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Maximum number of repetitions at different percentages of maximum strength in older men: a crossover study

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Abstract - Introduction: Based on the inverse relationship between the amount of weight lifted and the maximum number of repetitions (RM) performed, the intensity prescription method based on a percentage of maximum strength (%1RM) has been widely used in different populations, including older adults. However, considerable inter-individual variability in RM performed at a given %1RM has been reported in previous studies on this topic. **Aim:** To compare the number of repetitions performed at 60, 75, and 90%1RM in lower and upper limb resistance exercises in older adults. **Methods:** Fifteen men aged between 60 and 75 years performed two preliminary sessions (familiarization + and 1RM tests) and three experimental sessions (RM tests at 60, 75, and 90%1RM on knee extension and elbow flexion exercises). Movement velocity for each concentric and eccentric muscle action was 1.5-2 s. Statistical comparisons regarding the RM performed in each %1RM were tested using the Generalized Estimating Equations analysis. **Results:** The RM during knee extension exercise was significantly lower when compared to elbow flexion at 60% 1RM. On the other hand, the RM during knee extension exercise was significantly higher when compared to elbow flexion at 90%1RM. A similar number of repetitions at 75%1RM were performed in both exercises. **Conclusion:** Physically active older men can perform different RM at 60% and 90%1RM in knee extension and elbow flexion exercises, suggesting that the use of a specific RM range cannot be associated to the same percentage of 1RM in this individuals.

Keywords: strength training prescription, elderly, external load, aging and exercise.

Introduction

Biological aging is associated with a decrease in the neuromuscular system (i.e., loss of strength, power, and muscle mass), which directly impacts the independence of older adults[1,2]. Regular physical exercises, especially resistance training, are considered a cornerstone intervention to reduce the deleterious effects of aging[3-5]. The efficacy of a resistance-training program depends on the correct manipulation of different acute variables during the exercise session (i.e., sets, repetitions, exercises, load, among others)[6,7]. The prescription of the intensity of each exercise (i.e., external load) is particularly important since the best improvements in maximum strength, power, and local muscular endurance can be achieved when different percentages of maximum strength (i.e., one repetition maximum test - 1RM) are used for each objective[8,9].

Expressing training intensity as a percentage of 1RM (%1RM) is a common method used to adjust intensity during resistance training[10]. Based on the inverse relationship between the amount of weight lifted and the maximum number of repetitions (RM) performed, the intensity prescription method based on % 1RM has been widely used in different populations, including older adults[8,9]. However, considerable inter-individual variability in the RM range performed at a given %1RM has been reported in previous studies on this topic. Different factors can influence the RM range vs. %1RM relationship, including the participants' training status (i.e., trained and untrained individuals), the velocity of execution of each repetition, and the amount of muscle mass involved in the exercise[11,12]. In young adults, we have already demonstrated that the participants' training level and the amount of muscle mass involved in the exercise do not interfere with the number of RM performed at intensities of 60, 75, and 90%1RM in different upper limb exercises[12]. However, to the best of our knowledge, there is a lack of data on the relationship between %1RM and RM in older adults, a fact that may reduce the accuracy of this method to adjust intensity during resistance training in this population. In addition, studies that standardized the velocity of execution of each repetition and evaluated this relationship are scarce[13,14], and most of them have not compared the RM performed in upper and lower limb exercises[15].

The purpose of the present study was to compare the number of repetitions performed at 60, 75, and 90%1RM in lower and upper limb resistance exercises in older adults. The working hypothesis was that for the same % 1RM, on average, the same number of RM would be performed for upper and lower limb exercises.

Methods

Study Design

This is a randomized crossover trial, in which participants randomly performed three experimental sessions to verify the number of RM performed with the load corresponding to three different intensities: 60, 75, and 90% 1RM.

Participants

Fifteen men aged between 60 and 75 years, all physically active and engaged for at least 3 months in regular RT programs, took part in the study. All participants were free of musculoskeletal, joint, and cardiovascular diseases. In addition, all reported not taking medications, such as anabolic steroids or taking controlled hormone replacement. Prior to the study, all participants were informed about the procedures, possible risks, and benefits, and signed a Free and Informed Consent Term, previously approved by the Ethics Committee of the Federal University of Rio Grande do Sul (n° 2008106).

