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original article

Effects of resistance training on muscle strength of older women: a comparison between methods

Efeitos do treinamento resistido sobre a força muscular de idosas: uma comparação entre métodos

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Abstract – Strength training (ST) increases muscle strength (MS) in the elderly, but results may vary considerably depending on the method of evaluation. Objective: This study compared two MS methods to evaluate an ST program for elderly women. Methods: Sixty-one volunteers (mean age 66.8 ± 5.8 years) underwent ST for 24 weeks to work out the major muscle groups. Knee extensor MS was assessed using one-repetition maximum strength (1RM) and isokinetic dynamometry ($60^o.s^{-1}$) before and after ST. A 2x2 ANOVA was used to compare the methods and MS gains after the ST program. MS increased significantly after ST according to both methods. Increases in MS were in average 16.7% and 54.7% using dynamometry and 1RM. The improvement according to 1RM was significantly ($P<0.001$) greater than that measured using the isokinetic method. Although values lied within agreement limits, differences between methods (1RM vs. isokinetic) decreased as MS increased at the end of the ST program. ST increases MS in older women, but improvement varies considerably according to the method used to evaluate it. Measurements using 1RM seem to overestimate strength gains and may, thus, affect the potential results of resistance training.

Key words: Elderly; Muscle strength; Strength training.

Resumo – *O treinamento de força (TF) proporciona ganhos de força muscular (FM) em idosos. Entretanto, a magnitude pode variar consideravelmente conforme o método de avaliação utilizado. O estudo teve como objetivo comparar dois métodos de avaliação de força muscular após programa de TF em idosas. Participaram 61 idosas (idade média de 66,8 ± 5,8 anos), submetidas a um programa com duração de 24 semanas. Os exercícios contemplaram os principais grupos musculares. A FM dos extensores do joelho foi avaliada pelo teste da repetição máxima (1RM) e pelo dinamômetro isocinético ($60^o.s^{-1}$) antes e após o TF. Aplicou-se uma ANOVA 2X2 para comparar os métodos e a FM após o programa de TF. Observou-se que a FM aumentou significativamente após a intervenção, em ambos os métodos. Os incrementos na FM foram de 16,7% e 54,7% para o isocinético e 1RM respectivamente. Os incrementos avaliados pela 1RM foram significativamente ($P<0,001$) superiores aos mensurados pelo isocinético. Apesar dos valores estarem dentro dos limites de concordância, a diferença entre 1RM e Isocinético diminuiu conforme o aumento da FM pós-treinamento. Concluiu-se que, embora o TF promova aumento da FM em idosas, a magnitude desse ganho varia substancialmente em função do método utilizado. Ao que parece, o uso da 1RM pode superestimar os ganhos de FM e influenciar a interpretação funcional dos efeitos proporcionados pelo TF.*

Palavras-chave: *Envelhecimento; Força muscular; Treinamento de força.*

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INTRODUCTION

Because of increases in life expectancy, strategies to promote health and quality of life among the elderly have to be studied[1]. One of the consequences of natural ageing is the decline of several physiological functions, which expose the elderly to greater frailty and loss of autonomy[2]. Particularly, the muscle system undergoes changes, such as the decrease of strength and mass[3,4] (a process called sarcopenia), which is seen in both men and women[5] and may be associated with loss of autonomy, risk of falls[6], metabolic complications[7], reduction of mineral bone density[8] and decline in aerobic capacity[9]. Previous studies showed that the effects of sarcopenia raise healthcare costs[10], which stresses the importance of avoiding or delaying the loss of strength and muscle mass during ageing.

One of the successful strategies in fighting sarcopenia is the regular practice of physical activities[11]. Peterson and Gordon[2] reported that the practice of physical exercises is essential for the elderly because it minimizes the adverse effects of ageing. Goodpaster et al.[11] found that the regular practice of physical activities minimized the loss of strength and the infiltration of fat in the muscles of the elderly. Of all types of physical exercises,, strength training (ST) has been found to be efficient for muscle strength gains among the elderly[12-15], and it contributes to preserve lean mass and muscle strength[14-16].

