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SELF-REGULATION STRATEGIES FOR EXERCISING WITH OVERLOADS

BY M. DUCA AND G. ALBERTI

INTRODUCTION

The human being has an intrinsic variability with respect to its biological and psychological processes, which is also reflected in sports performance. Factors such as sleep (8), nutrition (35), supplementation (5) and daily stress (2) can, in fact, alter the ability to express strength, both during training and in tests. These are all elements that must be taken into consideration when setting an overload, intended as weights placed on the barbell or posing resistance on a machine used in training with overloads.

The two most known and commonly used strategies are the choice of a percentage of the single maximum repetition performed in an exercise (% 1RM), or the indication of areas in which to perform a certain number of maximum repetitions (RM) (41). As regards the first, the reasons for the popularity of% 1RM are given by the fact that, in almost all the exercises, most athletes are able to perform the same sum of repetitions at the same relative intensity (overload divided by 1RM). In literature there are tables that give precise indications regarding the number of possible repetitions at the different relative intensities (31) and so it is very simple to determine the overload to be used. However, the use of% 1RM has limitations: the exertion may not be the same in different athletes, as each could perform a different number of repetitions at the same relative intensity (27). Furthermore, the 1RM is not a stable measure in beginners training with overloads (28) and may decrease due to the fatigue accumulated following training sessions (22). Lastly, a periodic measurement, or an estimate, of the 1RM is required and if this test is performed in extraordinary conditions (accumulated fatigue or a particular physical condition), the chosen relative intensities may be higher or lower than desired.

The use of RM solves the problem both of inter-individual variability, in the number of repetitions performed at the same relative intensity, and of variability, in the number of repetitions performed at the same relative intensity between different exercises by the same subject. In addition, always reaching muscle failure, the applied exertion is always maximal compared to the overload used.

However, the problems associated with this method are the constant use of muscle failure training, making it difficult to manage the accumulated fatigue (20) and the difficulty in deciding the training volume from the start (the number of completed repetitions is, in fact, variable), which can change from athlete to athlete. Recently, numerous studies and reviews have shown that muscle failure training leads to results equal to or less than non-muscle failure training (21,24).

For all the reasons listed, it can therefore be advantageous to use strategies that are more flexible and allow self-regulation of the overload based on the conditions of the athlete, when the training is carried out. In this article, two methodologies that endorse these self-regulation elements will be presented: *Rating of Perceived Exertion* (RPE) and *relative intensity based on sets and repetitions* (IR_{SR}).

RATING OF PERCEIVED EXERTION

A scale for measuring the perception of exertion (Rating of Perceived Exertion, RPE) is a tool used to evaluate the perception of the response to a workout. It is a valid method for determining exertion during physical activity. The first RPE scale was developed by Gunnar Borg half a century ago (7) and was used to monitor aerobic activities. On the original scale, exertion was evaluated in a range from 6 to 20, so as to approximate heart rate by multiplying the value of exertion by ten. This strong relationship between exertion and cardiac activity has certainly limited its use in monitoring training with overloads and, more generally, in strength and power training. Subsequently, Borg also developed the category ratio scale, in which the perception of exertion is evaluated with a number between 0 and 10 (Borg CR10). This CR10 scale was recently used to attempt to monitor the perception of exertion during training with overloads (34).

RPE can be used differently in training with overloads. The RPE value can be requested from the athlete after each exercise or group of exercises performed. Alternatively, the RPE of the entire session may be requested. Thirty minutes after the end of the training session, the RPE value for the entire training session is detected (13). The RPE of the session can be used to determine the intensity of an entire training session or to monitor the overall response to training over time and make corrections and changes to the individual training schedule (12). However, the use of the RPE scale has limits to deciding the intensity during training, since,

if the set is continued until muscle failure, the RPE value reported by the athlete is lower than the maximum value (14). During a set, researchers assessed the difference between the estimate of the number of repetitions that the athlete would still have been able to perform, the actual number of completed repetitions and the RPE value. 17 bodybuilders were evaluated who performed 5 sets of 10 repetitions at 70% of their maximum (1RM) in squat and barbell presses. Upon completion of the tenth repetition, with their limbs in full extension, the participants were asked to report either the number of repetitions that they believed they could still complete or the RPE value, after which the set continued until muscle failure was reached.

