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Invited Editorial

Velocity-Based Training: Current Concepts and Future Directions

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ABSTRACT

Topics in Exercise Science and Kinesiology 3(1): Article 1, 2022. Velocity-based training (VBT) is a current approach to resistance training that relies on measured bar, implement, and/or athlete speed to formulate and adjust training for both long-term programming and daily training sessions. Relying on a number of available tools of varying levels of accuracy, VBT can help the strength and conditioning specialist and/or the rehabilitation professional to not only better predict strength and power over time, but also to adjust training loads in order to maximize training response in a given session. While the appeal and price points of available technology in the marketplace have made VBT more accessible than ever, a real need exists to establish the efficacy of the approach in practical settings.

KEY WORDS: VBT, long-term development, athletic development, performance enhancement, programming

INTRODUCTION

Strength and conditioning specialists have long searched for new and innovative strategies or tools to establish and adjust key aspects of exercise prescription like volume and load. At the same time, it can often be a challenge to know when to modify such factors in order to maximize each athlete's individual training response. While a variety of approaches like estimated and direct 1RM testing, along with a plethora of programming models including traditional linear progression and more contemporary periodization models (and its many variants like linear periodization, non-linear periodization, conjugate/block periodization, and a host of others) have been used for decades, most such strategies rely only on periodic testing. These approaches have also presented the professional with no small amount of inference and trial and error in making training prescriptions and progression schemes (3,5,13). As a result, professionals have long needed to develop a more specific, practical, and effective approach that incorporates direct measurements and daily adjustments in order to elicit peak performance.

Velocity-based training (VBT) is a means of measuring bar, implement, and/or athlete speed and subsequently formulating training based on the achievement of certain velocities (17,18,23). As athlete preparation has steadily become less dependent on unsubstantiated opinion and increasingly reliant on scientific evidence, many strength and conditioning specialists have transitioned their coaching strategies from trial and error to load percentages (%), rate of perceived exertion (RPE), or rep maxes (RM). Most have adopted their chosen system through a combination of experimentation along with the influence of previous or peer coaches. For many, the 1RM method has been a reliable but not error-proof system.

Most notably, 1RMs are typically calculated from testing sessions that occur periodically (every 4-6 weeks) and are most often only adjusted after (but rarely between) formal testing sessions. However, on any given day, an athlete may be influenced by a number of factors that could significantly impact their readiness to train. As a result, percentages may often miss the mark. Frequently, the goal for training athletes using percentage RM methods has been to make sure that the ideal stimulus was prescribed and subsequently completed during each training session. However, the stressors of a given day—school, job, family, significant others—can lead to huge fluctuations in daily readiness (8,11,16). Other factors like inadequate sleep/recovery or poor, improper, or inadequate nutrition can have a more subtle but still significant cumulative effect that can eventually lead to overtraining. At this point, percentage-based loads could be considered of limited utility. While these values are important, further refinement and adjustment of optimal training load for the day could potentially improve the appropriateness of the training load on a given day.

Conversely, measures of velocity are likely more reflective of day-to-day fluctuations in readiness to perform that could impact strength and power. By this logic, the strength and conditioning specialist would be better equipped to take advantage of days in which preparation and readiness to train is ideal, minimize the impact of days in which readiness to train is suboptimal, and adjust loading accordingly for maximum training response. While VBT is not a remedy for all potential issues associated with performance assessment and progression, it can provide highly informative real-time data for coaches and athletes to help inform choices during training. These informed decisions can then drive improved performance and injury resilience. While the science surrounding VBT is still emerging, in our experience, the approach has been highly effective in assuring that loading and intensity for a given training session are optimal, thereby maximizing effectiveness of training.

READINESS FOR TRAINING

Immediate and Direct Feedback

Over the years, a number of strategies have been employed to determine readiness for training, recovery, and appropriateness of loading in a given training session, including simple movements such as the squat jump, vertical jump, and grip strength (9,15,22). More commonly, RPE strategies have been employed to attempt to quantify the inherently subjective nature of how difficult a given set or session "feels" (9,19,21).

However, unlike these more subjective methods of assessment, VBT can provide measured real-time data to inform decision making while at the same time helping the athlete become more aware of their own readiness for training (9). Using this process, the strength and conditioning specialist can adjust the prescription of training to meet the athlete's levels in real time as a given session unfolds. Put most simply, VBT data and loading schemes can help both the athlete and the strength and conditioning specialist know when it might be most appropriate to "tap the brakes" to prevent injury versus when it might be better to "step on the gas" for optimal loading on any given day.

