Fundamentals of velocity-based resistance training

Juan José González Badillo
Luis Sánchez Medina
Fernando Pareja Blanco
David Rodríguez Rosell
Fundamentals of velocity-based resistance training

Juan José González Badillo
Luis Sánchez Medina
Fernando Pareja Blanco
David Rodríguez Rosell

Translated from the original Spanish 1st edition
(“La velocidad de ejecución como referencia para la programación, control y evaluación del entrenamiento de fuerza”)

Authors:
Juan José González Badillo
Luis Sánchez Medina
Fernando Pareja Blanco
David Rodríguez Rosell

DL NA 2450-2017

Publisher: ERGOTECH Consulting, S.L.
Editor: Luis Sánchez
Translated by: David Bañez, Luis Sánchez
Design & layout: Zesar Cebrián (photozesar)
Photography: Luis Sánchez, Carlos Pérez

No part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

Printed in Spain
© Copyright 2017 ERGOTECH Consulting, S.L.
Consequences of the incorrect measurement of the 1RM
The velocity of the 1RM influences the load that maximizes power output
The programming of training understood as an ordered succession of efforts with a dependent relationship between them
The origins of "training to failure"

Solving the problems arising from the use of the 1RM and nRM as references to dose the loads and evaluate the effect of training: the level of effort defined by velocity
The level of effort
Movement velocity
The level of effort defined by velocity
The level of effort as a function of the magnitude of velocity loss in the set

Movement velocity as a measure of loading intensity
Examples of load-velocity relationships before and after a period of training
Stability in the load-velocity relationship after modifying the 1RM
Stability in the load-velocity relationship regardless of the level of strength performance
Load-velocity relationship in different training exercises
Applications of the load-velocity relationship
Importance of the propulsive phase in isoinertial strength assessment

Loss of velocity in the set: the degree of fatigue
Velocity loss as an indicator of neuromuscular fatigue
Velocity loss and mechanical and physiological stress
Velocity loss against the 1 m·s⁻¹ load
Loss of height in the vertical jump
In search of the optimum velocity loss

Loss of velocity and the percentage of repetitions performed
Variability in the number of repetitions that can be performed against a given relative load
Relationship between velocity loss in the set and the level of effort
Summary of the basic ideas

Velocity and the level or degree of effort at different relative loads
Proposal for an index to express the level or degree of effort
The effort index as a control variable and an independent variable
Conclusions and practical applications

The velocity with which the 1RM is attained in each exercise. Should the 1RM be measured?
The velocity corresponding to the 1RM in different exercises
The velocity of the 1RM influences the load that maximizes power output
Consequences of the incorrect measurement of the 1RM

The decision not to measure the 1RM
Summary of the basic ideas

Movement velocity and the strength deficit
Evolution of the strength deficit depending on the changes observed in the velocity against each percentage of the 1RM
Summary of the basic ideas

Movement velocity and the relative training load
Possible advantages of the measurement of velocity at the beginning and end of the training cycle
Possible advantages of the measurement of the velocity at the beginning and end of the training cycle and during all of the sessions
Summary of the basic ideas

Monitoring and definition of the training load: effects of movement velocity
Importance of lifting loads at the maximal intended velocity
The effect of training at the maximal intended velocity or at half of the maximal velocity in the bench press
The effect of training at the maximal intended velocity or at half of the maximal velocity in the squat
Conclusions and practical applications

Monitoring and definition of the training load: effects of the magnitude of velocity loss in the set
The effects on physical performance of losing 20% vs. 40% of velocity in the set
The effects on muscle structure of losing 20% vs. 40% of velocity in the set
Advantages derived from measuring movement velocity during training
Conclusions and practical applications

Clarifications regarding the use of velocity in resistance training
Premises for the use of velocity as a referent for training monitoring
Some common but inappropriate terms
Considerations regarding training velocities
Functions of velocity monitoring in resistance training

Guidelines for the organization of velocity-based resistance training
Basic steps to follow in the organization or programming of a velocity-based training cycle
Specific adaptations of the training according to the strength requirements of each group of sports