The result of the study was twofold: in addition to reporting RPE values lower than 10 even when the set had run out, the bodybuilders were able to accurately estimate the number of repetitions missing in the set. Indeed, a strong correlation was found between the number of completed repetitions and the estimate for both exercises (r = 0.93 and r = 0.95). In addition, the researchers noted that, from set to set, the estimate was increasingly accurate. This happened because, due to the fatigue accumulated in the previous set, the participants were able to complete fewer and fewer repetitions and therefore the estimate of the missing repetitions was carried out closer to muscle failure. The use of two different values (missing repetitions and RPE), however, remains problematic as it can be confusing and impractical for athletes and coaches.

The first scale created for the regulation of training with overloads can be traced back to the article "The Reactive Training System Manual" (2008) for training in powerlifting by Mike Tuchsherer (42). The merit of having overcome the discrepancy between RPE and missing repetitions and having presented a scale, in scientific literature, however, must be given to Zourdos and colleagues. On the proposed scale, with values ranging from 1 to 10, the RPE is defined starting from the number of repetitions in reserve (RIR) i.e. the repetitions missing before muscle failure in a set. The RPE value is calculated as 10 - RIR (e.g. RIR = 1, RPE = 10 - 1 = 9) (43).

The previous discovery, that the evaluation of RIRs was more accurate the closer it was to muscle failure, led to grouping the lower RPE values (less than or equal to 4) and combining them with descriptions rather than a number of RIRs. Furthermore, since it is easier for athletes to report an interval, rather than a single RIR value greater than 3, the RPE values of 5 and 6 correspond to 4 - 6 RIR (Table 1).

RPE	DESCRIPTION OF THE PERCEIVED EXERTION
10	Maximum exertion
9,5	No repetition in reserve, possible to increase overload
9	1 repetition in reserve
8,5	1 or 2 repetitions in reserve
8	2 repetitions in reserve
7,5	2 or 3 repetitions in reserve
7	3 repetitions in reserve
5 – 6	4 – 6 repetitions in reserve
3 – 4	Light exertion
1 – 2	Minimum exertion or none

TABLE 1: Specific RPE for exercises with overloads (Helms et al. 2018)

However, a study by Zourdos study revealed a different accuracy between experts and inexperienced users in the use of the scale. The 1RM was tested for all participants and then 3 sets of 1 repetition were carried out with loads equal to 60%, 70% and 90%, and a set of eight repetitions at 80% of 1RM. For all the sets the RPE and the speed of the balance were evaluated. At 1RM and 90% of 1RM, expert lifters reported higher RPE and lower speeds than inexperienced lifters. For both experts and the inexperienced strong inverse correlations between RPE and speed of the balance at different percentages of 1RM (r = - 0.88 and r = - 0.77) were detected, although it should be noted that the strength of the relationship is greater in expert athletes. This consideration was then extended to the exercise of flat bench presses.

By replicating the same experimental protocol, it was possible to find that both expert and inexperienced lifters can accurately evaluate the RPE (25). The relationship between experience and accuracy was also confirmed in a sample of 141 German fitness centre users (36). It should be noted that in this case the sample included both men and women, with experience ranging from less than six months to more than three years. While confirming the hypothesis that the most experienced were more accurate in determining the RPE, a systematic error also emerged whereby the participants tended to underestimate the number of RIRs and therefore overestimate the RPE. The extent of the overestimation of the RPE value decreased as the length of practice increased but, over the whole sample, there was a 2.64 - 3.38 range (36). This overestimation can be traced back to the sample taken into consideration, that is, fitness centres users, certainly less accustomed to making maximum exertions compared to powerlifters and athletes considered in other studies (18,43). The fact that more experienced lifters moved the barbell at a lower speed with maximum loads shows that the more experienced have greater neuromuscular efficiency. In fact, the strongest athletes raise their ceiling at lower speeds, as they can maintain optimal postures and positions even with very high overloads. They are therefore able to continue to produce force at lower speeds and conclude the lift compared to weaker athletes who, as the speed of movement decreases, compromise their posture and are no longer able to produce enough force to move the overload.

