The Open Sports Sciences Journal, 2017, *10*, (Suppl 1: M7) 81-86

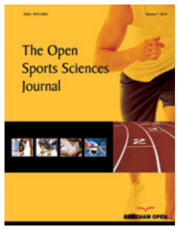
BENTHAM OPEN

CrossMark

The Open Sports Sciences Journal

Content list available at: www.benthamopen.com/TOSSJ/

DOI: 10.2174/1875399X01710010081



RESEARCH ARTICLE

Muscle Mass and Training Status Do Not Affect the Maximum Number of Repetitions in Different Upper-Body Resistance Exercises

Rodrigo Ferrari[1,*], Gabriela Kothe[1], Martim Bottaro[2], Eduardo Lusa Cadore[1] and Luiz Fernando Martins Kruel[1]

[1]*Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil*
[2]*University of Brasília, Brasília.DF, Brazil*

Received: July 15, 2016 Revised: December 01, 2016 Accepted: December 22, 2016

Abstract:

Background:

Data investigating the factors that influence the relationship between different percentages of one repetition maximum (1RM) and the maximum number of repetitions (RM's) performed are scarce when the movement velocity of each repetition is controlled during the RM's test.

Objective:

To evaluate the RM's performed at 60, 75, and 90% of 1RM in 4 different upper-body free weight exercises: bench press, barbell triceps extension, unilateral dumbbell elbow flexion, unilateral bent knee dumbbell row.

Method:

Thirty participants, 15 trained (T) and 15 untrained (UT) men, volunteered to participate in this study and attended six separate occasions, each separated by at least 48 h. In the first three sessions, familiarization and 1RM tests were evaluated. The last three sessions were designed to assess the performance of the RM's at 60%, 75%, and 90% 1RM. The exercise order and intensities performed in each session were randomized. Muscle action velocity for each repetition was controlled by an electronic metronome.

Results:

There was no significant difference between T and UT in any of the exercises at a given exercise intensity. Moreover, there was no significant difference in the number of repetitions performed when exercises with different muscle mass (*i.e.*, bench press *vs.* triceps extension, and dumbbell row *vs.* elbow flexion) at different intensities (*i.e.*, 60%, 75%, and 90%) were compared.

Conclusion:

Using the same percentage of 1RM, the participants performed a similar number of repetitions in the four free weight upper-body exercises evaluated.

Keywords: Strength training, Dose-response, Intensity, Load, Exercise prescription, One repetition maximum.

INTRODUCTION

One of the most important variables to consider in the development of the resistance training prescription is exercise intensity [1], which is considered one of the program variables that dictate the magnitude of training-induced neuromuscular adaptations [2]. Depending on an individual's training experience and current level of fitness, proper

* Address correspondence to this author at the Federal University of Rio Grande do Sul, Rua Ramiro Barcelos 2350, Centro de Pesquisa Clínica, 21301 – LaFiEx, CEP: 96055-630 – Porto Alegre,RS, Brazil; Tel: +5551 9604-0583; Fax: +5551 3334-6462; E-mail: rod.ferrari84@gmail.com

loading encompasses one or more of the following loading schemes: increasing load based on a percentage of 1RM, increasing absolute load based on a targeted repetition number, or increasing loading within a prescribed zone (e.g., 8–12 RM) [3].

Based on the inverse relationship between the amount of weight lifted and the maximum number of repetitions (RM's) performed [4 - 6], the prescription of resistance exercise intensity is usually based on a percentage of one repetition maximum test (%1RM) [7]. Previous studies investigating the relationship between RM`s and %1RM have shown that different factors influence the RM's during resistance exercises: the amount of muscle mass used [4, 5, 8], the training status of participants [5, 8, 9] and the movement velocity of each repetition [10, 11]. Hoeger *et al.* [5] reported that at 80% of 1RM an individual can perform 10-15 RM's for exercises such as the bench press, leg extension, lat pulldown, and leg press (*i.e.*, multi-joint exercises); while at the same intensity the same individual can perform only 6-8 RM's for the leg curl, and for the arm curl (*i.e.*, single-joint exercises).