The fact that ST increases muscle strength is widely accepted, but the reported magnitude of these gains varies considerably[17]. Such variations may be associated with different factors, such as training protocols, sample characteristics, intervention time and methods to measure muscle strength gains[18,19]. One-repetition maximum strength (1MR) has been widely used to measure the effects of ST on muscle strength[17]. Isokinetic dynamometry, in turn, has been used as the criterion standard in the evaluation of muscle strength, and has been frequently used in clinical routine and scientific research in recent years to evaluate the physical performance of the elderly[20,21].

Feiereisenet al.[19] recently showed that 1RM may overestimate force gains in patients with chronic heart failure when compared with isokinetic tests, particularly for individuals with higher strength levels. Similarly, the study conducted by Carvalho et al.[18] found that strength gains measured using isokinetics were lower than those resulting from isoinertial evaluations, which suggested that strength training might induce improvements strength levels among the elderly, but that the magnitude of such improvement might be associated with the specificity of the evaluation method. However, the sample used in the study by Carvalho et al. was small (n=19) and heterogeneous (12 men and 7 women). Moreover, the training protocol used by those authors was a combination of callisthenic, aerobic and strength exercises.

Factors associated with different types of training, measurement errors and method reliability may account for differences in the interpretation of outcomes associated with force gains after ST programs for elderly women.

This study compared strength gains after ST for elderly women evaluated isoinertially (1RM) or isokinetically. It also examined the correlation between methods. Based on the literature, our study raised the hypothesis that ST results in muscle strength gains, but that these gains are overestimated when evaluated using 1RM.

METHOD

Participants

This study included 61 post-menopausal volunteer women (characteristics shown in Table 1). All were selected using a University database and invited to participate by phone in a conversation during which the purposes of the study were explained. The invitations to other women failed because of changes in phone number, disease or lack of interest in participating.

To be included in the study, the participants should not have practiced exercises regularly for at least six months and not be taking hormone replacement therapy. Exclusion criteria were: (1) incapacity to walk without assistance; (2) unilateral or bilateral hip prosthesis; (3) smoking; (4) endocrine or metabolic disorder; and (5) cardiac conduction or perfusion defect that contraindicates physical activity.

Each volunteer was invited to sign an informed consent term that contained complete information about the study, such as the advantages and disadvantages of the study protocol, its meaning and possible use of results, according to the Brazilian National Health Committee Resolution # 196/96, duly approved by the Ethics Committee of Universidade Católica de Brasília (under no. 024/2007).

Table 1. Characteristics of the study population

Variables	
n	61
Age (years)	66.8 ± 5.8
Total body mass (kg)	64.2 ± 9.9
Height (m)	1.52 ± 0.1
BMI (kg/m^2)	27.5 ± 4.1
Total FFM (kg)	36.5 ± 4.2
Body fat (%)	40.2 ± 6.1

Values expressed as mean ± standard deviation.
BMI = body mass index. FFM = fat free mass

Anthropometric measurements

Body mass was measured at a 0.1 kg precision using a digital scale (model 2006 pp, Toledo, Brazil) with the participants wearing light clothes and no shoes. Height was measured at a precision of 0.1 cm using a stadiometer (Cardiomed, Brazil) fixed to the wall. Body mass index (BMI) was calculated as body mass divided by squared height (kg/m^2). In addition, to better define the sample characteristics, body composition was measured by means of dual energy X-ray absorptiometry using a Lunar unit, model DPX-IQ (Lunar Corporation, Madison, WI). The variation coefficients for the procedure were 2.1% and 1.9% for fat mass and fat-free mass (FFM).

One-repetition maximum strength (1RM) evaluation

Before the 1RM test, there was a 3-week adaptation period, during which the participants should become familiar with the procedures and learn the correct technique to perform the exercises.

The 1RM test was applied according to the protocol described by Kraemer and Fry[22]. After general warm-up exercises, similar to those that the volunteers were used to performing before their training sessions, all had a specific warm-up session to prepare for the exercise to be tested using submaximal loads. Resistance was then adjusted to estimated 1RM, and the participants received instructions to perform the movement at maximum strength. Up to five incremental attempts, separated by five-minute rest periods, were used to record 1RM results. The value of 1RM was the highest load that could be raised in one single repetition using the correct technique. Two evaluation sessions were necessary to obtain 1RM values for all exercises.

