

Effects of exercise intensity on perceived exertion during multiple sets of bench press to volitional failure

Vitor L. Silva, Arthur P. Azevedo, Joctan P. Cordeiro, Michael J. Duncan, Jason M. Cholewa; Mário A. Siqueira-Filho, Nelo E. Zanchi, Lucas Guimarães-Ferreira

Objectives: The purpose of this study was to investigate the effects of intensity on rating of perceived exertion (RPE) during multiple sets to volitional failure in bench press exercise.

Design and Methods: Thirteen moderately resistance trained men performed 2 experimental sessions in random order: 3 sets to failure in bench press with 1 minute rest at an intensity of 50% and 70% of 1 repetition maximum (1RM). RPE was measured using the OMNI scale after each set. Readiness to Invest in Physical (RTIPE) and Mental (RTIME) Effort were assessed before each set.

Results: Repetitions to failure (46.46 ± 9.43 vs 26.62 ± 8.19 ; $P < 0.001$) and total weight lifted (2044.31 ± 414.5 vs 1650.15 ± 507.83 kg; $P < 0.001$) were greater at 50% when compared to the 70% 1RM condition. There were no differences in RPE, RTIPE, RTIME and heart rate across conditions.

Conclusions: These results indicate that when repetitions are done to volitional failure, monitoring RPE is not a useful technique in regulating intensity during resistance training.

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Key words: resistance training ■ perceptual response ■ training intensity ■ intensity monitoring

INTRODUCTION

The positive effects of resistance training (RT) on neuromuscular function and its impact on health and fitness status are well documented.¹⁻³ The strength effects of RT are often seen after a short period of training in novice untrained individuals⁴; however, to ensure continuous improvements on the physiological adaptations to RT, training variables such as exercise intensity, total repetitions performed, repetition speed/tempo, rest period between sets and training volume are often manipulated according to the training objective and athlete's progression.^{4,5}

Intensity with regards to strength training can be defined as the repetition maximum weight used to perform a single repetition (repetition maximum, 1 RM), and the term volume can be described as the total number of repetitions performed, as a product of the total number of sets, number of repetitions per set and the number of exercise performed.⁶ A "repetition training continuum" was hypothesized by Anderson and Kearney⁷ relating the number of repetitions performed to exercise intensity, and the subsequent physiological adaptations, such skeletal muscle hypertrophy and strength. As an example, Campos et al⁸ assigned healthy active men to one of 3 formats of resistance training programs: low repetitions/high intensity (3 sets of 3-5 RM with 3 min rest); moderate repetitions/intensity (3 sets of 9-11 RM with 2 min rest); and high repetitions/low intensity (2 sets of 20-28 RM with 1 min rest). They demon-

strated that while maximum strength gains were greater during the high intensity RT protocol, muscular endurance gain was associated with the low intensity/high repetitions scheme. It was also demonstrated that modulation of intensity could influence the acute hormonal⁹⁻¹¹, metabolic^{9,12}, neural¹³, and cardiovascular² responses to a RT session. In this context, monitoring the intensity during RT could be important to maximize the physiological adaptations according to the objectives and training status of the individuals engaged in such exercise programs.

Rating of perceived exertion (RPE) was proposed as a tool to quantify an individual's subjective perception of exertion during exercise, in order to determine or control the exercise intensity that correlated with percentage of maximal heart rate (%HR_{max}) and percentage of maximum oxygen consumption (VO_{2max}) during continuous exercise¹⁴. RPE has been widely used within exercise settings to quantify perceived exertion despite some limitations which have been previously reported.^{15,16} Similarly, RPE has been used to monitor the intensity during an RT program.¹⁷⁻¹⁹ Previous investigations have demonstrated a relationship between intensity of resistance exercise and RPE within or after sets¹⁹⁻²⁷, during the session (session-RPE), and after a RT session.^{28,29} While these aforementioned studies provide useful information, all employed a predetermined number of repetitions in single or multiple sets. Lins-Filho et al²⁰ stated that an advantage of the RPE scales is

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From the Laboratory of Experimental Physiology and Biochemistry, Center of Physical Education and Sports, Federal University of Espírito Santo, Vitória, ES, Brazil (V.L.S., J.P.C., N.E.Z., L.G-F.), Department of Biomolecular and Sports Sciences, Coventry University, Coventry, United Kingdom (M.J.D.), Department of Kinesiology Recreation and Sport Studies, Coastal Carolina University, Conway, SC, USA (J.M.C.), and Center of Health Sciences, Federal University of Maranhão, São Luiz, MA, Brazil (M.A.S-F.).

