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Validation of equation based on repetitions to failure to adjust the training load in women undergoing resistance training

Validação de equação baseada em repetições até a falha para ajuste da carga de treinamento em mulheres submetidas ao treinamento de força

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Abstract – The objective of this study was to analyze the validation of the equation based on repetitions to failure for training load adjustment in middle-aged women undergoing resistance training (RT). Ten women (35.5 ± 5.0 years, 67.8 ± 11.6 kg, 165.9 ± 4.5 cm, 24.5 ± 3.8 m/kg2) with previous experience in RT of at least one year were selected to participate in this research. The participants performed two resistance exercise sessions, separated by intervals of at least 48 h. In the first session, the participants completed the maximum repetition test to determine the load for the following session. The equation based on repetitions to failure aimed to adjust the load for 8-12 RM load was applied. The second session was conducted with the load adjusted according to the equation, in which the participants performed three sets to failure. The eight exercises tested showed averages within the 8-12 RM repetition zone. Leg press 45º = 11.3 (8.8-13.6), seated row = 11.3 (8.9-13.7), knee extension = 9.3 (8.5-10.0), bench press = 9, 2 (8.2-10.1), leg curl = 7.5 (6.5-8.4), lat pulldown = 8.6 (7.4-9.8), standing calf raise = 13.6 (11.3 -15.9), and triceps pushdown = 11.6 (9.8-13.3). Results suggest that the equation based on repetitions to failure is a valid strategy for adjusting the training load intensity in resistance exercises in women with previous experience in RT.

Key words: Strength training; Predictive equations; Repetition maximum.

Resumo – *O objetivo deste estudo foi analisar a validação da equação baseada em repetições até a falha para ajuste da carga de treinamento em mulheres de meia-idade submetidas ao Treinamento Resistido (TR). Dez mulheres (35,5 ± 5,0 anos, 67,8 ± 11,6 kg, 165,9 ± 4,5 cm, 24,5 ± 3,8 m/kg²), com experiência prévia em TR de pelo menos um ano, foram selecionadas para participar desta pesquisa. As participantes realizaram duas sessões de exercício resistido, separadas por intervalos de pelo menos 48 h. Na primeira sessão, as participantes realizaram o teste de repetições máximas para determinar a carga para a sessão seguinte. A equação baseada em repetições até a falha teve como objetivo ajustar a carga para carga de 8-12 RM. A segunda sessão foi conduzida com a carga ajustada de acordo com a equação, na qual as participantes realizaram três séries até a falha. Os oito exercícios testados apresentaram médias dentro da zona de repetições de 8-12 RM. Leg press 45° = 11,3 (8,8 - 13,6), remada sentada = 11,3 (8,9 - 13,7), extensão de joelhos = 9,3 (8,5 - 10,0), supino reto = 9,2 (8,2 - 10,1), flexão de pernas = 7,5 (6,5 - 8,4), puxada alta = 8,6 (7,4 - 9,8), elevação de panturrilhas em pé = 13,6 (11,3 - 15,9) e tríceps pushdown = 11,6 (9,8 - 13,3). Os resultados sugerem que a equação baseada em repetições até a falha é uma estratégia válida para ajustar a intensidade da carga de treinamento em exercícios resistidos em mulheres com experiência prévia em treinamento resistido.*

Palavras-chave: *Treinamento de força; Equações preditivas; Repetições máximas.*

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INTRODUCTION

Resistance training (RT) has been widely recommended due to the benefits of this type of physical exercise in promoting healthy morphological, functional, and metabolic adaptations, reducing the risk of developing diseases and premature death[1,2]. The benefits provided by RT depend on the appropriate manipulation of the variables that make up a training session, such as training intensity and volume, and the selection and organization of exercises[2].

Specifically, the intensity of the load is related to the amount of weight mobilized in an exercise. It can influence the metabolic[3] and hemodynamic responses[4], muscle protein synthesis[5,6], motor units recruitment[7], and psychophysiological responses, such as the perception of effort, pleasure/displeasure, and discomfort[8,9]. In addition to the acute effects, the intensity of the load is also associated with chronic adaptations, being the primary moderating variable of strength gains, in which there is a dose-response relationship between the intensity used and the increase in maximum strength[9,10]. Therefore, an adequate prescription of the training load is of fundamental importance to guarantee the necessary intensity to reach the planned goals.