The 1RM test was repeated monthly to define training loads for each of the exercises performed in the sessions. In addition, 1RM values were used to evaluate the effects of training and for the comparisons between gains measured using the isokinetic dynamometer. The 1RM tests and the exercise sessions were performed using the same equipment (*High on*, Righeto Fitness Equipment, São Paulo, Brazil).

Isokinetic evaluation

Knee extension strength was measured using a Biodex System 3 isokinetic dynamometer (Biodex, New York, NY) before and after the training period. The equipment was calibrated according to the manufacturer's instructions. Before the test, the participants had a five-minute warm-up in a cycle ergometer at low load and comfortable speed. After detailed explanation of the evaluation procedure, the volunteers were carefully positioned in the seat of the equipment.

The axis of the dynamometer rotation arm was aligned with the lateral epicondyle of the femur of the dominant leg for all volunteers. The place of force application was positioned at about two centimeters from the medial malleolus. Velcro belts were used in the trunk, pelvis and thigh to avoid possible compensation movements that might affect force generation[23]. After a series of exercises to familiarize participants with the equipment, three series of four muscle contractions were performed at 30-second intervals between series[21]. The values recorded for later analysis were the highest peak torque (PT) of the three series, which was expressed in absolute values (Nm). The participants were told to perform the contractions using maximal strength, and the same examiner gave them verbal encouragement during the tests. Isokinetic evaluation was conducted at an interval of at least 48 hours, but not more than 96 hours, from the 1RM test.

Strength training program

The exercises performed in each of the training sessions were: chest press, seated leg extension, lat pull-down, seated leg curl, side raises with weights, side leg raise and sitting leg press. In addition, exercises to strengthen abdominal muscles and the sacrospinalis were prescribed, as well as standing plantar flexion.

Each session was preceded by a 5-minute warm-up and followed by a 10-minute cool-down session. Warm-up exercises comprised light stretching and playful activities, such as dance, games and calisthenics. The cool-down session was in a separate room at a controlled temperature of 22° C and comprised relaxation exercises, such as controlled breathing and light stretching. Each session was assisted by an experienced professional and at least three interns[24].

After adaptation, the ST program lasted 6 months and was performed 3 times a week (Monday, Wednesday and Friday). The adaptation period was conducted with a comfortable load, and the performance was described, observed and corrected using the same exercises. Training was progressive, from 60% 1RM to up to 80% 1RM. The exercises were performed in three series of 8 to 12 repetitions with 1-minute rest periods between series and between exercises[25]. The load progression followed the monthly 1RM evaluations.

The volunteers received instructions to breathe during the performance of exercises to avoid the Valsalva maneuver. During the intervention, the participants were asked not to change their usual physical activities and not to join any other exercise program. Only data of participants that participated in at least 75% of the sessions were analyzed. A total of 61 participants satisfactorily completed the training program and the evaluation protocol.

The intraclass correlation coefficient and the standard error of the mean at baseline were 0.98 and 2.3%.

Data analysis

The SPSS 13.0 was used for data analysis. Data were reported using descriptive statistics and mean and standard deviations after normal distribution was evaluated using the Shapiro-Wilk test. The level of significance was set at 5% ($P<0.05$). To compare methods, strength data were normalized to body weight[26], and repeated measures 2x2 ANOVA (methods [isokinetic and 1RM] X time [pre- and posttest]) was used to evaluate differences between conditions.

Percent changes of gross values were calculated for both methods using the following equation:

$$\Delta\% = \left(\frac{Post-training\ value\ -\ Pre-training\ value}{Pre-training\ value}\right) x\ 10$$

The Pearson correlation coefficient was used to evaluate the association between methods and percent changes induced by training. Data dispersion between the regression line and the limits of agreement were plotted according to the approach described by Bland and Altman[27] to evaluate agreement between evaluation methods.