Instruments to measure movement velocity
Origins
Linear position and velocity transducers
The T-FORCE System
Accelerometer-based devices

Acronyms and abbreviations

References
Juan José González Badillo

Considered one of the world’s leading experts in resistance training, Professor González Badillo has dedicated his life to sports training, research and teaching. Specializing in “Theory and Practice of Sports Training”, he holds a Chair at the Pablo de Olavide University (UPO) in Seville, where he has been Dean of the Faculty of Sports Sciences and has worked prolifically in teaching and research activities. He was the creator and director of the University’s official Master’s Degree in Physical and Sports Performance and the Doctorate Program in Physical Activity and Sport Sciences at the UPO, where he was the driving force behind the creation of the Physical and Sports Performance Research Centre (CIRFD). At the UPO, he has directed 20 doctoral theses and numerous degree and Master’s theses.

He was the technical director and coach of the national team of the Spanish Weightlifting Federation for 20 years, and as a coach he has achieved over 600 national and several European records. He has been a member of the Technical Committees of the European Weightlifting Federation (4 years), the International Weightlifting Federation (8 years) (IWF) and the Scientific and Research Committee of the IWF. He has taken part at four Olympic Games as a coach. He has contributed to medals won at European and World Championships and at the Olympic Games in five different sports: weightlifting, track sprint cycling, women’s field hockey, sailing and wrestling. He was also the designer and author of the base document for the Andalusian Olympic Plan of the Andalusian Olympic Foundation, and was responsible for the design, development and monitoring of the program for the “Detection, perfecting and monitoring of sporting talent” of the Andalusian Regional Government.

The author of four books and numerous chapters in books, he has published more than 80 scientific articles in English included in the Journal Citation Reports (JCR) database of the Science Citation Index, in the Sports Science section.

He has been the Head of Studies and a teacher on the Master’s Degree in High Performance Sports Training of the Spanish Olympic Committee (COE) since 1993. He has taken part in numerous research projects won by public competition. He received a “Special Mention” at the 2015 Andalusian Sports Prizes awarded by the Regional Ministry of Tourism and Sports of the Andalusian Regional Government as a lifetime award for his dedication to sport in different areas including research, teaching and sports training. He also recently received the 2016 First Prize for Sports Research from the Andalusian Regional Government for the R&D&I Project on the “Assessment and effect of different types of resistance training protocols through changes in force, movement velocity, metabolic and hormonal stress and entropy”, subsidized by the Ministry of Science and Innovation of the Spanish central government (reference DEP2011-29501), in which he was the lead researcher.
Luis Sánchez Medina

He is a graduate in Physical Activity and Sports Science. Holder of a European Doctorate from the Pablo de Olavide University of Seville, where, under the supervision of Professor González Badillo, he wrote his Doctoral Thesis “Movement velocity as a determining factor of the degree of effort in resistance training”. He holds a Master’s Degree in High Performance Sports Training awarded by the COE, and is a National Track & Field Coach and Level III Triathlon Coach.

He developed the T-FORCE System, an electromechanical measuring instrument for resistance training and assessment. As the programmer of the system’s software, he has implemented different updates in the system to incorporate the latest findings and advances achieved by our research group on the applications of velocity-based resistance training.

He has over 27 JCR-listed scientific publications in the Sports Science section. He is currently a lecturer on the Master’s Degree in High Performance Sports Training of the COE, on the Master’s Degree in Physical and Sports Performance at the UPO and on the Master’s Degree in High Performance in Cyclic Sports at the University of Murcia.

He is currently working as a Higher Sports Technician at the Centre for Studies, Research and Sports Medicine (CEIMD), of the Navarre Institute of Sports and Youth of the Regional Government of Navarre. His main tasks are to assist high-performance athletes (assessment of muscular strength and biomechanical analysis), research (both into sporting performance and the improvement of health) and the training of sports technicians.

