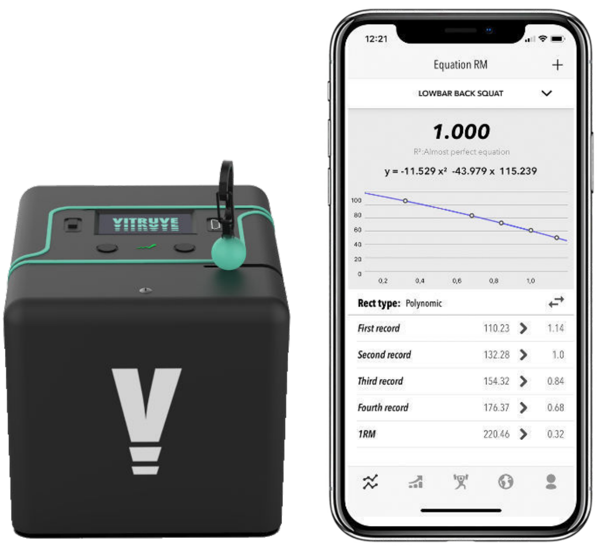
THE KEY GUIDE FOR VELOCITY-BASED TRAINING



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What is this guide?

While there are many studies related to the importance of quantifying certain variables such as the movement velocity of a lift, it is difficult to find this information in an orderly and simple way to understand both for someone new to training planning and for an experienced coach that has never worked with these variables.

This guide aims to be an introduction to the world of **velocity-based training**, where not only the theory drawn from the most relevant and current scientific studies will be exposed, but also certain guidelines will be given and examples will be presented. Practical examples of how to take advantage of and adapt all that information in real scenarios.

Level of Effort

The level of effort (LE) is the expression that is used when speaking of the degree of effort. This expresses the relationship between what a subject does and what he could do. A strength training with weights would be the number of repetitions performed by a subject in a set compared to the total number of repetitions that could be done. The higher the percentage (100% are all the repetitions that can be made in a series until reaching the failure) of repetitions made in a series, the greater the LE. If we do 4 repetitions of 7 possible "4 (7)", the LE will be smaller than if we do 6 repetitions of 7 possible "6 (7)"

To properly define the LE, it is necessary to take into account both:

- The **difference** between the repetitions made and the possible ones and
- **The total number of doable repetitions**.

For example, if we do 2 (4) or 8 (10), in both cases we leave 2 repetitions without doing, however, the% of repetitions performed versus the possible ones are different. In the first case 50% of the possible repetitions are done and in the second 80%. This difference implies different effects: Degree of fatigue, metabolic stress, velocity loss in the series (we will talk about it later and about the relation with accumulated fatigue) ...

That said, the best way to define LE would be by using the velocity of the first repetition and the velocity loss in the series.

The speed of the first repetition will define the % of the 1RM with we are working with. The higher the initial speed, the more repetitions we can do and, therefore, the % of the 1RM that weight will be lower. With the speed, you can know the total number of doable repeats (the second of the two indicators we have discussed above).

Now we need the first indicator which is the difference of the made repetitions and the possible ones. This can be measured with the **velocity loss** intra series. As we go through repetitions we get more fatigued, and therefore the speed decreases. The closer the number of repetitions made to the doable repetitions approaches, the greater the % lost velocity will be and therefore the greater the cumulative fatigue will be.

These two indicators, which will be explained further below, are the most accurate and reliable indicators (in addition to easily quantifiable) to know the degree of effort in training with external loads.

The movement velocity to estimate the 1RM

*"If we could measure **the maximum velocity** of the movements every day and with immediate information, this would possibly be the best point of reference to know if the weight is adequate or not. A determined descent of the speed is a valid indicator to suspend the training or to lower the weight in the bar. "*

(González Badillo, 1991)

The movement velocity of a lift has proven to be a fundamental variable to know the actual intensity of the lift. This means that knowing the speed at which a certain load rises, you can know the % of the 1RM that it represents, and thanks to this, know the daily 1RM very precisely without having to lift it. In the image below, you can see the average speeds obtained in different exercises for each % of the 1RM. These speeds can vary between different athletes. Ideally, each athlete should do a test (explained later) to know the speed at which they move each % of their own 1RM. But even so, it is very useful to have it as a reference.

