the velocity attained during 1RM attempts may be lower.

ONE REPETITION MAXIMUM PREDICTION METHODS

One interesting application of VBT is the possibility of estimating 1RM strength from the velocity recorded against submaximal loads. General load-velocity (L-V) relationships (36) and individual L-V relationships (52) have previously been proposed to estimate the 1RM. The general L-V relationship was introduced by González-Badillo and Sánchez-Medina (32) who used a second-order polynomial regression equation to estimate the %1RM during the bench press exercise. After this seminal work, similar equations have been proposed in other resistance training exercises (3,5,13,28,30,31,54,65,75). Although general L-V relationship equations enable a quick estimation of the 1RM from the MV recorded during a single repetition, coaches should be aware of several limitations that may limit their use in practice. Briefly, the relationship between the MV recorded during a single repetition and the %1RM may be influenced by the type of exercise (e.g., squat versus leg press) (13,38,75), execution technique (e.g., concentric-only vs. eccentric-concentric) (28,65), sex (higher values for men at lower %1RM) (3,84), and measurement device (4,22,26,91). Of even more importance could be that the MV-%1RM relationship, especially at light relative loads, is subject-specific (70). Finally, from a statistical point of view, another problem of the general

L-V relationships is an overestimation of the data fit because of the presence of autocorrelation because authors included more than one observation from the same participant to calculate the general L-V relationships (60).

The individual L-V relationship was proposed to overcome the limitations highlighted above. The standard test used to determine the individual L-V relationship consists of recording MV against multiple submaximal loads (≈5 loads) and, subsequently, modeling the L-V relationship through a linear regression to estimate the 1RM as the load associated with the MV of the 1RM (V1RM) (6,73) (Table 2). The biggest challenge associated with individualized L-V profiling is the selection of the V1RM used to predict the 1RM. Previous studies have used the individual V1RM (6,73) or mean V1RM for all subjects (24). However, because of the low reliability of the individual V1RM (6,29,73), and the trivial differences between the between- and within-subject variability for the V1RM (70), the use of a general V1RM for all subjects could be recommended to simplify the testing procedure. The V1RM reported in the scientific literature for commonly used resistance training exercises is provided in Table 2. It is also possible that using the individual V1RM would provide a more accurate estimation of the 1RM compared with using a general V1RM. However, this assumption needs to be supported with experimental data. To date, no study has compared the precision in the estimation of the 1RM when using the individual and general V1RM.

Since the individual L-V relationship is highly linear (6,47,73), a solution to reduce the duration of the testing procedure could be to determine the individual L-V relationship from the MV recorded against only 2 loads (i.e., 2-point method) (24,25). This has been demonstrated by García-Ramos et al. (24) who have shown that the individual L-V relationship modeled through the 2-point method provides a more accurate

Table 2
Minimum velocity threshold for commonly used resistance training exercises

Exercise	Study	Sample	1RM MV (mean ± SD)	V1RM
Bench press	González-Badillo and Sánchez-Medina[a] (32) Sánchez-Medina[a] et al. (75) García-Ramos[a] et al. (27) Helms et al. (38)	120 young healthy males 75 athletes 30 healthy males 15 powerlifters	0.16 ± 0.04 m/s 0.17 ± 0.04 m/s 0.17 ± 0.03 m/s 0.10 ± 0.04 m/s	0.17 m/s
Prone bench pull	Loturco et al. (54) Sánchez-Medina[a] et al. (75) García-Ramos et al. (30)	30 athletes 75 athletes 26 athletes	0.51 ± 0.07 m/s 0.52 ± 0.06 m/s 0.48 ± 0.04 m/s	0.50 m/s
Prone pull-up	Sánchez-Moreno et al. (78) Muñoz-Lopez et al. (58)	52 firefighter candidates 82 resistance-trained males	0.20 ± 0.05 m/s 0.26 ± 0.05 m/s	0.23 m/s
Seated military press	Balsalobre-Fernández[a] et al. (3) García-Ramos[a] et al. (29)	39 resistance trained participants 24 healthy participants	0.19 ± 0.05 m/s 0.20 ± 0.05 m/s	0.19 m/s
Lat pulldown	Perez-Castilla et al. (69)	23 healthy participants	0.47 ± 0.04 m/s	0.47 m/s
Seated cable row	Perez-Castilla et al. (69)	23 healthy participants	0.40 ± 0.05 m/s	0.40 m/s
Squat	Conceição[a] et al. (13) Sánchez-Medina and[a] González-Badillo (74)[a] Banyard et al. (6) Helms et al. (38)	15 male athletes 80 strength-trained males 17 strength-trained males 15 powerlifters	0.32 ± 0.04 m/s 0.32 ± 0.03 m/s 0.24 ± 0.06 m/s 0.23 ± 0.05 m/s	0.30 m/s
Deadlift	Ruf et al. (73) Helms et al. (38) Lake et al. (51)	11 resistance-trained athletes 15 powerlifters 12 active males	Not stated 0.14 ± 0.05 m/s 0.16 ± 0.05 m/s	0.15 m/s
Hip-thrust	de Hoyo et al. (20)	102 sport science students	0.25 ± 0.03 m/s	0.25 m/s
Leg press	Conceição et al. (13)	15 male athletes	0.21 ± 0.04 m/s	0.21 m/s

[a] Smith machine variation of the exercise.

1RM = one repetition maximum; MV = mean velocity; V1RM = velocity at 1RM.

estimation of the bench press 1RM performed in a Smith machine than previously published general L-V relationships. Furthermore, provided that 2 distant loads are used (e.g., approximately 45% 1RM and 85% 1RM), the addition of intermediate loads does not significantly improve the precision in the estimation of the 1RM (69). The validity of the 2-point method has also been confirmed for upper-body free-weight exercises (e.g., bench pull (31) and bench press (48)) and also during the lat pull-down and seated cable row exercises (69), but its validity has never been explored during lower-body exercises. Therefore, coaches are encouraged to use the 2-point method as an accurate, quick, and relatively fatigue-free method to estimate the 1RM during upper-body exercises. This can be performed in 3 simple steps: (I) setting of the exercise-specific V1RM (found within Table 2), (II) recording of the MV against a light ($\approx$45% 1RM) and a heavy load ($\approx$85% 1RM), and (III) modelling of the individual load-velocity relationship and determining the 1RM as the load associated with the V1RM. However, coaches should be aware that the accuracy of the 2-point method and other velocity-based 1RM prediction methods is expected to be compromised during free-weight lower-body exercises (6,43,44,52). Therefore, although the recommendations provided in this section can be followed to obtain an accurate estimation of the 1RM during some upper-body exercises, it should be noted that the available scientific evidence indicates that velocity recordings cannot be used to obtain an accurate estimation of the 1RM during lower-body exercises such as the squat or deadlift. It is hypothesized that discrepancies in the accuracy of prediction may be due to the greater technical complexity of lower-body exercises (e.g., squat or deadlift) compared with upper-body exercises (e.g., bench press or bench pull). Finally, it should also be noted that the direct measurement of the 1RM is more reliable than the estimation from the L-V relationship (24).