Fernando Pareja Blanco

A graduate in Physical Activity and Sports Science and holder of a Doctorate from the Pablo de Olavide University of Seville, where, under the supervision of Professor González Badillo, he wrote his Doctoral Thesis on “Movement velocity as a determining factor in the adaptations brought about through resistance training”. He holds a Master’s Degree in High Performance Sports Training from the COE and a Master’s Degree in Physical and Sports Performance from the UPO.

He has published over 20 scientific articles in JCR journals in the Sports Science section. In recent years, he has researched intensely at the Physical and Sports Performance Research Centre at the UPO. He has spent periods both in Spain and abroad working under the supervision of researchers of recognized prestige, such as Professor Per Aagaard (Syddansk Universitet, Denmark) and Professor José Antonio López Calbet (University of Las Palmas de Gran Canaria), during which he has analyzed the effect of different resistance training protocols on the adaptations of muscle fibers and the response of satellite cells to this type of efforts.

He is currently an associate lecturer on the Degree in Physical Activity and Sports Sciences at the UPO, where he teaches the subjects “Theory and Practice of Sports Training” and “Methodology and Programming of Sports Training”. He has also supervised over 10 degree theses in recent years. From a practical point of view, he has worked as a fitness trainer for football clubs and teams, both with the youth academies and the first teams, at several professional clubs in Spain and abroad.

David Rodríguez Rosell

A graduate in Physical Activity and Sports Science and recent holder of a Doctorate from the Pablo de Olavide University of Seville, where, under the supervision of Professor González Badillo, he wrote his Doctoral Thesis on “Movement velocity as a variable for the monitoring and prescription of resistance training”. He holds a Master’s Degree in High Performance Sports Training from the COE and a Master’s Degree in Physical and Sports Performance from the UPO.

He has published 19 scientific articles in JCR journals in the Sports Science section. In recent years, he has undertaken prolific research work at the Physical and Sports Performance Research Centre of the UPO. A significant part of the results of the latest work at the CIRFD are included in this book.

His interests include the analysis and improvement of performance-determining factors in different sporting disciplines, mainly football, basketball and volleyball. From 2012 to 2015, he worked as the coordinator of physical training for all of the teams (7 in total) of Coria Football Club. Since 2013, he has worked on the assessment of the physical fitness and training prescription for several teams, in different categories, of Basketball Sevilla.
Preface

“If we could measure the maximum velocity of the movements every day while gathering immediate information, that would possibly be the best way to determine whether or not the weight is appropriate. A given reduction in the velocity is a valid indicator that training should be suspended or the weight on the bar reduced. We could also record the maximum velocity achieved by each weightlifter with each percentage, and on the basis of that, evaluate the effort: a much lower velocity than that achieved on other occasions with the same percentage would indicate that the weightlifter is working above the planned effort or, on the contrary, if the velocity is greater, he is possibly above his best performance and, therefore, the effort is less than that programmed. If we cannot measure the velocity precisely, we have to judge it subjectively: we must observe the fluidity of movement, coordination, ease of fixing the bar, of recovering in the power clean and snatch, the higher or lower elevation of the bar, the velocity/ease of lift-off…”

Halterofilia, page 172 (González Badillo, 1991)

The above quote demonstrates how, by the 1970s-80s, we already perceived that the answer to the central element of the problem of training –the dosing, control and evaluation of training, and the daily assessment of physical fitness– could be found in monitoring movement velocity.

This perception is based on the fact that, for many years, we have daily observed the evolution of the physical fitness of athletes by means of a subjective assessment of the "ease" or "difficulty" of the execution of training loads. We based this assessment on a personal estimate of the velocity at which the loads were lifted. This means of estimating the velocity had the "advantage" of not needing any equipment to be assembled in order to observe several athletes simultaneously, but it did not offer the possibility of obtaining and storing precise and objective data about the desired information.

At that time, we had to make do with a solution indicated at the end of the quotation: “If we cannot measure the velocity precisely, we have to judge it subjectively…” It can be deduced
from the quotation that, at that time, we already believed that “we had to take velocity as a reference”, even though we were unable to measure it. That is to say, the control of velocity was already considered essential.