As suggested by Helms and colleagues (16), inexperienced lifters should initially simply collect RIR values, but should not base their training solely on the RIR scale until they have achieved a greater level of accuracy. It must be remembered that the RIR scale should be used mainly for sets to exhaustion or close to muscle exhaustion. Therefore, this strategy of deciding the load is feasible in the training of maximal strength, hypertrophy and muscular endurance, it must instead be limited with regard to power training. To adjust the overload with respect to the RPE values reported by the athlete, a 2% variation of the load has been proposed for each point of RPE (17): if a person has to perform sets of 8 repetitions at RPE 8 and in carrying out the first set, using an overload of 100 kg, reports an RPE of 7.5, they must then increase the overload by 2% and carry out the next set with 102 kg. In the event that muscle failure is reached before the desired number of repetitions in a set, the overload must be reduced by 4% for each repetition not performed, as a repetition is equal to 1 point of RPE (17): if a another subject, in performing set of 8 repetitions at RPE 8 with 100 kg were to reach muscle failure at the seventh repetition, the load would be reduced by 12% (4% for the repetition not performed and 8% for lowering from RPE 10 to RPE 8) and therefore would carry out the following set with 88 kg.

Compared to the training programme, the use of the RIR-based scale has advantages similar to those of the traditional RPE scale. In fact, you can use this tool to self-regulate your training load. By choosing different RPEs for the same overload, athletes complete a different number of repetitions and consequently the training load (17). This indication is valid on different combinations of repetitions per set and RPE and has been specifically tested in squat, bench and deadlift exercises. 14 Powerlifters were evaluated who performed, in random order, 3 weekly sessions, completing, after warming up with incremental overloads, a first set of 8 repetitions at RPE 8, or 2 repetitions at RPE 8 or 3 repetitions at RPE 8. This training was repeated for three weeks and for each week, after carrying out the first set, the overload was reduced by 2%, 4% or 6%, which correspond in terms of RPE to a reduction of 0.5, 1 and 1.5 points.

As many sets as possible were then completed, keeping the number of repetitions constant, until the RPE value assigned for that day was reached or exceeded. The number of additional sets completed could therefore vary from a minimum of 1, so the powerlifter immediately reached the set RPE, to a maximum of 8, a value set as a threshold for excessive prolonged training. The total relative load completed (in relation to the 1RM of each athlete in each exercise) was therefore lower, in the case of a 2% reduction, intermediate for a 4% reduction and greater for a 6% reduction. Being able to adjust the training load, it is therefore possible to use the RPE to indicate the training intensities in the context of a schedule.

The effectiveness of this methodology to improve the level of muscle hypertrophy and the performance of maximum strength was tested by comparing it with the use of the percentages of 1RM to assign the overload to be used (15). Subsequently, 24 trained subjects were divided into 2 groups - in one the load was indicated by RPE, in the second by a percentage of 1RM.

The training involved performing squats and a flat bench for three sessions per week for a total of eight weeks. The number of sets and training intensities varied from week to week but were specular between the two groups.

The two strategies proved equally effective both as regards the improvements in maximal strength and hypertrophy; in fact, no significant difference emerged, although the size of the effect seems to favour the RPE group in the measures of maximum strength.

RELATIVE INTENSITY BASED ON SET SAND REPETITIONS

Determining the training intensity based on the estimate of the overload that the athlete can use for a certain combination of sets and repetitions (IRSR) can overcome some of the limits of RM, 1RM% and RPE. IR_{SR} is a strategy that has been developed for the training of weightlifting athletes (37) and which has been applied to other individual sports such as athletics (3) and also to team sports (4). This method consists in determining the maximum load that can be used in training for each combination of sets (S) and repetitions (R): SxR, e.g. 3x3, 5x3, 3x10, etc. Once these values are known, it is possible to determine the overload to be used using seven intensity categories, starting from 65% of the maximum load and with 5% increments for each category (Table 2) (38).

CATEGORY	LOWER LIMIT (IR_{SR}%)	UPPER LIMIT (IR_{SR}%)
Very Heavy (VH)		100%
Heavy (H)	90%	95%
Moderate – Heavy (MH)	85%	90%
Moderate (M)	80%	85%
Moderate – Light (ML)	75%	80%
Light (L)	70%	75%
Very Light (VL)	65%	75%

TABLE 2: Intensity categories based on sets and reps.

The determination of the maximum value for each exercise and combination of sets and repetitions (VH) takes place iteratively through the weeks of training. It is, in fact, possible to assign to each of the upper categories a description based on according to the presence or absence of a *sticking point*. The sticking point is a point of concentric movement where the lifting speed decreases markedly and approaches zero. For a very heavy intensity, the sticking point is evident for all the last three repetitions in a set (two in the case of a set of two repetitions). At Heavy intensity (H) the sticking point occurs only in the last repetition of the set, while there is a slowdown in the execution, without an evident sticking point at Moderate - Heavy intensity (MH). The Moderate intensity (M) corresponds to the greater overload that can be lifted without slowing down in the concentric phase of the movement.