DEVELOPING A LOAD-VELOCITY PROFILE FOR THE PRESCRIPTION OF MEAN SET VELOCITIES

A key aspect of training with L-V profiles is for a coach to differentiate between normal variation in velocity across training sessions and legitimate fluctuations in velocity that occur from training-induced adaptation. This is critical, so that decisions regarding training load modification can be made with a high degree of accuracy. Recent studies have shown that the L-V relationship is stable when using MV, PV, or MPV in the free-weight back squat and Smith machine bench press (8,27). In terms of meaningful changes in velocity, the smallest detectable difference in MV, PV, and MPV for the free-weight back squat has been reported to be $\pm$0.06–0.08 m·s^{-1}, $\pm$0.11–0.19 m·s^{-1}, and $\pm$0.08–0.11 m·s^{-1}, respectively (6). This suggests that if valid velocity measuring devices are used for monitoring, meaningful changes in velocity between training sessions are likely to reflect acute fatigue or gains in strength. Furthermore, it may also allow for the accurate prescription of resistance training load during training and across mesocycles.

There are 4 simple steps for the development of an individualized L-V profile (Table 3) (8). First, the athlete performs a 1RM assessment in the relevant exercise to determine their maximum strength and to allow for monitoring

Table 3
Steps for developing an L-V profile for an athlete in the back squat

Session 1	Session 2
1. Warm-up with dynamic movements and stretches	1. After 48-h rest, the athlete returns and completes repetitions with 20, 40, 60, 80, and 90% of 1RM
2. Complete 3 repetitions at 20, 40, and 60%.	2. Three repetitions should be used for loads 20–60% and 1 repetition for 80–90%.
3. Complete 1 repetition at 80 and 90%.	3. For sets that involved multiple repetitions (i.e., loads 20–60%), the repetition with the fastest MV should be recorded.
4. Then 5 maximal attempts at achieving a 1RM are permitted	4. With this information, individualized L-V profiles can be constructed within Microsoft Excel using the MV plotted against relative load and by applying a line of best fit.
5. After successful attempts, barbell load can be increased in consultation with the athlete with loads between 0.5 and 2.5 kg.	5. A linear regression equation can then be used to modify training loads within and between sessions
6. The last successful attempt with a full depth squat with correct technique can be established as the 1RM.	

48 hours have been provided between testing occasions.

1RM = one repetition maximum.

of velocity against %1RM over time. Second (if completing a 1RM assessment provide at least 24 hours recovery), perform an incremental loading test. Previous research has used either method 1: 3 repetitions with 20, 40, and 60%, and one repetition with 80 and 90% 1RM, with sets performed 2 minutes apart (8,9) or method 2: the "2-point method" with repetitions performed at 2 approximate loads of ~45% 1RM and ~85% 1RM (24). In step 3, the velocity data of the fastest repetition from each intensity (Figure 2A) are plotted against the corresponding relative load (%1RM), and then, a linear line of best fit is applied to extrapolate the regression equation (Figure 2B). The final step is to create a velocity table from the regression equation. This table uses the MV of the training set, corresponds with a percentage of maximum, and can be implemented in much the same way a coach would traditionally prescribe from a relative load (%RM) table (refer to Helms et al. (37)). In the example table (Table 4) if this athlete wanted to complete 6 repetitions at a "heavy" intensity, the mean set velocity should be approximately $0.58\ \mathrm{m \cdot s^{-1}}$. This information may be particularly useful for practitioners when accounting for differing rates in adaptation and for the adjustment of training loads within and across training sessions.

METHODS TO INTERPRET CHANGES IN VELOCITY-BASED DATA

Velocity-based testing can serve as a useful tool for coaches to gain a "snapshot" of an athlete's fitness-fatigue status. For example, when lifting a fixed external load, changes in peak or mean concentric velocities may be indicative of altered neuromuscular qualities (91). Reductions in velocity may be symptomatic of fatigue, overreaching/overtraining, or detraining/maladaptation, whereas faster velocities could signify improvements in neuromuscular capacity or acute potentiation (17).

When interpreting an athlete's velocity-based testing data, coaches must consider both the reliability of test performance, as well as the practical importance of a change. The reliability of test performance is influenced by measurement error (which is a fundamental consideration when purchasing velocity tracking equipment) and normal variation within the body's biological systems. A useful metric to quantify performance reliability is the within-athlete standard (typical) error (SE). This can be estimated from a group-based test-retest reliability study (2,39) or from the trend in an athlete's individual test performance repeated across a theoretically stable period (e.g., days, weeks, months) (36,41) (see Appendix 1, Supplemental Digital Content 1, http://links.lww.com/SCJ/A277).

The SE is reflective of the "typical" variation in an athlete's performance (e.g., mean concentric velocity) that are due to random factors causing natural fluctuation. Therefore, applying the SE to observed test scores as a ± value can be used to represent a "normal" range of performance, should the test be hypothetically repeated over and over (Figure 3). When assessing changes in performance, the SE can be used to create an individual confidence interval (CI) around change scores and represent uncertainty in an observed performance change (i.e., accounting for the "noise"). This provides the practitioner a plausible range of values that are compatible with the data assumptions (34) (Figure 4, see Appendix 2, Supplemental Digital Content 2, http://links.lww.com/SCJ/A278).

To know how practically important a change might be, coaches must decide on a threshold for a decisive change and evaluate changes against this value. Importantly, this concept is entirely separate from the previously discussed issues of performance reliability, noise, and uncertainty. In a hypothetical world where performance is entirely stable and changes only due to systematic effects (i.e., fitness or fatigue), changes could simply be evaluated against a threshold that represents some value representing practical significance. In this regard, we recommend using an anchor-based approach (79), whereby changes can be evaluated against a value representing a "real-world" difference in performance. For example, an increase of one-third of the competition-to-competition variability in solo athlete performance, such as weight lifted, best time, distance thrown, etc., results in one extra medal every 10 competitions

%1RM	Mean Velocity
20	1.41
40	1.16
60	0.86
80	0.55
90	0.40

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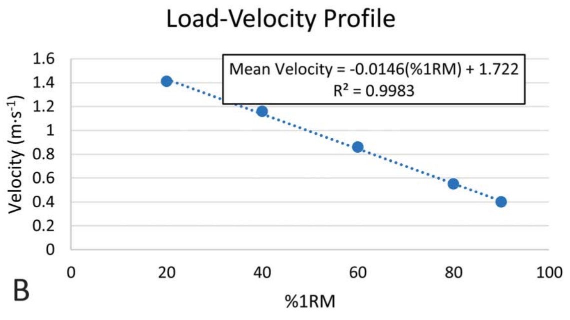


Figure 2. (A) Mean velocity data attained from an athlete's L-V profile during the barbell back squat; (B) data, linear regression, and equation for this athlete's L-V profile.