Nevertheless, by the late 1970s (1977-78), we were already measuring the movement velocity using a camera (in position B). This procedure involved photographing a luminous body while it moved in a space. To do this, we used the electric motor of a record player, a black disc with a small radial slot and an x-ray plate, which was fixed on the axis of the record player motor, and a point of light emitted by a small incandescent lamp attached to the end of the bar. The motor and the disc made one rotation in front of the camera lens every 0.03 s. Therefore, the slots on the black disc passed the height of the lens every 30 ms and it was possible to obtain an image of the spot of light attached to the end of the bar. The use of this device would not have been possible without the inestimable collaboration of David del Rosario, an ophthalmologist specialized in optics at the University of La Laguna, who prepared all of the apparatus.

These measurements allowed us to obtain information about the velocity of movement calculated from the space covered between two consecutive captures of the point of light. From this information, other calculations were made in relation to acceleration, force and power. Furthermore, from the succession of points, we obtained the trajectory of the movement (specifically, of the end of the bar) and the displacement. Despite the value of this information at that time, it was not useful for the control of training in each session and immediate decision-making, since the analysis of single movements required the film to be developed and the data then had to be extracted manually, which meant that it could take several weeks to obtain the results of the measurement.

We published two articles on these studies in the "Boletín Informativo de Halterofilia", the journal of the Spanish Weightlifting Federation, one on the measuring system (del Rosario & González Badillo, 1978) and another on the analysis of one of the movements (González Badillo, 1979). This second publication appears to have been the first to appear in Spain on the biomechanical analysis of a specific competition movement, namely, the snatch, executed by one of our best weightlifters, Joaquín Valle.

In 1991, we published "Halterofilia", the book which is quoted as an introduction to this preface, and in which, as reflected in the quotation, we made a proposal-hypothesis on the possible applications of monitoring movement velocity.

In 1993, we began to measure the velocity with almost immediate information. This took place in the mid-2000s, we again took part in the development of a new measuring device, in this case, in collaboration with José Antonio Santamaría (industrial engineer) was responsible for all of the hardware and the programming of the software. José Manuel García García, an ex-student on the COE Master, who asked me to collaborate on the project, also took part. For many years, this measuring instrument was known as "Badillo’s apparatus".

In the mid-2000s, we again took part in the development of a new measuring device, in this case, in collaboration with Luis Sánchez Medina. The result of this work was the appearance of a new instrument, a linear velocity measuring device, known as the "T-Force System". We have worked with this device for the last 10 years, incorporating new features into the system’s software as we have discovered new applications for velocity-based resistance training.

In 2000, we published the first data on the velocities attained with each percentage of 1RM, the loading percentages with which maximum power was achieved in different exercises and the velocity with which those power output values were obtained [González Badillo JJ (2000) Bases teóricas y experimentales para la aplicación del entrenamiento de fuerza al entrenamiento deportivo. Infocoes S(2): 3-14]. In the same publication, we also included proof that each exercise has its own movement velocity for its repetition maximum (RM). This data determines the characteristics of all exercises and the way they should be used during training.
In 2010, we finally published our work in English for the first time, giving the velocity corresponding to each percentage of the RM. In this case, we did so with the bench press exercise [González Badillo JJ, Sánchez Medina L (2010) Movement velocity as a measure of loading intensity in resistance training. Int J Sports Med 31(5): 347-352]. This publication was the first of a series of works in which the analysis and knowledge of the importance of velocity in resistance training has been completed.

In effect, the latest advances in knowledge of the role of movement velocity in resistance training have come about over the last 10-15 years. Initially with Luis Sánchez Medina, and later with the Physical and Sports Performance Research Centre (CIRFD) of the Pablo de Olavide University (UPO) of Seville, with the decisive collaboration of Fernando Pareja and David Rodríguez, ex-students on the Bachelor’s Degree in Physical Activity and Sport Sciences, who, on finishing their degree courses, joined the Sports Training Laboratory and later, the CIRFD. The participation of these two ex-students has been very significant in almost all of the studies which have formed the basis of the theoretical and experimental foundations of the content of this book. Ricardo Mora and Juanma Yáñez, also newly graduated ex-students at the UPO, later joined in the work on the studies.

