



Velocity Based Training for Maximal Strength

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By [Tom Turner](#), Senior Strength & Conditioning Coach at Leinster Rugby.

Interest in Velocity Based Training (VBT) methods in the strength and conditioning community has exploded in recent times. This has undoubtedly been driven by the increased availability of products that measure the velocity of gym based movements, such as GymAware, Tendo FitroDyne, Bar Sensei and the [PUSH Band](#). Another reason

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has been the work of individuals like Bryan Mann, Eamonn Flanagan and Mladen Jovanovic who have popularised and shed much light on the topic. I don't want to repeat much of what has been previously written but will instead attempt to provide you with some practical, real-world examples from a highly trained group of athletes, showing how measuring velocity could be applied to your training programme. More specifically, I am going to focus on VBT in the realm of maximal strength training as I believe the potential for VBT in this area of training has yet to be fully exploited. After three years of trial and error with a large squad of professional rugby players, the majority of whom are performing at the highest level of the game, I can present to you, some of the methods that have worked for us and the data that supports it. In order to do this we need to briefly revisit some theoretical context, however, for a much more intelligent and detailed background on the topic, I urge you to read the work of the previously mentioned coaches.

The Nuts and Bolts of Velocity Based Training

1. The Load-Velocity Relationship

So without overstating the obvious, as the load in a given lift increases (and maximal intent to lift it as fast as possible is applied), the speed at which it moves decreases in a linear fashion¹⁴. This is a fundamental tenet on which VBT principles operate – the load-velocity relationship. The relationship between load and mean concentric velocity in simple strength exercises such as the squat and bench press is extremely stable and very strong, as evidenced by a number of researchers^{1, 4, 7}. The relationship holds true regardless of strength level and after increases or decreases in strength⁴. All of the research cited here has utilised recreational athletes, with the highest average bench press reported at 88kg. However, our testing data from 1RM attempts in the bench press in an elite group (mean 1RM of 140 ± 16 kg, top performers lifting between

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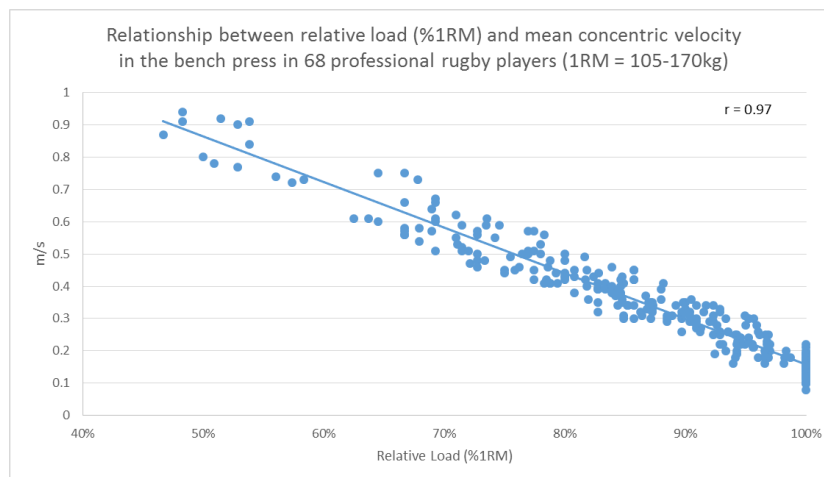
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170-180kg) support these research findings. With a sample size of 68 different players, there is a nearly perfect correlation of -0.97 between load (relative % of 1RM) and velocity (mean concentric) (figure 1). Irrespective of strength level or experience, the load-velocity relationship holds true and is at the core of VBT methods for maximal strength development.