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MEAN PROPULSIVE VELOCITY (m/s) FOR EACH % OF 1RM

Exercise	Source	1RM	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%
Bench Pull	Sánchez Medina et al (2014) Prone lying rowing on bench with Smith machine	0.53	0.59	0.65	0.72	0.78	0.85	0.92	0.99	1.06	1.13	1.21	1.28	1.36
Back Squat	Sánchez Medina et al (2014) Deep squat with Smith Machine and pauses	0.32	0.42	0.51	0.59	0.68	0.76	0.84	0.92	1.00	1.07	1.14	1.21	1.28
Pull Up	Sánchez Moreno et al. (2017) Prone Pull up	0.22	0.31	0.39	0.50	0.57	0.65	0.74	0.83	0.91	1.00	1.09	-	-
Military Press	Muñoz et al. (2014) Militar Press behind the neck with Smith Machine	0.20	0.27	0.34	0.41	0.49	0.55	0.62	0.69	0.75	0.81	0.86	0.92	0.97
Bench Press	González Badillo and Sánchez Medina (2010): Bench press with Smith machine and pauses	0.18	0.25	0.32	0.39	0.47	0.55	0.62	0.70	0.78	0.87	0.95	1.07	1.13
Deadlift	Helms et al. 2017: Dead-lift with expert powerlifters 1RM=237,3kg	0.14	0.21	0.29	0.37	0.46	-	-	-	-	-	-	-	-
Hip Thrust	Hoyo, M, Núñez et al (2017)Predicting Loading Intensity Measuring Velocity in Barbell Hip Thrust Exercise	0.24	-	0.36	-	0.48	-	0.6	-	0.72	-	-	-	-

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Illustration 1 Data from different researches. It shows mean propulsive velocity for each % of the 1 RM for each exercise.

To be able to estimate the real 1RM each day without having to lift it, it is necessary to create an individual load-velocity profile for each athlete. In the study by González Badillo and Sánchez Medina (2010), it was possible to verify and demonstrate how the average propulsive speed of a lift for a given % of the 1RM does not change practically with the passage of time. Although the athletes improved their marks due to the training, the speed at which each one moved, for example, 80% of the 1RM did not change with time.

LOAD	T1	T2	Difference T1-T2
30%	1,33 ± 0,08	1,33 ± 0,08	0
35%	1,21 ± 0,07	1,23 ± 0,07	0,01
40%	1,15 ± 0,06	1,14 ± 0,06	0,01
45%	1,06 ± 0,05	1,05 ± 0,05	0,01
50%	0,97 ± 0,05	0,96 ± 0,05	0,01
55%	0,89 ± 0,05	0,87 ± 0,05	0,01
60%	0,80 ± 0,05	0,79 ± 0,05	0,01
65%	0,72 ± 0,05	0,71 ± 0,05	0,01
70%	0,64 ± 0,05	0,63 ± 0,05	0,01
75%	0,56 ± 0,04	0,55 ± 0,04	0,01
80%	0,48 ± 0,04	0,47 ± 0,04	0,01
85%	0,41 ± 0,004	0,40 ± 0,004	0,01
90%	0,33 ± 0,04	0,32 ± 0,04	0,01
95%	0,26 ± 0,03	0,25 ± 0,03	0,01
100%	0,19 ± 0,04	0,18 ± 0,04	0

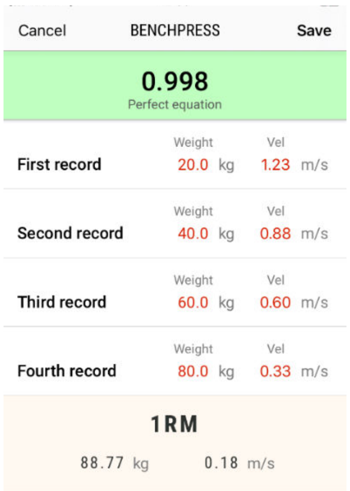
Illustration 2 Changes in the average propulsive speed (m / s) achieved with each relative load, from the initial test (T1) to the second test (T2) after 6 weeks of training, in the bench press exercise.