Though at the end of this text some basic ideas are offered about how to organize training through movement velocity, it is very important that the reader takes into account that the purpose of this text is not to discuss or propose how to train using velocity. The main objective is to explain the contribution that velocity monitoring can make to the improvement of training methodology. This improvement will come about if, using the variable velocity correctly, we can accurately ascertain what load has been applied and what effect has been produced by that load. In other words, the appropriate use of velocity will allow us to determine with very little margin of error what load has produced a given effect, both in cases when the effect is positive and when it is not.

We believe that this contribution is decisive to progress in the Science of Sports Training. Until now, we have not been able to determine what load has produced a given effect, and this not only, and inevitably, puts a brake on our progress in terms of knowledge of training methodology, but also, and also inevitably, leads to constant unfounded proposals for “new training methodologies”, when we have never really got to know or applied or experimented with any of the supposedly “old” methodologies.

Therefore, what this work presents in detail is the great practical importance of monitoring the movement velocity of exercises in what is usually known as “resistance training”.

One of the sources of error when programming training is the reference taken for dosing the load. We begin by explaining the disadvantages of the usual references, such as 1RM and the traditional XRM, which in the text we express as nRM. We go on to propose a solution to these disadvantages, based on the relationship between the percentages of the RM and their corresponding velocities, and on the loss of velocity incurred in the sets. The two proposals jointly define the concept of level of effort which we have been proposing since the 1980s.

As a consequence of the above concepts, we suggest that we never need to measure 1RM in any exercise, since it is not necessary either for dosing the training or for evaluating the effect of training.

The only possible use of the RM value is to estimate the strength deficit. But not even in this case is it necessary to measure it, since the result obtained by estimating it is more reliable than the measurement itself. In this text, it is demonstrated how, by applying velocity appropriately, a very precise estimate can be made of the strength deficit. This is an interesting contribution, since it is practically impossible to determine the strength deficit without using velocity, and if well applied, this provides us with important information regarding the effect of training.

Several studies of the effect on performance of the voluntary movement velocity and the involuntary loss of velocity in the sets are analyzed, not as a primary objective of the text, but rather as support material to analyze and extract the contributions related to velocity that can be deduced from these studies.

A section is also devoted to explaining what velocity does not really contribute to training. This can be summarized in a couple of sentences: 1) velocity-based training is not necessarily good training, 2) a given velocity value is not associated with a given effect: to obtain a given effect, there are many different velocities that could be used.

Finally, some basic guidance is offered on how to organize training through velocity, for which an outline is given of what the evolution of the main training load indicators could be, differentiating them in five levels of strength requirements.

Each chapter ends with a summary of the main ideas developed and their practical applications.

Juan José González Badillo
Seville, February 2017
To all of the students and athletes who disinterestedly volunteered to take part in the numerous studies undertaken by our research group over the last 10 years. Without their generous cooperation, it would not have been possible to generate the knowledge that we have obtained and to contribute to the development of training methodology and, thereby, to the improvement of physical and sporting performance. Many thanks!
The indicators that have traditionally been used as references for dosing and prescribing the resistance training load (1RM and nRM) have significant limitations which have led us to seek a solution which allows a better definition and quantification of the degree of effort involved in the performance of an exercise or a training session.
Though at the end of this book some basic ideas are offered about how to organize resistance training through the monitoring of movement velocity, it is very important that the reader take into account that the purpose of this text is not to discuss or propose how to train using velocity. The main objective is to explain the contribution that velocity monitoring can make to the improvement of training methodology. This is why we suggest that, in order to understand the text better, the reader should carefully review the preface, which summarizes the original problem and the evolution of the process, leading up to the current situation.

Three of the main problems in sport training are the dosing of the programmed load, the control or monitoring of the applied load and the evaluation of the effect of training.

