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Literature Review

Movement velocity contributions to resistance training: a narrative review

Contribuições da velocidade de movimento para o treinamento resistido: uma revisão narrativa

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ABSTRACT

Introduction: Aiming a more effective intensity control in resistance training (RT), the measurement of movement velocity (MV) has gained attention from the scientific community and strength and conditioning professionals. **Objectives:** First, to analyze from a critical point of view the indicators that serve as a reference for the expression and control of intensity in the RT. These indicators created from the world of bodybuilding have been used for decades, without any relevant modification, to improve the physical performance of athletes from different sports. The second objective was to describe a rational and precise proposal for the best determination and control of intensity in the RT. **Methods:** Systematic review articles with and without meta-analysis and clinical trials on the measurement of MV in RT were selected. **Conclusion:** Monitoring MV allows more precise control of the RT intensity.

Key-words: Exercise, Velocity Measurement, Muscle Strength.

RESUMO

Introdução: Para o melhor controle da intensidade no treinamento resistido (TR), a medida da velocidade de movimento (VM) tem ganhado atenção da comunidade científica e dos profissionais de força e condicionamento. **Objetivos:** Primeiramente, analisar desde um ponto de vista crítico os indicadores que servem como referência para a expressão e controle da intensidade no TR. Tais indicadores, advindos do mundo do fisiculturismo têm sido usados há décadas, sem qualquer modificação, para a melhora do rendimento físico de atletas de distintas modalidades esportivas. O segundo objetivo foi descrever uma proposta racional e precisa, para a melhor expressão e controle da intensidade no TR. **Métodos:** Foram selecionados artigos de revisão sistemática com e sem metanálise e ensaios clínicos sobre a medição da VM no TR. **Conclusão:** O monitoramento da VM permite o controle mais preciso da intensidade do TR.

Palavras-chave: Exercício, Medição de Velocidade, Força Muscular.

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Introduction

A training program is an ordered sequence or series of efforts that have a dependency relationship with each other. Therefore, designing a strength training program is not a simple task. There is interference from many factors and it is necessary to have extensive knowledge about principles of training (adaptation, progressive overload, biological individuality) that govern the safety and effectiveness of the training session [1,2].

Regardless of the purpose of the training session, its effectiveness depends on the correct manipulation of acute training variables (intensity, volume, frequency, movement velocity, exercise selection, inter-set rest, etc.) that govern the program design and determine the training stimulus [3]. These variables can be manipulated in different ways to achieve different goals. Thus, these variables are crucial to produce the training stimulus determining the magnitude and type of responses and physiological adaptations, and consequently the training effect [1,4,5].

Some authors suggest that the resistance training (RT) stimulus depends mainly on the control of three variables: type of exercise, training volume and intensity. Once the exercises are selected, the training load will be composed of the training volume and intensity [3]. According to these authors, among these two variables, the intensity is the most important because it determines volume (number of repetitions that can be performed) more precisely. In addition, exercise intensity is considered the most important variable to produce increases in muscle strength [1,4-7].

Traditionally, the main indicators that serve as a reference for the control of RT intensity are the value of a maximum repetition (1RM) and the load that the individual can lift for a certain number of times (nRM) or within a range of maximum repetitions (for example, 3-6RM). In addition to serving the load measuring, these indicators have been used to assess the training effect. However, there is still no consensus in the scientific literature on the best way to express the RT intensity.

The 1RM value represents the load in kg that an individual can lift in a specific exercise during the entire range of motion only once and without external help. This value has also been recognized as an indicator of maximum dynamic strength. When using 1RM value, the loading dose is prescribed in 1RM percentages (% 1RM), also called relative load once the absolute load (the 1RM load in kg) is obtained [2].

The nRM value (the load that an individual can lift for a certain number of times or maximum repetitions (12RM)) assumes that such effort determines the relative load. Thus, this approach indicates that the effort required to perform the same amount of nRM will be the same even if individuals lift different loads. In this way, these individuals would be training at the same intensity with the same relative load. This practice led to the development of a continuum in which 3RM with a given load represented 85% of 1RM for example.