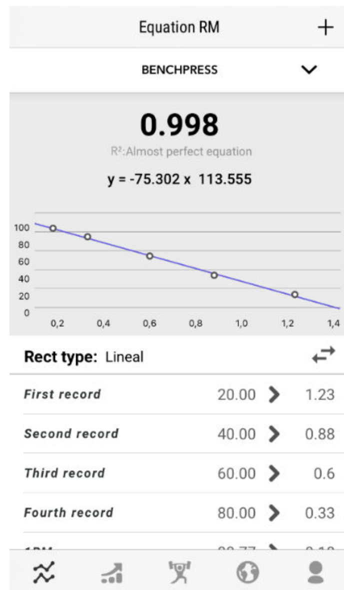
These results are very interesting since they allow to know at what speed the different % of the RM are raised, and as we have just said, to know the% of the 1 RM (very accurately and reliably) that this load represents only knowing the speed at which the uprising has been done.

What is a load-velocity profile and how can it be created?

The fact that the speed at which a particular % moves does not change practically anything over time, relating the average propulsive speed with the load we can obtain a regression line with which to estimate our 1RM in each session.

To create the profile, you simply have to make an initial TEST to know at what mean propulsive velocity (MPV) we move the different % of the 1RM. In the image below, we can see a real example. There are 4 lifts, first record is from 50-60% of the estimation of your 1RM; second record is about 60-70%; third record is about 70-80%; and fourth record is about 80-90% of your 1RM. The Vitruve app was used together with the Vitruve linear encoder to calculate the 1RM for the given exercise and it's MPV.





Once the 4 data have been taken, the same application generates a linear regression where it relates the MPV and the load. As can be seen, there is a very high correlation between the increase in load and the decrease in the speed of the lift.

What is the advantage of estimating the 1RM without lifting it?

Basically, 1RM varies every day. The best would be to be aware of your physical share every day (to train based on how you are that same day and at that moment) without having to fatigue yourself nor raise your 1RM in each workout. In addition to considerably increase the risk of injury, increases fatigue considerably. That's why being able to estimate the 1RM with a single lift of a sub maximum load (70% for example) thanks to a load-velocity profile is the best option.

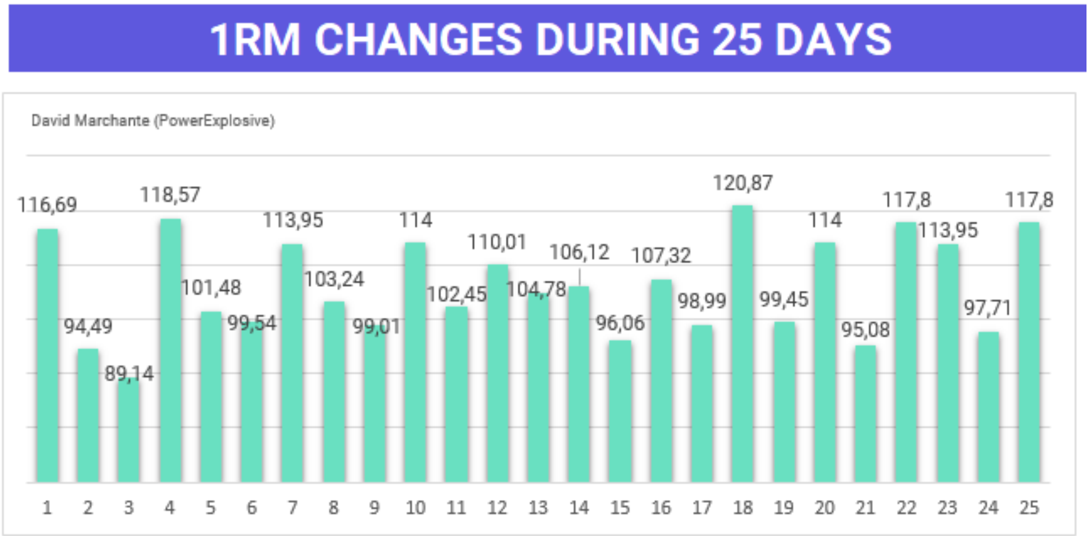


Illustration 3 Variation of David Marchante's daily 1RM (POWEREXPLOSIVE) in his preparation for the RECORD GUINNESS of the heaviest pull up.

