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Effect of 12 weeks of strength training on the static balance of the elderly

Efeito de 12 semanas de treinamento de força sobre o equilíbrio estático de idosos

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Abstract – Aging has a direct impact on balance due to changes in sensory and motor response, sarcopenia, reduced muscle strength and range of motion that occur in the elderly. In this context, strength training (ST) programs are seen as a valuable strategy to minimize the deleterious effect of aging on strength production and balance in this population. The purpose of the study was to evaluate the effect of 12 weeks of progressive intensity ST on static balance variables in the elderly. The study included 23 elderly with an average age of 65±8.61 years, of both sexes, who performed a twelve-week strength training program, with a frequency of three times a week and with progressive intensity (60 – 85% of 1-RM). Balance was assessed before and after the intervention period, through stabilometric assessment on a force plate. After the intervention, there was a reduction in the anteroposterior amplitude (p=0.01), in the anteroposterior velocity (p=0.01) and in the total displaced area (p=0.04). It is concluded that the strength training can be used as a key tool to minimize the deleterious effect of aging on the maintenance of static balance.

Key words: Aging; Postural balance; Training.

Resumo – *O envelhecimento tem impacto direto no equilíbrio devido a alterações da resposta sensorial e motora, sarcopenia e redução da força muscular e da amplitude de movimento que ocorre nos idosos. Nesse contexto, programas de treinamento de força (TF) são vistos como valiosa estratégia para minimizar o efeito deletério do envelhecimento na produção de força e no equilíbrio dessa população. O objetivo do estudo foi avaliar o efeito de 12 semanas de TF com intensidade progressiva sobre as variáveis de equilíbrio estático em idosos. Participaram do estudo 23 idosos com idade média de 65±8,61 anos, de ambos os sexos, que realizaram um programa de TF de doze semanas, com frequência de três vezes por semana e com intensidade progressiva (60 – 85% de 1-RM). O equilíbrio foi avaliado antes e após o período de intervenção, por meio de avaliação estabilométrica em plataforma de força. Após a intervenção houve redução na amplitude anteroposterior (p=0,01), na velocidade anteroposterior (p=0,01) e na área total deslocada (p= 0,04). Conclui-se que o treinamento de força pode ser utilizado como ferramenta chave para minimizar o efeito deletério do envelhecimento na manutenção do equilíbrio estático.*

Palavras-chave: *Envelhecimento; Equilíbrio postural; Treinamento.*

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INTRODUCTION

The increase in life expectancy demands the planning of actions to guarantee a better quality of life for the elderly. Aging impacts balance due to changes in range of motion, sarcopenia and reduction in muscle strength[1,2]. In addition, long-term postural changes impair the functionality of the antigravity musculature, with lower static compensations and greater trunk oscillations[3,4]. Sensorimotor dysfunctions and structural changes in the gray and white matter of the brain have also been reported, contributing to a greater challenge in maintaining postural control, due to increased response time of the sensory and nervous systems in the elderly[2,5].

Difficulty in maintaining balance and postural control with a decline in physical performance are the main contributors to falls in the elderly[5-7]. Although the assessment of postural control is challenging, the literature shows that stabilometry has been widely used for the assessment of orthostatic postural balance, through the quantification of body oscillations in the anteroposterior and medio-lateral directions on a force plate[8].

There is strong evidence that physical exercise can reduce the risk of falls in the elderly, by improving balance and mobility control and minimizing muscle mass reduction[1,9,10]. Thus, strength training (ST) programs have been recommended as a strategy to minimize the deleterious effect of aging on strength production and balance, being important to include the strengthening of the upper and lower static chains to preserve postural biomechanics[3,4,11,12].

In this context, the primary objective of the present study was to evaluate the results of 12 weeks of upper and lower limb ST in the elderly as an alternative to improve static balance in this population. By contemplating exercises usually used in gyms, the study has high external validity. The secondary objective was to evaluate the increase in muscle strength, a fundamental mechanism for the correction of balance loss.

METHOD

Sample

The sample calculation was performed using the formula for comparing paired groups with a quantitative variable as proposed by Miot[13], considering a 95% confidence level and 80% power. A total of 27 volunteers were determined, 32 were recruited and 23 remained at the end of the study. There was an adherence rate of 71.88%.

The inclusion criteria were: being 60 years of age or older; residing in the same city of study and not having suffered any fracture in the last six months. Volunteers were excluded if they had diseases that affect balance (i.e. self-reported vision loss; vestibular system; cerebellar or degenerative neural diseases); when frequency in the training program was below 70%; if they presented cardiovascular, neurological, cognitive and orthopedic diseases prohibiting physical activity.

The use of medication was reported mainly for the control of hypertension, hypercholesterolemia, diabetes mellitus, heart failure.

The recruitment of volunteers took place through posters in places where groups of coexistence and practice of physical and recreational activities meet. The study was approved by the research ethics committee of the local institution (CAAE: 82376117.3.0000.5150) and all volunteers signed the informed consent form. All data were collected before the COVID-19 pandemic.

Experimental design

An intra-subject longitudinal study was carried out to evaluate the effect of 12 weeks of ST involving exercises for the lower and upper limbs muscles on the postural balance of the elderly.

Anthropometric measurements (weight, height and body mass index (BMI)) were determined, followed by the individual assessment of postural balance parameters on a force plate, as well as maximum strength through the 1-RM prediction test. Participants were released for participation after medical approval.

The measurements were repeated after the 12 weeks of intervention.

Anthropometry

Body mass and height were determined according to the Lohman et al[14]. protocol. After evaluating the two anthropometric components, the BMI was calculated (BMI = weight/*height*^{2}) according to Lipschitz[15].