Procedures

All participants performed two preliminary sessions (familiarization + and 1RM tests) and three experimental sessions (the RM tests at 60, 75, and 90%1RM), each separated by at least 48 h. The 1RM and RM tests were performed at the same time of day to avoid variations related to circadian rhythms and under the same conditions (i.e., no physical exercise for at least 24 h and no stimulant substances for 12 h before each experimental session). All strength tests were conducted by the same investigator, with previous experience in the strength assessment methods adopted.

Preliminary assessment

Initially, all participants performed anthropometric assessments. The height and body mass of the individuals were measured using a stadiometer and an analog scale, and BMI was calculated using the equation body mass (kg)/height^2(m). Body fat was measured using the sum of 7 skinfolds, which was used to calculate body density using the protocol proposed by Jackson & Pollock[16], and later used to estimate the percentage of body fat through the Siri equation[17]. In the same session, a familiarization was performed in order to practice the resistance exercises and standardize the technique and range of motion of these exercises. Up to 3 sets of 12-6 repetitions were performed, with the load progressively increased.

In the next session, the 1RM tests were performed in the knee extension and elbow flexion exercises, two classic lower and upper limb resistance exercises, respectively. A 5-min warm-up on the treadmill and a specific warm-up of 5-10 repetitions at 40-50% of the estimated maximum load were performed before the tests. After the first attempt, the load was adjusted through Lombardi coefficients, if necessary. Each participant's 1RM was determined with no more than three attempts with a five-minute recovery between attempts and a two-minute recovery between exercises. These results were used to determine the intensity/load of the experimental sessions (i.e., RM tests).

Experimental sessions

In the last 3 sessions, the RM tests were randomly performed at the percentages of 60, 75, and 90%1RM in the same exercises evaluated in the 1RM tests. The loads corresponding to each percentage and exercise were calculated from the results obtained in the 1RM tests. Such intensities were chosen because they are used in RT programs to increase localized muscular resistance, muscular hypertrophy, and maximum strength, respectively[6]. In addition, these two exercises were chosen because they are commonly used to assess the upper and lower-limb strength of older adults. In each session, one attempt until failure of each exercise at 60, 75, or 90%1RM was performed. The exercise order and intensities performed in each session were randomized. In order to perform the RM tests, the participants warmed up for 5 min on a cycle ergometer and performed a warm-up set of ten repetitions using 50%1RM. Thereafter, each participant performed a maximal attempt using the load corresponding to the selected %1RM. Movement velocity for each muscle action (i.e., concentric and eccentric) was 1.5-2 s 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). The normal distribution of data was checked with Shapiro- Wilk. Statistical comparisons regarding the RM performed in each exercise (elbow flexion and knee extension) and each session (RM tests at 60, 75, and 90% 1RM) were tested using the Generalized Estimating Equations (GEE) analysis. Post-hoc comparisons were performed with the Bonferroni test. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using SPSS Statistics for Windows, version 22.0 (IBM, Armonk, NY).

Results

Participants' characteristics are shown in Table 1. There were no reported adverse events during the preliminary and experimental sessions of this trial.

The number of repetitions performed at 60, 75, and 90%1RM on knee extension and elbow flexion are described in Table 2. Exercise vs. session interaction was found for the RM performed in each session ($p < 0.001$). The RM during knee extension exercise was significantly lower when compared to elbow flexion at 60%1RM. On the other hand, the RM during knee extension exercise was significantly higher when compared to elbow flexion at 90%1RM. A similar number of repetitions at 75%1RM were performed in both exercises.

As expected, during both exercises, a higher RM was performed when using a lower percentage of 1RM (RM: 60 > 75 > 90%1RM). During elbow flexion exercise, the RM performed at 60%1RM was higher than RM at 75%1RM (Δ 4.5 ± 0.4 repetitions; $p < 0.001$) and 90% 1RM (Δ 10.3 ± 0.4 repetitions; $p < 0.001$), and a higher RM was performed at 75%1RM compared to 90%1RM (Δ 5.8 ± 0.3 repetitions; $p < 0.001$). Similarly, the RM performed during knee extension was significant higher at 60%1RM compared to 75%1RM (Δ 4 ± 0.4 RM; $p < 0.001$) and 90%1RM (Δ 7.4 ± 0.5 RM; $p < 0.001$), and at 75%1RM than 90%1RM (Δ 3.4 ± 0.3 repetitions; $p < 0.001$).

Table 1 - Characteristics of the participants.