Furthermore, sound VBT data can be valuable markers of readiness for training, as it takes into account the athlete's true physiological and mental state (4,8,12,16,20,23). Percentage-based programs have been shown to miss the mark by up to +/- 18% with respect to loading based on how the athlete feels on a given day (16). Within this margin of error, if a given workout prescribed loading at 90% of the measured or predicted 1RM on a day when the athlete felt stressed, fatigued, etc., loading could feel like greater than 100% of the 1RM—most likely leading to a failed set. Conversely, on a day when the athlete was feeling particularly strong and well prepared for training, the same load could feel significantly less than the 1RM. This could mean inadequate potential adaptation and/or a missed opportunity to establish a new personal best.

Negative deviations from an athlete's norm with VBT test performance most likely indicates an unrecovered state (4). It is understood that as load increases, concentric velocity decreases. However, this view alone provides an incomplete picture. Velocity data can be used to further augment loading decisions based on percentages of 1RM. Simply put, VBT provides richness, context, and increased specificity in loading than can be obtained through either RPE, percentages, or other such strategies alone. If RPE and percentages are the "what," velocities are the "how" that can be used to dramatically improve the appropriateness of exercise and load prescription from day to day and ultimately across the duration of development.

QUANTIFYING STRENGTH TRAINING

Differing tempos in strength training can be used for eliciting a variety of responses, but regardless of the training tempo prescribed, speed is almost always advantageous. As it turns out, the old coaching maxim of "train fast to *be* fast" holds true. If an athlete wants to be fast, move fast, and/or move something with speed, then timely and appropriate motor unit recruitment is key to that goal.

More specifically, "train fast to *be* fast" could also be more completely stated as "train fast to be strong," because when training at or near maximal velocity, it is possible to trigger greater strength improvements than with standard/slow speed training (5,10,16). For example, in relatively short duration studies, max-velocity training has been shown to increase strength significantly over alternative methods involving slower speeds (7). However, this does not mean that all strength efforts should revolve around moving the bar with maximum speed. Instead, providing the athlete with a target velocity has proven more effective than the cue to simply move "as fast as possible," making the specific measures afforded by VBT essential for maximum performance (11).

Additionally, quantifying bar speed is important for reasons other than directly impacting performance. If we do not know the precise speed at which an athlete is able to train or perform, then it becomes increasingly difficult to train to improve the quality. Certainly, a skilled coach or strength and conditioning specialist's eye can subjectively assess the athlete's speed, specifically as it relates to the bar/implement. However, when the velocity of movement becomes high, it is much more difficult to be able to discern differences in velocity with only the naked eye. This is where a tool such as a VBT instrument is particularly helpful.

When lifts require rapid movement for successful completion as in the case of most weightlifting movements (to name but one category), significant differences in performance that could mark the difference between a successfully completed lift and a miss may rely on velocity differences as small as 0.1-0.2 m/s. The difference between these attempts would be all but imperceptible to most. As such, having a tool and method to objectify and quantify performance and remove the guesswork can be incredibly beneficial to both the strength specialist and the athlete.

PRACTICAL ASPECTS OF IMPLEMENTATION

Hardware and Technology Types

Once the decision is made to implement VBT, the next choice is related to determining which of the available tools is best suited to actually measure and track velocity. A wide variety of hardware is currently available on the market with substantial differences in cost and features. With the growing availability of differing devices to track velocity and other second-level metrics in the weight room, it can be confusing for the coach or strength and conditioning specialist to sort through the technical aspects most important in a given application. With the reduction in price for many of these devices, technology that was well out of the budget just a few years ago is now affordable and attainable, and as more competitors have entered the marketplace, price continues to go down while features have continued to go up.

For example, just a decade ago (or less in some instances), purchasing a device for implementing VBT-based methods typically meant upwards of $1500+ per big, bulky device—not to mention the difficulty associated with actually using and applying the raw data they produced in any beneficial way. Contrast that to today, where devices that sync wirelessly to a smart phone can fit easily in a gym bag. Concurrently, data use and calculations are no longer difficult because the user interfaces (UIs) and software employed in modern devices have become far more straightforward, intuitive, user-friendly, and most are designed to work on smartphones and/or tablets.

The ultimate choice as to what device or device type would be considered best in a given application is primarily based on the strength and conditioning specialist's unique situation and available budget. Table 1 provides a comparison of the different device types currently available on the market in the United States.