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Correspondence to Dr. Lucas Guimarães-Ferreira, Universidade Federal do Espírito Santo, Centro de Educação Física e Desportos. Av. Fernando Ferrari, 514, Campus Universitário, Goiabeiras – Vitória – ES. CEP: 29075810. Brazil. E-mail: lucas.ferreira@ufes.br

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its use for adjustments in loads without the constant need for strength tests during the RT program. However, Shimano et al²⁹ and Naclerio et al³⁰ demonstrated that RPE after a single set to volitional failure was no different despite different intensities used on RT exercises. Thus, the use of perceptual scales during RT to monitor intensity could be limited when repetitions are performed to failure, although this relation during multiple sets has not been investigated.

Therefore, to clarify this issue, the purpose of this study was to investigate the effects of intensity on RPE during multiple sets to volitional failure in bench press exercise.

METHODS

Experimental Approach to the Problem

This study used within-subjects, repeated-measures design. The investigation employed 13 moderately resistance trained men with at least 1 year of previous experience in resistance training and previous experience with high load bench press exercise. Subjects were informed they were participating in a study examining the effects of exercise intensity on RPE. On the first visit to laboratory, subjects executed 1RM testing on the bench press and were familiarized with the RPE, RTIPE and RTIME scales. In two subsequent visits they performed 3 sets of exercise to failure at an intensity of 50% or 70% 1RM with 1 minute interval between sets, using a random crossover design. Each visit to the laboratory was separated by at least 72 hours. For our purposes, failure was defined as the inability to perform a repetition through a full range of motion, which coincides with the point of lower mechanical efficiency. The exercise intensities (50 and 70% 1RM) were selected based on previous work demonstrating differences on RPE with total weight lifted matched using the percentages of 1RM.¹⁹ The aims of this study were to examine the effect of the independent variable (exercise intensity) on RPE, Readiness to invest in both physical and mental effort (RTIPE and RTIME, respectively) and peak heart rate (HR_{peak}).

Subjects

Fifteen men between 18 and 25 years of age were recruited from a university following written informed consent. The procedures used in this study were approved by the institution's Human Research Ethics Committee. Inclusion criteria included previous experience in resistance exercise and exclusion criteria included obesity (body mass index higher than 30) and cardiovascular, musculoskeletal or metabolic diseases (assessed by interview during the first visit to the laboratory). The characteristics of the subjects are presented in Table 1. Subjects were asked to abstain from foods and liquids contain-

ing caffeine, nutritional supplements, as well as any alcoholic products and intense exercise for at least 24 h prior to test sessions.

Maximal Strength Assessment

Maximal dynamic strength was evaluated using the 1RM test, according to methods described by Baechle and Earle.³¹ All subjects had experience in resistance training for at least 1 year. However, before commencing the 1RM, the proper technique of barbell bench press was demonstrated to each participant. The hand position was not prescribed, however subjects were instructed to use the same hand position in all trials as they do in training, and were required to lower the bar to their sternum and then press it back up while maintaining the feet in contact with the floor, and buttocks and shoulders in contact with the bench. Subjects were given a 3-min rest prior to the strength specific warm ups. Subjects performed three sets of four repetitions with a progressively heavier load, three sets of one repetition with a progressively heavier load, and then a 3 min rest prior to attempting the first 1RM. According to Warpeha³², an experienced lifter is able to estimate his/her 1 RM based on recent previous attempts and the last set of the warm up. The first load used was 90% of the 1 RM estimated by the subject. Loads were increased by 5-10% and then the 1RM was determined in fewer than 5 sets with a rest interval of 3-5 min between sets. Two-experienced researchers accompanied the tests. Strong verbal encouragement was provided during the procedure. The 1RM was recorded as the weight that the subject was able to complete during a single execution and was used to set the 50% and 70% 1RM intensity undertaken during the proceeding experimental trials.