The mentioned indicators used as reference for load dosing in RT have some advantages. However, all of them have significant disadvantages that have been explained below and none of these methods are fully adequate to precisely monitor the actual effort experimented by an individual during training [3]. Intensity is a complex variable and cannot be understood only as load (kg) lifted but as the degree of effort exerted during each repetition of an exercise. Thus, a recent solution has been studied based on the movement velocity (MV) measurement and the main objective of this review was to explain the contributions that MV monitoring can give to improve the RT methods.

Disadvantages of using percentages of a maximum repetition (% 1RM) to determine resistance exercise intensity

The use of %1RM to determine training intensity has important drawbacks to be highlighted. Firstly, 1RM measurement generates a high effort and is related to increased injury risk, especially in untrained individuals with no RT experience since it is performed with maximum loads. So not everyone can, or should not, be submitted to this test. Furthermore, in these individuals, 1RM measurement will be inaccurate since they are unable to express their real maximum strength if it is possible to discover it [3,4,8,9].

Moreover, 1RM value changes daily after a few training sessions, especially in individuals who are not highly trained. Thus, if a training month is programmed based on 1RM value in some days this value will be different from that used for the training program. In this perspective, training can be done above or below the intensity at which it was programmed. To prevent this from happening, it would be necessary to perform constantly 1RM testing for the proper load's adjustment. However, this will interfere in the training schedule and may interfere the proposed objectives due to the high degree of fatigue generated, many times greater than the training itself. In addition, 1RM testing is time-consuming and is impractical in very large groups [3,4].

Besides, 1RM value tends to be different in many exercises. Thus, you cannot use 1RM value from one exercise to another. It is necessary to perform a 1RM test for each exercise programmed in training. Also, the effort represented by each %1RM is different according to the exercise type used. The effort made with a load that represents 70% of 1RM in a basic weightlifting exercise, such as the bench press is not the same as an Olympic weightlifting exercise, such as the snatch. This occurs because each exercise has its 1RM velocity [10,11]. This topic will be better addressed ahead.

Disadvantages of using n maximum repetitions (nRM) to determine resistance exercise intensity

To avoid disadvantages of direct 1RM measurement, indirect methods, such as the nRM test, were created to express the intensity of resistance exercise. The nRM test measures the number of maximum repetitions that can be performed with submaximal load, for example, 8RM (refers to a load that can only be lifted eight times) [6]. In some studies, a continuum of nRM was established, which represents a certain %1RM. Regression equations to predict 1RM value were also created [4,7,9,12]. Besides, it was found that some adaptations can be achieved using specific RM ranges (example: 1-6 RM to develop maximal strength and 8-12 RM for muscle hypertrophy) [4,5,13]. This method eliminates the necessity to perform a direct measurement of 1RM. However, it also has important disadvantages [4].

First, although each %1RM has a certain average number of maximum repetitions with which it can be performed, this number is quite different from individual to individual. Due to this high intersubject variability, performing the same number of RM with a certain load does not mean that the intensity or relative load is the same [14,15]. Thus, 10RM can represent 70% of 1RM for an individual, but represent 75% of 1RM for another. Thus, the same %1RM cannot always be performed with the same number of repetitions in all individuals and not in all exercises, so that if 10RM is prescribed for the same individuals to program a relative load of 75% of 1RM, each individual may be using a different relative load, and consequently receiving a different stimulus [16].

Furthermore, to use this method is needed to train near or even until muscular failure. However, scientific studies have shown that training to failure does not induce greater gains on the manifestations of muscle strength and can disrupt the training schedule by generating an excessive degree of mechanical and metabolic fatigue for subsequent training sessions [4,17-23]. In addition, since training sets to failure is performed at very slow velocities this can cause a transition from fast muscle fibers (type II) to slower fibers (type I) impacting the capacity to produce explosive strength [6]. Another problem is that if the programmed load is with multiple sets of 10RM, 10 repetitions must be performed in each set. However, if three sets are programmed, it is very likely that in the second and third sets the same 10RMs achieved during the first set will not be reached even with high rest intervals, such as five minutes [24] (Figure 1).