In the image above, we can see the variation of the estimated/projected 1RM in different sessions. As you can see there is a lot of variation, for experienced lifters, these variations could be up to 15% between different sessions. If you do not measure the performance in each training, you can't know the athlete's fitness status and, therefore, you can't know the actual work done and the difference between what was planned for that training and what was actually done. With an example you will understand much better:

Suppose that an athlete makes a 1RM test on a specific day to be able to plan the next 4 weeks based on that 1RM (this method is widely used, but as we are going to see now, it is far from ideal). That 1RM was set on 100lb and this athlete plans the following sessions with their respective % of that 1RM. The 3rd day of training he should be lifting the 90% x2x2 (90lb on 2 series and 2 repetitions). For different reasons, the previous day that athlete rested badly and his performance in this 3rd session decreased, and his REAL 1RM has gone from 100lb to 90lb.

What will happen if the athlete trains with 90% (90lb) of the 1RM that he calculated a few days ago (100lb)?

The athlete will be unable to do 2 sets at 2 repetitions and will fail since according to what he puts in his plan he will work with 90% of the 1RM but he is working with 100%.

The best would be for that athlete to know his REAL 1RM every day, so he can be sure that he's working with the optimal load. The most accurate way to estimate the 1RM each day is by the velocity of each lift.

Another way to measure the progress and the state of an athlete is to take a load as a reference (100lb for example, 50% of their 1RM) and measure in each training the speed at which they lift it. This gives us direct information about their performance. If the speed of the lift increases in each session, it means that the 1RM is higher and those 100lbs won't reach the 50% of the 1RM anymore, the athlete is working with a lower % of the 1RM. Therefore, the workout won't be as optimal as planned.

Velocity loss and fatigue

Speaking of velocity loss within the series and talking about fatigue is practically the same. It has been shown that lactate accumulation (fatigue indicator) and velocity loss are directly related.

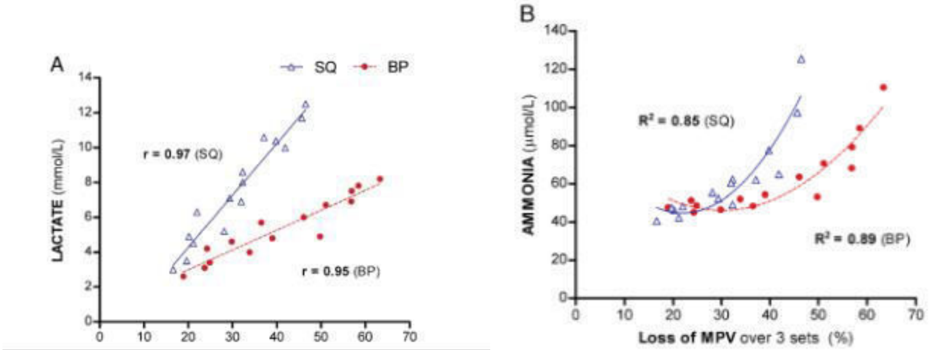


Illustration 4 Relationship between propulsive velocity loss and lactate (A) and ammonium (B). SQ = Squat; BP = Bench Press (extracted from Sánchez-Medina & González-Badillo, 2011).

To calculate the fatigue within a series, the fastest lift is taken as reference (usually the first lift, but it can also be the second) and the speed that has been lost compared to the last repetition of the series.

The best-known way to program a workout is to work with X percentage of 1 RM and do Y series and Z repetitions (Ex: 80% x5x5). Now we know how to calculate the 80% of the 1RM in each session, but why do we have to do 5 series and 5 repetitions? Do we really know the fatigue that will imply for that athlete to do 5 sets of 5 repetitions?

It has been shown that two athletes who do, for example, 5 repetitions with same intensities (same X% of their own 1RM) do not fatigue the same. In other words, it is possible that, even if they work with the same % of the 1RM, the maximum number of repetitions they can do is different. Let's say one of them can do 7 repetitions with their 80% of the 1RM and the other can do 5 reps of the same %. If both of them do 5 repetitions, one of them will be 2 repetitions from muscle failure and the other, however, will not be able to do any other repetition. Therefore, the **level of effort** will be different even if they are training with the same intensity (%) and same reps.

However, if instead of working with fixed repetitions, you work with a pre-established % velocity loss, the degree of effort will be the same. One of the subjects will do more repetitions than the other, but even so, the fatigue that they will accumulate will be the same.