Table 4
An example of an individualized mean set velocity table for the free-weight back squat with each mean set velocity corresponding to a prescribed number of repetitions and intensity range

Mean velocity table (m·s^{-1})

	Repetitions									
Intensity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Maximum	0.26	0.34	0.38	0.41	0.47	0.51	0.54	0.57	0.60	0.63
Very heavy	0.29	0.35	0.39	0.42	0.48	0.52	0.55	0.58	0.61	0.64
Heavy	0.35	0.42	0.46	0.49	0.54	0.58	0.61	0.64	0.67	0.69
Moderately heavy	0.42	0.49	0.53	0.55	0.60	0.64	0.67	0.70	0.72	0.75
Moderate	0.50	0.56	0.59	0.62	0.67	0.70	0.73	0.75	0.78	0.80
Moderately light	0.57	0.63	0.66	0.68	0.73	0.76	0.79	0.81	0.83	0.86
Light	0.64	0.70	0.73	0.75	0.79	0.83	0.85	0.87	0.89	0.91
Very light	0.71	0.76	0.80	0.82	0.86	0.89	0.91	0.93	0.95	0.97

(40). This is often a practice intuitive to expert coaches who set performance targets based on their knowledge and experience of what changes really make a difference. This threshold information could therefore be derived from expert coach opinion or existing research on the associations between test and competitive performance. Other approaches, such as distribution-based (e.g., smallest worthwhile effect), are available, but can produce arbitrary values lacking real-world relevance (14).

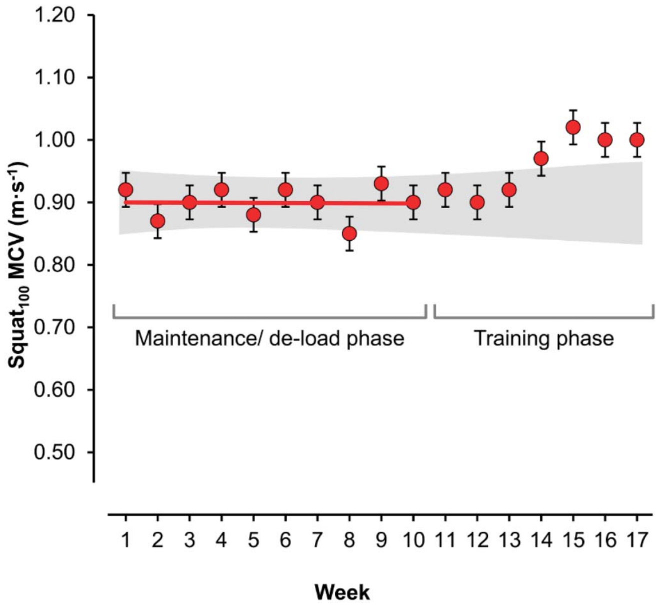


Figure 3. Mean concentric velocity (MCV) from 100-kg warm-up sets of the barbell back squat throughout a powerlifter's 17-week training phase. Data are shown as the fastest performance achieved each week ± the standard (typical) error, derived from the maintenance phase trend (i.e., baseline; straight red line, weeks 1–10; see Appendix 2, Supplemental Digital Content 2, http://links.lww.com/SCJ/A278). Loading phase changes from baseline are evaluated at an alpha of 0.20 (i.e., 80% confidence level). Gray shaded area = trivial, based on a minimum practically important difference of ± 0.03 m·s^{-1} and the maintenance trend standard error. From the athletes' known load-velocity profile, a 0.03-m·s^{-1} change in mean concentric velocity is indicative of a ~1% change in 1 repetition maximum, which is 0.3 × the competition-to-competition variability of 3.1%.

Once a threshold of practical importance has been established, coaches can combine the previously mentioned concepts and make a decision on an athlete's velocity-based testing data. Of course, we do not operate in a world where performance is entirely stable, and therefore, coaches must also consider performance uncertainty. A very simple and effective way of achieving this is to visualize the performance change with its CI against the region of practical importance (16) (Figure 3). The decision process is informed by interpreting the amount of overlap between the CI and the decisive threshold. Two such methods that can assist this include the second-generation *p*-value (SGPV) (10,11) and tests of equivalence using 2 one-sided tests (TOST) (52,53). In particular, the SGPV is intended as a descriptive statistic (10) and may therefore be useful when applied to monitoring changes in an athlete's velocity-based performance. It is beyond the scope of our review to discuss the application of SGPV and TOST in detail (refer to Blume et al. (10,11), Lakens (52) and Lakens et al. (53)), but we provide several recommendations for coaches using the aforementioned principles to interpret velocity-based testing data (see Appendix 3, Supplemental Digital Content 3, http://links.lww.com/SCJ/A279). An analysis of changes in a powerlifter's mean concentric velocity from 100-kg warm-up sets of the barbell back squat throughout a 7-week training phase (Figure 3) using several of the concepts we have discussed is displayed in Figure 5.

MANAGEMENT OF FATIGUE USING RELATIVE VELOCITY LOSS THRESHOLDS

It is common knowledge that humans come in different shapes and sizes and

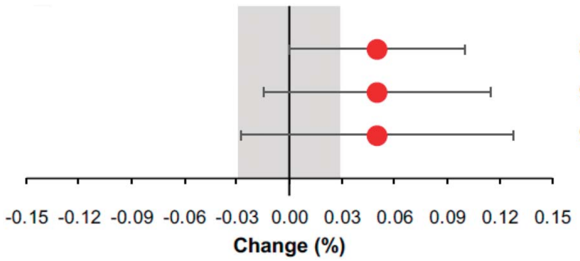
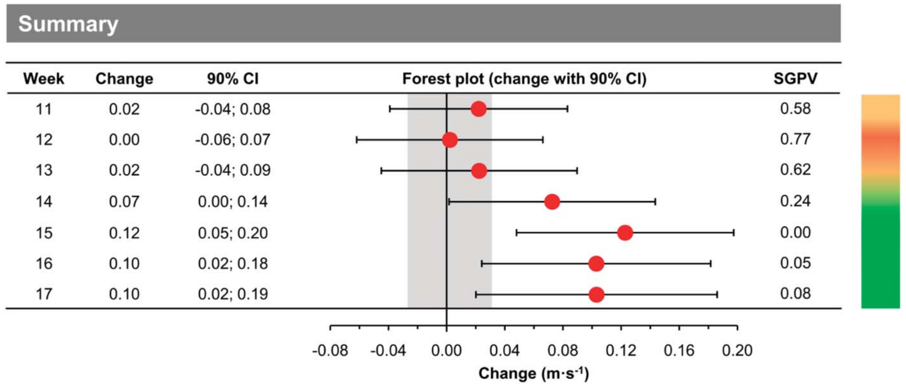