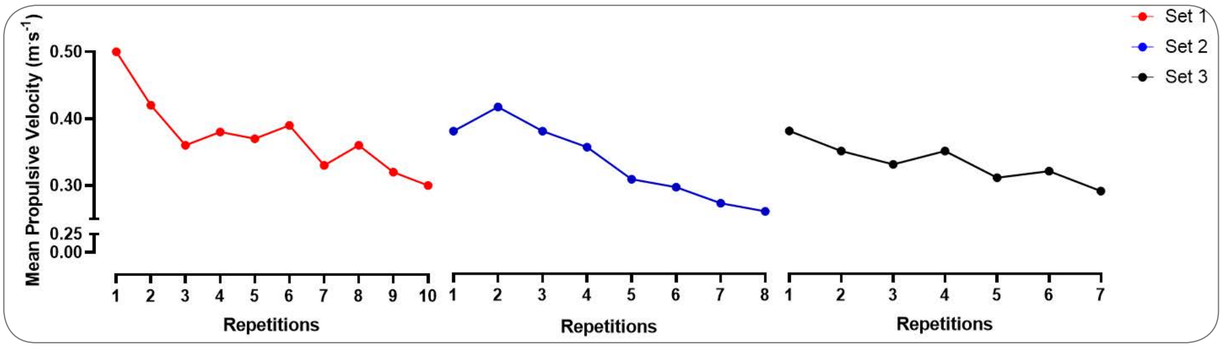

Figure 1 - A real example of movement velocity loss of an individual over three sets until muscle failure during the parallel squat with the representative load of 10 RM (rest intervals between sets of 5 min). Each circle represents a repetition and the mean propulsive velocity with which it was performed. Unpublished data from our laboratory. Figure based on the book of González Badillo *et al.* [38].

Finally, the fatigue developed during training to failure not only significantly reduces the ability to produce muscle strength, but also the ability of the nervous system to activate skeletal muscles voluntarily [3,25]. This can cause negative effects on the strength production in a shorter time and faster way, being undesirable especially for practitioners of sports modalities with greater power character [3,26]. In this perspective, even with the development of the indirect methods the trainer still does not know the real exercise intensity. This can lead to program and believe that a certain intensity (% 1RM) is responsible for a certain adaptation, when, in fact, the programmed intensity was not the actual intensity performed during the training sessions. Thus, due to reasons explained above, both 1RM value and nRM bring crucial disadvantages for determining the resistance exercise intensity in such a way that it is not possible to precisely control the real effort exerted during resistance exercise.

MV as a determinant of resistance exercise intensity

A scientific line of research has been developed to solve the problems exposed to the control and expression of resistance exercise intensity. It was found that MV is the best way to determine resistance exercise intensity [3,4,27-31]. These studies showed a strong, almost perfect relationship between relative load (%1RM) and MV in many resistance exercises [11,32-34]. Thus, when measuring MV it is possible to estimate precisely what %1RM a specific load (kg) represents from the first repetition performed at the maximum possible velocity during a resistance exercise.

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The benefits that execution velocity monitoring can bring to RT programming were reported in 1991 by Juan José González-Badillo [35]. However, the first scientific study to verify the relative load-velocity relationship during resistance exercise was published only in 2010 [4]. This happened because during this time it was not possible to measure the MV accurately during isoinertial resistance exercises. Nowadays, several instruments have been validated for measuring MV during resistance exercise [36]. Among them, linear position and velocity transducers have been more used [36]. However, accelerometers, cell phone applications, and wearable technologies have gained attention from the scientific community and strength and conditioning professionals, due to their low cost and practicality [37,38].

Degree of effort expressed from MV measurement

Currently, MV of each repetition during resistance exercise sets is the best reference to indicate the real effort developed by the practitioner during a training session [3]. As mentioned in the first paragraph of this narrative review, training programming is manipulating and controlling a succession of efforts that have a dependent relationship with each other. The term effort means the actual degree of demand concerning the current possibilities for an individual. In strength training, this term refers to the number of repetitions performed (actual degree of demand) concerning the maximum number of repetitions possible to be performed (current possibility) with a load during the performance of a resistance exercise. It is the relationship between what was done and what could be done. This relationship is called the level or degree of effort [3].

The degree of effort is different when the individual performs 12 repetitions even being able to perform 15 (12) in comparison to execute all repetitions as possible 15 (15) in an exercise set with a specific load, for example [3]. The closer to how much you can do (maximum number of repetitions possible), the greater will be the level of effort, and consequently, greater will be the fatigue generated by the exercise. In summary, the greater the difficulty in performing repetitions in a set, the greater the degree of effort.