In the chart below, it’s shown how the velocity loss in the series is closely related to the % of repetitions made.

SQUAT		BENCH PRESS	
Velocity Loss	*CE*	*Velocity Loss*	*CE*
~ 45%	12 (12) 10(10)	**≥ 60%**	12 (12) 10(10)
~40%	10 (12) 8 (8) 6 (6)	**~55%**	8 (8) 6 (6)
~30%	8 (12) 8 (10) 6 (8) 4 (6) 4 (4)	**~45-50%** **~40%**	10 (12) 8 (10) 4 (4) 8 (12) 6 (8)
≤ 20%	6 (12) 6 (10) 4 (8) 3 (6) 2 (4)	**~30%** **≤ 25%**	6 (10) 4 (6) 6 (12) 4 (8) 3 (6) 2 (4)

Illustration 5 Velocity loss and RIR comparison. (Sánchez Medina, 2010).

In bench press, taking a 40% of speed loss in a series is similar to performing for example 6 (8). In this specific case, the loss will be calculated taking the fastest speed of the series and the speed of the 6th (last) repetition. Below we can see a real example using the linear encoder and the Vitruve application.

In the image, you can see the relation between the velocity loss in the series and the % of repetitions that are made. A series of **8RM** in Bench Press has been registered randomly, there has not been a great control of the stop at the chest of each repetition and because of that, the results may vary a bit regarding to the scientific studies. But still, let's analyze it to see what conclusions can be drawn:

Illustration 6 8RM series in free bench press with Vitruve application

If we calculate the speed loss of the image above, in case of having made a 4 (8), we obtain that the accumulated fatigue was: (1-0.31/0.42) * 100 = 26.19%

In the chart of Sánchez Medina, we can see that for a 4 (8) bench press the velocity loss is around **25%**, so it is very close to reality.

Let's continue with another example, let's analyze the 6 (8): **(1-0.26/0.42) * 100 = 38.09%**

According to the chart above, the velocity loss associated with 6 (8) is around **40%,** as we can see, it is also very close to reality.

And finally, the 8 (8) obtained has been a velocity loss of **(1-0.16/0.42) *100** = **61.9%,** a little higher than that obtained in the charts.

As we can see, it is easy to verify the usefulness of scientific studies in practical and real scenarios, also, we must bear in mind that the results of these studies are the average of many subjects who have participated, there will always be people who move away a little of those numbers, but it doesn't matter. Even if the data doesn't look alike, what is important is that for the same subject they are totally valid and will be able to use them for their workout planning, to evaluate their progress and to be able to replicate it in the future.

What fatigue should I program?

It is a very difficult question to answer since it will depend a lot on each athlete and the personal goal they have. But, thanks to the number of studies that exist, some basic guidelines can work for the vast majority of people.

For example, ammonium is barely modified concerning to resting values in bench press and full squat exercises if the number of repetitions performed doesn't exceed half of the doable repetitions (Sanchez Medina and González Badillo, 2011).

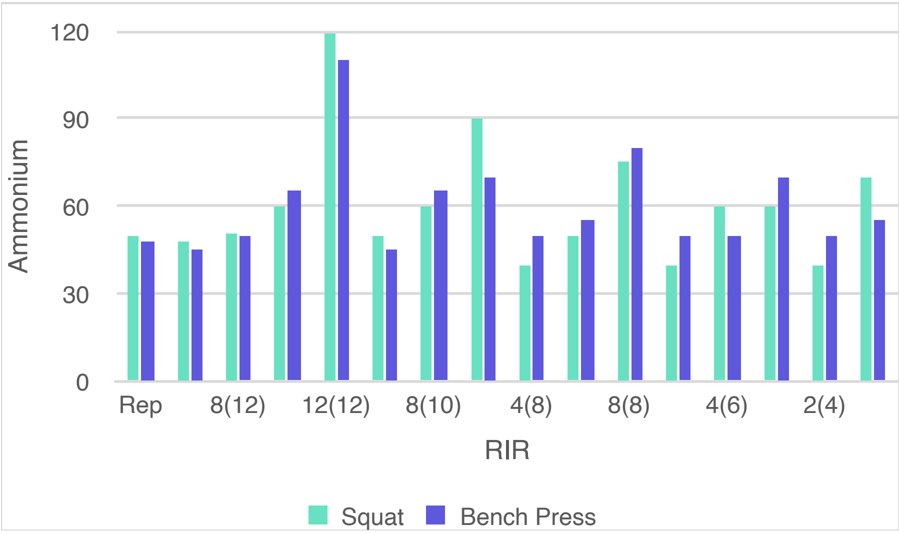


Illustration 7 Concentration of ammonium in capillary blood. Taken from Sánchez-Medina (2010)