Figure 4. Hypothetical example of confidence intervals (CIs) applied to a change in mean concentric velocity. Data are shown as the change ± CI, scaled against a minimum practically important difference of ± 0.03 $m \cdot s^{-1}$ (gray area).

individuals have different physical and physiological capacities (e.g., marathon runners compared to sprinters). However, strength and conditioning practitioners are often taught to use predictive tables to prescribe resistance training loads and repetitions (12,35,80). This is despite the extremely large variance in the number of repetitions that can be completed with a given percentage of maximum (19). For example, at 80% of 1RM, some individuals can complete twice as many repetitions as others (e.g., 8 vs. 16 repetitions) (72). Thus, when prescribing 3 sets of 8 repetitions at 80% of 1RM, some athletes will be working to concentric failure, while others will complete these sets with relative ease. This heterogeneity is likely due to a range of factors including training history, gender, absolute strength levels, and recent training exposure (19,42,72). Consequently, to ensure improved prescription and to mitigate divergency in fatigue and adaptive responses, relative velocity loss thresholds can be implemented (63,89).

Recent research (89) has highlighted the ability of velocity loss thresholds to maintain velocity and power outputs when resistance training (Figure 5). Furthermore, this work has demonstrated how these thresholds can account for differences in individual work capacity. Weakley et al. (89) showed that when using velocity loss thresholds, changes in mean barbell velocity between athletes are possibly to likely trivial across 5 sets of the back squat. This is in direct contrast to traditional prescription methods that cause very large reductions in velocity as exercise goes on (85,94). These differences in the maintenance of kinetic and kinematic outputs are due to the unique “flexible-repetition” schemes that occur when relative velocity loss thresholds are applied and allows for individualization during each set and at each load/velocity (89). This diverges from percentage-based methods that promotes the strength coach to set arbitrary repetition and set schemes (e.g., 4 sets of 10 repetitions) that do not account for athlete differences, daily readiness, or within-session fatigue accrual.

Perhaps more important than the control over training session kinetic and kinematic outputs is the improved ability to dictate internal and subsequent fatigue outcomes by using velocity loss thresholds (Figure 6). Recent work investigating changes in neuromuscular function have shown that with each incremental increase in velocity loss (e.g., 10, 20, and 30% velocity loss), linear reductions in function occur (88). This is supported by earlier work by Sanchez-Medina and González-Badillo (74) that assessed velocity and estimated proximity to concentric failure. Furthermore, near identical trends in perceived effort and metabolic responses also exist (i.e., greater exertion and metabolic responses in line with greater increases in velocity loss) (88). These responses have been found to be consistent within and between athletes and demonstrate exceptional levels of reliability within athletes across moderate- to long-term training periods (88).


Summary

Week	Change	90% CI	Forest plot (change with 90% CI)	SGPV
11	0.02	-0.04; 0.08		0.58
12	0.00	-0.06; 0.07		0.77
13	0.02	-0.04; 0.09		0.62
14	0.07	0.00; 0.14		0.24
15	0.12	0.05; 0.20		0.00
16	0.10	0.02; 0.18		0.05
17	0.10	0.02; 0.19		0.08

Figure 5. Analysis of changes in a powerlifter’s mean concentric velocity from 100-kg warm-up sets of the barbell back squat throughout a 7-week training phase (raw data are showing in Figure 3). Changes are derived from baseline performance established during a priori maintenance phase. CI = confidence interval; SGPV = second-generation *p*-value.

PROGRAMMING WITH VELOCITY-BASED TRAINING

Although the ability to have greater control over training outcomes is an exciting prospect for the strength and conditioning practitioner, understanding the varying methods of programming that are available through VBT is vital for designing effective training programs. Several studies have suggested that the velocity associated with a given percentage of 1RM is consistent across training sessions (3,8,18,24). However, it has been shown that the velocity at a given %1RM may shift due to fatigue (86) or after a short-term power-oriented resistance training program (64). Therefore, for accurate prescription of relative loads, it is advised to periodically assess the L-V relationship. Considering this, between athletes and training sessions, relative losses in exercise velocity cause consistent internal and external responses at

