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Impact of resistance exercise program on functional capacity and muscular strength of knee extensor in pre-frail community-dwelling older women: a randomized crossover trial

Efeito de um programa de resistência muscular na capacidade funcional e na força muscular dos extensores do joelho em idosas pré-frágeis da comunidade: ensaio clínico aleatorizado do tipo *crossover*

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Abstract

Background: Frailty syndrome in elderly people is characterized by a reduction of energy reserves and also by a decreased of resistance to stressors, resulting in an increase of vulnerability. **Objective:** The aim of this study was to verify the effect of a muscle-strengthening program with load in pre-frail elder women with regards to the functional capacity, knee extensor muscle strength and their correlation. **Methods:** Thrity-two pre-frail community-dwelling women participated in this study. Potential participants with cognitive impairment (MEEM), lower extremities orthopedic surgery, fractures, inability to walk unaided, neurological diseases, acute inflammatory disease, tumor growth, regular physical activity and current use of immunomodulators were excluded. All partcipants were evaluated by a blinded assessor using: Timed up and go (TUG), 10-Meter Walk Test (10MWT) and knee extensor muscle strength (*Byodex System 3 Pro*® isokinetic dynamometer at angular speeds of 60 and 180^0/s). The intervention consisted of strengthening exercises of the lower extremities at 70% of 1RM, three times/ week for ten weeks. The statistical analysis was performed using the ANOVA and Spearman tests. **Results:** After the intervention, it was observed statistical significance on the work at 180^0/s (F=12.71, p=0.02), on the power at 180^0/s (F=15.40, p=0.02) and on the functional capacity (TUG, F=9.54, p=0.01; TC10, F=3.80, p=0.01). There was a good negative and statistically significant correlation between the TUG and work at 60^0/s, such as the TUG and work at 180^0/s (r=-0.65, p=0.01; r=-0.72, p=0.01). **Conclusion:** The intervention improved the muscular power and the functional capacity. The increase of the power correlated with function, which is an important variable of the quality of life in the pre-frail elders.
Article registered in the ISRCT register under number ISRCTN62824599.

Keywords: physical therapy; rehabilitation; elderly; functional performance; muscle strength.

Resumo

Contextualização: Na síndrome de fragilidade em idosos, há diminuição das reservas de energia e resistência aos estressores, com aumento da vulnerabilidade. **Objetivo:** Verificar o efeito do treinamento de força muscular com carga na capacidade funcional e força muscular dos extensores do joelho e sua associação, após treinamento, em idosas pré-frágeis da comunidade. **Métodos:** Participaram 32 idosas, pré-frágeis, da comunidade. Excluíram-se aquelas com Miniexame do Estado Mental (MEEM) incompatível; cirurgias ortopédicas dos membros inferiores; fraturas; doenças neurológicas; doenças inflamatórias agudas; neoplasias; atividade física regular; uso de medicamento com ação no sistema imunológico e sem marcha independente. Avaliou-se a capacidade funcional (*Timed Up and Go* – TUG e velocidade de marcha – TC10) e a força muscular dos extensores do joelho (*Byodex System 3 Pro*®) nas velocidades angulares de 60 e 180^0/s. Para o fortalecimento muscular, utilizou-se carga de 75% de resistência máxima (1RM), durante dez semanas, três vezes/semana. A análise estatística foi feita pela ANOVA e Spearman (α=5%). **Resultados:** Após o treinamento, houve melhora estatística do trabalho normalizado em 180^0/s (F=12,71, p=0,02), na potência, em 180^0/s (F=15,40, p=0,02) e na capacidade funcional (TUG, F=9,54, p=0,01; TC10, F=3,80, p=0,01). Houve boa correlação negativa significativa do TUG com as medidas de trabalho normalizado em 60 e 180^0/s

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(r=-0,65, p=0,01; r=-0,72, p=0,01). **Conclusão:** O treinamento produziu melhora da potência muscular e capacidade funcional. A melhora da potência associou-se à melhora funcional, importante variável para a qualidade de vida de idosas pré-frágeis.
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Palavras-chave: fisioterapia; reabilitação; idoso; desempenho funcional; força muscular.