Table 1. Examples of selected commercially-available VBT systems, type of technology employed, and their current cost (May 2021).

Name	Type	Cost*
GymAware *Kinetic Performance Technology, Canberra, Australia*	Camera	$2750
RepOne *Squats and Science Labs, New York, NY*	LPT	$399
Tendo *Tendo Sport, London, UK*	LPT	$1329
Bar Sensei *Assess2Perform, Montrose, CO*	Accelerometer/IMU	$375
Beast Sensor *Beast Technologies, Brescia, Italy*	Accelerometer/IMU	$289
FLEX *Kinetic Performance Technology, Canberra, Australia*	Accelerometer/IMU	$495
PUSH Band *PUSH, Inc., Toronto, ON Canada*	Accelerometer/IMU	$449
VMaxPro VBT Tracker *SimpliFaster, Pleasanton, CA*	Accelerometer/IMU	$329
Perch *CataLyft Labs, Inc., Cambridge, MA*	Camera	$1999
EliteForm *Nebraska Global/EliteForm, Lincoln, NE*	Camera	Not currently available for individual use/purchase

* For a single basic configuration unit only. Many have available options with desirable add-ons.

There are three primary device types available to track velocity: linear position transducers (LPT), inertial measurement units (IMU/accelerometers), and camera-based systems. Each of the differing types of products have inherent strengths and weaknesses, with some being considered better suited for team settings while others likely more useful for individual use. Implement type is another consideration, with LPT better suited for barbell exercises, while IMU technology is likely more valuable when athletes perform plyometrics and dumbbell/kettlebell/odd implement training.

Linear Position Transducers (LPT)

Of the three available device types on the market, linear position transducers have been available in the marketplace the longest and are viewed by most as the "original" widely-available method for measuring barbell velocity (Note: nearly all of the practical application/implementation information to follow has been developed through the use of an

LPT unit). LPTs have been shown to be more accurate than accelerometers in measures of peak velocity and average velocity (2,6). At the same time, cost of these units has come down significantly in recent years.

The LPT works by measuring a physical attribute: the speed at which a tether within the unit is pulled during concentric motion of a given repetition of an exercise. When the tether is drawn out of the unit, a spindle turns inside the unit's housing. Measuring the revolutions of the spindle per unit of time allows the LPT to measure and display an accurate direct physical measurement. Specifically, LPTs measure the distance the tether moves over time, providing the most accurate velocity measurement relative to alternative approaches. Information other than velocity is also easily calculated. When including data regarding load, the unit can easily covert acceleration data to compute power produced in a given repetition or set, as well.

Figure 1. Linear Position Transducer (LPT) unit hooked to bar. Circle indicates tether attachment to bar.

It should be noted that some strength and conditioning specialists have expressed concern about having something physically attached to the barbell, fearing that this might cause issues in lifting or potentially pose a safety hazard. However, these fears can typically be dispelled after a single use. LPT devices are designed to minimize friction, resulting in virtually no perceptible effect on the bar. The LPT unit itself is usually on the floor near the bar with the tether affixed either through a magnet or lightweight collar, so there is minimal chance of the device coming free with the bar overhead.

Contemporary LPT units can estimate not only force and power production but also interpolate range of motion. This information can be valuable in helping to quantify—for example—if the athlete is failing to hit depth in every repetition of a squat set. Newer units (GymAware, Kinetic Performance Technology, Canberra, Australia and RepOne, Squats and Science Labs, New York, NY) can also measure barbell path and trace other 3D motions, making them extremely powerful to use.

In our experience, for weightlifting purposes—snatch, clean, jerk, and squatting—LPT is probably the best available option for reliable data to be used to help improve training. Practically speaking, the only drawback with LPT units is that they measure every time the tether goes "out," or all concentric movements. This means when completing something like two clean and jerks, the strength and conditioning specialist might notice readings for both the athlete's front squat as well as the bounce when the bar is dropped. Learning and knowing how to spot these artifacts in the data is easy with minimal experience (front squats and bounces have distinct characteristics like the distance traveled by the bar and bounces are almost always extremely fast).

If reliability and accuracy is what is most important, then LPT is a more expensive but also more desirable option when compared to accelerometer/IMU units to be explored next. On the other hand, if weightlifting movements are employed only occasionally in a given setting but power-based lifts are more common, then an accelerometer will probably suffice. Technology rapidly advances and it is entirely possible that newer technology may eventually surpass LPT systems. However, for now, all things considered, the versatility, accuracy, and price point afforded by LPT systems make them difficult to beat.