Regarding the Olympic lifts (snatch and clean) and their variants (40) starting from the ground, the assessment of the possible sticking point or slowing down of the barbell must be carried out when passing the knees. For movements in which there is no sticking point, such as, for example, partial exercises (e.g. squats, pulls from the knee, etc.) or explosive ones (clean & jerk, bench press, etc.), the evaluation will be made in relation to the exertion used by the athlete to begin the concentric phase of the movement and the ability to maintain posture during the exercise. In this case, VH corresponds to the maximum load for which the movement can be performed, accepting that the execution technique is compromised only in the last three repetitions of the set, while at intensity H the technique is compromised only in the last repetition of the set.

Authors' NOTE

Coaches and trainers can obtain a rough estimate of the value of VH for a given combination of sets and reps starting from the value of 1RM, referring to the conversion tables between RM and 1RM %. The overload can be calculated from the percentage of 1RM corresponding to the number of RM per selected set, subtracting 2.5% for each additional set. Take for example the case of an athlete who in the squat has a 1RM equal to 200 kg and wants to estimate the VH overload for 3x5. The conversion table should therefore be consulted: 87.5% of 1RM corresponds to 5RM; then 5% will be subtracted (twice 2.5%, one for each additional set), so as to obtain 82.5% of 1RM, equal to 165kg

The 5% interval associated with each intensity allows the athlete and coach to adjust the overload based on the athlete's condition at the time of the training session.

An athlete with a 3x5 VH squat of 170 who is given an MH intensity will have to select an overload between 85% and 90%, then between 145 kg and 153 kg. However, it should be noted that the selection of the overload must be given only based on the athlete's subjective feeling. In fact, the athlete should perform warm-up sets and then consult with the coach. The coach, also based on the visual criteria relating to the presence of sticking points, will be able to advise the athlete on the choice of overload, a choice that may correspond to the lower limit of the interval if the athlete's conditions prove to be poor.

This methodology allows you to easily calculate the training load and solve problems present in the use of 1RM%, such as changes in the ability of the athletes to express their strength over time and the different relative exertion expressed by different athletes at the same percentage of the 1RM, as they individually estimate the maximum load for the different combinations of sets and repetitions. Compared to the RM method, the progression of the training programme can be planned in advance and the presence of an interval for each intensity allows to "accommodate" the overload according to the athlete's fatigue level. In addition, the possibility of deciding and planning different intensities during a week and/or a training cycle, enables better management of the athlete's accumulated fatigue (11).

However, the effort required to put IR_{SR} into practice usually makes its application difficult. It must also be added that, especially in the case of "new" athletes for the coach, it is difficult to make a proper estimate of the different VHs, especially with those inexperienced in training with overloads. This method certainly requires more time and effort from coaches, as they will have to constantly monitor the execution of the different exercises and may be restricted in the choice of combinations of sets and repetitions to be used. In order to have indications regarding the overload, the coach must in fact limit himself to those combinations already used with that athlete.

The effectiveness of this methodology has recently been compared with the RM method by Carroll and colleagues (10.11). In this study, 15 trained people followed a 10-week periodized workout, performing 3 workouts per week, using MRI or IR_{SR}.

The athletes faced 3 training blocks, the first of hypertrophy (3 weeks), the second of maximal strength (5 weeks) and the third of muscle power (2 weeks). The analysis of the effect sizes showed a more favourable adaptation for the IR_{SR} group compared to the RM group in terms of muscle hypertrophy, vertical jumping ability and force application. Muscle biopsies were used to evaluate type I and type II fibre hypertrophy, ultrasound was used to measure the anatomical cross section of the muscle and the muscle thickness, and the latter had increased similarly in both groups (10). Then squat jump and countermovement jump were performed with 0 kg and 20 kg of overload; in all cases the power peak and the jump height improved most in the IR_{SR} group. The application of force of the subjects was tested through the isometric mid-thigh pull. Regarding peak force, no differences were found between the two groups, while in the *rate of force development* (RFD), especially in the initial moments of the pull (0-50ms and 0-100ms), the IRSR group was significantly better.