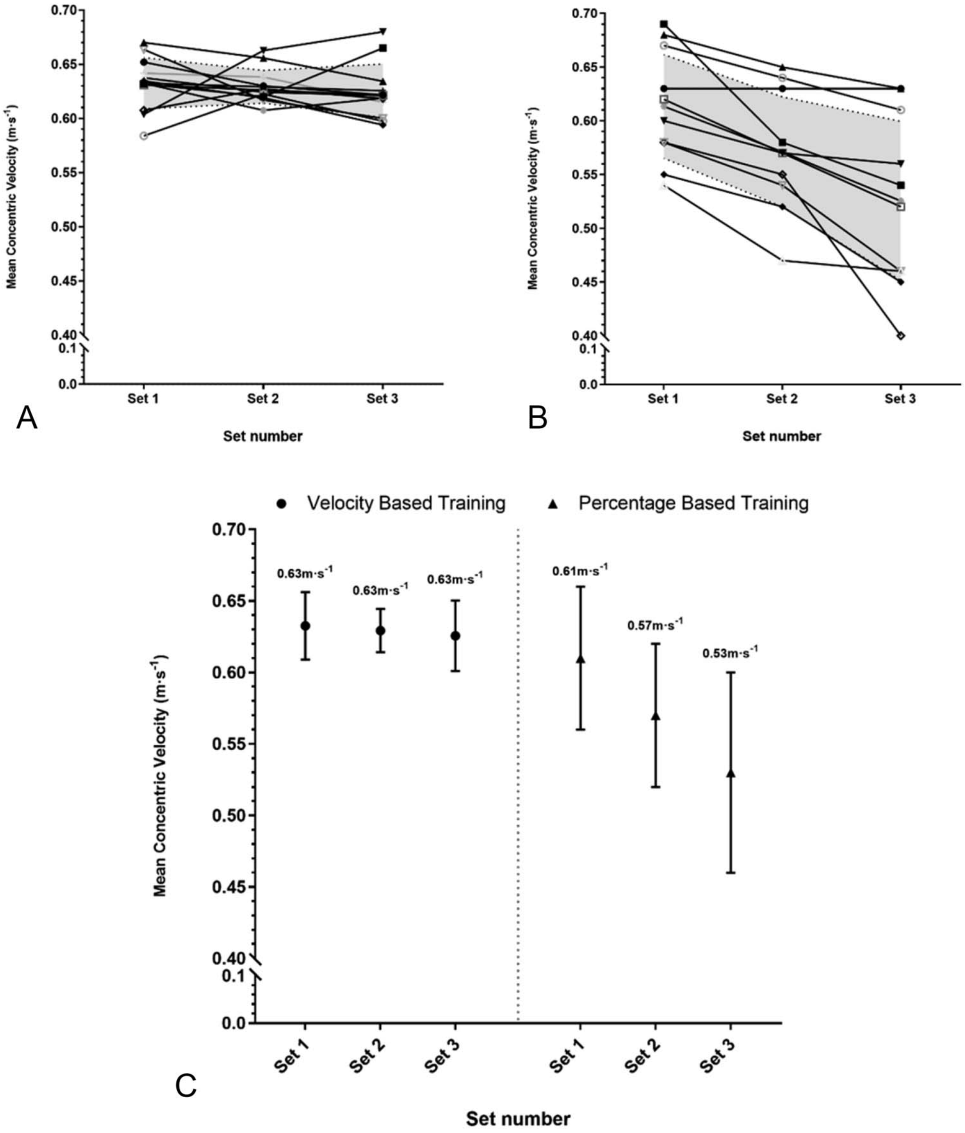


Figure 6. (A) The individual and mean group velocity (SD represented by the shaded area) when training with a 20% velocity loss threshold across 3 sets of the back squat. Data from Weakley et al. (89). (B) The individual and mean group velocity (SD represented by the shaded area) when training with 3 sets of the back squat with a set repetition scheme (i.e., 10 repetitions for all participants). Unpublished data from Weakley et al. (95). (C) The mean (±SD) velocity from graphs A and B. Note the maintenance of velocity in the velocity-based training condition compared with the linear loss of velocity in the percentage condition.

a given relative intensity (88,89). Consequently, previously well-established training methods and their periodization models can still be implemented. However, by using velocity to monitor and guide exercise prescription, improved individualization and control of training and subsequent responses can occur (21,89).

Due to changes in strength across the training cycle, one issue with percentage-based prescription is that the relative load prescribed by the strength coach may not match the relative load that is completed during training. For example, a maximal strength test from 4 weeks earlier will not enable accurate prescription of load.

Table 5
Commonly used velocity-based training methods

Method (reference)	Load	Sets	Repetitions	Load
Set average velocity (9)	The external load is prescribed from the athlete's LVP. A set and repetition scheme is prescribed. At the completion of the set, the average set velocity is required to be within 0.06 $m \cdot s^{-1}$ of initial prescribed velocity. If average set velocity ±0.06 $m \cdot s^{-1}$, external load is adjusted by 4–5% of 1RM.	Prescribed	Prescribed	Flexible
Set average velocity + VL thresholds (9,21)	The external load is prescribed from an LVP. A number of sets are prescribed with a velocity loss threshold used to guide when set termination occurs (e.g., 20% velocity loss). At the completion of the set, the average set velocity is required to be within a required velocity zone (e.g., 0.74–0.88 $m \cdot s^{-1}$ during the back squat). If average set velocity is not within this zone, the external load can be manipulated.	Prescribed	Flexible	Flexible
Targeted velocity + VL thresholds (62,63,88,89)	The athlete is prescribed a starting velocity or velocity range (e.g., 0.70–0.75 $m \cdot s^{-1}$) with the external load being altered to meet the desired velocity. A velocity loss threshold (e.g., 10%) is used to guide set termination. During subsequent sets, if initial repetition velocity is greater than ±0.06 $m \cdot s^{-1}$ of targeted velocity, an additional 30-s recovery is provided. If the following repetition's velocity remains outside this range, external load is adjusted by 4–5% of 1RM.	Prescribed	Flexible	Flexible
Fixed set + velocity loss threshold (9)	The external load is prescribed from the athlete's LVP. A velocity loss threshold (e.g., 10%) is supplied with the athlete terminating the set when velocity drops below the velocity threshold.	Prescribed	Flexible	Prescribed
Fixed total repetition + flexible set + velocity loss threshold (9)	Before the session, a total number of repetitions are prescribed (e.g., 25 repetitions). A load is prescribed from the LVP, and a velocity loss threshold is used to guide set termination. Athletes are allowed as many sets as they require to complete the prescribed number of repetitions.	Flexible	Prescribed	Prescribed
Fixed set + velocity threshold + repetition cap (9)	Load is prescribed from LVP or targeted velocity, and a velocity loss threshold is prescribed (e.g., 10%). In addition, an upper limit of repetitions that can be completed is prescribed (e.g., 5 repetitions). Athletes exercise using the prescribed load until repetition velocity decreases below velocity loss threshold or the repetition limit is reached.	Prescribed	Flexible	Prescribed

1RM = one repetition maximum; Flexible = an unknown amount that is often dictated by athlete fatigue/readiness (e.g., the athlete will complete repetitions until barbell velocity drops below a certain threshold); LVP = load-velocity profile; Prescribed = dictated before the session or after set (e.g., 5 sets).

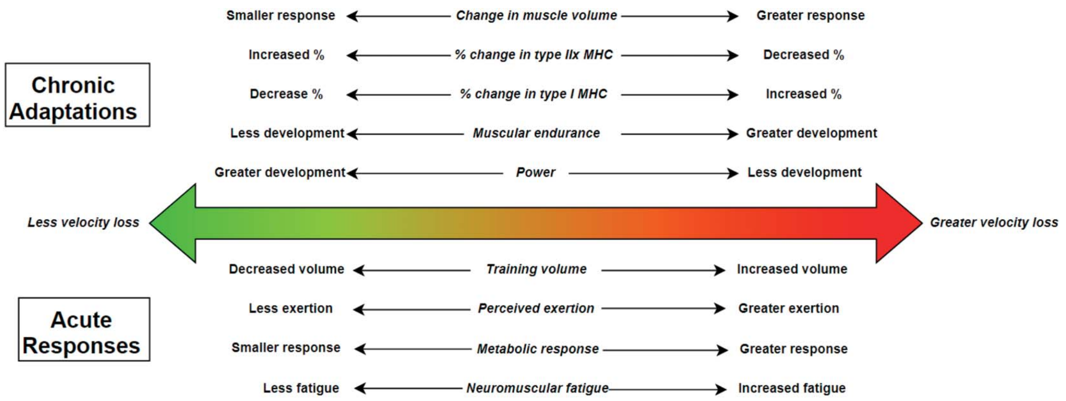


Figure 7. Acute and chronic responses to training with smaller or larger velocity loss thresholds. MHC = myosin heavy chain. Adapted from (62,63,88,89).

As a result, external loads that are supplied by practitioners are often too light or heavy. Established VBT methods can account for these fluctuations by monitoring velocity during the warm-up and training session (89). Two of the most common methods use either (I) a targeted training velocity (e.g., an athlete finds an external load within a given range that is being targeted that day [e.g., 0.70 ± 0.05 $\text{m}\cdot\text{s}^{-1}$]) (89) or (II) a load (as a percentage of 1RM) that meets a velocity from a previously established L-V profile (21). Both these methods enable reliable and accurate long-term planning. Furthermore, within-session alterations in the external load can be made by the athlete or coach by simply referring to the MV of the previous set (21) or the first repetition of the subsequent set (88,89) to ensure appropriate loading is occurring during training. Alternatively, this information can be used to guide the termination of a training session (e.g., if an athlete consistently cannot meet required velocities at a given load this may indicate fatigue).