Accelerometer/Inertial Measurement Units (IMU)

Accelerometers/inertial measurement units (IMUs) are relatively new to the market and include wearable tech but have now migrated to units that can be placed on the barbell or implement directly. The price point of these devices is usually considerably lower than LPT units, however the user interface for the applications associated with them are still most often full-featured and highly flexible. It is also worth mentioning to note that while IMU technology has radically exploded in recent years, relatively little published research establishing the validity and reliability of these units—let alone their practical application and use—currently exists, especially compared to older LPT technology.

Accelerometers require information regarding the specific movement being performed coupled with data measured by the unit that is then used to calculate velocity and other metrics through a series of algorithms. Relying on a series of computations rather than a direct physical measure, the possibility of inaccuracy is higher in IMU technologies than in LPT units. However, as the technology has continued to advance, these devices have become increasingly reliable (2). In our experience, accelerometers have proven to provide the most inconsistent readings when placed in different locations on the bar or after a weightlifting movement is dropped. Additionally, these units tend to perform well in measuring movements like the squat and bench press but are less effective when the athlete moves dynamically as in movements like lunges or multiplanar skills.

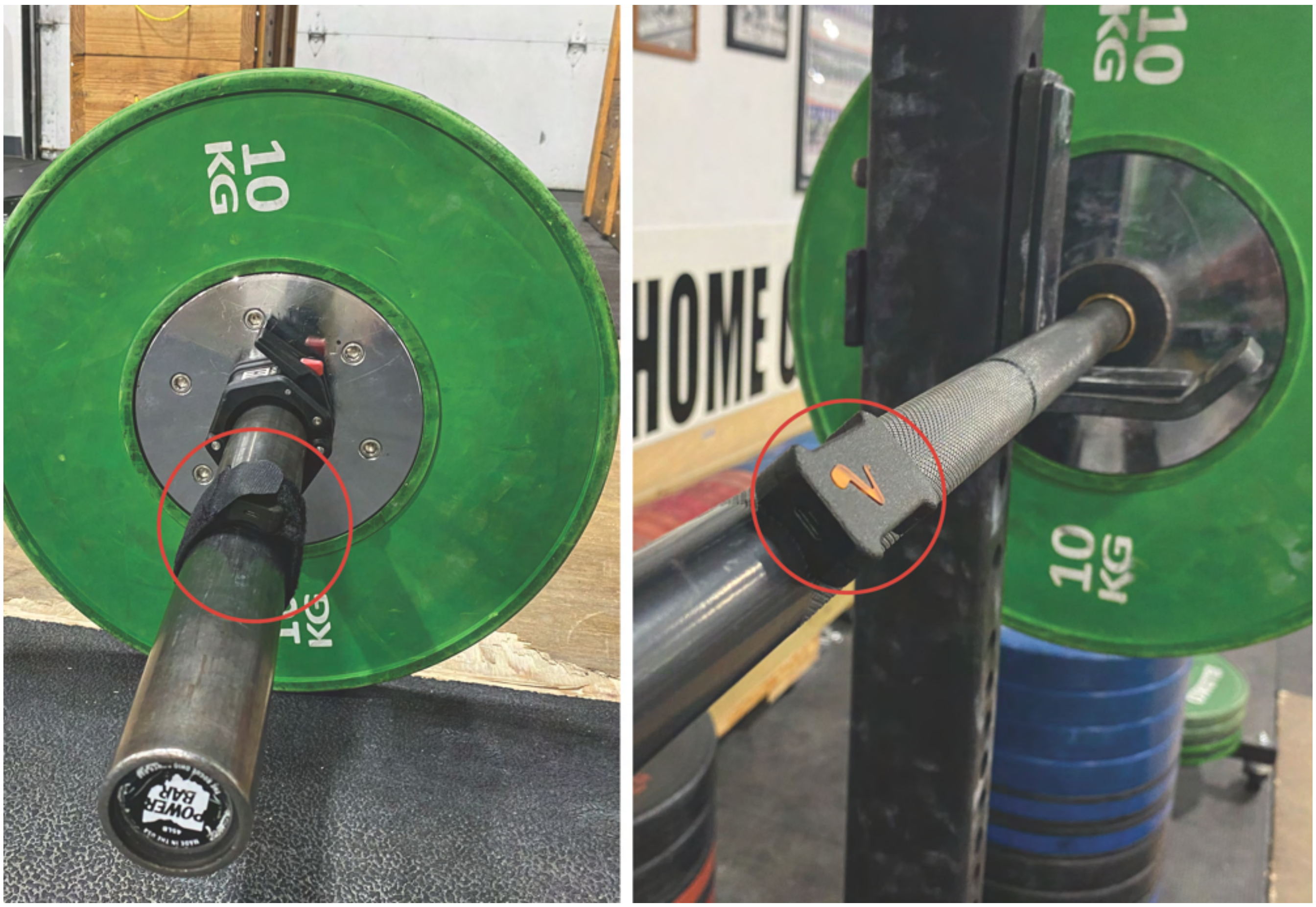

Figure 2. Accelerometer/Inertial Measurement Units (IMU). Circles indicates units attached to bar.

In practice, accelerometers may be better than nothing at all, but are not yet considered particularly accurate compared to LPT units (1,10). That said, they do provide some advantages, though, as some units can be attached to the athlete while sprinting or jumping or attached to different implements like bands, kettlebells, dumbbells, etc. When considering weightlifting movements alone, accelerometers are fairly limited in providing accurate or reliable readings (1). Their light weight and portability also make them a preferred tool for field-based work outside the typical training facility.

Camera Systems

Camera-based systems are newest to the market, and the current leaders in the marketplace are Perch (CataLyft Labs, Inc., Cambridge, MA) and EliteForm (Nebraska Global/EliteForm, Lincoln, NE). Both of these systems are built on a multi-camera array similar to the technology used in Microsoft Xbox Kinect systems. Camera systems work by determining depth through the pixels in the frame. This then provides information about barbell velocity, athlete velocity, and 3D movement. Because the system is not measuring a single point but rather countless multiples of points, it can not only provide basic info like bar speed but also more advanced data like movement relative to the cardinal planes, allowing the strength and conditioning specialist or rehabilitation professional to identify muscular imbalances or other functional limitations.

Figure 3. Camera-based system affixed to a power rack. Note the main unit above the rack, dual camera arrays mounted to the upper crossbeam, and touch panel video display mounted to the right upright.