The greatest load that can be lifted in a specific repetition zone is a method often applied to determine the intensity of load[1]. This strategy is suitable from a practical point of view, as it has excellent ecological validity, precision, applicability, and effectiveness in promoting muscular adaptations[1]. Of note, estimating repetitions to failure is a very useful strategy to find the desired load for the repetition zone. This approach of adjusting the load according to the number of repetitions performed has been used in some scientific experiments, making training load adjustment entirely objective[11-13] and, briefly, it represents a valid and accurate procedure to determine if changes on training load are necessary.

However, no experiment has verified this equation's validity in determining the load for a specific zone of repetitions. In addition, most experiments were conducted with young or older adults; therefore, there is a gap related to middle-aged individuals, especially women. Considering the scarcity of information oriented to the professional responsible for prescribing the RT program regarding the parameters used to determine the training load, the purpose of this study was to analyze the validation of the equation based on repetitions to failure for training load adjustment in middle-aged women undergoing RT.

METHODS

Experimental design

The participants made two visits to the laboratory, separated by 48 h. Anthropometric measurements and individual interviews were performed on the first visit. In addition, on the first visit, the participants performed the maximum repetition test to determine the load for the following session. On the second visit, the equation was validated, in which the participants performed three sets to failure with the load adjusted according to the equation in eight exercises. All sessions were conducted at the same time of the day to avoid possible confounding effects of the circadian cycle and to reduce possible climatic interference on the evaluation days.

Participants

A convenience sample of 10 women with at least one year of previous experience with RT was selected to participate in this research. All participants completed a detailed health history questionnaire, were free of orthopedic injuries that could prevent or hinder the exercise performed, and reported not being on hormone replacement therapy. All participants were informed about the research procedures and signed an informed consent form to participate in the study. The investigation was carried out according to the principles described in the Declaration of Helsinki and was approved by the Research Ethics Committee of the local university.

Anthropometry

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Balmak, Laboratory Equipment Labstore, Curitiba, PR, Brazil), with participants wearing light workout clothing and no shoes. Height was measured to the nearest 0.1 cm by a stadiometer attached to the scale with participants standing and no shoes. Body mass index (BMI) was calculated as body mass in kilograms divided by the square of height in meters.

Procedures

The 8-12 RM repetition zone was used as the reference standard for test validation. Therefore, the equation adjustment was applied to find the load corresponding to 8-12 RM. The order of the exercises performed in the two sessions was: 1) leg press 45º, 2) seated row, 3) knee extension, 4) bench press, 5) leg curl, 6) lat pulldown, 7) standing calf raise, and 8) triceps pushdown.

In the first experimental session, the participants performed three sets. In the first two sets, they performed eight repetitions, and in the third set, the participants performed as many repetitions as possible. Muscle failure for the third set was defined as the moment when the participant tried to perform the concentric action but could not complete the repetition or maintain proper technique during the repetition. In the second experimental session, the participants performed three sets per exercise until momentary concentric failure, with the load adjusted according to the following equation.

- Upper limb exercises: $FL = TL + ER/2$
- Lower limb exercises: $FL = TL + ER$

Where FL is the final load (kg) used in the experimental session (second session), TL is the load (kg) used in the test (first session), and ER is how many repetitions exceeded eight repetitions in the third set of the first session. Therefore, for upper limb exercises, 1 kg was added for every two repetitions that exceeded eight repetitions of the third set in the first session. For the lower limb exercises, 1 kg was added for each repetition that exceeded eight repetitions of the third set in the first session. Thus, the ratio between load increase and repetitions was 1:2 for upper limb exercises and 1:1 for lower limb exercises.