Previously, Painter and colleagues (26) had reported similar results in college athletes. In this study, however, while the IRSR group followed a block periodization, similar to that used by Carroll, the RM group used a daily wave periodization. At the end of the 10 weeks of training, both groups had significantly improved the maximum strength, measured by the peak force in the isometric mid-thigh pull and the 1RM of squats. Although without significance, in the isometric mid-thigh pull, the interpretation of the effect sizes favoured the IRSR group in the rate of force development measurements: 0-50ms and 0-90ms.

In the studies described, the greater effectiveness of IR_{SR} may be due to the improved ability to manage the fatigue accumulated by the athlete (41). In fact, the protocols using IR_{SR} predicted a progressive increase in training intensity from week to week and provided for low intensity workouts and weeks (L and VL). The groups that used the RM method instead predicted that muscle failure would be reached in the last set of each exercise, therefore the exertion applied by the athletes during the training weeks was always maximal.

INDICATIONS FOR XXX TRAINING

Having understood how to use the RPE scale and the IRSR method, it is now possible to present guidelines with respect to the different training objectives.

Muscle hypertrophy

As for the development of muscle hypertrophy, the muscle factor is the total training load (overload x set x repetitions) (32,33). Although there is still debate in literature on the range of repetitions or intensity more favourable to the development of muscle hypertrophy (32), it must however be taken into consideration that to accumulate the same training load sessions of different duration are required depending on the intensity used. It should be reiterated here that the intensity refers to the % of 1RM. Carrying out sets with very high overloads (e.g. 3RM) takes much longer than completing the same training load with moderate overloads (e.g. 10RM), due both to the need to complete a greater number of sets and to the longer recovery required to maintain very high intensities (33). Another factor to be considered is muscle failure, which, according to some authors, is not necessary for the development of a greater degree of hypertrophy (24,30). The achievement of muscle failure can, in fact, compromise the number of repetitions completed in the following set (23) and therefore limit the total load of the training session. To ensure that the number of repetitions and intensity are maintained during training, the recovery period must be sufficiently long. The strategies aimed at reducing recovery are in fact contraindicated with respect to the possibility of accumulating the highest possible load (19,29).

RPE: sets composed of 6 to 12 repetitions, with an RPE of 7-10.

IRSR: 3x10 or 5x10 with increasing intensity over the weeks, from Moderate to Heavy.

Muscle Endurance

The goal of training muscle endurance is to continue the exercise even in fatigued conditions. It is therefore similar to hypertrophy training

even if it does not involve the development of maximum muscle mass. Therefore, it is carried out with sets composed of a high number of repetitions, at intensities that are therefore low (> 12 RM). Effective strategies for the development of muscle endurance also extend the exercise to exhaustion (21), perform a greater number of repetitions per set (9) and reduce the recovery period (29).
RPE: sets consisting of more than 12 repetitions, with RPE of 9-10 and recoveries of less than two minutes.
IRSR: in literature there is no information regarding this methodology for training muscle endurance. However, it is recommended to perform more than 2 sets of minimum 12 repetitions at H or VH intensity.

Maximal strength

For the development of strength, it would appear that intensities between 80% and 100% of 1RM (or 1 - 6 RM) give greater results in the case of expert athletes (1). In this case, training that is specific to the goal of developing maximal strength must include sets carried out with real maximal commitment. The use of sets to failure, however, must be limited because, if used repeatedly and prolonged, it can lead to an excessive accumulation of fatigue which can therefore inhibit performance (24).
RPE: Referring therefore to the indications given in the chapter on RPE, whereby each repetition not performed corresponds to a load reduction of 4% and each half point of RPE to a load reduction of 2%, an intensity> 80% of the 1RM can be obtained with: 6 repetitions at RPE 10, 5 repetitions at RPE 9, 4 repetitions at RPE 8, 3 repetitions at RPE 7 and 1 - 2 repetitions at RPE 5 - 6.
IR_{SR}: 3x2, 3x3, 3x5, 3x5 with progressively increasing intensity MH, H, VH, predicting the insertion of lighter sessions, at intensities 10 - 15% lower than the first weekly session. It should be noted that, in the case of overloads that are light enough to allow a modification of the execution speed, the athlete must try to move the overload with the aim of reaching the maximum possible speed, even for loads that do not allow for speed modification (6). In fact, to reach a higher speed the athlete must apply a greater force to the overload. This can be demonstrated by reformulating Newton's second law, according to which the acceleration of an object is equal to the force applied to it divided by the mass of the object.