RESULTS

Table 2 shows muscle strength results for knee extension using both methods (1RM and isokinetic dynamometry) before and after training. Findings showed that muscle strength increased significantly after the intervention according to both evaluation methods. Percent variation (Δ%) of strength levels are shown in Figure 1. Strength increases were 16.7% and 54.7% for isokinetics and 1RM, and the increases evaluated using 1RM were significantly higher (*P*=0.001) than those measured using isokinetic dynamometry.

Table 2. One-repetition maximum strength (1RM) and isokinetic peak torque ($60^o.s^{-1}$) of knee extensors before and after strength training program

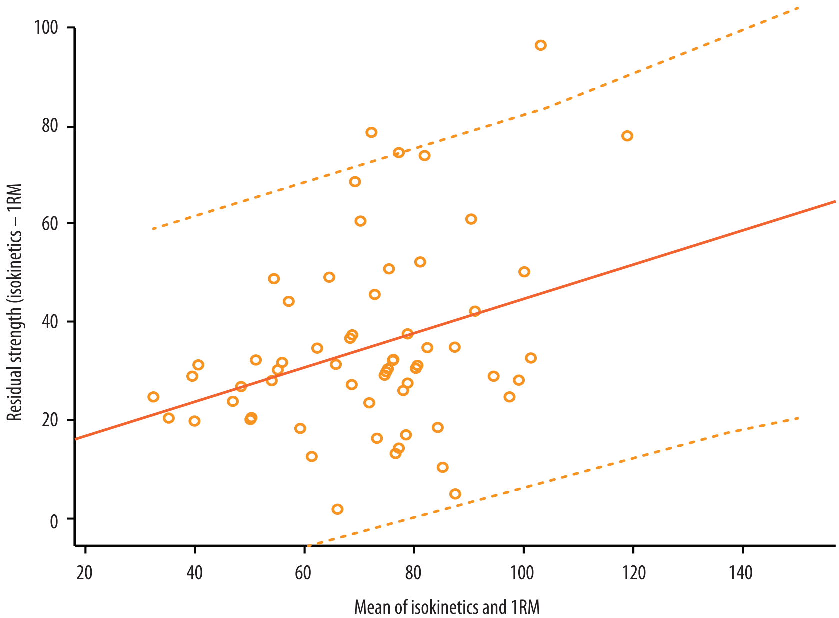
	Before ‡	After ‡	Δ%‡
1RM Seated leg curl (kg)	54.2 ± 17.3	80.0 ± 19.1*	54.7 ± 35.8
Isokinetic PT (Nm)	89.0 ± 23.0	102.4 ± 23.2*	16.7 ± 14.0

Δ%: Percent different between measurements before and after training
* Significant difference from value before training (*P*=0.01)
‡ Significant difference between methods (*P*=0.001)

Quadriceps strength evaluated using isokinetic dynamometry had a positive and significant correlation with measures obtained using 1RM, both before (r=0.59, *P*=0.001) and after training (r=0.72, *P*=0.001). However, isokinetic strength values before training were negatively correlated with the percent changes evaluated according to isokinetics (r=-0.47, *P*=0.001). The same pattern was seen for the 1RM method (r=0.63, *P*=0.001).

In the comparison of gross strength values found using the two methods (Figures 2A and 2B), data distribution indicated a decrease in this difference, that is, the greater the strength, the closer the values between methods.