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Introduction

Since the early 60's the elderly population has been increasing rapidly[1], with a higher prevalence in women[2]. This aging process has different symptoms and consequences including frail, vulnerable and dependent elderly[3]. In this context, the frailty syndrome is defined as a decrease in energy reserves and a reduction in resistance to stressors, with a consequent decline in the physiological systems[4,5]. It is considered a multifactorial syndrome, based on a tripod of alterations, i.e. sarcopenia, neuroendocrine deregulation and immunological dysfunction[4-6]. This condition may increase the risk of higher levels of morbidity, mortality and dependence. To identify this phenomenon, Fried et al.[5] proposed a phenotype composed of five components. There is an assumption that physical exercise interventions proposed for frail and pre-frail elderly can minimize the risk of developing acute complications, such as musculoskeletal inflammatory conditions and heart diseases[3,4,6].

Under normal conditions the human muscle strength reaches its peak between the ages of 20-30 years, with a slow or imperceptible decrease until about 50 years of age[7]. After the age of 65 years, the human muscle strength begins to decline at a rate of approximately 12 to 15% per decade[7] which is observed a decrease in type II fibers and an increase in type I fibers. Consequently, neuromuscular changes occur which may explain a reduction of muscle power, the motor decrease, functional dependence and the increase in disability and morbidity[8,9].

The habit of doing exercises on a regular basis has been suggested as one of the preventive methods for the muscular alterations that occur in the aging process[10-14]. However, there is no consensus about which exercise program is the best to increase muscle strength with regards to frequency, duration and intensity for elderly patients with frailty syndrome. Nevertheless, it is known that the benefits of training depend on the combination of the number of repetitions and sets, the overload, the sequence and the time interval between sets and exercises[15]. Eyigor, Karapolat and Durmaz[13] proposed a program of concentric exercises, using moderate loads for a period of eight weeks, and found an improvement in muscle strength in elderly population. Kryger and Andersen[16] demonstrated the efficacy in improving muscle strength in the elderly after conducting an exercise program with 80% of the one-repetition maximum (1RM) over a period of 12 weeks. The authors observed an increase in the size of the type II fibers measured by biopsy. Similarly, Rubenstein et al.[17] observed, not only the increase in muscle strength, but also an improvement in functional performance as well as in gait speed, by offering a program of moderate intensity resistance exercises. However, these studies did not consider the frailty syndrome, demonstrating a lack of information in the literature about this condition[18].

A systematic review[18] concluded that there is little evidence on the effects of interventions in the frailty syndrome in the elderly and discussed the difficulty of comparing the studies retrieved due to the differences in classification and diagnosis of frailty. The authors concluded that although there is a consensus regarding the improvements in muscle strength, functional capacity and balance, it was not possible to establish the best treatment as well as to verify if it prevents or reverses the progression of the frailty syndrome[18].

In the absence of evidence on the parameters (intensity, duration and frequency) of training programs in elderly women with frailty syndrome, as well as on the number of repetitions, sequences and time intervals to be used, this study's hypothesis was that the performance of specific exercises, controlled in its intensity, frequency and duration, would be sufficient to produce changes in muscle and functional capacity. Likewise, it is necessary to verify the effect of training programs used in daily clinical practice. Thus, the aims of this study were to: verify the effect of a muscle-strengthening program with load, for ten weeks, for the outcomes functional capacity and muscle strength of knee extensors in pre-frail community-dwelling elderly women and to verify the association between functional capacity and concentric muscle strength of knee extensors, analyzed after the intervention.

Methods

Study design

This is a randomized, crossover assessor-blinded trial. The study was approved by the Committee of Ethics and Research of the Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, MG, Brazil, protocol ETIC 321/2007. The study's protocol was prospectively registered under the number ISRCTN62824599. All participants signed a consent form before starting the study.

The volunteers were recruited, through a waiting list from two Universities. After initial assessment, which confirmed the inclusion and exclusion criteria, they were randomly allocated into experimental (EG) and control groups (CG). The EG's participants started training soon after the first assessment, for a period of ten weeks, three times/week while the CG's participants were instructed to remain with the same activities of normal life, without doing any training. After this period, all subjects were reassessed, as the first assessment. Thereafter, the EG's volunteers were instructed to continue performing activities of normal life, but stopped training. The CG's volunteers started training, the same way as the first group. Again, after ten weeks, all participants were reassessed the same way as for the first and second time. The researcher responsible for the intervention had no knowledge of the assessments performed. The outcome assessors were unaware with regards to the group allocation. The training program included exercises with an intensity of 75% of repetition maximum (1RM), with a frequency and duration of three times/week, for ten weeks, with eight repetitions in three sets, for each muscle group. This protocol was previously published[19].