Procedures

The number of repetitions per set was recorded and total weight lifted was calculated by multiplying the mass lifted by the number of repetitions performed. Tempo was not prescribed, however subjects were instructed to lower and raise the load under control at the same tempo they usually do in their training programs with no pause and through the full range of motion of movement. Super slow and ballistic reps were not allowed. Immediately after each set, RPE was assessed using the OMNI-RES RPE scale.³⁰ Subjects were asked to rate how difficult it was to perform the previous set using a visual scale ranging from 0 (extremely easy) to 10 (extremely hard). RTIPE and RTIME were assessed prior each set. Subjects were asked to rate how physically and mentally ready they were to invest effort using visual scales ranging from 0 to 10, with higher scores reflecting greater readiness to invest effort, as described.³³ Resting and HR_{peak} was assessed using telemetry (Polar Electro Oy, Kempele, Finland). Data from our laboratory indicate two-way mixed intraclass correlation coefficients (ICC R's) of 0.839 for repetitions, 0.994 for total weight lifted, 0.861 for OMNI-RES RPE, 0.947 for RTIPE, 0.844 for RTIME and 0.774 for HR_{peak} in bench press exercise. These ICC R's indicate good reliability across experimental conditions for the variables used in this study.

Table 1. Subjects' characteristics and resistance exercise loads in the 1RM* test.

	Mean ± SD
Age (years)	21.07 ± 1.98
Body weight (Kg)	80.13 ± 9.64
Bench Press 1RM (Kg)	88.67 ± 9.45

* 1RM: 1 repetition maximum

Statistical Analysis

Repetitions, weight lifted and HR_{peak} were assessed using parametric measures: paired samples t-tests and 2 (condition: 50% vs. 70% 1RM) x 3 (sets) repeated measures analysis of variance (ANOVA). OMNI-RES RPE, RTIPE and RTIME were assessed using nonparametric measures: Wilcoxon matched pair test and 2 (condition: 50% vs. 70% 1RM) x 3 (sets) ways repeated measures ANOVA after data rank transformation procedure. Post Hoc analysis using Bonferroni adjustments were performed where any significant interactions or main effects were found in ANOVA analysis. The statistical software SigmaPlot for Windows (Systat Software Inc. CA, USA) version 12.5 was used for all analysis, and an alpha level of $P \leq .05$ was set a priori.

RESULTS

Total repetitions and weight lifted (the sum of three sets) were significantly higher during 50% 1RM in comparison to 70% 1RM condition ($P < 0.001$). Despite the differences in total volume, mean perceptual responses values (OMNI-RES RPE, RTIPE and RTIME) were not different across conditions ($P > 0.05$).

As indicated in Table 2, significant main effect of exercise intensity on repetitions ($F[1,12] = 6.16$, $p = 0.027$) and total weight lifted ($F[1,12] = 6.16$, $p = 0.027$) during multiple sets to failure were demonstrated. There were no significant differences in OMNI-RES RPE across conditions ($F[1,12] = 0.21$, $p = 0.65$). Likewise, RTIPE ($F[1,12] = 0.93$, $p = 0.35$; table 2), RTIME ($F[1,12] = 0.37$, $p = 0.55$) and HR_{peak} ($F[1,12] = 6.16$, $p = 0.27$) were not different between 50% and 70% 1RM.

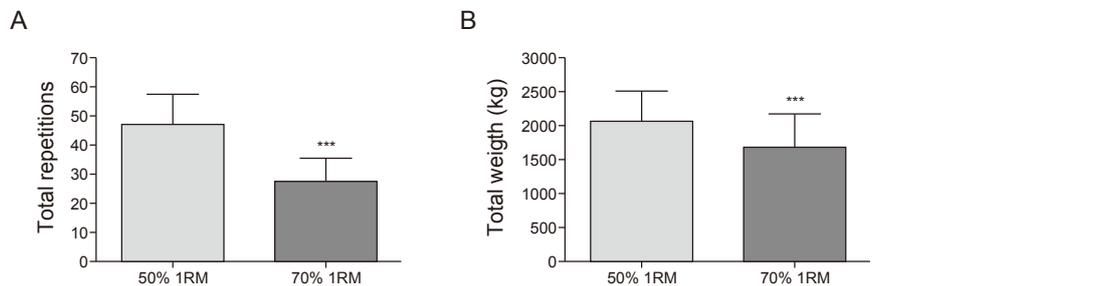


Figure 1. A) Total repetitions (50% 1RM: 47.06 ± 2.67 ; 70% 1RM: 27.20 ± 2.08) and B) total weight lifted (50% 1RM: 2071 ± 117.4 ; 70% 1RM: 1686 ± 129.1) during 3 sets of bench press. Data expressed as Mean \pm SEM. *** $P < 0.001$.