Characteristics	Participants (n = 15)
Anthropometry	
Age (years)	63.0 ± 3.0
Body weight (kg)	78.9 ± 12.4
Height (cm)	172.0 ± 0.1
BMI (kg/m^2)	26.5 ± 2.9
Body fat (%)	26.3 ± 2.9
Neuromuscular	
1RM Knee extension (kg)	102.6 ± 16.2
1RM Elbow flexion (kg)	32.9 ± 3.4
1RM/BW Knee extension	1.32 ± 0.2
1RM/BW Elbow flexion	0.42 ± 0.1

Data are presented in mean ± standard deviation. BMI, body mass index; 1RM, 1 repetition maximum; BW, body weight.

Table 2 - Number of repetitions performed at 60%, 75% e 90%1RM.

Session (%1RM)	Exercise	Number of repetitions	p value
60%1RM			
	Elbow flexion	14.4 ± 1.5 (13.9 to 15.6)	0.011*
	Knee extension	13.3 ± 1.3 (12.6 to 14.1)	
75%1RM			
	Elbow flexion	9.9 ± 1.2 (9.3 to 10.6)	0.189
	Knee extension	9.3 ± 1.1 (8.7 to 10)	
90%1RM			
	Elbow flexion	4.1 ± 1.1 (3.5 to 4.8)	< 0.001*
	Knee extension	5.9 ± 1.2 (5.2 to 6.5)	

Data are mean ± standard deviation (95% confidence interval). 1RM, 1 repetition maximum.
*Represents the statistically significant difference between elbow flexion and knee extension exercises.

Discussion

We found that, in physically active older adults, different RM ranges can be performed at 60 and 90%1RM, when comparing elbow flexion and knee extension exercises. However, at 75%1RM, a similar RM range can be performed. This finding brings important implications for exercise prescription, helping professionals to prescribe a more individualized resistance exercise session for older adults since a higher or lower RM range can be performed at the same %1RM.

The inter-individual variability in RM performed at a given %1RM seems to be an important aspect for resistance exercise intensity prescription and should be taken into account when using the method based on %1RM. In young adults, Hoeger et al.[8] were the first to investigate the %1RM vs. RM relationship in different resistance exercises, all performed on resistance training equipment. This pioneering study suggested that, for the same %1RM, an individual can perform more RM in exercises that involve a greater amount of muscle mass, when compared to those that involve a smaller amount of muscle mass. Controversially, we have shown that the same RM can be performed at a given percentage of 1RM, when movement velocity is controlled, during free weight upper-body exercises[18]. Most studies on this topic did not describe how the movement velocity of each repetition was controlled, which can potentially explain these discrepancies between studies[14,19]. 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.

Other potential differences among methodologies (i.e., young versus older men; trained versus untrained participants) could also help explain these controversial findings[20,21]. Concerning the training status of participants, we included older individuals with previous experience in resistance training. We have already investigated the difference between trained and untrained adults in the

RMs performed in different %1RM of young adults[15]. This former study suggested that 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. However, the absence of other studies evaluating the relationship between %1RM vs. RM in older adults makes it speculative, and comparisons between young and older on this topic should be further investigated.

Interestingly, the RM during knee extension at 60% 1RM was lower and at 90%1RM was higher than RM of elbow flexion. The muscle mass involved in each exercise partially helps to explain this finding. A greater absolute number of motor units is available for recruitment during exercises involving a greater amount of muscle mass[9], which may delay the fatigue during knee extension RM test at 90%1RM. However, this explanation is insufficient to explain the difference during the RM test at 60%1RM. We could speculate that differences in muscle fiber composition, with a higher percentage of type II fibers in muscles involved in knee extension exercise, may provide earlier fatigue at the lower intensity (60%1RM). Unfortunately, muscular biopsies were not performed and future studies are necessary to confirm this explanation.

Some limitations should be addressed in the present study. We only included male participants, limiting the generalization of the present findings to the female population. In addition, only two exercises were evaluated, one for the lower limbs and another for the upper limbs. For future studies, other exercises should be analyzed to obtain more information on this topic.

Conclusion

In summary, physically active older men can perform different RM at 60% and 90%1RM in knee extension and elbow flexion exercises.

Common goals of resistance training such as strength, power, and local muscular endurance are optimized when a specified percentage of 1RM is used[7]. From a practical standpoint, to define the exercise intensity of upper and lower limb resistance exercises, the use of a specific RM range cannot be associated to the same percentage of 1RM in older men.

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