(figure 1)

2. The Minimum Velocity Threshold

As the load in a lift progresses or the number of reps in a set increase, at some point, the weight will be too heavy and the athlete will fail; essentially they won't be able to move the load at a sufficient speed to overcome gravity. The last successful rep in a maximum effort set is therefore associated with a specific minimum velocity in order to be successful, anything below this would result in a failed rep. This is another core principle of VBT. This value, termed the minimal velocity threshold (MVT), remains stable regardless of strength level and is true irrespective of the number of reps performed. Izquierdo et al⁶ reported in sets to failure in both the bench press and squat, no significant difference between the average absolute velocities attained during the last repetition completed during sets at 75%, 70%, 65% and 60% of 1RM. In the example below (figure 2), you can see that as the load

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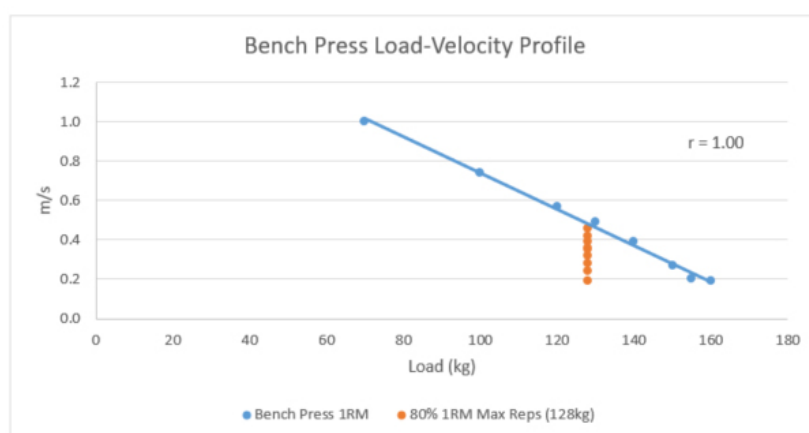
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increases in the 1RM Bench Press test or as the reps increase in an 80% 1RM max reps effort, the velocity decreases in a linear fashion to the same MVT. In the case of this athlete, their individual MVT appears to be 0.19 m.s⁻¹.

Bench Press 1RM			80% 1RM Max Reps (128kg)	
Load (kg)	% 1RM	Velocity (m/s)	Rep	Velocity (m/s)
70	43.8%	1.00	1	0.46
100	62.5%	0.74	2	0.42
120	75.0%	0.57	3	0.39
130	81.3%	0.49	4	0.36
140	87.5%	0.39	5	0.35
150	93.8%	0.27	6	0.32
155	96.9%	0.20	7	0.28
160	100.0%	0.19	8	0.24
			9	0.19



(figure 2)

An important point to note is that the MVT varies by exercise¹⁴. There is a consensus in the literature that the MVT for the bench press is approximately 0.15 m.s⁻¹. With our group of players (in 68 trials), velocity at 1RM in the bench press is consistent with research findings, with a group average of 0.15 ± 0.03 m.s⁻¹. The squat has been reported to be approximately $0.27 - 0.30$ m.s⁻¹^{2, 6}, although with our population (who generally box squat and rarely go to 1RM or failure), we found that in a small sample of 12 players velocity at 1RM in the box squat was found to be 0.25 ± 0.03 m.s⁻¹. Knowledge of the specific velocity characteristics of key strength exercises is vital for using velocity to predict 1RM based off sub-maximal loads

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or understanding how close to failure an athlete may be in a lift.

These two fundamental principles; the relationship between load and velocity and the MVT of core strength exercises are central to implementing VBT methods in strength training. In the next section, we will explore five VBT strategies that we have used with a large group of professional rugby players that rely on these basic principles. It is worth noting that we have used the GymAware system in all of our experimentation with VBT. The five methods we will explore are as follows:

1. Gauging effort and managing progressive overload
2. Estimating 1RM from sub-maximal loads
3. Profiling strength qualities
4. Controlling fatigue and level of effort
5. Monitoring changes in strength characteristics