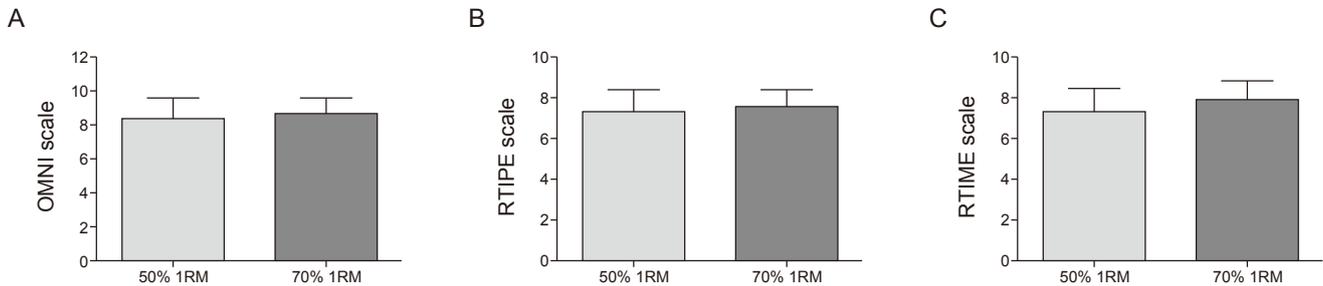


Figure 2. A) Mean RPE OMNI (50% 1RM: 8.44 ± 0.30 ; 70% 1RM: 8.64 ± 0.24), B) RTIPE (50% 1RM: 7.35 ± 0.29 ; 70% 1RM: 7.64 ± 0.21) and C) RTIME (50% 1RM: 7.36 ± 0.29 ; 70% 1RM: 7.96 ± 0.23) during 3 sets of bench press. Data expressed as Mean \pm SEM.

Table 2. Mean \pm SEM for repetitions, weight lifted, RPE, RTIPE, RTIME, and HR_{peak} after 3 sets of bench press repetitions to failure at 50% 1RM and 70% 1RM conditions.

	50% 1RM			70% 1RM		
	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3
Repetitions	26.47 ± 3.83^a	12.67 ± 4.17^b	7.93 ± 3.35^c	$14.53 \pm 4.09^{a*}$	$7.67 \pm 2.32^{b*}$	$5.0 \pm 2.45^{b*}$
Weight Lifted (Kg)	1164.53 ± 168.67^a	557.33 ± 183.44^b	349.07 ± 147.31^c	$901.07 \pm 253.33^{a*}$	$475.33 \pm 143.82^{b*}$	310.00 ± 151.87^c
OMNI-RES RPE	7.40 ± 1.96^a	8.60 ± 0.99^b	9.33 ± 0.82^c	7.73 ± 1.44^a	8.73 ± 0.80^a	9.47 ± 0.74^b
RTIPE	8.73 ± 0.88^a	7.33 ± 1.40^b	6.00 ± 1.65^c	9.13 ± 0.74^a	7.67 ± 0.82^b	6.13 ± 1.13^c
RTIME	9.07 ± 0.88^a	7.80 ± 0.77^b	6.73 ± 1.10^c	9.13 ± 0.99^a	7.93 ± 0.96^b	6.42 ± 1.42^c
HR _{peak} (bpm)	170.93 ± 33.88	168.80 ± 34.70	168.53 ± 34.65	161.40 ± 29.66	152.87 ± 21.01	159.27 ± 25.82

RPE: Rating of perceived effort; RTIPE: readiness to invest in physical effort; RTIME: readiness to invest in mental effort; HR_{peak}: Peak Heart Rate. Letters and asterisks indicate single effects found after Bonferroni post hoc analysis. Different letters indicates difference between sets in the same experimental session. * Indicates difference from the correspondent set in the other experimental session.