Muscle Power

As previously reported, the use of RPE is less accurate when the set is interrupted far from muscle exhaustion. It is therefore not practical to use this methodology to decide the intensity of power training, even if other indications can be found.
RPE: can be used if you intend to train power with high overloads or as a threshold for training with low loads. In the first case, the authors suggest limiting to sets of 1 - 5 repetitions with RPE of 7 - 8, indications that are very similar to those relating to maximal strength training. In the second case, always proposing 1 - 5 repetitions per set, to ensure that the speed of the movement is the maximum possible, a threshold RPE value of 4 can be used, corresponding to a light exertion. If the athlete was able to accurately estimate the number of missing repetitions, then the overload chosen would be too high in order to train power.
IRSR: 3x2, 3x3, with variable intensity from VL to VH depending on whether the aim is to train muscle power at high and low strength speeds or at low and high strength speeds. What also differentiates muscle power training from maximal strength is the length of the movement and the speed reached by the barbell (39).

CONCLUSIONS

In this article, two traditional training overload selection methods have been shown (RM and 1RM%) and two that allow self-regulation based on the athlete's conditions during the training session.
The RPE scale based on repetitions in reserve, from powerlifters training, is a valid tool for selecting overloads in exercises that are interrupted when close to muscle failure. It has thus far been more applied for training of maximal strength and muscle hypertrophy.

The relative intensity based on sets and repetitions, developed for the training of weightlifters, involves the use of intensity categories in relation to the maximum overloads identified for each combination of sets and repetitions used for an exercise. Its use has been tested in the context of athletic preparation for individual and team sports, which present a combination of exercises aimed at improving hypertrophy, maximal strength, and muscle power.
The coach can then choose the most appropriate load strategy with respect to the practice, experience and goals of the person or group being trained.

GIAMPIETRO ALBERTI
ASSOCIATE PROFESSOR OF SPORTS SCIENCES AND METHODOLOGY
PRESIDENT OF SPORTS SCIENCE DEGREE COURSES, DEPARTMENT OF BIOMEDICAL SCIENCES FOR HEALTH, UNIVERSITY OF MILAN
GIAMPIETRO.ALBERTI@UNIMI.IT

MARCO DUCA
VISITING RESEARCH SCHOLAR AT THE EAST TENNESSEE STATE UNIVERSITY.
PH. D. STUDENT IN INTEGRATED BIOMEDICAL RESEARCH AT THE UNIVERSITY OF MILAN
M.S. IN SPORT SCIENCE AT THE UNIVERSITY OF MILAN
(TRACK & FIELD COACH AT ATLETICA BERGAMO 1959 ORIOCENTER)

REFERENCES:

1. American College of Sports Medicine, Position Stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc 41: 687–708, 2009.
2. Bartholomew, JB, Stults-Kolehmainen, MA, Elrod, CC, and Todd, JS. Strength Gains after Resistance Training: The Effect of Stressful, Negative Life Events. J Strength Cond Res 22: 1215–1221, 2008.
3. Bazyler, CD, Mizuguchi, S, Harrison, AP, Sato, K, Kavanaugh, AA, DeWeese, BH, et al. Changes in Muscle Architecture, Explosive Ability, and Track and Field Throwing Performance Throughout a Competitive Season and After a Taper. J Strength Cond Res 31: 2785–2793, 2017.Available from: http://journals.lww.com/00124278-201710000-00017
4. Bazyler, CD, Mizuguchi, S, Kavanaugh, AA, McMahon, JJ, Comfort, P, and Stone, MH. Returners Exhibit Greater Jumping Performance Improvements During a Peaking Phase Compared with New Players on a Volleyball Team. Int J Sports Physiol Perform 13: 709–716, 2018. Available from: https://journals.humankinetics.com/view/journals/ijspp/13/6/article-p709.xml
5. Beck, TW, Housh, TJ, Schmidt, RJ, Johnson, GO, Housh, DJ, Coburn, J, et al. The Acute Effects of a Caffeine-Containing Supplement on Strength, Muscular Endurance and Aerobic Capabilities. J Strength Cond 20: 506–510, 2006.Available from: https://pdfs.semanticscholar.org/12b4/7c27f774c7968b80d8309a3300a9a9901f09.pdf
6. Behm, D and Sale, D. Intended rather than actual movement velocity determines velocity-specific training response. J Appl Physiol 74: 359–368, 1993.
7. Borg, G. Perceived exertion as an indicator of somatic stress. Scand J Rehabil Med 2: 92–8, 1970.
8. Bulbulian, R, Heaney, JH, Leake, CN, Sucec, AA, and Sjoholm, NT. The effect of sleep deprivation and exercise load on isokinetic leg strength and endurance. Eur J Appl Physiol Occup Physiol 73: 273–277, 1996.Available from: https://doi.org/10.1007/BF02425487
9. Campos, GER, Luecke, TJ, Wendeln, HK, Toma, K, Hagerman, FC, Murray, TF, et al. Muscular adaptations in response to three different resistance-training regimens: Specificity of repetition maximum training zones. Eur J Appl Physiol 88: 50–60, 2002.
10. Carroll, KM, Bazyler, CD, Bernards, JR, Taber, CB, Stuart, CA, DeWeese, BH, et al. Skeletal Muscle Fiber Adaptations Following Resistance Training Using Repetition Maximums or Relative Intensity. Sports 7: 169, 2019.Available from: https://www.mdpi.com/2075-4663/7/7/169
11. Carroll, KM, Bernards, JR, Bazylev, CD, Taber, CB, Stuart, CA, DeWeese, BH, et al. Divergent performance outcomes following resistance training using repetition maximums or relative intensity. Int J Sports Physiol Perform 14: 46–54, 2018.
12. Day, ML, McGuigan, MiR, Brice, G, and Foster, C. Monitoring Exercise Intensity During Resistance Training Using the Session RPE Scale. J strength Cond Res 18: 353–358, 2004.
13. Ferreira, SS, Krinski, K, Alves, RC, Benites, ML, Redkva, PE, Elsangedy, HM, et al. The use of session RPE to monitor the intensity of weight training in older women: Acute responses to eccentric, concentric, and dynamic exercises. J Aging Res 2014, 2014.
14. Hackett, DA, Johnson, NA, Halaki, M, and Chow, CM. A novel scale to assess resistance-exercise exertion. J Sports Sci 30: 1405–1413, 2012.
15. Helms, ER, Byrnes, RK, Cooke, DM, Haischer, MH, Carzoli, JP, Johnson, TK, et al. RPE vs. Percentage 1RM loading in periodized programs matched for sets and repetitions. Front Physiol 9: 1–10, 2018.