Velocity Based Training Methods in Maximal Strength Training

1. Gauging effort and managing progressive overload

Undoubtedly the easiest to implement, and possibly the most successful strategy we have employed, has been to determine how taxing a set has been. Let's say in the bench press, if an athlete has built up to a heavy set of five reps, the further away the velocity outputs for those reps are from the MVT ($0.15 \text{ m}\cdot\text{s}^{-1}$), the easier that set was. In a pre-season phase where we target weekly increases in load, improvement is dependent on the player adapting to the training stimulus and recovering suitably to lift heavier the next time. If loads prescribed are too intense or fatiguing, progress can stall. Applying one single generic minimum velocity for all loads can go some way to safeguarding against loads being too heavy which may impede adaptation week on week. For us, we set a

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minimum velocity of $0.35 \text{ m}\cdot\text{s}^{-1}$ in the box squat and $0.25 \text{ m}\cdot\text{s}^{-1}$ in the bench press (both a nominally $0.10 \text{ m}\cdot\text{s}^{-1}$ away from failure). These thresholds were not based on any hard evidence, but rather a rational and logical assumption that a player would have at least one, or likely more reps still 'left in the tank' (based on the MVT of each exercise). In a similar vein, Bryan Mann¹⁰ recommends not allowing the speed to drop below $0.3 \text{ m}\cdot\text{s}^{-1}$ in strength orientated exercises. If an athlete failed to keep their speed of movement above our arbitrary minimum velocity for any of their reps, that load would be repeated in the next session. This ensured that players rarely failed reps. In approximately 460 final sets of the squat (the heaviest set), on 54 occasions the minimum speed was not attained and in only 6 sets did a player fail a repetition.

Despite rarely lifting at maximum load intensity, lower limb strength increased by 17.5% over the course of the pre-season and improved by 7.4% from end of pre-season strength levels one year previously. Upper limb strength increased by 7% over the pre-season and improved by 4.7% from the same time one year previously. Although not lifting at maximal level of effort for much of the training block, i.e. above our velocity threshold, comparable strength improvements were made to similar training blocks where VBT was not used. The reason why this may be the case, I believe, is a matter of intent. It has been well documented^{1,9} that when an athlete is given velocity or power feedback, their output increases. I believe that the intent improves across all sets, including build up sets, and hence the overall quality is improved as athletes produce more force (from a higher acceleration in $F=MA$) across more of their sets.

2. Estimating 1RM from sub-maximal loads

Perhaps one of the most well-known benefits of VBT is the ability to estimate 1RM from sub-maximal loads. The strength of the relationship between load and velocity

means that we can, with a degree of accuracy, use one variable to estimate the other (provided that maximal intent to lift fast is applied and we know the MVT of the exercise). This is a valuable method to gauge the strength of an athlete without exposing them to the risk of maximal loads. We have found this useful with young or inexperienced lifters, player's that are new to our system or with player's who are returning from injury. To do this, we need to establish a load-velocity profile and an excellent step-by-step guide on how to gather and implement the data into something meaningful is provided by Jovanovic and Flanagan⁸. All the remaining practical examples are based on this important dataset. Below (figure 3) is an example of a bench press load-velocity profile and the 1RM estimation for a player who was returning from a pec injury. Predicting his strength levels after a block of training was felt to be a safer method than direct 1RM testing. Jovanovic and Flanagan⁸ give a detailed demonstration of how to calculate 1RM and take into consideration levels of confidence from this data. For simplicity, only the estimation of 1RM is presented below.

	A	B	C	D
1	Load-Velocity Profile - Bench Press			
2	<i>Load (kg)</i>	<i>% 1RM</i>	<i>Velocity (m/s)</i>	
3	70	41.1%	0.86	
4	100	58.8%	0.66	
5	120	70.5%	0.51	
6	130	76.4%	0.42	
7	140	82.3%	0.38	
8	150	88.2%	0.29	
9				
10		MVT	0.15	
11				
12	Slope	-140.0	=SLOPE(A3:A8,C3:C8)	
13	Intercept	191.2	=INTERCEPT(A3:A8,C3:C8)	
14	Est 1RM	170.1	=(SLOPE*MVT)+INTERCEPT	
15				