The procedures described above were repeated for the eight exercises that made up the RT sessions. The load used in the sets of the first session was based on previous information provided by the participants and the perception of the researchers. The rest interval between sets and exercises was two minutes in both experimental conditions. Participants were instructed to perform concentric and eccentric actions at one and two seconds, respectively. Figure 1 displays the experimental design adopted for this investigation.

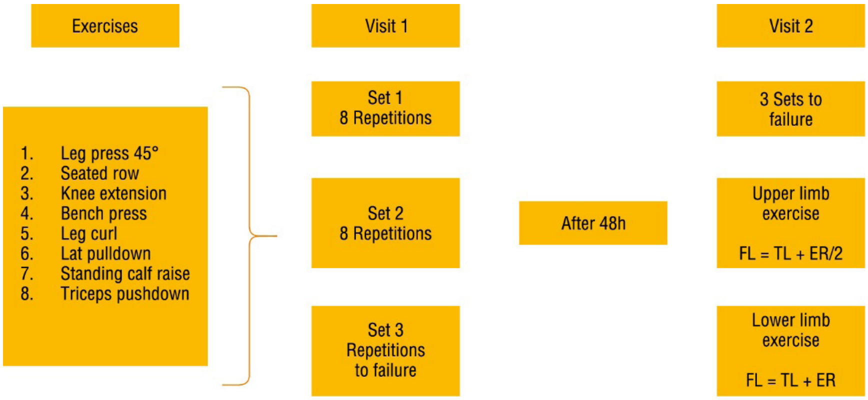

Figure 1. Experimental design of the study.

Statistical analysis

Normality was checked by the Shapiro-Wilk's test. The data were expressed as means, standard deviations, and 95% confidence intervals. The 8 and 12 repetitions values were adopted as standard reference parameters for comparison. The comparison between the total number of repetitions performed with the reference values was carried out using the 95% confidence interval; thus, it was possible to analyze when the repetitions performed were different from the reference values. The data were stored and analyzed using the statistical program SPSS version 21.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Table 1 presents information regarding the general characteristics of the participants. The number of repetitions performed in each set according to the exercise is shown in Table 2. In the leg press 45°, seated row, and standing calf raise exercises, the three sets had repetitions greater than eight repetitions; however, they were similar to 12 repetitions. For the knee extensor, bench press, knee flexor, and lat pulldown exercises, the three sets showed results similar to eight repetitions; however, less than 12 repetitions. In the triceps pushdown, the first two sets presented values greater than eight repetitions; however, similar to 12 repetitions, in the third set, an average of 10.5 repetitions was observed, and the 95% confidence interval was greater than eight and less than 12 repetitions.

Table 1. General characteristics of the participants (n = 10).

Variables	Mean	SD	95% CI
Age (years)	35.5	5.0	31.9 – 39.1
Body mass (kg)	67.8	11.6	59.4 – 76.1
Height (cm)	165.9	4.5	162.6 – 169.1
BMI (m/kg2)	24.5	3.8	21.8 – 27.3
Resistance training experience (months)	85.2	66.3	37.7 – 132.6

Note: BMI = body mass index. Data are presented as mean, standard deviation (SD) and 95% confidence interval (95% CI).

Table 2. Maximum number of repetitions to failure in each set according to the exercise in women (n = 10).

Exercises	Sets	Mean	SD	95% CI
Leg press	1	12.1#	5.4	8.2 – 15.9
	2	10.6#	2.5	8.7 – 12.4
	3	11.0#	2.8	8.9 – 13.0
Seated row	1	11.8#	3.9	8.9 – 14.6
	2	11.4#	3.2	9.0 – 13.7
	3	10.8#	3.3	8.7 – 13.2
Knee extension	1	10.7*	1.5	9.5 – 11.8
	2	9.0*	1.0	8.2 – 9.7
	3	8.2*	1.3	7.2 – 9.1
Bench press	1	10.5*	1.5	9.3 – 11.6
	2	9.1*	1.5	8.0 – 10.1
	3	8.0*	2.0	6.5 – 9.4
Leg curl	1	7.9*	1.3	6.9 – 8.8
	2	7.5*	1.7	6.2 – 8.7
	3	7.1*	1.4	6.0 – 8.1
Lat pulldown	1	9.8*	2.4	8.0 – 11.5
	2	8.6*	1.7	7.3 – 9.8
	3	7.5*	1.9	6.4 – 8.8
Standing calf raise	1	13.8#	3.8	11.0 – 16.5
	2	13.5#	3.2	11.1 – 15.8
	3	13.7#	3.4	11.2 – 16.1
Triceps pushdown	1	12.5#	3.9	9.6 – 15.3
	2	11.9 #	3.4	9.4 – 14.3
	3	10.5*#	1.2	9.5 – 11.4