The main component in the dosing of the programmed load is the intensity. When moving or lifting a load, we understand the intensity to be the degree of effort involved when performing the exercise in the first action (repetition). This represents the degree of neuromuscular activity developed in order to oppose a resistance, both in the case that the resistance is the athlete's own body weight and in the case of overcoming an external resistance, or both together.

Traditionally, the most common indicators which have served as a reference for dosing the training load in what we usually call "resistance training" have been the value of one repetition maximum (1RM) and the value of a given number of repetition maximums (nRM).

The value of 1RM is the maximum load (mass) that can be lifted only once in a dynamic concentric action in a given exercise (while completing full range of motion and without any external help). We have called this force value the "maximum dynamic force" and in training jargon it is also sometimes known as "absolute force". It is usually expressed in kilograms (kg). The dosing of the load taking the 1RM as a reference uses the percentages of 1RM.

The nRM represents the maximum number of consecutive repetitions that can be performed with a given load (mass). Thus, for example, 10RM is that load which can be lifted a maximum of 10 times in a concentric action in a given exercise. It is supposed that the number of repetitions that can be performed determines the relative intensity of the effort made by the subject. This is based on the supposition that if two subjects perform the same number of possible repetitions with a given mass, this would mean that both have trained with the same relative intensity, even though the masses which they use are different. The nRM is characterized by the fact that as well as serving as a reference for dosing the intensity and the number of repetitions to be performed, it can also be considered a type of training. This type of training is usually called "training to failure" and involves the performance in each exercise set of the maximum number of repetitions possible.

The use of these references (1RM and nRM) for dosing the training load could have some advantages but, above all, they have some significant disadvantages, as we shall see below.

### 1.1 Advantages and disadvantages of using 1RM percentages as a reference for dosing the training load

#### Advantages

- By using 1RM percentages, it would be possible to simply individualize the load (mass) that should be used by each subject, no matter how numerous the training group. It would simply be necessary to indicate the percentage of the RM to be used in the training (for example, 60% 1RM). But this "individualization" is only apparent, for the reasons explained below in the section on disadvantages.

- If the 1RM percentage is considered and interpreted as a "degree of effort", and not simply as an arithmetic calculation, it could also have an important application to indicate the evolution of the maximum relative intensity used in each session or week of training. If a person wishes to honestly inform about the most determinant characteristic of their training program, they should do so in a quick, simple, precise manner, indicating the maximum intensity of each session in the fundamental exercises, which in this case is done through the maximum 1RM percentage used. This percentage should be considered the "real degree of effort". This information is the most important, although, naturally, if the values of the volume performed at each intensity (%1RM) were added, the information would be more complete.

#### Disadvantages

- **Disadjustment in time of the theoretical percentage.** The 1RM value is not the same every day. It tends to increase in just a few sessions if the subject is not highly trained, and it is generally below the maximum value measured prior to the beginning of the training cycle when subjects are highly trained. However, in no case are the changes stable, but there are oscillations in the 1RM value. For these reasons, the effort made during the session could differ clearly from the programmed or intended effort. A clear, and negative, consequence of this situation, whatever the level of performance of the subject, is that we will never know at what intensity we have trained, which is fairly serious, since we will be assuming that the effect obtained from the training, whether positive or negative, is due to degrees of effort (training loads) which are different from the real loads. With this problem, we will never improve our training methodology, as we would almost always be using very inaccurate data.

- **The 1RM value may not be real.** A high percentage of the repetition maximums (RMs) measured are false. As we said almost two decades ago, each exercise has its own velocity for its 1RM (González Badillo, 2000). Therefore, the RMs are false whenever the subject achieves them at velocities higher than the exercise's own 1RM velocity. The further the velocity from the exercise's own 1RM velocity, the less accurate the measurement. Therefore, this lack of accuracy is always manifested in a 1RM value which is lower than the
This circumstance means that the error will have less negative consequences for the training than other errors, since we would always be training with loads lower than those programmed and, in many cases, when we train with less than the programmed load, the results are often better. Although, as we have noted, the result of this error is usually the lesser of two evils or, paradoxically, it could even bring greater benefits with respect to the result of the training, it does unquestionably confuse the trainer, as the trainer believes that the results obtained are due to the intensity that they programmed, when in fact they are due to other very different intensities, which in this case are lower than those programmed.