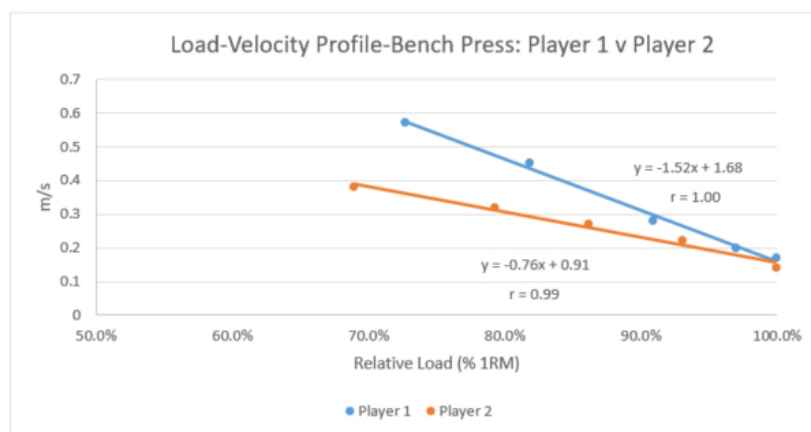
(figure 3)

The use of the load-velocity relationship to estimate 1RM appears accurate and in most cases, corresponds closely to

the actual strength level of most of our players. Jidovtseff et al⁷ postulate that predictions from the load-velocity relationship are at least as accurate as the reps to failure method. However, while Bosquet et al¹ reported very high correlations between predicted 1RM and actual 1RM, they highlighted the largely differing absolute values. This was in a group of male and female PE students with a mean bench press in a Smith machine of 62 kg. In our sample of 68 professional rugby players, the correlation between the predicted 1RM from a sub-maximal load-velocity profile and their actual 1RM on the same day was 0.98, while the actual mean difference between the predicted and actual values was 3.5kg (SD $\pm$ 2.9kg). It could be assumed that in our highly trained, elite group of players, predicting 1RM's from the load-velocity relationship could be more reliable due to how frequently they train at a high intensity of loading, therefore the estimation should be more accurate. Regardless, it is advisable not to use predicted 1RM's from the load-velocity relationship interchangeably with actual 1RM values⁸.

3. Profiling strength qualities

A load-velocity profile can also highlight individual athlete characteristics and individual strengths and weaknesses. It can highlight areas along the load-velocity curve where a player might need some directed training to improve, information a 1RM test alone will not provide. To demonstrate this, figure 4 compares the load-velocity profile in the bench press of two forwards with very different characteristics across a range of loads. One player is clearly more dynamic at sub-maximal loads which may have important implications for programming and transfer to athletic performance.



(figure 4)

The slope of the line, which can be represented as a value (the m in $y=mx+c$) and compared to group norms, may provide some information on the strength qualities of the player. The slope of the line measures its “steepness”. A steeper load velocity profile means that increases in load are having a larger effect on velocity. A shallower profile means that increases in load are having less of an effect on velocity. We ranked all of our playing group on the steepness of their bench press load-velocity profile and tailored their main pushing exercise to this. So a player with a shallow line and therefore poor movement speed at sub-maximal loads, had training directed towards more dynamic, speed-strength methods (in this case a light bench press with bands for maximal power output). Conversely, a player who possessed a steep slope in the load-velocity profile, who was explosive with lower relative intensities, was directed to some very heavy, absolute strength development (in the form of a heavy, concentric only bench press from pins). This is undoubtedly an area where more research is needed as to why this might be the case, however, logical training interventions can be made from profiling the load-velocity relationship in your athletes.

4. Controlling fatigue and level of effort

It is well established that training to repetition failure

(maximum effort) does not necessarily improve the magnitude of strength gains³. In fact it may even be counterproductive, with excessive fatigue leading to greater mechanical and metabolic strain, a reduction in muscle force production, RFD and power output^{5, 13}. One method to mitigate this is to set a velocity loss threshold which could avoid performing unnecessary reps that may not be contributing to the desired training effect. Researchers have recommended terminating a set after a certain % velocity loss from the first (and usually fastest) rep, 30% in the squat and 35% in the bench press. We have found this to generally work well, especially as the percentage drop value is often a convenient readout in most devices, but its success ultimately hinges on the athlete giving maximal intent on the first and all reps.