Regarding the training status of participants, controversial results have been found. Pick and Becque [9] reported that trained individuals are able to perform more repetitions in the squat exercise at 85% 1RM compared to untrained subjects. In contrast, Shimano *et al.* [8] showed that untrained participants performed a significantly greater number of repetitions than trained subjects during bench press at 90% 1RM, although no differences between groups at 60 or 80% 1RM for bench press were found. In addition, previous studies have demonstrated that the RM's can vary with different movement velocities, with a higher number of RM's produced under faster conditions, and this effect becomes greater with lower intensities [10 - 12]. Although the relationship between the percent of 1RM and the RM's performed is affected by the movement velocity, the previous above-mentioned studies did not control this variable [4, 5, 8, 9]. Consequently, studies on the relationship RM`s and %1RM that controlled the movement velocity are scarce [13]. In addition, controversial results have been shown in studies comparing this relationship in trained and untrained participants [8, 9]. Therefore, the purpose of the present study was to compare the number of repetitions performed at 60, 75%, and 90% of 1RM in 4 different upper-body free weight exercises, controlling the movement velocity of each repetition. The working hypothesis was that, using the same percentage of 1RM, trained and untrained subjects would perform similar number of repetitions in four different muscle groups of upper-body exercises.

MATERIAL AND METHODS

Participants

Thirty participants (15 trained and 15 untrained men) volunteered to participate in this study. The trained group (T) had been engaged in regular resistance training in the last 2 years at least three times per week using free weight exercises. The untrained participants (UT) were physically active but had not engaged in any resistance-training program before the study. All participants were free of any musculoskeletal, bone and joint, or cardiovascular diseases. Moreover, the participants reported that were not taking steroid anabolic medications. In order to participate in this study all subjects were informed about the procedures and potential risks and gave their written informed consent. The study was approved by the local Research Ethics Committee and is in accordance with the Declaration of Helsinki. Sample size was calculated based in a previous study [8] using PEPI software (version 4.0) and determined that a sample size of n=15 subjects would provide a statistical power of 90% and a correlation coefficient of 0.8 for all variables.

Experimental Design

In order to evaluate the efficacy of resistance exercise prescription based on percentages of 1RM, the number of repetitions performed at 60%, 75%, and 90% of 1RM in 4 different upper-body free weight exercises (*i.e.*, bench press, barbell triceps extension, unilateral dumbbell elbow flexion, unilateral bent knee dumbbell row – Fig. (**1**)) were determined. The loads corresponding to 60, 75, and 90% of 1RM were used due its potential to maximize adaptations in local muscular endurance, hypertrophy, and muscular strength, respectively [7]. Participants attended six separate occasions, each separated by at least 48 h. The tests and experimental protocols were performed at the same time of day to avoid variations related to circadian rhythms and under the same conditions (*i.e.*, no resistance exercise for at least 24 h and no stimulants for 12 h before each experimental session).

Fig. (1). Resistance exercises performed (initial and final position) during the experimental protocols.

In the initial session, body mass, height and body composition using a 7-sites skinfold prediction technique [14] were assessed. After that, participants performed a familiarization in order to practice the resistance exercises and standardize the technique and range of motion of the resistance exercises. The next two sessions were randomly performed (*i.e.*, exercise sequence and the percentages) to determine 1RM in four upper-body free weight exercises: bench press, bilateral triceps extension, unilateral dumbbell elbow flexion and unilateral bent knee dumbbell row. The participants warmed up for 5 min on a cycle ergometer, and performed specific movements with 1 set of 10 repetitions with light load (50% of the first test load) in the exercise tests. Two 1RM tests were performed each day (bench press or barbell triceps extension and unilateral dumbbell elbow flexion or unilateral bent knee dumbbell row) and a ten-minute recovery was used between exercises. Each subject's 1RM was determined with no more than five attempts with a three-minute recovery between each. Participant performance characteristics are reported in (Table **1**).

Table 1. Participants characteristics by group.