As can be seen, the closer the repetitions are made to the doable repetitions, the greater the accumulation of ammonium, which, among other things, could increase the recovery time necessary after each training session.

The increase in ammonium concentration can easily be controlled with the velocity loss since a great relation between these two variables has been demonstrated. Taking into account the graphs, the ideal way would be not to exceed half of the doable repetitions. In the case of bench press and squat. It is not recommended to work with a velocity loss higher than 20%. In fact, it has been shown that squat losing 20% speed in the series gives better results than losing 40% speed.

Stress index

Once analyzed the two indicators that define the LE (level of effort) are the speed of the first repetition and % of velocity loss in the series. To relate these two to each other, González Badillo et al. (8) proposed the effort index (EI).

Stress index (EI) = MPV of the 1st repetition * average loss of MPV in the session

As can be observed in the equation, this index relates the speed of the first repetition (the fastest) with the average loss of MPV in the session (if 3 series are made and the velocity loss for each of them is of 30%, 28.7% and 30.4%, the average loss of the session will be (30+28.7+30.4)/3 = 29.7%

What practical utility does the effort index have?

It allows to compare the effort involved when working with X% of the 1RM to Y velocity loss in each series. Keep in mind that the velocity loss in the series must be different for each relative intensity to be able to equalize the efforts, and thanks to the below it is very easy to adjust the % of work and the % of velocity loss to match them.

For example, in the case of the bench press, it would be practically the same effort to work with 80% of the 1RM with a velocity loss of 15% than to work with 65% of the 1RM with a fatigue of 10%

Load	MPV loss in the series										
% 1RM	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%
40%	10,9	16,3	21,7	27,0	32,4	37,4	43,2	48,6	54,0	59,3	64,0
45%	10,1	15,2	20,2	25,2	30,2	34,8	40,2	45,3	50,3	55,3	60,3
50%	9,4	14,0	18,7	23,3	28,0	32,1	37,3	41,9	46,6	51,2	55,9
55%	8,6	12,9	17,2	21,5	25,8	29,5	34,3	38,6	42,9	47,2	51,5
60%	7,9	11,8	15,7	19,6	23,5	26,9	31,4	35,3	39,2	43,1	47,0
65%	7,1	10,7	14,2	17,8	21,3	24,2	28,4	32,0	35,5	39,1	42,6
70%	6,4	9,6	12,7	15,9	19,1	21,6	25,5	28,6	31,8	35,0	38,2
75%	5,6	8,4	11,3	14,1	16,9	19,0	22,5	25,3	28,1	31,0	33,8
80%	4,9	7,3	9,8	12,2	14,7	16,3	19,6	22,0	24,5	26,9	29,4
85%	4,1	6,2	8,3	10,4	12,4	13,7	16,6	18,7	20,8	22,9	24,9
90%	3,4	5,1	6,8	8,5	10,2	11,0	13,7	15,4	17,1	18,8	20,5
95%	2,6	4,0	5,3	6,7	8,0	8,4	10,7	12,0	13,4	14,7	16,1

Illustration 8 EI corresponding to different % of velocity loss (10-60%) regarding different loads (40-95%). González-Badillo et al.2017b

From Theory to Application

The first thing we are going to do is to program the LE. This is, the intensity (speed of the first series) and the volume (speed loss).

To program each training cycle, we will need the index of effort, which as mentioned, is nothing but the LE, but defined much precisely, as we have seen before including the intensity, series and repetitions.

Once the previous warm-up is done before the training session, warm-up and approximation series will be made until reaching the reference weight to estimate the 1RM. It is recommended to always lift the same weight to see the performance of that day. Once you know the weight that you have to use that day (programmed REAL %), you will start making series, and these will be stopped at the time you reach the scheduled intra-series speed (the device should have the option to activate auditory feedback in real-time to know when to stop the series) and stop the training when the effort index is the same as the programmed.