One unique aspect of programming with VBT is that it allows for "flexible" or "fixed" set and repetition schemes. Traditional programming methods provide rigid programming (i.e., a number of sets and repetitions are prescribed), but VBT can mitigate the differences in athletes and their physiological characteristics (89). For example, a fixed number of sets may be applied (e.g., 5 sets) with a flexible repetition scheme (e.g., athletes exercise until a 20% velocity loss has occurred) (89). Alternatively, a fixed number of repetitions could be prescribed (e.g., 25 repetitions) with a flexible number of sets (e.g., each set is terminated

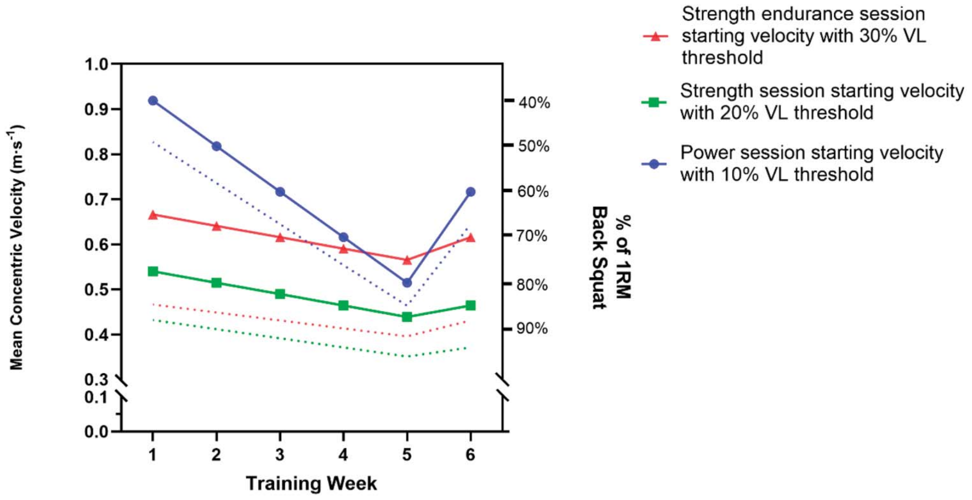


Figure 8. An example of a 6-week daily undulating mesocycle with athletes completing a strength endurance, strength, and power session each week. The bullet point within each connected line signifies the average starting velocity from a given session (e.g., strength session 1 = 0.54 $\text{m}\cdot\text{s}^{-1}$). The dotted line indicates the stopping velocity (strength session 1 = 0.43 $\text{m}\cdot\text{s}^{-1}$). Note the altering starting velocity and changes in velocity loss thresholds. VL = velocity loss.

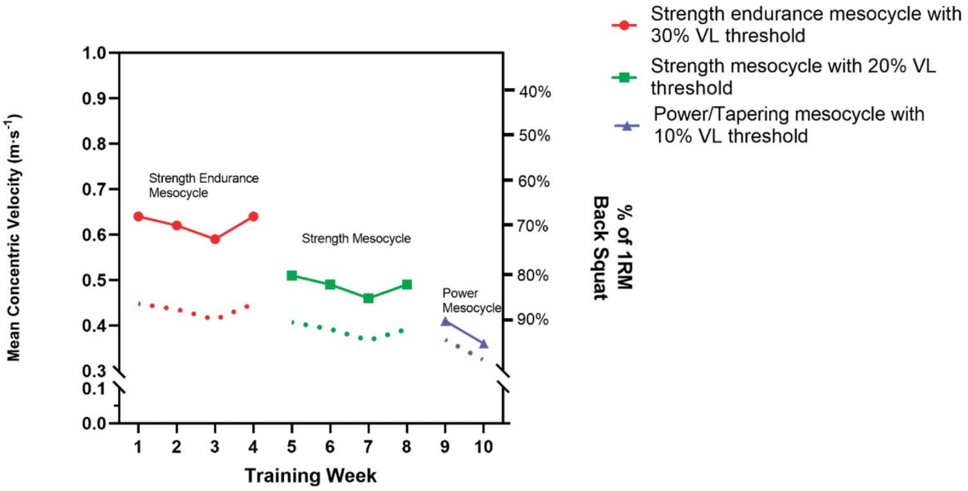


Figure 9. Ten-week block periodization approach to programming the back-squat exercise. The bullet point within each connected line signifies the average starting mean concentric velocity from a given week (e.g., week 1 = 0.64 $m \cdot s^{-1}$). The dotted line indicates the average stopping velocity (e.g., week 1 = 0.45 $m \cdot s^{-1}$). Note that the velocity loss threshold reduces across each mesocycle, while intensity increases. VL = velocity loss.

Table 6

Example of how velocity-based training for the back-squat exercise can be applied during a training week with one match

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1-Match training wk							
Velocity loss threshold	Rest	30% velocity loss	Rest	20% velocity loss	10% velocity loss	Rest	Match day
Intensity[a] (~$m \cdot s^{-1}$/% 1RM)	Rest	~0.70 $m \cdot s^{-1}$/~65% 1RM	Rest	~0.55$m \cdot s^{-1}$/~82% 1RM	~1.00–0.60 $m \cdot s^{-1}$/~30–75% 1RM	Rest	Match day
Volume	Rest	~9 repetitions per set	Rest	~4–5 repetitions per set	~2–6 repetitions	Rest	Match day
Internal response	Rest	↑↑↑ *Metabolic response & perception of effort*	Rest	↑↑ *Metabolic response and perception of effort*	↑ *Metabolic response* ↑ ↔ *perception of effort*	Rest	Match day
Fatigue response	Rest	↑↑ *Perceived soreness* ↓↓ *Neuromuscular function*	Rest	↑ *Perceived soreness* ↔↓ *Neuromuscular function*	↔↓ *Perceived soreness* ↑ ↔ *Neuromuscular function*	Rest	Match day

Velocity loss thresholds, initial intensity, approximate number of repetitions that will be completed, and estimated internal (during training) and fatigue responses (24 h following training) are supplied are supplied to assist the practitioner. Information adapted from (6,8,9,88,89).

[a] Initial velocity (mean concentric velocity) and relative percentage of 1RM may show slight deviations between athletes.

↑↑↑ = *large increase;* ↑↑ = *moderate increase;* ↑ = *small increase;* ↔ = *trivial change;* ↔↓ = *trivial to small decrease;* ↓↓ = *moderate decrease;* 1RM = one repetition maximum.