	Trained (n=15)	Untrained (n=15)
Age, yr	25.73 ± 3.97	25.53 ± 3.76
Height, m	178.21 ± 6.58	175.53 ± 6.70
Body mass, kg	77.58 ± 7.70	76.14 ± 7.51
Body fat, %	11.9 ± 2.37*	16.4 ± 4.43
1RM bench press, kg	104 ± 8.88*	72.13 ± 5.93
1RM unilateral dumbbell row, kg	49.75 ± 6.21*	35.4 ± 3.85
1RM triceps extension, kg	48.25 ± 5.72*	34.33 ± 2.92
1RM unilateral elbow flexion, kg	21.88 ± 2.09*	14.8 ± 1.66

Data are means ± SD, *p<0.05 *vs.* Untrained

The last three sessions were designed for the performance the maximum number of repetitions (RM's) tests, in which three different percent of 1RM were used in each exercise (*i.e.*, 60%, 75%, and 90% of 1RM). Each day the participants performed one exercise; the exercise order and intensities performed in each session were randomized. In order to perform the RM's tests, the participants warmed up for 5 min on a cycle ergometer, and performed a warm up set of ten repetitions using 50% of 1RM [15, 16]. Thereafter, each participant performed a maximal attempt using the load corresponding to the selected percentage of 1RM. Movement velocity for each muscle action (*i.e.*, concentric and eccentric) was two seconds and was controlled by an electronic metronome (MA-30, KORG; Tokyo, Japan). If the individuals could not maintain the controlled velocity the exercise was interrupted and the test was ended and considered completed.

Statistical Analysis

Results are reported as mean ± standard deviation (SD). Normal distribution of data was checked with Shapiro-Wilk. The comparison between performance characteristics by group was performed using Student's independent t-tests. Statistical comparisons regarding the number of repetitions among different exercises in each load and between groups were tested using a mixed model two-way ANOVA, using repeated measures for different exercises in each percentage evaluated. Significance was accepted when $P < 0.05$ and the SPSS statistical software package (version 22.0) was used to analyze all data.

RESULTS

The performance characteristics presented in Table **1** showed higher 1RM values for all exercises in trained subjects ($p<0.001$), which reinforce the different training status of participants in the present study.

The number of repetitions performed at 60, 75, and 90% of 1RM on bench press, barbell triceps extension, unilateral dumbbell elbow flexion and unilateral bent knee dumbbell row are described in (Table **2**). There was no significant difference between T and UT in any of the exercises and loads evaluated. The number of repetitions during the row exercise was significant lower when compared to other exercises at 60 and 75% 1RM. However, comparing exercises with different muscle mass (*i.e.*, bench press *vs.* triceps extension, and dumbbell row *vs.* elbow flexion), the same number of repetitions in each percentage was performed in those that utilize greater muscle mass (*i.e.*, bench press and dumbbell row) compared to the exercises with less amount of muscle mass.

Table 2. Number of repetitions at 60, 75, and 90% 1RM in trained (T) and untrained (UT) groups.

	60%1RM		75%1RM		90%1RM	
	T	NT	T	NT	T	NT
Bench press	15.5 ± 1.5	16.07 ± 1.33	10.44 ± 1.67	10.08 ± 0.95	4.69 ± 0.95	4.93 ± 1.03
	95% CI: 14.8 to 16.3	95% CI: 15.2 to 16.9	95% CI: 9.7 to 11.2	95% CI: 9.3 to 10.9	95% CI: 4.2 to 5.2	95% CI: 4.3 to 5.4
Dumbbell row	13.8 ±1.2*	14.15 ±1.21*	9.25 ± 1.29*	9.33 ± 0.98*	4.88 ± 0.62	4.67 ± 0.82
	95% CI: 13.1 to 14.4	95% CI: 13.4 to 14.9	95% CI: 8.7 to 9.8	95% CI: 8.5 to 9.8	95% CI: 4.5 to 5.3	95% CI: 4.2 to 5.0
Triceps extension	16.2 ± 1.5	16.07 ± 1.33	11.19 ± 1.6	10.53 ± 1.3	4.74 ± 1.0	5.23 ± 1.17
	95% CI: 15.4 to 17.0	95% CI: 15.2 to 16.9	95% CI: 10.4 to 11.9	95% CI: 9.9 to 11.6	95% CI: 4.2 to 5.3	95% CI: 4.6 to 5.8
Elbow flexion	16.6 ± 2.7	16.43 ± 1.45	9.69 ± 1.14	10.21 ± 1.93	4.31 ± 0.7	4.73 ± 0.8
	95% CI: 15.4 to 17.8	95% CI: 15.2 to 17.8	95% CI: 8.9 to 10.5	95% CI: 9.4 to 11.2	95% CI: 3.9 to 4.7	95% CI: 4.3 to 5.2

Data are means ± SD or 95% Confidence Interval *p<0.05 D umbbell row vs others at 60 and 75%1RM

As expected, for all exercises, participants could complete significantly more repetitions at 60% of 1RM compared with 75 and 90% of 1RM and more repetitions at 75% of 1RM than 90% of 1RM (*i.e.*, number of repetitions: 60 > 75 > 90% of 1RM).