Sample

Thirty-two women, over 65 years old, community-dwelling, without restriction regarding race and/or social class, classified as pre-frail according to the criteria established by Fried et al.[5] were selected.

Exclusion criteria were elderly women who have been submitted to orthopedic surgery of the lower limbs and/or with history of fracture; those who were not able to walk without walking aid devices and those with neurological conditions. Elderly women who reported having some kind of musculoskeletal inflammation process in the acute phase, which could interfere with the tests and/or with the training program; those who performed regularly physical activity, two or more times per week; those who reported active neoplasia over the past five years and who used drugs with broad action on the immune system were also excluded. Finally we have also excluded those who had cognitive alterations detected by the Mini Mental State Examination (MMSE), according to the educational status[20].

Measures and instruments

The primary outcome was functional performance, assessed through the Timed Up and Go (TUG) test[13,21] and by the 10-Meter Walk Test (10MWT)[22]. There are several tests to verify the functional performance in the elderly with the intention to objectively assess various aspects of physical function, being the TUG[21], the 10MWT[23-25] and the Sitting-Rising test (SRT)[26] the most widely used in clinical practice and research. The TUG consists in counting the time to perform the task of standing (without support) from a chair of 45 cm height (having as reference the height from the ground), walking three meters, turning, going back and sitting down on the same chair[21]. The test-retest reliability of the TUG was reported as good (r=0.93) and the inter rater reliability yielded an ICC of 0.99[21]. For the 10MWT, the volunteer was asked to walk, in her normal speed[23,27], on a flat course of 10 meters. The initial 2 meters for acceleration and the last 2 meters for deceleration were disregarded. Skinkai et al.[22] reported that this test is the best predictor of falls and functional independence in the elderly, using the normal speed, i.e, comfortable, to verify functional limitations in everyday life, such as the ability to cross a street[23].

The secondary outcome was the muscle strength of knee extensors assessed by isokinetic dynamometer *Byodex System 3 Pro*®, in the angular speed of 60 and 180º/s. The variable used was the measure of maximum work produced by the knee extensors, in concentric mode, normalized by the participant's body weight. In addition, the variable power, at the same speeds above, was used to check possible changes. To perform the test, there was previous guidance, and participants were informed about the need to perform the test with their maximal effort. At each speed, a familiarization test of three repetitions was performed. Then, the isokinetic assessment was performed by measuring five and 15 repetitions of maximal effort, in the angular speeds of 60 and 180º/s, respectively. The volunteer was driven during the test by clapping and encouraging phrases. This standardization of the test has already been used in previous studies[28].

Training program

The training program was conducted for a period of ten weeks, three times/week, for one hour[19]. Each session consisted of exercises performed in small groups of elderly women who received direct guidance of the physical therapist. The exercises targeting the lower limbs, used in open and closed kinetic chain of large muscle groups and with the use of appropriate load to each of the volunteers, by calculating the percentage of repetition maximum[13,19]. For loads, ankle weights were used, which ranged from 0.5 to 3 kg. The closed kinetic chain exercises were conducted by performing of semi-squat, using the participant's body weight, and were chosen because they are more functional, they decrease the compressive forces in the patellofemoral joint and minimize the risk of knee pain[13,19].

Statistical analysis

The sample size calculation was performed based on a previous pilot study, involving 12 volunteers. A confidence interval of 95%, an error of 20%, an effect size of 0.50 and $\alpha=0.05$ were considered. Using the measure of functional performance, this calculation showed the need for 13 volunteers in each group.

To check the normality of data, the Anderson Darling test and the *Box Cox transformation for optimal lambda* were carried out for the variable TUG, which did not show normal distribution. The comparison of measures of muscle performance and functional performance before and after intervention, inter and intra-group, was carried out by mixed factorial ANOVA with the t-Student test as *post hoc*. Correlations were analyzed using the Spearman's test. The level of significance considered was $\alpha=5\%$.

Results

Thirty-two elderly women classified as pre-frail were included in the study. Due to the crossover methodological design, the analysis was performed considering the CG, with 16 elderly women, and the EG, with the 32 trained elderly women. The clinical and demographic characteristics of each group are shown in Table 1, showing that the groups were similar.