Significant differences regarding the time effect (sets) were found ($P < 0.05$) in all variables tested, with exception to HR_{peak} ($P > 0.05$). Factorial ANOVA indicated no interaction effect in all variables tested ($P > 0.05$).

DISCUSSION

The purpose of present study was to evaluate the relationship between resistance exercise intensity and perceptual responses (RPE, RTIPE and RTIME) during repeated sets to failure in bench press. The main findings were that despite a 22.8% greater volume (total weight lifted) during 3 sets at 50% 1RM when compared to 70% 1RM (Figure 1B), perceptual responses were not different, indicating that when bench press exercise is performed until failure, the perceived exertion is not influenced by the percentage of 1RM used.

Previous investigations have examined the effects of exercise intensity on RPE responses using a pre-determined number of repetitions. For example, Lagally et al²¹ demonstrated that RPE and electro-myographic activity increased as bench press exercise intensity increased from 60% to 80% 1RM. In that study the repetitions were pre-determined and not completed to failure (8 reps for 60% 1RM and 6 reps for 80% 1RM) in order to equalize the total work (i.e., total weight lifted). Other studies have shown both active muscle RPE and whole body RPE increased as the intensity increases (across 30% to 90% 1RM) in both the biceps curl²⁵ and leg extension exercise.²⁴ To determine if differences in RPE exist at different intensities with different exercises Lagally et al²² and Gearhart et al²³ used a similar multi exercise protocol consisting of 7 different exercises with a high intensity (5 repetitions at 90% 1RM) and a low intensity (15 repetitions at 30% 1RM) protocol and assessed both whole body and active muscle RPE. Both studies demonstrated a higher RPE for the high-intensity trial after each a set, regardless of the exercise. These results indicate that performing fewer repetitions using heavier weight elicits a greater RPE during resistance training, when total volume is matched between conditions.

In contrast to Lagally et al²² and Gearhart et al²³, Singh et al³⁵ demonstrated no difference in session-RPE values during a hypertrophy (3 sets of 10 repetitions at 70% 1RM with 1 minute rest) and strength (3 sets of 5 repetitions at 90% 1RM with 3 minutes rest) schemes. Lack of difference in RPE may have been due to the lower volume of work in the strength scheme, or a result of the repetitions being prescribed and the sets not taken to failure. Additionally, the shorter interval used between sets during the hypertrophy oriented schemes could have affected the session-RPE response. Thus, it's difficult to address the RPE response solely based upon the intensities used. In the present study, we also demonstrated no effect of exercise intensity on the perceptual responses at different intensities and the rest intervals between sets were maintained constant (1 minute), in order to evaluate the effect of intensity per se. Further investigation is necessary to elucidate the influence varying rest intervals between sets on RPE responses.

Recently, Lodo et al³⁴ examined three resistance exercise protocols using the bench press exercise: a strength oriented protocol (10 sets of 4RM with 3-minute rest), a endurance ori-

ented protocol (4 sets of 20RM with 1-minute rest) and a hypertrophy oriented protocol (8 sets of 8RM with 2-minute rest). RPE was assessed after each set. A mean RPE was calculated for each condition and a session RPE was assessed after the training session. There was no difference in total load-volume between strength and hypertrophy orientated training schemes, and both schemes had a greater total load-volume compared to muscular endurance orientated training. Positive relationships were observed between total volume and RPE (both mean and session RPE), suggesting that this scale could be used to monitor total volume of weight lifted during resistance exercise sessions when repetitions are pre-determined. These results most likely contradict the results of Gearhart et al²³ where RPE was greater for higher intensities despite identical workload due to differences in the load selected. Lodo et al³⁴ used a load that elicited a 20RM, which likely corresponded to approximately 45-50% of the subjects 1RM. In contrast, 15 repetitions (as assigned by Gearhart et al²³) generally correspond to about 60-65% of the 1RM according to most estimates. These results therefore support the finding of the present study, in that the use of RPE to differentiate training intensity is only useful when the set is not performed to muscular failure.