Despite their high-tech nature and the rich data sets these systems can produce, camera-based systems are not necessarily the best tools for measuring bar speed accurately at all times. These systems monitor and measure displacement of an object and use computations to calculate velocity. While the technology is radically different from IMU systems, the result is the same: indirect measurement. This distillation of information could potentially result in errors or dropped data if the athlete happens to move out of frame momentarily. When this occurs, data for that rep or set is compromised or lost.

These emerging technologies are not yet considered well-suited or currently competitively priced for most individuals or even small training facilities largely because they require highly specific installations and a considerable amount of computing power in order to capture, process, and present the veritable mountain of data that is being collected. As with most emerging technology, it is probably only a matter of time until such solutions become available at lower price points or more basic but competitively priced units become available, but for now, widespread applications are limited.

Camera-based systems have been embraced extensively in the past few years in strength and conditioning programs at the upper levels of collegiate and professional sport. Units are typically installed on every individual training station or rack and provide an incredible amount of data and real-time feedback for an entire team training together at the same time. Such systems can provide a great user experience in terms of readouts and feedback to the athlete. Likewise, they can also be extremely convenient, as there is no battery to charge and no device or tether that must be connected to the bar for each set or moved between exercises. These systems are ready to use right away with the touch of a handheld or fixed mount tablet or wireless enabled device, with some units even employing facial recognition to load an athlete's profile when they enter the training space in the rack.

SOFTWARE, USER INTERFACES, AND OTHER CONSIDERATIONS

The final piece of the puzzle with all of the available options is the user experience. For many years, the Tendo (Tendo Sport, London, UK), an LPT unit, was considered by many to be the only viable option for coaches and strength and conditioning specialists looking to track and employ VBT methodologies. Long-time adopters of VBT methods often still prefer the reliability and simplicity of the Tendo unit. However, the "user experience" consists of a small digital readout with LED indicators and simple numbers. In the past, there was nothing else on the market more advanced and the process of recording the data for a team or multiple athletes was (and remains) somewhat arduous.

Conversely, most of the newer entrants into the marketplace provide comparable data, but provide it via an improved user experience through the use of intuitive and versatile computer applications. Several devices on the market process or provide data regarding bar path, lateral movement, verbal cues employed by the coach, and more. These apps can provide feedback if the athlete achieves or misses a target velocity (up or down). At the same time, these systems can even be used to run the entire training program for one or even multiple teams. The power previously reserved for sports scientists and well-funded, elite athletics programs is now available and affordable to most, making VBT methods at long last a possibility rather than a theory.