The ANOVA revealed significant interactions between the CG and EG, indicating that both had differentiated behavior. The EG showed significant improvement in the normalized work at 180º/s ($F=12.71$, $p=0.02$) and in power at 180º/s ($F=15.40$, $p=0.02$), indicating that, after training, the elderly women were more able to generate muscle power. Likewise, there was a statistical significant improvement in functional performance after training, in the performance of TUG ($F=9.54$, $p=0.01$) and 10MWT ($F=3.80$, $p=0.01$), demonstrating decrease in the time for tests performance (Table 2). In the angular speed of 60º/ s, there was a small percentage increase, with no statistical difference, which can be interpreted only as a variability of the measure. These values were 2.6% in work normalized by body weight ($F=3.39$, $p=0.07$) and 1.8% in power ($F=3.77$, $p=0.06$) (Table 2).

In the analysis of correlation between the functional variables and muscle performance measures, after training, there was a good, statistically significant and negative correlation of the TUG with measures of work at 60 and 180º/s, showing that, with improvement in muscle strength, there was decrease in the time spent on the performance of the test, ie, improvement in the task execution (Table 3). Other associations were not significant.

Table 1. Characteristics of the participants at baseline.

Variables	GE (n=32)	GC (n=16)
Age (yrs), mean (SD)	72 (4)	72 (3.5)
BMI (kg/m²) (SD)	29.15 (4.2)	29 (4.5)
White, number (%)	10 (31.3)	4 (25)
non-white, number (%)	20 (62.5)	12 (75)
Married, number (%)	12 (37.5)	6 (37.5)
Widow, number (%)	15 (46.9)	7 (43.8)
Literate, number yes (%)	26 (81.3)	13 (81.3)

GE=experimental group; GC=control group; SD=standard deviation; BMI=body mass indices; n=sample.

Table 2. Variable pre and pos-intervention on the experimental and control groups

Variable	Control group		Experimental group		P
	Pre-test (n=16)	Post-test (n=16)	Pre intervention (n=32)	Post intervention (n=32)	
TUG, seconds (DP)	10.81 (2.4)	10.09 (1.7)	11.09 (2.3)	10.41 (1.9)	0.01*
Gait speed, seconds (DP)	4.90 (1.1)	4.87 (0.8)	4.85 (0.7)	4.36 (0.7)	0.01*
Work/ weight at 60⁰/s (%)	122.49 (43.1)	128.95 (38.8)	119.16 (36.6)	122.36 (33.2)	0.07
Work/ weight at 180⁰/s (%)	76.28 (26.2)	84.48 (28.3)	77.79 (26.8)	83.14 (24.0)	0.02*
Power at 60⁰/s (W)	40.16 (12.5)	46.00 (11.2)	44.78 (12.7)	45.55 (10.7)	0.06
Power at 180⁰/s (W)	58.38 (17.9)	66.69 (18.2)	67.17 (20.4)	72.66 (18.1)	0.02*

* Significant difference; TUG=*Timed up and go*; SD=standard deviation; n=sample.

Table 3. Correlations on TUG and work/ body weight, pos-intervention.

Variable	Variable	Correlation
TUG	Work/ body weigh at 60 °/s	-0.65 (0.01)*
	Work/ body weigh at 180 °/s	-0.72 (0.01)*

* significante difference; TUG=*Timed up and go.*

Discussion

This study aimed to verify the effect of a muscle-strengthening program with load, for ten weeks, for the outcomes functional capacity and muscle strength of knee extensors, in pre-frail community-dwelling elderly women. The results showed that, after completion of the program, there was improvement in muscle power and functional performance. However, there was no increase in muscle strength on low speed after the proposed training period.

The current literature shows a great discussion regarding the muscle-strengthening programs proposed for the elderly, indicating a large variability in the volume, intensity and duration of muscle strength training[15]. According to Ernesto et al.[29], programs based on a low-speed muscle contractions tend to show a greater recruitment of motor units, contributing to a greater muscle performance, but also to a greater accumulation of metabolites[29]. On the other hand, the gain in muscle power has been associated with a greater ability to perform functional activities, improvement in the independence and in the quality of life of the elderly[30-33]. Probably, this should be explained by the phenomenon of decrease in type II fibers in the elderly and its consequences[8,9]. However, these studies found in the literature should be compared to the present study with caution, since they were conducted in the elderly, but in people without presenting frailty syndrome. To our knowledge, so far, this is the first study that conducted a program of muscle strengthening, with a percentage of repetition maximum, in elderly women classified as pre-frail according to the criteria established by Fried et al.[5].