Lins-Filho et al²⁰ used a different approach to investigate the effect of exercise intensity on RPE during resistance training. OMNI-RPE was assessed after the first and sixth repetition in five exercises at 50% and 70% 1RM. Resistance-trained individuals performed 3 sets of 12, 9 and 6 repetitions, respectively. The authors demonstrated that RPE was higher at 70% 1RM, suggesting that RPE can be effectively used to monitor resistance exercise intensity. However, Lins-Filho et al did not measure RPE after the end of each set, which may have been different following the 12th rep between conditions. Additionally, the total volume lifted was not normalized as the number of repetitions was fixed across conditions and not performed to failure eliciting a higher total volume performed during the 70% 1RM condition.

To our knowledge, the first study to investigate the effects of intensity on RPE during resistance exercise to failure was conducted by Shimano et al.²⁹ Trained and untrained subjects performed 1 set to failure at 60, 80, and 90% of 1RM in the back squat, bench press, and arm curl. There were no differences in RPE across conditions (training status or exercise intensity) among the 3 exercises, with the exception of the back squat, where RPE was slightly but statistically higher at 60% 1RM in comparison to 80% and 90% 1RM only in the trained group (8.8 ± 0.7 , 7.4 ± 1.4 and 6.9 ± 2.5 , respectively). Recently, Naclerio et al³⁰ used several intensity ranges (from 30 to >90% 1RM) in bench press to demonstrate that the RPE in the first 3 repetitions is related to the intensity used; however, the RPE was not different after the set performed to volitional failure despite the intensity used. These results are in accordance with the present study, indicating that during upper body resistance exercises performed to failure there are no differences in RPE despite differing loads. Our results also demonstrate that during multiple sets of bench press exercise performed to failure, the RPE increases following the sets, but there are no differ-

ences between 50 and 70% 1RM conditions. The discrepancies between the study of Shimano et al²⁹, Naclerio et al³⁰, and the present study may also be attributed to different muscular groups evaluated, i.e. upper vs. lower body exercises. Although some authors stated that monitoring RPE might be a useful technique for regulating resistance exercise intensity, our results suggest that RPE response is not different when distinct percentages of 1RM are used and repetitions are performed to volitional failure, with subjects exerting maximal effort in each set.

Although RPE is well established as a measure of perceived exertion in the literature its use as a sole measure of effort has been questioned.³⁶ The use of RPE is commonly employed to assess perceived exertion during or post exercise.³⁶ However, there are instances where psychophysiological changes occur prior to performance of physical and/or cognitive tasks. In such instances other measures are required to gauge psychophysiological preparation for performance.³⁷ This state, also termed readiness to invest effort, may impact on future task perseverance and has been related to in-task coping.³⁸ Prior work has suggested that acute caffeine ingestion increases readiness to invest effort in young, trained adults³⁸ prior to a resistance exercise bout. Also, both RTIPE and RTIME values are significantly decreased during multiples sets to failure in bench press when assessed before each set (unpublished results). However, no research has examined the effects of exercise intensity on RTIPE and RTIME during multiple sets to volitional failure in RT. Our results demonstrated that similarly to RPE, the readiness to invest effort is not affected by RT intensity when repetitions are performed to failure.

While the results of this study suggest that the use of RPE is not a valid tool to control or estimate the exercise the intensity when sets are taken to volitional failure, the results of this and other RPE investigations may be used in other practical applications of resistance training. The results reported by Lagally et al.¹⁹ demonstrate that RPE may be valid for differentiating intensity with predetermined rep ranges below the failure. With this in mind, measuring RPE following each set may be useful in determining how much load to add when testing an individual's 1 or 5 RM. Additionally, measuring RPE may also be useful for working with the elderly or individuals of limited capacity whereby avoiding taking an exercise close to volitional failure or measuring a repetition may be necessary. Asking for RPE after each set will allow the strength coach or trainer to determine when to progress the load over a series of workouts while minimizing the placement of unneeded physiological or mechanical stress upon the individual. More research, however, is required to correlate RPE scale and how close to failure an individual is working over a given repetition range.

CONCLUSIONS

In conclusion, the present investigation demonstrated that although RPE increases with each subsequent set, and RTIPE and RTIME are decreased with each set, perceptual responses were not different between 50 and 70% 1RM conditions during multiple sets of bench press exercise to volitional failure. Contrary to prior observations when total volume is matched

across different intensities and the number of repetitions is predetermined and do not reach fatigue, during multiple sets to failure there is no correlation with the intensity used, expressed as the percentage of 1RM.

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