The decision regarding the type and specific brand of device employed will be heavily influenced by available budget. While the convenience, versatility, and sheer "wow-factor" of a camera-based system may sound great, it means spending tens of thousands of dollars to fully outfit your training facility with a unit on each rack. If such is outside the bounds of available resources, then this type of system will simply not be a viable option.

Budget aside, the purchase decision should be based around the specific needs within a given application. Considerations like convenience, user experience, analytics of data, precision, and reliability are all critical in making an informed decision. By considering these and other important factors, the strength and conditioning specialist should ultimately be able to make the best choice and begin using velocity-based methodologies in training prescription and application.

IMPLEMENTATION

The Velocity Profile

A velocity profile (***Figure 4***) is a data table consisting of athlete and movement-specific data that demonstrates the velocities an athlete attains through different percentages as they progress toward their 1RM. Interestingly, even when an athlete's strength improves (i.e.: their 1RM increases), the speed at a given percentage remains the same (7,23). For example, consider an athlete who squats 100 kg as their initial 1RM. This athlete will squat an 80% load (80kg) at roughly 0.5 m/s. If that athlete increases their 1RM to 150 kg over a given time, it is anticipated that they will then be able to move their *new* 80% 1RM (120 kg) at roughly 0.5 m/s, as well. For any movement that is valued in the weight room, it is probably a wise choice to get a velocity profile on each athlete. Most commonly, that will involve profiles on the back squat (mean velocity), front squat (mean velocity), snatch (peak velocity), and clean and jerk (peak velocity).

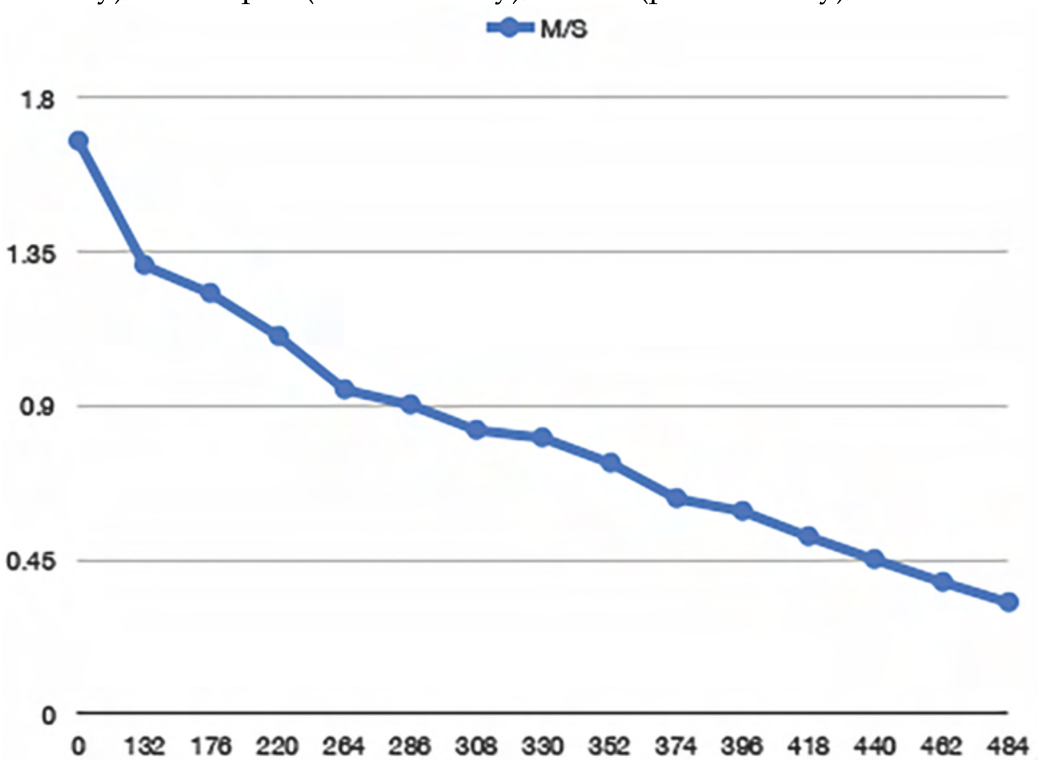

Figure 4. Sample velocity profile for an athlete's barbell back squat.