Table 7
Example of how velocity-based training for the back-squat exercise can be applied during a training week with 2 matches

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
2-Match training wk							
Velocity loss threshold	Rest	10% velocity loss	Rest	Match day	10% velocity loss	Rest	Match day
Intensity[a] ($\sim \text{m} \cdot \text{s}^{-1}$/% 1RM)	Rest	$\sim 0.55 \text{m} \cdot \text{s}^{-1}/\sim 82\%$ 1RM	Rest	Match day	$\sim 0.70 \text{m} \cdot \text{s}^{-1}/\sim 65\%$ 1RM	Rest	Match day
Volume	Rest	~2–3 repetitions	Rest	Match day	~5 repetitions	Rest	Match day
Internal response	Rest	↔ *Metabolic response* ↑ ↔ *perception of effort*	Rest	Match day	↑ *Metabolic response* ↑ ↔ *perception of effort*	Rest	Match day
Fatigue response	Rest	↔↓ *Perceived soreness* ↑ ↔ *Neuromuscular function*	Rest	Match day	↔↓ *Perceived soreness* ↑ ↔ *Neuromuscular function*	Rest	Match day

Velocity loss thresholds, initial intensity, approximate number of repetitions that will be completed, and estimated internal (during training) and fatigue responses (24 h after training) are supplied to assist the practitioner. Information adapted from (6,8,9,88,89).

[a] Initial velocity (mean concentric velocity) and relative percentage of 1RM may show slight deviations between athletes.

↑ = *small increase;* ↑ ↔ = *trivial to small increase;* ↔ *trivial change;* ↔↓ = *trivial to small decrease;* 1RM = one repetition maximum.

when velocity is reduced by 20%, with athletes implementing as many sets as necessary to complete the 25 repetitions) (9). With identification of appropriate velocity loss cutoffs and their subsequent fatigue responses, these flexible programming methods can account for differing rates of fatigue, between-athlete heterogeneity, and daily readiness (89). This is shown in recent research (89), with flexible programming enabling high levels of consistency of both velocity and power outputs between and within athletes when compared with regimented set and repetition schemes based off a percentage of an athlete's previous maximum (19,95). Table 5 outlines some of the most commonly applied methods of prescribing sets and repetitions using VBT.

Owing to the ability to accurately prescribe training load and volumes, it is also feasible to implement VBT in traditional programming models. Accurate load prescription and velocity loss thresholds (e.g., 10% vs. 30%) that induce a desired amount of fatigue can ensure that specific physical and physiological characteristics can be targeted. For example, block periodization models that use phase potentiation and greater volumes before heavier loads and lower volumes can be applied and still follow traditional concepts (17,57). In a block periodized model that uses VBT, initial phases that aim to promote changes in strength endurance and improvements in body composition may use 30% velocity loss thresholds. This could be followed by a strength mesocycle that allows for greater loads (i.e., lower starting velocities) and a smaller velocity loss threshold (e.g., 20%) that causes less peripheral fatigue (63,89). Finally, this could be followed by a strength-power or tapering mesocycle which uses a range of initial starting velocities with a very small velocity loss threshold (e.g., 10%). These smaller thresholds have been shown to minimize fatigue while also ensuring greater power outputs during training (89). These concepts can be applied across a range of different programming models (e.g., linear, daily/weekly undulating, conjugated) and can assist coaches in applying traditional approaches with greater control and prescription (Figures 7–10).

PRACTICAL APPLICATIONS FOR THE STRENGTH COACH

Maximizing performance through physical training is the primary goal of all strength and conditioning professionals. Therefore, applying VBT methods efficaciously is of great importance. It is acknowledged that individualization and greater homogeneity of fatigue responses can occur when VBT is appropriately applied (88,89). However, strategic implementation can enhance athlete buy-in and improve outcomes. Below are practical suggestions that can assist in the integration of VBT into the training program.

It has previously been recognized that providing feedback to athletes as they train can enhance velocity and power outputs by up to 10% (92,93,96). Furthermore, because of the naturally competitive nature of athletes, by allowing individuals of similar ability or position to train together and observe each other's kinematic outputs, greater competition may occur. However, the intended purpose of the exercise must

Table 8
Example of how velocity-based training for the back-squat exercise can be applied during preseason

Preseason training wk	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Velocity loss threshold	Rest	30% velocity loss	30% velocity loss	Rest	20% velocity loss	Rest	Match day
Intensity[a] (~m·s^{-1}/% 1RM)	Rest	~0.60 m·s^{-1}/~80% 1RM	~0.70 m·s^{-1}/65% 1RM	Rest	~0.70 m·s^{-1}/~65% 1RM	Rest	Match day
Volume	Rest	~9 repetitions per-set	~9 repetitions per-set	Rest	~7 repetitions per-set	Rest	Match day
Internal response	Rest	↑↑↑ *Metabolic response & perception of effort*	↑↑↑ *Metabolic response & perception of effort*	Rest	↑↑ *Metabolic response & perception of effort*	Rest	Match day
Fatigue response	Rest	↑↑ *Perceived soreness* ↓↓↓ *Neuromuscular function*	↑↑ *Perceived soreness* ↓↓ *Neuromuscular function*	Rest	↑ *Perceived soreness* ↔↓ *Neuromuscular function*	Rest	Match day

Velocity loss thresholds, initial intensity, approximate number of repetitions that will be completed, and estimated internal (during training) and fatigue responses (24 h following training) are supplied to assist the practitioner. Information adapted from (6,8,9,88,89).

[a] Initial velocity (mean concentric velocity) and relative percentage of 1RM may show slight deviations between athletes.

↑↑↑ = *large increase;* ↑↑ = *moderate increase;* ↑ = *small increase.* ↔ = *trivial change;* ↔↓ = *trivial to small decrease;* ↓↓ = *moderate decrease;* ↓↓↓ = *large decrease;* 1RM = one repetition maximum.

also be considered, as the feedback provided may cause an athlete to sacrifice technique for greater velocities. Although a great amount of publicity has been given to VBT in recent years, this has also led to practitioners occasionally attempting to maximize velocities on exercises that are traditionally performed for stability and range of motion development, such as an overhead squat. When these movements are performed quickly, they often lose their intended purpose and benefits. Consequently, feedback is suggested to be best applied during exercises with the greatest force and power outputs (e.g., Olympic-style lifts, jumps, squats, and bench press) (1,50,92,93,96).

As athletes participate in much more than simply strength training, the management of fatigue is of great importance for the strength coach. With relative velocity loss thresholds, one can manage the accrual of fatigue and cause more homogenous responses between athletes. It is advised that during the "off-season" or general preparatory phase, that greater velocity loss thresholds are implemented as this period tends to enable frequent strength training and residual neuromuscular fatigue is unlikely to have detrimental effects. Therefore, 20–40% velocity loss thresholds may be effective in these periods to elicit greater adaptations in conditioning, lean body mass, and muscular endurance (63). Alternatively, in-season, smaller velocity loss thresholds (<20%) may be of benefit in reducing fatigue and ensuring training does not cause substantial reductions in performance (88,89). These concepts can also be applied within an athlete's training mesocycle (refer to Tables 6–9) with previous research (88,89) implying that greater velocity losses (e.g., 30%) be applied at the start of the week (e.g., match day [MD] −5), with reductions occurring as game day draws closer (e.g., 20% at MD −3 and 10% at MD −2).