A



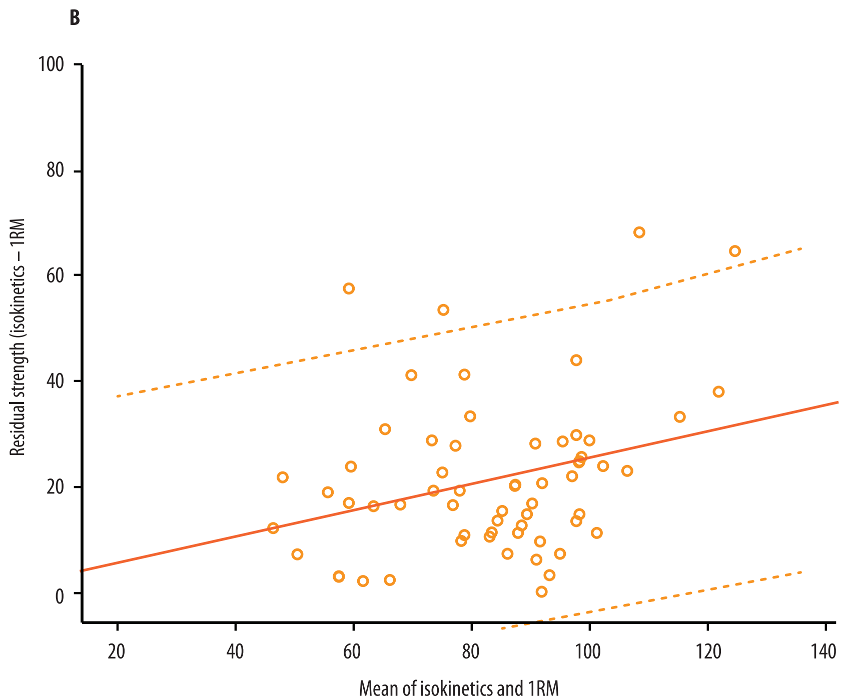


Figure 2. Comparison of strength values measured using two methods (isokinetic vs. 1RM) before (A) and after (B) training. Dotted lines show 95% confidence interval.

DISCUSSION

Among the elderly, ST has been shown to efficiently delay force and muscle mass delicne[28], common in ageing. This study showed that muscle strength levels of knee extensors had significant increases when measured using two methods as a result of 24 weeks of progressive ST. However, although the intervention efficiently improved muscle strength levels, gains varied significantly according to the method used for evaluation. Increases measured using 1RM were greater than those estimated with isokinetics dynamometry (54.7% vs. 16.7%). As a secondary finding, there was a negative correlation between initial force and gains after training, which demonstrated that the greater the level of force at baseline, the smaller the change induced by training. Finally, as force increased in the evaluation after training, value dispersion in the comparison between isokinetic and 1RM methods decreased.

Although ST is one of the most frequently used activities to induce muscle strength increases in the elderly, values are different in different studies. Carvalho et al.[18] evaluated the effect of a complementary physical activity program on muscle strength of the elderly according to method, and found knee extensor strength gains of 24.4% in 1RM and 5.1% in isokinetics after six months of training, which differs from the gains found in our study (54.7% and 16.7%). This discrepancy may be explained by the type of training in our study, which was based on resistance training at a frequency of three times a week, whereas Carvalho et al.[18] adopted a comprehensive fitness program 4 times a week, characterized by resistance exercises only two times a week. However, both our study and the one conducted by Carvalho et al.[18] found that strength gains evaluated using 1RM were higher than those found when using the isokinetic method.

In our study, there were significant differences between methods both before and after the ST program. Moreover, the comparison between isokinetics and 1RM did not reveal any good agreement in magnitude of strength gains for physically active elderly women. Apparently, 1RM findings overestimated strength gains (according to Δ%) when compared with isokinetic results, which confirmed our initial hypothesis. Feiere-isenet al.[19] also found that strength values measured using isokinetic and 1RM methods were not the same, and reported that, although values were within the limits of agreement, the difference between both increased as the mean values increased too. However, in our study, strength values followed a pattern contrary to the one found by Feiereisenet al.[19] (Figure 2), and strength after the program increased at the same time that the difference between methods tended to decrease. This result may indicate that, among physically active elderly women, force gains from chronic adaptations to ST may promote a smaller difference between isokinetic and 1RM results. However, this hypothesis should be confirmed in longer exercise programs.

The 1RM technique was biased when compared with the isokinetic method. This bias was not explained by training method or time point (before or after training). Therefore, the use of the isokinetic method should be strongly recommended, particularly in experimental studies that lead to improvement in muscle performance, so that measurement biases are limited.

CONCLUSION

Although ST promotes muscle strength increases of the knee extensors of elderly women, the magnitude of these gains varies significantly according to the used evaluation method, with significantly greater values for 1RM technique when compared to the isokinetic dynamometer. Both the 1RM and the isokinetic methods were correlated, especially at the end of the training program, and there was a negative correlation between initial force and training gains. Future studies should investigate the possible decrease in the differences according to strength gains for elderly women when using different evaluation methods.

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