Creating a profile is fairly straightforward. When testing for 1RM, the strength and conditioning specialist should record the velocities the athlete hits for every given percentage of the 1RM along the way and record those data points. Each of those velocities can then correspond to a percentage on future training days. The most important of these is likely the velocity at maximum, especially on weightlifting exercises. This can be accomplished without loading all the way to a true 1RM. With enough data points, the slope of the decline in speed can be extrapolated for weights not yet used and the minimum speed necessary for a made lift can be placed along that slope. Strength and conditioning specialists could choose to do a repetition every 5% increase from 30% until 90%+ but that many repetitions are not always practical. Increases in 10% increments from 50-70% and 5% thereafter to 90%+ are typically sufficient.

Table 2. Sample velocity profile for the barbell back squat.

KG/LBS	Mean Velocity (M/S)
0	1.67
60/132	1.31
80/176	1.23
100/220	1.1
120/264	0.95
130/286	0.9
140/308	0.83
150/330	0.81
160/352	0.73
170/374	0.63
180/396	0.59
190/418	0.52
200/440	0.454
(Was not attempted) 210/462	0.388
(Was not attempted) 220/484	0.322

Table 3. Sample velocity range per percentage 1RM for the barbell back squat.

Percentage of 1RM Back Squat	Velocity Range
90%	0.4-0.5 m/s
80%	0.6-0.7 m/s
70%	0.7-0.8 m/s
60%	0.8-0.9 m/s
50%	1.0 m/s

In the example provided in Table 2, data consists of loading on a day when the athlete was working toward a heavy squat. The highest load actually completed during the session was 200 kg. However, using the velocity profile, it could be predicted that the athlete was most likely capable of 220 kg. if the accepted minimum velocity for a made squat held up at >.30 m/s. From the raw test of the 1RM, that information could then be used to set target velocity ranges for percentages to use in training going forward. Using this model, the strength and conditioning specialist could prescribe a *velocity* at which to train rather than a percentage of the 1RM, which is a more accurate prescription on a day-to-day basis (8). This is presented in Table 3.

Unlike % 1RM loading schemes which are built around data acquired during periodic test days (most often every 4-6 weeks in practice), the use of VBT and the application of the velocity profile can allow the strength and conditioning professional to perform a relatively quick and easy velocity assessment and determine with a fair amount of accuracy what kind of day a given athlete is likely to have in the weight room. While this approach has proven effective in our practice, formal investigation via empirical studies is necessary to establish its scientific validity and further refine its practical implementation.

EVALUATING READINESS FOR DAILY TRAINING

We believe that one of the most practical and critical potential benefits of using VBT in training is in applying it as a means of readiness testing for individual athletes. Readiness has been a topic of growing concern over the last several years. While technology to measure readiness has increased dramatically and costs have come down substantially over the past five years, VBT has established itself as a viable alternative. Of particular importance, such readiness for training strategies could be especially helpful not only for healthy athletes but also for athletes who are rehabilitating from serious injury, where things such as pain, soreness, and even aspects of physiological recovery or reestablishing appropriate motor control can significantly impact performance on a given day.

In practice, we have incorporated VBT as a potential marker of readiness in a variety of ways. Most notably, peak velocity of a baseline muscle snatch at the beginning of a training session has proven an excellent tool to determine readiness, with higher peak velocities being indicative of an athlete who is well primed to perform. The muscle snatch is particularly well suited to readiness assessment for several reasons. First, it is one of several high-velocity movements the athlete commonly performs in the weight room, thereby making it safe and familiar. It closely mimics the movements necessary in training (unlike something like a loaded squat jump or vertical jump), thereby increasing specificity. Additionally, the muscle snatch has no termination point and velocity will not be altered to receive it (compared to the snatch or power snatch where the athlete may need to slow the bar down artificially at light loads). Lastly, the muscle snatch is not an overly technical movement, so it can be taught quickly and completed by most all athletes.

To begin, we typically have the athlete load at between 45 to 50% of the snatch 1RM as the base load (precise loading of this percentage is not critical; use "ballpark" amounts that are convenient to load). The athlete then takes 1-2 warm-up sets prior to testing and on the second set at the testing load, peak velocity is measured for 2-3 reps of the movement. The highest recorded rep is the day's testing speed.