Finally, the ability to objectively dictate load can be of great use for the practitioner (56). Regardless of the method of implementation, the ability to autoregulate loads based off velocity can support

Table 9
Example of how velocity-based training for the back-squat exercise can be applied during a tapering wk

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Deload training wk							
Velocity loss threshold	Rest	10% velocity loss	Rest	Rest	10% velocity loss	Rest	Match day
Intensity[a] ($\sim\text{m}\cdot\text{s}^{-1}$/% 1RM)	Rest	$\sim$0.50 $\text{m}\cdot\text{s}^{-1}$/85% 1RM	Rest	Rest	$\sim$1.00–0.60 $\text{m}\cdot\text{s}^{-1}$/ 30–75% 1RM	Rest	Match day
Volume	Rest	~2–3 repetitions per-set	Rest	Rest	~2–6 repetitions	Rest	Match day
Internal response	Rest	↑ *Metabolic response & perception of effort*	Rest	Rest	↑ *Metabolic response* ↑ ↔ *perception of effort*	Rest	Match day
Fatigue response	Rest	↔ ↓ *Perceived soreness* ↑ ↔ *Neuromuscular function*	Rest	Rest	↔ ↓ *Perceived soreness* ↑ ↔ *Neuromuscular function*	Rest	Match day

Velocity loss thresholds, initial intensity, approximate number of repetitions that will be completed, and estimated internal (during training) and fatigue responses (24 h following training) are supplied to assist the practitioner. Adapted from (6,8,9,88,89).

[a] Initial velocity (mean concentric velocity) and relative percentage of 1RM may show slight deviations between athletes.

↑ = *small increase;* ↑ ↔ = *trivial to small increase;* ↔ *Trivial change;* ↔ ↓ = *trivial to small decrease;* 1RM = one repetition maximum.

the management of not only acute-fatigue responses (e.g., between sets) but also the accrual of fatigue across sessions. This can enable practitioners to be confident in their exercise prescription, even during periods of congested training or match play. For example, practitioners are commonly faced with the issue of athletes coming straight off the training field and into the weight room. This often means that the athlete is fatigued and that the loads prescribed before the training session are no longer valid. However, VBT does not face these issues as athletes are prescribed a velocity range rather than a specific external load. In addition, because of the many outside stressors that can impact an athlete (e.g., academic stress) (55), VBT may support load management.

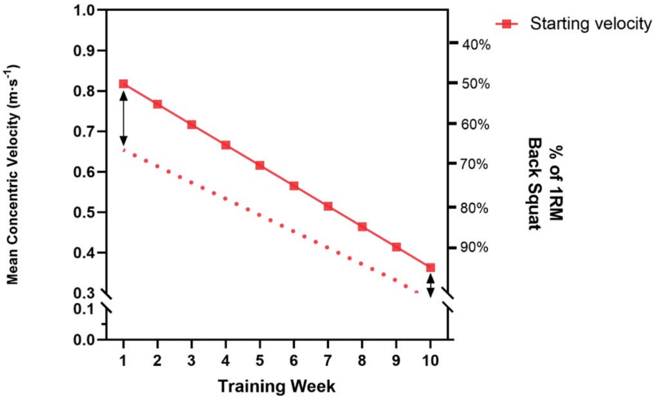


Figure 10. An example of a linear periodization approach to programming the back squat with a 20% velocity loss threshold applied across a 10-week training macrocycle. The bullet point within each connected line signifies the starting velocity from a given week (e.g., week 1 = 0.82 $\text{m}\cdot\text{s}^{-1}$). The dotted line indicates the set termination velocity (e.g., week 1 = 0.66 $\text{m}\cdot\text{s}^{-1}$). Note that the velocity loss threshold reduces across the macrocycle (emphasized by the arrows) despite the threshold not changing. This allows for increased intensity but reduced volumes across time.

CONCLUSIONS

VBT uses exercise velocity to inform or enhance training practice. It can be implemented as a tool that works alongside traditional percentage-based methods (e.g., the provision of feedback), or it can be used to autoregulate the training volume and intensity for each athlete. From this review, it is advised that:

- An important consideration for the practitioner is the validity of the device that is used to monitor velocity. Current evidence suggests that linear position transducers should be used due to their greater accuracy.
- Feedback of performance is provided either visually or verbally to athletes as they train. This feedback should be at frequent intervals (e.g., after each repetition) and used during high force and power exercises (i.e., primary, multijoint exercises).
- For testing performance during ballistic exercises with loads that are ≤70% of 1RM, PV should be used. Alternatively, PV or MV could be used for testing performance >70%.
- For the prediction of 1RM ability, MV should be used. This is due to smaller differences between different testing devices, greater linearity of the L-V relationship, and smaller between-athlete variation in the velocity that 1RM occurs.
- The "2-point method" has been shown to be a valid method of calculating the 1RM from the L-V profile during upper-body exercises. This involves (I) identifying the exercise-specific V1RM, (II) recording the MV against a light (≈45% 1RM) and a heavy load (≈85% 1RM), and (III) modeling the individual L-V relationship and determining the 1RM as the load associated with the V1RM. Coaches should be aware that the accuracy of the 2-point method and other velocity-based 1RM prediction methods is expected to be lower during lower-body exercises.
- By quantifying an athlete's L-V profile and using an accurate velocity measuring device, practitioners can equate a given velocity with a percentage up to 90% 1RM of an athlete's maximum capability. By having this information, differing amounts of fatigue and rates of adaptation across athletes can be managed through accurate daily prescription of intensities and volume.
- Practitioners should consider regularly monitoring velocity (this could be performed at the start of a training session) to help objectively monitor changes in athlete fitness/fatigue. By monitoring the typical day-to-day fluctuations in velocity (i.e., the SE) and applying this to a meaningful threshold (e.g., change in strength), practitioners can gain regular objective insight into the effects of their training program.
- Velocity loss thresholds can account for between-athlete differences in muscular endurance and also mitigate heterogeneity in short-term fatigue responses. By altering the velocity loss threshold, internal and subsequent fatigue responses increase or decrease.
- Prescription of training using VBT can occur in many ways. These methods can fit within traditional periodization models and can be used to guide exercise prescription with greater confidence.

Conflicts of Interest and Source of Funding: The authors report no conflicts of interest and no source of funding.

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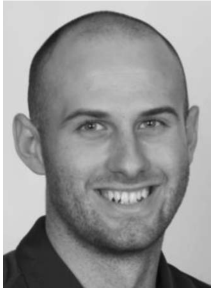

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