We have implemented a similar concept whereby the set is terminated when repetition velocity drops below a pre-determined *velocity stop value*. This number that is generated from the load-velocity data will be what that player should be able to hit with maximal effort so it's unlikely that more than one rep will be possible with that value as the cut-off velocity. Therefore, depending on the adaptation we want to target, we need to drop that number down, bearing in mind what the MVT is for the exercise in question. Jovanovic and Flanagan⁸ suggest deriving the velocity stop from exertion/velocity tables but we have simply used an arbitrary 80% of the full value as a cut-off velocity with good results. So for instance, if lifting a relative intensity of 75% of 1RM in the bench press, the expected speed from a typical load-velocity profile might be 0.7 m.s⁻¹, therefore, the velocity stop would be 80% of this which is 0.56 m.s⁻¹. The player would then lift as many reps as possible until the speed drops below 0.56 m.s⁻¹. This approach is more practical than the percentage drop off method as it allows for some reps that may not be at absolute maximal intent, which will happen, but would otherwise skew the calculation of the percentage decrease

in velocity and perhaps terminate a set too early.

We initially calculated the velocity stops used in this approach from all the individual load-velocity data grouped together. However this caused problems. By working off a group average, it resulted in some players, as outliers, experiencing a very different training stimulus to the majority of the group. In some extreme cases, a player might get 7-8 reps all over the minimum group velocity stop. At the other end of the spectrum, a player might not get a single rep that would be deemed fast enough at the group number. For this approach to work, the athlete needs to have individually prescribed velocity stops unique to their load-velocity profile.

The example below (figure 5) is from a young back and lays out how the individual velocity stops are calculated from a load-velocity profile. You can see that the player has a load to lift and a corresponding velocity stop. Once they drop below that value the set is terminated. Note that the cut-off value is safely far enough away from the MVT in this exercise ($0.15 \text{ m}\cdot\text{s}^{-1}$). How individual player's respond to this protocol, like any training intervention, isn't always predictable or uniform, it is assumed that this is because of their individual fibre types, load-profile characteristics and daily fluctuations in neuromuscular capability.

Despite less volume in this method than traditional training, the magnitude of strength improvements is considerable and potentially much higher than training to failure. The benefits of maximising rep speed compared to self-selected speeds was explored in a training study by Padulo et al¹¹. An experienced group of lifters were split into two groups and trained twice per week with 85% 1RM load in the bench press. The first group lifted with a fixed pushing speed with a velocity of 80-100% maximal speed and were stopped when velocity dropped by 20%. Sets continued until they couldn't hit the minimum velocity. The second group lifted with a self-selected speed to failure on all sets until forced exhaustion. Rest between sets was the same between groups. After three weeks, the fixed speed group increased 1RM strength by 10.2% with greater EMG activation of working muscles compared to 0.17% in the self-selected speed group. The fixed speed group did about two thirds of the overall volume of the self-selected group. The only difference between groups was speed of lifting which highlights the importance of movement velocity in determining the neuromuscular response to training. So despite in the majority of cases where we utilise VBT, not lifting to repetition maximum, the player is lifting with maximum velocity which in itself is perhaps just as intense. The greater activation of the neuromuscular system as a result, is undoubtedly one of the key reasons behind the effectiveness of VBT. In environments where the use of velocity measuring devices is not feasible, similar improvements could be garnered by emphasising maximal speed of movement along with the appropriate selection of load with respect to level of effort.