It hasn't been mentioned so far, but it is implied that ALL lifts should be performed at the **maximum possible speed**. Otherwise, the information obtained would not be very useful nor could be compared between different sessions.

What device is recommended to quantify?

Taking into account all these variables that are necessary to measure properly, you must have a device that provides at least the following information:

- MPV: mean propulsive velocity, it is not the same as the mean velocity. In this variable, the breaking phase caused by the subject is discriminated with low % of the 1RM so that the bar does not go off. If the device is not capable of measuring the MPV, that breaking phase won't be discriminated, and with medium and low % it will be difficult to quantify the fatigue correctly and any another type of variables as well.

- Intra-series fatigue with auditory feedback: The device has to offer auditory feedback in real-time to know exactly when to stop the series.

These two variables are the most important, but it would be interesting if the device could also allow the creation of load-velocity curves, the estimation of the 1RM and be able to calculate the weight to work with in each session.

It is also very important that the device is validated scientifically to ensure that the data it provides is valid and that it will allow the correct quantification of the training. While it is something that is expected from a device that is available in the market, you will be surprised to know the number of devices that are appearing, especially wearables based on accelerometers, which once tested have proven unreliable and far from being valid for strength training.

Today the most reliable and precise devices are linear encoders. In fact, all scientific studies are carried out with this type of technology. The only downside they have had so far has been its high cost (600-3000 €) and its low portability (they require a laptop and cables to be able to use them), that's why from here we recommend the Vitruve encoder.

Vitruve is a linear encoder of low cost compared to the rest ($397), scientifically validated, fully portable with an application for iOS and also allows quantifying the fundamental variables that have been analyzed and commented in this guide.

CONCLUSIONS

The speed is the essential variable to calculate both the intensity and the volume, and in this way to know the LE and the EI. Thanks to this, we can control practically everything that happens within a session of strength training with weights allowing thus, adjust and fine-tune the programming based on the results obtained in the training sessions so that the programmed efforts and the made coincide as much as possible.

References

1. González-Badillo JJ, Ribas-Serna, Juan. Fuerza, velocidad y rendimiento físico y deportivo 2019;

2. González-Badillo JJ, Sánchez-Medina L. Movement velocity as a measure of loading intensity in resistance training. International journal of sports medicine 2010; 31(05): 347352.

3. Sánchez-Medina L, Pérez CE, González-Badillo JJ. Importance of the propulsive phase in strength assessment. International journal of sports medicine 2010; 31(02): 123-129.

4. Sánchez-Medina L, González-Badillo JJ. (2011). Velocity loss as an indicator of neuromuscular fatigue during resistance training. Medicine & Science in Sports & Exercise 2011; 43(9): 1725-1734.

5. González-Badillo JJ, Rodríguez-Rosell D, Sánchez-Medina L, Gorostiaga EM, ParejaBlanco F. Maximal intended velocity training induces greater gains in bench press performance than deliberately slower half-velocity training. European journal of sport science 2014; 14(8): 772-781.

6. González-Badillo J. Bases teóricas y experimentales para la aplicación del entrenamiento de fuerza al entrenamiento deportivo. Infocoes 2000; 5(2): 3-14.

7. Pareja-Blanco F, Rodríguez-Rosell D, Sánchez-Medina L, Gorostiaga EM, GonzálezBadillo JJ. Effect of movement velocity during resistance training on neuromuscular performance. International journal of sports medicine 2014; 35(11): 916-924.

8. González-Badillo JJ, Sánchez-Medina L, Pareja Blanco F, Rodríguez Rosell D. La velocidad de ejecución como referencia para la programación, control y evaluación del entrenamiento de la fuerza. 2017.

9. González-Badillo JJ, Yañez-García JM, Mora-Custodio R, Rodríguez-Rosell D. Velocity Loss as a Variable for Monitoring Resistance Exercise. International journal of sports medicine 2017; 38(03): 217-225.

10. Sánchez-Medina L, Pallarés JG, Pérez CE, Morán-Navarro R, González-Badillo JJ. (2017). Estimation of relative load from bar velocity in the full back squat exercise. Sports Medicine International Open 2017; 1(02): E80-E88.