**1.2 Disadvantages of using the number of repetition maximums (nRM) as a reference for dosing the training load**

This way of expressing the intensity of training indicates that the maximum possible number of repetitions with the load (mass) used in training should always be performed. The “n” represents the number of repetitions to be performed. It is understood that being able to perform a given number of repetitions means that we are working at a given relative intensity or percentage of 1RM since, with each percentage of 1RM, a given number of repetitions, on average, can be performed. Our research revealed no advantages in using this reference for dosing the training load, but we have found some disadvantages.

- Performing the same repetitions with a given load does not mean that the subject is working with the same relative intensity. The maximum value of the range where we find the number of repetitions performed at the same relative intensity, from 50% to 85% of 1RM, could duplicate the minimum value, with a mean coefficient of variation of ~20% (González-Badillo et al., 2017). Therefore, there could be a case in which two subjects have trained with the same number of repetition maximums per set but have exercised at very different relative intensities.

- It is not possible to perform two consecutive sets with the same load and the same number of repetition maximums. Effectively, it is not possible to perform more than one set with the same absolute load and the same number of repetitions when it really is the maximum number possible for the subject in the first set. This is true even if the subject recovers for several minutes between the two sets. Therefore, it is not realistic to propose training such as, for example, 3x12RM, which would mean that the subject would have to perform 3 sets of 12 repetitions with a load with which they could only perform 12 repetitions in the first set.
Introduction

Fig. 1 gives this same example with real data, showing the velocity achieved in each repetition. Three sets of the bench press exercise were performed, with 5 minutes of recovery between them. A moderately-trained subject was asked to perform the maximum possible number of repetitions in each set. The load chosen was 58.5 kg, which represented approximately 75% of the 1RM of the subject (77.5 kg), measured (correctly) one week previously. In the first set, 12 repetitions were completed. However, as can be seen, the enormous fatigue brought about by the effort in the first set, despite the following 5 minutes of recovery, caused the number of repetitions performed to fall sharply (8 repetitions in the second set and 7 repetitions in the third set). Note how the velocity in the last repetition of each set was very similar (0.13 m·s⁻¹ in the first two and 0.11 m·s⁻¹ in the third). This velocity value, as we shall see later, falls within the range of velocities that we could consider to be a criterion for an RM to be classified as “true” in the bench press. See also how the initial velocity in sets 2 and 3 fell considerably with respect to set 1. The lower number of repetitions performed in the second and third sets is in a practically perfect inverse proportion to the loss of velocity in the first repetition in each set (r = -0.99).

- Training always with the maximum possible number of repetitions per set could produce, at least, the following negative effects: excessive fatigue, increased risk of injury and reduction of movement velocity against all loads, all of which can lead to a reduction in sporting performance.

- It has been observed that performing the maximum possible number of repetitions in each set does not bring the best results. Recent research has demonstrated that training to failure brings equal or inferior results than not training to failure (Folland et al., 2002; Izquierdo et al., 2006; Drinkwater et al., 2007; Willardson et al., 2008; Pareja Blanco et al., 2017a; Sampson & Groeller, 2016).

These two references (1RM and nRM), therefore, bring such disadvantages to the dosing of training that a solution must be found.

1.3 The programming of training understood as an ordered succession of efforts with a dependent relationship between them

To find the right reference variable or variables, we should start from the concept of the programming of training. A useful, operative definition to understand what training is would be the definition that we have been proposing for some time: "programming is the expression of an ordered series or succession of efforts with a dependent relationship between them". What is characteristic of this definition is that programming is the management of a series of "efforts". We must therefore clarify what we understand effort to mean. An effort is defined by the relationship between what is done and what could be done. We have called this relationship the "level of effort" (LE) (González-Badillo & Gorostiaga, 1993, 1995). The closer we come to what we can do, the greater the "level or degree of effort", and the greater the fatigue.