The strengthening program used in this study had no specific characteristics (high or low training speed), in order to achieve isolated gain of strength or muscle power. The main objective was to test an exercise program, similar to those used in clinical practice, in a specific population of elderly women classified as pre-frail, with the primary outcome in functional performance. The results demonstrated a greater benefit in the higher speeds tested by the isokinetic dynamometer, suggesting increase in muscle power, which may have been critical for the functional improvement observed in the assessed sample.

Signorile et al.[34] compared gains in power and torque after high and low speed programs. They showed that the greater increases in power occurred in the seventh and eighth weeks of training, while the strength gain was best seen in the third and fourth weeks of training[34]. As in this study, subjects were assessed only in the beginning and after ten weeks of training, which may have contributed to the better observation of the gain in muscle power and not in muscle strength, which was assessed at low speed. Similarly, as there was no determination of the training speed, one can assume that the program performance, as it was proposed, may have increased the gain of type II fibers. In this context, Kryger and Andersen[16], after a training program with 80% of 1RM, for 12 weeks, observed an increase in the size of type II fibers, with gains in muscle strength and improvement in the angle to reach the peak of torque[16]. As in the present study, there were major gains in speed at 180º/s, once again; we can infer that probably there was an improvement in relation to type II fibers.

Although this is an assumption, it should be remembered that, in the elderly, a greater muscle deficit occurs in type II fibers[35]. Frail and pre-frail elderly, because they have greater vulnerability and clinical instability, probably show greater muscle involvement and, presumably, respond quickly and positively to interventions[3,6], which may explain the results observed in this study. On the other hand, Theou et al.[36] after analyzing the muscle activation through electromyography, found significant between-group differences of women characterized as non-frail, pre-frail and frail. However, as it was not the aim of this study to analyze the metabolism and muscle activation, this may have been a limitation and should, therefore, be further investigated.

In addition, to maintain functional independence, among other factors, it is necessary a good muscle performance, at speeds that are compatible with the various daily activities. This was confirmed in this study, which demonstrated an improvement of muscle power after the exercise program, assessed at the speed of 180º/s and a decrease in the time to perform functional tasks (TUG and 10MWT). The systematic review performed by Daniels et al.[37] concluded that there is no evidence that a program of muscle strength can contribute to functional gain in the elderly. However, the authors found that programs with greater duration and high intensity had a positive effect on activities of daily living (ADLs) and instrumental activities of daily living (IADL). Likewise, Arantes et al.[18] through a systematic review of physical therapy interventions in the frailty syndrome, discussed the positive effects of muscle strengthening programs in strength gains, balance and functional capacity. They concluded that there is no evidence of a program to ensure specific changes in relation to the frailty syndrome. Thus, based on the results obtained, it can be argued that programs that promote the muscle power gain should be considered for the elderly in order to also improve their functional performance.

Another point of debate in the literature is the use of weights, the amount of exercises proposed, the number of repetitions and rest intervals between sets and specific exercises for the elderly[15]. It is a consensus that a greater number of repetitions of the exercise can be a trigger mechanism of fatigue that can interfere with the gain in muscle strength. Likewise, the use of heavy weights can contribute to a greater accumulation of metabolites and a depletion of energy substrates[38]. In this study, the percentage of repetition maximum (75% 1RM), the number of sets (three for each exercise) and the number of repetitions (eight in each serie) were used. However, there was no concern about the recovery time, despite having been kept in a range around 40 seconds between sets and one minute between exercises.

Ernesto et al.[29] studied the influence of recovery time in a group of elderly during tests with isokinetic contractions. The authors found that 30 seconds would be sufficient for recovery before the start of a new series of exercises[29]. Also, regarding the influence of this variable in the muscle strength gain, they concluded that there is insufficient information about the best recovery time in daily clinical programs[29]. Despite the consensus that the work volume is essential in the increase in muscle strength and that the recovery time is important to keep this volume[29], this variable remains to be further investigated and should be subject of future studies.

Although a randomized crossover trial was conducted, respecting all the methodological steps of the study, the results should be interpreted and generalized with caution. The elderly have specific muscle alterations that may respond differently to training programs, for example, sarcopenia. Since this condition was not controlled in this study, this may be considered a limitation. We still know little about the frailty syndrome, it is difficult to interpret, compare, and generalize the results.

Conclusion

The results showed that ten weeks of training with 75% of repetition maximum, applied at low speed, three times/week, were not sufficient to produce gain in muscle strength in pre-frail community-dwelling elderly women. However, after the training program, there was improvement in muscle power and functional performance, thus demonstrating that the improvement of muscle power was associated with functional improvement.

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