DISCUSSION

The primary finding of the present study was that, independent of the muscle group exercised, there was no difference on the number of repetitions performed by different upper-body free weight exercises at 60%, 75% and 90% 1RM. In addition, the training status of subjects does not affect the number of repetitions performed in each percentage of 1RM. To the best of our knowledge, this was the first study design that controlled all main factors that could potentially interfere in the number of repetitions performed at a given percentage of 1RM (*i.e.*, training status, amount of muscle mass, and movement velocity of each repetition). The present results showed that RM's performed at a given percentage of 1RM, when movement velocity is controlled, is not dependent on the absolute muscle mass involved during free weight upper-body exercises. However, previous studies have found that large muscle mass exercises allow a higher RM's when compared small groups [4, 5, 8].

Hoeger *et al.* [5] investigate the relationship between RM's at different percentages of 1RM and reported that at 80% of 1RM an individual can perform 10-15 RM's for bench press, leg extension, lat pulldown, and leg press exercises, while for the same intensity the individual can perform 6-8 RM's for the leg curl, and for the arm curl exercises. Likewise, Shimano *et al.* [8] try to determine the RM's that trained and untrained men could perform at 60, 80, and 90% of 1RM in 3 different exercises: hack squat, bench press, and arm curl. The authors also concluded that the RM's performed during free weight exercises are influenced by the amount of muscle mass used. It has been shown that faster velocities allow performing a higher RM's during resistance exercises [10, 11, 16]. However, the previous above-mentioned studies did not describe how the movement velocity of each repetition was controlled, which can potentially explain these controversial findings. Because the movement velocity influences the number of repetitions achieved, it is not possible to compare properly different exercises, as well as different intensities with no velocity control. In addition, the number of repetitions performed at a given intensity influences the mechanical overload, and consequently, the neurophysiological, hormonal, and metabolic responses, which can also influence the strength gains and muscle hypertrophy resulted from resistance training [17]. Besides, it has been suggested that increasing the repetition duration without changes in the repetition numbers per set could increase the metabolic response provided by resistance training [18].

Another interesting result of the present study was that the training status of participants does not affect the number of repetitions performed in each percentage of 1RM. Previously, Pick and Becque [9] demonstrated that trained individuals performed a higher RM's in the squat exercise at 85% 1RM compared to untrained. In contrast, Shimano *et al.* [8] showed that untrained participants performed a significantly greater number of repetitions than trained during bench press at 90% 1RM, although no differences between groups at 60 or 80% 1RM for bench press were found. Methodological differences, especially regarding the movement velocity of each repetition during the RM's tests and the use of different resistance exercises could be an explanation for those discrepancies.

Our findings have an important implication for resistance exercise intensity prescription, since the use of a specific percentage of 1RM can be used for target the same maximum number of repetitions in different free weight upper limb exercises. Second, movement velocity of each repetition throughout each set should be standardized in order to allow the same goal using the same percentage of 1RM, facilitating the exercise prescription and management of a group of athletes or recreational weight lifters. However, some limitations should be taken into account in order to interpret the results. Our sample consisted of men only, therefore limiting the generalization of our findings to the female population. Moreover, lower limb resistance exercises were not evaluated and should take into account in future studies.

CONCLUSION

In conclusion, the amount of muscle mass used during upper-body resistance exercises does not influence the number of repetitions performed at 60, 75 and 90%1RM. Likewise, the training status of participants does not affect the maximum number of repetitions performed when the movement velocity of each repetition is controlled and maintained constant throughout the set.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

The authors specially thank CAPES and CNPq, Brazilian Government Associations for support this project.