16. Helms, ER, Cronin, JB, Storey, A, and Zourdos, MC. Application of the Repetitions in Reserve- Based Rating of Perceived Exertion Scale for Resistance Training. Evid based Pers Train 38: 42–49, 2016.
17. Helms, ER, Cross, MR, Brown, SR, Storey, A, Cronin, J, and Zourdos, MC. Rating of Perceived Exertion as a Method of Volume Autoregulation Within a Periodized Program. J Strength Cond Res 32: 1627–1636, 2018.
18. Helms, ER, Storey, A, Cross, MR, Brown, SR, Lenetsky, S, Ramsay, H, et al. RPE and velocity relationships for the Back Squat, Bench Press, and Deadlift in Powerlifters. J Strength Cond Res 31: 292–297, 2017.
19. Henselmans, M and Schoenfeld, BJ. The Effect of Inter-Set Rest Intervals on Resistance Exercise-Induced Muscle Hypertrophy. Sport Med 44: 1635–1643, 2014.
20. Izquierdo, M, Ibañez, J, Calbet, JAL, González-Izal, M, Navarro-Amézqueta, I, Granados, C, et al. Neuromuscular fatigue after resistance training. Int J Sports Med 30: 614–623, 2009.
21. Izquierdo, M, Ibañez, J, González-Badillo, JJ, Häkkinen, K, Ratamess, NA, Kraemer, WJ, et al. Differential effects of strength training leading to failure versus not to failure on hormonal responses, strength, and muscle power gains. J Appl Physiol 100: 1647–1656, 2006.
22. Moore, CA and Fry, AC. Nonfunctional overreaching during off-season training for skill position players in collegiate American football. J Strength Cond Res 21: 793–800, 2007.
23. Morán-Navarro, R, Pérez, CE, Mora-Rodríguez, R, de la Cruz-Sánchez, E, González-Badillo, JJ, Sánchez-Medina, L, et al. Time course of recovery following resistance training leading or not to failure. Eur J Appl Physiol 117: 2387–2399, 2017.Available from: http://dx.doi.org/10.1007/s00421-017-3725-7
24. Nóbrega, SR and Libardi, CA. Is resistance training to muscular failure necessary? Front Physiol 7: 75–78, 2016.
25. Ormsbee, MJ, Carzoli, JP, Klemp, A, Allmann, BR, Zourdos, MC, Kim, J-S, et al. Efficacy of The Repetitions In Reserve-Based Rating Of Perceived Exertion For The Bench Press In Experienced And Novice Benchers. J Strength Cond Res 33: 337–345, 2019.
26. Painter, K, Haff, G, Ramsey, M, McBride, J, Triplett, T, Sands, W, et al. Strength gains: Block versus daily undulating periodization weight training among track and field athletes. Int J Sport Physiol Perform 7: 161–169, 2012.Available from: http://ro.ecu.edu.au/ecuworks2012/497/
27. Richens, B and Cleather, DJ. The relationship between the number of repetitions performed at given intensities is different in endurance and strength trained athletes. Biol Sport 31: 157–161, 2014.
28. Sales Bocalini, D, Portes, LA, Ribeiro, KJ, Tonicelo, R, Rica, RL, Junior, FLP, et al. Insight for learning and stability of one repetition maximum test in subjects with or without experience on resistance training. Gazz Medica Ital - Arch per le Sci Mediche 172: 1–7, 2013.
29. De Salles, BF, Simão, R, Miranda, F, Da Silva Novaes, J, Lemos, A, and Willardson, JM. Rest interval between sets in strength training. Sport Med 39: 766–777, 2009.
30. Sampson, JA and Groeller, H. Is repetition failure critical for the development of muscle hypertrophy and strength? Scand J Med Sci Sport 26: 375–383, 2016.
31. Sands, W a, Wurth, JJ, and Hewit, JK. Basics of Strength and Conditioning Manual. 2012.Available from: http://www.ncbi.nlm.nih.gov/pubmed/23447811
32. Schoenfeld, BJ, Grcic, J, Ogborn, D, and Krieger, JW. Strength and Hypertrophy Adaptations Between Low- vs. High Load Resistance Training: A Systematic Review and Meta-Analysis. J Strength Cond Res 31: 3508–3523, 2017.
33. Schoenfeld, BJ, Ratamess, NA, Peterson, MD, Contreras, B, Sonmez, GT, and Alvar, BA. Effects of Different Volume-Equated Resistance Training Loading Strategies on Muscular Adaptations in Well-Trained Men. J Strength Cond Res 28: 2909–2918, 2014.
34. Shinya Yamauchi, SM. Rating of Perceived Exertion for Quantification of the Intensity of Resistance Exercise. Int J Phys Med Rehabil 01: 1–4, 2013.
35. Slater, G and Phillips, SM. Nutrition guidelines for strength sports: Sprinting, weightlifting, throwing events, and bodybuilding. J Sports Sci 29: S67-77, 2011.
36. Steele, J, Endres, A, Fisher, J, Gentil, P, and Giessing, J. Ability to predict repetitions to momentary failure is not perfectly accurate, though improves with resistance training experience. PeerJ 2017: 1–14, 2017.
37. Stone, MH and O'Bryant, HS. Weight Training: A Scientific Approach. 2nd ed. Burgess Publishing Company, 1987.
38. Suarez, DG, Mizuguchi, S, Hornsby, WG, Cunanan, AJ, Marsh, DJ, and Stone, MH. Phase-Specific Changes in Rate of Force Development and Muscle Morphology Throughout a Block Periodized Training Cycle in Weightlifters. Sports 7: 129, 2019.
39. Suchomel, TJ, Comfort, P, and Lake, JP. Enhancing the force-velocity profile of athletes using weightlifting derivatives. Strength Cond J 39: 10–20, 2017.
40. Suchomel, TJ, Comfort, P, and Stone, MH. Weightlifting Pulling Derivatives: Rationale for Implementation and Application. Sport Med 45: 823–839, 2015.
41. Thompson, SW, Rogerson, D, Ruddock, A, and Barnes, A. The Effectiveness of Two Methods of Prescribing Load on Maximal Strength Development: A Systematic Review. Sport Med , 2019.Available from: https://doi.org/10.1007/s40279-019-01241-3
42. Tuchscherer, M. The Reactive Training Manual. Self. 2008.
43. Zourdos, M, Klemp, A, Dolan, C, Quiles, J, Schau, K, Jo, E, et al. Novel resistance training-specific rating of perceived exertion scale measuring repetitions in reserve. J strength Cond Res 30: 267–275, 2016.