Note: *difference from 12 repetitions. #difference from 8 repetitions. Data presented as mean, standard deviation (SD) and 95% confidence interval (95% CI).

Figure 2 shows the average of repetitions performed in the three sets according to the exercise. The leg press 45°, seated row, standing calf raise, and triceps pushdown exercises presented a 95% IC that indicated similarity with 12 repetitions; however, superior to eight repetitions. In turn, knee flexion and lat pulldown exercises showed results of less than 12 repetitions, however, similar to eight repetitions. In the knee extensor and bench press exercises, the average was between eight and 12 repetitions, not crossing the confidence intervals for 12 and eight repetitions.

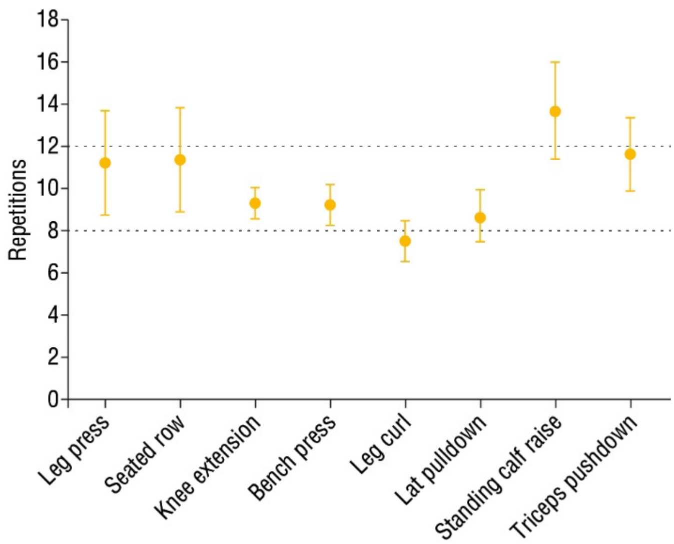

Figure 2. Average repetitions of three sets according to the exercise in middle-aged women (n = 10). Data presented as mean and 95% confidence interval.

DISCUSSION

The objective of this study was to verify whether the equation based on repetitions to failure is a valid tool for adjusting the training load intensity for the 8-12 RM in women practicing resistance training. The main finding was that the equation could adjust the load to the 8-12 RM zone.

Training intensity, specifically based on the load applied to the exercises, is one of the most important RT variables to promote muscular adaptations[1]. Generally, specific zones of repetitions can express the load intensity; thus, finding a load that leads the practitioner to a specific number of repetitions is needed. Our results indicate that the equation based on repetition to failure is a valid alternative for training load adjustment to the 8-12 RM zone since, in all sets of all exercises, the repetitions did not differ from 8 RM or 12RM.

The repetition zone of 8-12 RM was chosen as a comparison parameter since this zone is suggested to promote muscle hypertrophy[1]. In addition, this specific repetition zone may also promote an increase in maximum strength and localized muscular endurance[14]. Still, it is a repetition zone that promotes better sensations of pleasure and less discomfort than other intensities[12,15].

The equation applicability suggests that the load needed to increase at a ratio between repetition exceeded and load of 1:2 for upper limb exercises and 1:1 for lower limb exercises. This means that it is necessary to perform two repetitions above eight repetitions to add 1 kg in the upper limb exercises, while for the lower limb exercises, the load is added by 1 kg for each repetition exceeding eight repetitions. The American College of Sports Medicine, in its position on the prescription and progression of RT, suggests that load progression should occur in greater magnitude for the lower limbs compared to the upper limbs[1]. Therefore, increasing the absolute load in the upper limbs is more difficult than in the lower limbs.