REFERENCES

[1] Naclerio F, Rodríguez-Romo G, Barriopedro-Moro MI, Jiménez A, Alvar BA, Triplett NT. Control of resistance training intensity by the OMNI perceived exertion scale. J Strength Cond Res 2011; 25(7): 1879-88.
[http://dx.doi.org/10.1519/JSC.0b013e3181e501e9] [PMID: 21399534]

[2] Ratamess NA, Faigenbaum AD, Hoffman JR, Kang J. Self-selected resistance training intensity in healthy women: the influence of a personal trainer. J Strength Cond Res 2008; 22(1): 103-11.
[http://dx.doi.org/10.1519/JSC.0b013e31815f29cc] [PMID: 18296962]

[3] American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc 2009; 41(3): 687-708.
[http://dx.doi.org/10.1249/MSS.0b013e3181915670] [PMID: 19204579]

[4] Hoeger W, Barette S, Hale D, Hopkins D. The relationship between repetitions and selected percentages of one repetition maximum. J Appl Sport Sci Res 1987; 1: 11-3.

[5] Hoeger W, Hopkins D, Barette S, Hale D. Relationship between repetitions and selected percentages of one repetition maximum: a comparison between untrained and trained males and females. J Appl Sport Sci Res 1990; 4: 47-54.

[6] Iglesias E, Boullosa DA, Dopico X, Carballeira E. Analysis of factors that influence the maximum number of repetitions in two upper-body resistance exercises: curl biceps and bench press. J Strength Cond Res 2010; 24(6): 1566-72.
[http://dx.doi.org/10.1519/JSC.0b013e3181d8eabe] [PMID: 20508460]

[7] Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. Med Sci Sports Exerc 2004; 36(4): 674-88.
[http://dx.doi.org/10.1249/01.MSS.0000121945.36635.61] [PMID: 15064596]

[8] Shimano T, Kraemer WJ, Spiering BA, *et al.* Relationship between the number of repetitions and selected percentages of one repetition maximum in free weight exercises in trained and untrained men. J Strength Cond Res 2006; 20(4): 819-23.
[PMID: 17194239]

[9] Pick J, Becque MD. The relationship between training status and intensity on muscle activation and relative submaximal lifting capacity during the back squat. J Strength Cond Res 2000; 14: 175-81.

[10] Sakamoto A, Sinclair PJ. Effect of movement velocity on the relationship between training load and the number of repetitions of bench press. J Strength Cond Res 2006; 20(3): 523-7.
[PMID: 16937964]

[11] Hatfield DL, Kraemer WJ, Spiering BA, *et al.* The impact of velocity of movement on performance factors in resistance exercise. J Strength Cond Res 2006; 20(4): 760-6.
[PMID: 17194227]

[12] Pereira MI, Gomes PS. Movement velocity in resistance training. Sports Med 2003; 33(6): 427-38.
[http://dx.doi.org/10.2165/00007256-200333060-00004] [PMID: 12744716]

[13] Pekünlü E, Atalağ O. Relationship between fatigue index and number of repetition maxima with sub-maximal loads in biceps curl. J Hum Kinet 2013; 38: 169-81.
[http://dx.doi.org/10.2478/hukin-2013-0057] [PMID: 24235992]

[14] Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Br J Nutr 1978; 40(3): 497-504.
[http://dx.doi.org/10.1079/BJN19780152] [PMID: 718832]

[15] Ribeiro AS, Romanzini M, Schoenfeld BJ, Souza MF, Avelar A, Cyrino ES. Effect of different warm-up procedures on the performance of resistance training exercises. Percept Mot Skills 2014; 119(1): 133-45.
[http://dx.doi.org/10.2466/25.29.PMS.119c17z7] [PMID: 25153744]

[16] Sakamoto A, Sinclair PJ. Muscle activations under varying lifting speeds and intensities during bench press. Eur J Appl Physiol 2012; 112(3): 1015-25.
[http://dx.doi.org/10.1007/s00421-011-2059-0] [PMID: 21735215]

[17] Schoenfeld BJ, Ogborn DI, Krieger JW. Effect of repetition duration during resistance training on muscle hypertrophy: a systematic review and meta-analysis. Sports Med 2015; 45(4): 577-85.
[http://dx.doi.org/10.1007/s40279-015-0304-0] [PMID: 25601394]

[18] Lacerda LT, Martins-Costa HC, Diniz RC, *et al.* Variations in repetition duration and repetition numbers influence muscular activation and blood lactate response in protocols equalized by time under tension. J Strength Cond Res 2016; 30(1): 251-8.
[http://dx.doi.org/10.1519/JSC.0000000000001044] [PMID: 26691414]