Tracked over time, this technique has proven reliable as a method for assessing athlete readiness. In our experience, when muscle snatch speeds exceed 3.15 m/s on testing, big lifts tend to follow. More typically, normal ranges of 3.0-3.1 m/s indicate "typical" days and values under 2.9 m/s tend to indicate an overtrained state or the presence of muscle soreness or even a potential injury. A sample of an athlete's muscle snatch performance and subsequent training results appears in Table 4.

Table 4. Sample of measured muscle snatch and the result of the session for that day. This athlete's numbers demonstrate good results for training, including a new PR on day 5.

Session	**Muscle Snatch Speed**	**Session result**
1	3.06 m/s	90% 1RM snatch, 3x1
2	3.05 m/s	90% 1RM clean, 1+1 pull + clean from deficit
3	3.19 m/s	94% 1RM snatch, 5x2 from deficit
4	3.19 m/s	92% 1RM clean, 1+1 pull + clean from deficit
5	*3.47 m/s*	100%+ 1RM snatch *(new PR)*
6	*3.29 m/s*	98% 1RM snatch + overhead squat (OHS)

This strategy is highly practical because it does not require a VBT device for every athlete. Instead, a single testing station can be set up where each athlete completes all testing trials for that given day. While other movements such as the jump squat with a barbell (15) have been suggested, the authors have found the muscle snatch to be a better balance between practicality and reliability while minimizing risk of athlete injury.

When using VBT to prescribe loads to the athlete, the goal is to deliver an ideal stimulus. If that has been delivered, the athlete should not be so tired or fatigued that they cannot deliver a decent result the next day. Regardless of the method for testing readiness, the strength and conditioning specialist must have a sound understanding of the athlete and whether or not they are well equipped both mentally and physically to make best use of the data.

FUTURE DIRECTIONS

While VBT methodologies are not necessarily new, the continued development of newer technologies and systems has made velocity-based protocols more accessible than ever before. As with any cutting-edge training advancement, the science currently lags behind the marketing in many such systems. However, whether it be a more traditional LPT unit, a low price point IMU system, or a cutting-edge five-figure plus camera-based system, all VBT tools promise to afford the strength and conditioning professional with additional data with which to make more informed decisions regarding loading.

Most notably, one area of particular concern is the reliability and validity of the three primary types of currently available VBT systems. For example, while IMU-based units are increasingly popular due to their affordability and typical rich user experience, the accuracy of such systems is still being established. Likewise, camera-based systems have been marketed for their ability to not only track and measure data points previously not possible before but also to allow athletes in a team-based training session with the ability to compete against one another for fastest peak par speed, highest overall power production, etc., very little research has yet investigated the merit of such approaches.

There is considerable evidence within the sport science literature that suggests that athletes are at greatest risk of acute and chronic musculoskeletal injuries (including tendinopathies, ACL injuries, and other significant conditions) when speeding up and slowing down (e.g. accelerating and decelerating). While beyond the scope of this paper, newer contemporary technology including wearable activity trackers and full-featured load management platforms (such as Polar Team Pro, Catapult, Kinexion, iMeasureU, and others) can provide a veritable mountain of additional data regarding many aspects of athletic performance. This data, gathered in games and practices then aggregated by analytics specialists and other sports medicine professionals, can then be leveraged. The interdisciplinary sports performance team will then be armed with the most complete information possible to prescribe loads, progressions, and base all training decisions in real-time evidence of program effectiveness.

Furthermore, while VBT has been used for decades for healthy athletes, rehabilitation professionals have begun to recognize the utility of VBT-related data in providing a recovering athlete with valuable feedback, optimizing training loads on a given day to adjust for pain, soreness, and other factors, and generally informing decisions related to exercise progression. To our knowledge, no current study has attempted to establish the scientific viability of VBT as a resource for post-operative rehabilitation or other long-term recovery. Future work in this area could prove invaluable in making VBT a critical piece of the rehabilitation puzzle, providing the rehabilitation professional with highly informative data to track athlete recovery day to day and over time.

SUMMARY

Admittedly, VBT methodologies are certainly not new. However, the rapid pace of technological advancement, the ever-increasing affordability of available hardware, and the intuitive utility of emerging software applications have made velocity-based methodologies more accessible than at any time in the past. By applying this technology and strategy to regular training, the strength and conditioning specialist and rehabilitation professional alike can better quantify athlete performance, more clearly understand how, when, and to what extent to progress, and also determine readiness for training on any given day. Simply stated, VBT methods can help all parties involved in an athlete's development make the most informed decisions possible regarding training.

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