However, if two individuals perform a set with the same %1RM (difficulty) and both can perform 10RM in such exercise, but one individual performs three repetitions, leaving seven in reserve 3 (10), while the other performs eight, leaving only two repetitions in reserve 8 (10), the degree of effort will never be the same. The degree of effort of the two individuals is represented by the loss of velocity that both experienced during the set. The greater the velocity loss during the set, the closer this individual will be to 10RM (maximum number of repetitions that can be performed). The closer to this number, the greater the degree of effort, and consequently, the greater the fatigue experienced during exercise. Thus, the solution to the precise dosing of resistance exercise intensity lies in the determination of this degree of effort. From the MV measurement, we can define it precisely, knowing the difficulty to perform the first repetition of an exercise and the velocity loss experienced until the set end [3,16,38].

Since each %1RM has its MV in each resistance exercise, as soon as the first repetition is performed, it is possible to determine the difficulty that the lifted load imposes on the athlete. Some studies have proved that this velocity is very stable [4,10]. It does not change even after improving performance (increasing the value of 1RM) in a few weeks of training for the same person and even among individuals with different strength levels.

In both studies [4,10], general prediction equations for %1RM, and consequently, for 1RM value, were created. Thus, it would not be necessary to carry out a progressive test with loads to discover the load-velocity relationship. When applying these equations, from the first repetition, it would be possible to estimate what %1RM the lifted load represents. Even if the 1RM value changes every day, the velocity with each %1RM is quite stable. Thus, with the execution velocity monitoring, it is possible to estimate the real effort or the %1RM applied at any moment of the training.

In this approach, the velocity with each %1RM is treated as if it were similar for all individuals. However, recent scientific studies have shown that this relationship is individual and dependent on sex, suggesting the use of individual load-velocity relationships for a more accurate prescription and training load monitoring [39,40].

In addition to the usefulness of MV control to quantify strength training, velocity control can be useful to know the degree of fatigue that the individual is achieving during exercise [16], as well as to know the neural and/or structural orientation of the work out [41]. The different adaptations that occur in the human body were demonstrated when performing exercises with 20% and 40% velocity losses, the 20% velocity loss being more associated with neural and functional adaptations and 40% the most associated with the gain of structural hypertrophy after eight weeks of training [41].

Knowing the execution velocity of each of the repetitions that make up the set, we can know the proximity of muscle failure, being able to end the set before this occurs due to the non-recommendation of training until muscle failure [42]. Likewise, the number of repetitions in reserve and the maximum number of repetitions can be predicted by knowing the execution velocity [43], which results in much more precise training control and training volume decrease [44]. As, through the knowledge of the execution velocity, we can know the degree of fatigue of the athlete during the set and the degree of recovery achieved during the rest time between sets, so the rest time between sets can be much better adjusted [45].

Table I - Classification of the effort that can be performed during resistance training.

Level of effort	Performed repetitions	Examples*
Light or low	Less than half of the possible repetitions	3x4-6 (20), 3x3-4 (14)
Medium	Around half of the possible repetitions	3x6-7 (12-14), 3x4-5 (8-10)
High	More than half of the possible repetitions	3x3 (5), 3x4 (7), 3x5-6 (8), 3x8 (12)

*Sets x performed repetitions (Possible repetitions/Maximum repetitions). Modified from the book of Badillo and Serna [46].

Conclusion

The contributions of MV monitoring are striking and revolutionary. In this perspective, the velocity-based approach to RT has gained attention from the scientific community and from strength and conditioning professionals, since the dose, monitoring and control of the training load can be carried out more precisely than previously imagined. The degree of effort during RT can be known at any time, solving the training dose control problem faced by Physical Education professionals, besides eliminating methodological errors and possible negative effects that the traditional way of dosing and controlling the load resulting from of the world of bodybuilding and transferred to the practice of other sports can generate.

Potential conflict of interest
No conflicts of interest with potential potential for this article have been reported.

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Academic link
This study is not linked to graduate programs.

Authors' contributions
Conception and design of the research: Oliveira LA, Da Silva-Grigoletto. Data collection: Oliveira LA. Analysis and interpretation of data: Not applicable. Statistical analysis: Not applicable. Obtaining financing: Not applicable. Writing of the manuscript: de Oliveira LA, Martín-Rivera F, Da Silva-Grigoletto ME. Critical review of the manuscript for important intellectual content: de Oliveira LA, Martín-Rivera F, Da Silva-Grigoletto ME.

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