Another performance-based method to adjust the training load for a specific number of repetitions was proposed by Mann et al.[16], which consists of adapting the load based on the number of repetitions performed in the last two sets of a given exercise. In the proposed model, participants perform four sets per exercise, the first set with 50% of the load for 6RM, the second set with 75% of the load for 6RM, and the third set with 100% of the load for 6RM. The repetitions are performed until muscle failure in the third set. Then, the load for the fourth set is adjusted based on the number of repetitions achieved during the third set, and the fourth set is also performed until muscle failure and, according to the number of repetitions performed in the fourth set, the load will be adjusted for the next session.

A traditional method for adjusting training intensity is based on the percentage of maximum strength obtained through the 1RM test[1]. However, although the 1RM test has wide acceptance in the scientific community, a wide range of studies have observed that to obtain a reliable measurement, more than a single session of evaluations would be necessary to guarantee load stabilization[17-19]. Furthermore, load stabilization in the 1RM test depends on the type of exercise involved[18]. In addition, the number of repetitions performed at the same percentage of maximum strength, based on 1RM estimates, may differ among exercises[19], between men and women[14], and among individuals with different levels of training[20]. Regarding the effectiveness of load intensity prescription methods on muscle adaptations, Nóbrega et al.[21] reported that the repetition zone is superior in promoting hypertrophy than the percentage of 1RM and similar for strength increase. Considering all these factors, the prescription of load by percentages of 1RM is limited in the practical field.

Scales to determine the rate of perceived effort (RPE) are also used to determine the training load, mainly because it is a low-cost method with easy applicability[22]. However, it may present great heterogeneity among participants[23], therefore being more susceptible to variability. Since RPE is a translation of internal load into representative scores, this report can be affected by factors that vary from individual to individual, such as training level and psychological and genetic factors, resulting in distinct experiences during exercise when exposed to the same external load. In addition, the RPE scale presents limitations in identifying the point of maximum effort since many studies have observed that RPE values are not always maximally reported, even when the maximum number of repetitions is performed[9,24].

In this sense, the repetition in reserve is also a suggested tool to measure how far the muscle failure point is. This approach aims to determine how many repetitions the individual could perform beyond those achieved. Therefore, this may help to determine how much weight will be increased. However, the prediction error is greater with lighter loads, and the amount of sets[25] is dependent on the level of training[26] and the type of exercise[27].

Studies indicate that it is unnecessary to perform sets to muscular failure to maximize muscle hypertrophy and strength gains[28,29], and training near muscle failure (approximately 2-3 repetitions in reserve) will be enough to optimize muscular adaptations[30]. However, our findings indicate that performing the final set until muscle failure is an interesting strategy to adjust the training load and verify the moment of load progression. Meantime, future studies should address the timing of testing application to adjust training load.

Our study has some limitations, such as the small number of participants. Furthermore, the results are specific to the exercises, session configuration, and population studied. Therefore, caution must be taken in extrapolating the results to different training session configurations and populations. As strong points of our study, we highlight the employment of a typical RT training program; the sample was composed of women with previous experience in RT, so they probably performed the exercises at an optimal technique, which altogether reinforces the ecological validity of this research.

CONCLUSION

Results suggest that the equation based on repetitions to failure is a valid strategy for adjusting the training load intensity in RT program. From a practical point of view, the equation presents a viable strategy due to its validity, low financial cost, easy application, and versatility concerning exercises since it can be applied in practically all resistance exercises.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee – 99306718.1.0000.0108 and the protocol (no. 3.145.335) was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed experiments: MA, DVM, MAN, BFS, MRO, LS, ASR; Performed experiments: MA, MAN, MRO, ASR; Analyzed data: BFS, LS, ASR; Contributed with reagents/materials/analysis tools: MA, DVM, MAN, BFS, MRO, LS, ASR ; Wrote the paper: MA, DVM, MAN, BFS, MRO, LS, ASR.

Data Availability Statement

Research data is only available upon request.

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