5. Monitoring changes in strength characteristics

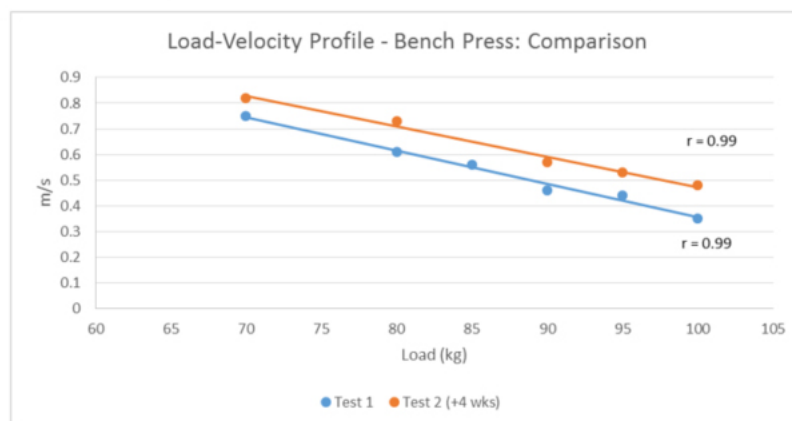
Where a load-velocity profile and 1RM estimation provides another valuable adjunct to traditional strength training is as a practical and repeatable method of monitoring an athlete over time. Figure 6 shows the change in the load-

velocity profile in the bench press of the previously presented player following a block of training using velocity stops. It can clearly be seen that an improvement in movement velocity translates to an increase in strength.

Gonzalez-Badillo and Sanchez-Medina⁴ proposed that an increase in velocity of 0.07 – 0.09 m.s⁻¹ at a set load or across a range of loads yields a 5% improvement in 1RM.

The data presented in figure 6 represents a 7.7% increase in 1RM strength with an average increase in velocity across the four common loads of 0.15 m.s⁻¹. A similar profile of a staff member saw an average increase in velocity over four loads of 0.11 m.s⁻¹ for a 6.9% increase in 1RM strength. By monitoring velocity in our key lifts, we have a tangible way of tracking strength levels over time. This provides us with a very unobtrusive method of assessing the effectiveness of a training stimulus.

Load-Velocity Profile - Bench Press		
	Test 1	Test 2 (+4 wks)
Load (kg)	Velocity (m/s)	Velocity (m/s)
70	0.75	0.82
80	0.61	0.73
85	0.56	
90	0.46	0.57
95	0.44	0.53
100	0.35	0.48
	MVT	0.15
Est 1RM	115.2 kg	126.8 kg
(90% CI)	113.1 - 117.3 kg	124.3 - 129.3 kg



(figure 6)

Concluding thoughts

The information presented here is just an insight into some of the practical uses of VBT that we have found useful in a professional rugby setting. There is undoubtedly a need for more research in this area, especially with elite level athletes, something that is not always feasible in many environments. However, the evidence presented to date is extremely exciting and its use in a practical sense is having tangible effects on the value of our training interventions.

On a cautionary note, VBT training should by no means lead to a fixation and reliance on technology at the expense of core coaching skills and a 'feel' for the individual players and their distinct lifting characteristics. Rather it should be employed to complement existing methods already working effectively. Padulo et al¹¹ recommend that VBT is more suited to experienced lifters with traditional methods more appropriate for novice athletes as a means to become familiar with technique and to improve the muscle tendon adaptation to a specific exercise. This is important to remember as the addition of velocity based measures adds a new dimension of intensity which may be unsuitable to certain individuals or at certain times. However, in the vast majority of cases, the advantages of VBT far outweigh the potential disadvantages. The use of VBT methods ultimately minimises the fatigue effect of the strength training stimulus, while maximising the performance aspect, which in a holistic rugby training programme where the strength training is but one component, is undoubtedly a substantial benefit of utilising VBT.

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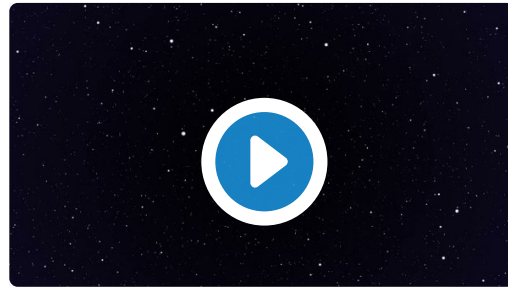
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