Balance

Static balance was quantified by the stabilometry technique, through the BIOMEC400® force plate, which measures the changes in vertical forces that are exerted by the body's oscillation during the upright posture. The platform data acquisition frequency was 80 Hz. These measurements allow inferring the center of pressure (CoP), the oscillation of the body or a variable associated with such oscillation. Participants were instructed to remain for 30 seconds barefoot on the platform in bipedal support, upright posture, arms along the body, looking fixedly at a predetermined point at eye level, feet forming an angle of approximately 30°, with the heels 2 cm apart[16].

The platform was connected to a microcomputer and the data were registered using Brazil's EMG System program. Postural oscillations were recorded throughout the assessment time and the following measurements were performed: amplitude of the center of pressure oscillation in the anteroposterior (AMP-AP) and mediolateral (AMP-ML) axis - in centimeters; anteroposterior (VEL-AP) and mediolateral oscillation velocity (VEL-ML) - in centimeters per second (cm/s); anteroposterior (FREQ-AP) and mediolateral (FREQ-ML) average oscillation frequency – in Hertz (Hz), and total area displaced – in square centimeters (cm^2)[17].

Repetition Maximum (1RM) prediction test

Maximum dynamic strength was assessed using the 1RM prediction test, considering the lower potential for pressure and muscle overload of submaximal loads, especially for the elderly[18].

The protocol described by Brzycki[18] for the 1RM prediction test, consisted of five trials with a maximum of 10 repetitions. Two weeks of familiarization with the exercises were held, which were performed with minimal load and considering the limitations of each volunteer. After familiarization, the 1RM prediction test was applied for the following exercises: anterior pull (supinated), triceps pulley, dumbbell curl, bench press (bar or apparatus), seated row, leg extension and flexor chair. The test was performed before and after the 12 weeks of training, being the same examiner for all participants and for the pre and post intervention moments.

Strength training

After two weeks of familiarization that preceded the RM tests, the volunteers performed the ST for a period of 12 weeks (three months), varying the percentage of the predicted 1-RM load. The frequency of training was three times a week, on non-consecutive days (Monday, Wednesday, and Friday) with a duration of one hour each training, always in the morning. Throughout the training, the elderly were accompanied by Physical Education professionals, who monitored the correct performance of the exercises and helped possible complications with a correction ratio of 4 volunteers per teacher.

In the first two weeks of the ST, the volunteers trained at an intensity of 60% (12 to 15 repetitions); during the 3rd and 4th weeks they trained at 70% (10 to 12 repetitions) and during the 5th and 6th weeks at 80% (8 to 10 repetitions). From the 7th week on, they trained at 85% (6 to 8 repetitions) until completing 12 weeks of training. The protocol adopted followed the most used strength training regulations. After the 12-week intervention period, the volunteers underwent a new 1RM prediction test. Three sets of each exercise were always performed.

The exercises performed during the training program were: anterior pull (supinate), triceps (high pulley), alternating biceps curl, bench press (bar or apparatus), seated row, leg extension and flexor chair. The following exercises were also performed: infra-abdominal (hands on chest), oblique abdominal, gastrocnemius (bench or apparatus) and squat holding a ring. The training load for these last exercises were determined in a subjective way of effort, because of the difficulty in measuring exercises that use body weight, or because of the large volume of tests impairs adherence to the training program.

Statistical analysis

To assess the normality of the data, the Shapiro-Wilk test was applied. Then, the paired T-test was performed to compare pre and post-interventions of the parametric variables of balance (AMP-AP, FREQ-AP and FREQ-ML) and the 1RM test (curl, row, leg extension and flexor). And the Wilcoxon test for comparison of non-parametric variables of balance: AMP-ML, total area displaced, VEL-AP, VEL-ML and 1RM of triceps and bench press exercises. Parametric results were expressed as average and standard deviation, and non-parametric results as median (minimum and maximum). All analyses were performed adopting a significance level of $p \leq 0.05$. The GraphPad Prism software version 6.0 was used to perform all analyses.

RESULTS

Sample characteristics

Table 1 shows the sample characterization.

Table 1. Sample characteristics.

N	Age (years)	Height (cm)	Body mass (kg)	BMI (kg/m^2)
23	65±8.61	162±0.07	72.57±13.70	27.54±4.39

Note: Values presented as average and standard deviation. N: number; cm: centimeters; Kg: kilogram; body mass index (BMI); m: meters.

Balance data

After 12 weeks of ST, there was a decrease in the AMP-AP (p=0.01), in the VEL-AP (p=0.01) and in the total displaced area (p=0.04). However, there was no change in the AMP-ML (p=0.26), VEL-ML (p=0.52), in the average FREQ-AP (p=0.57) and in the average FREQ-ML (p=0.77) (Table 2).

Table 2. Performance on balance variables before and after the intervention period.

Variable	Pre	Post	P Value	Variation (%)
Ampl. AP (cm)	2.68 ± 0.68	2.31 ± 0.46	0.01	-13.81
Ampli. ML (cm)	0.89 (0.40–2.40)	0.86 (0.44–1.40)	0.26	-13
Vel. AP (cm/sec)	1.32 (0.79–1.52)	1.28 (0.79–1.54)	0.01	-5.51
Vel. ML (cm/sec)	0.97 (0.69–1.40)	1.01 (0.71–1.22)	0.52	-2
Freq. AP (W)	0.29 ± 0.11	0.28 ± 0.11	0.57	-3.44
Freq. ML (W)	1.00 ± 0.38	1.05 ± 0.42	0.77	+0.05
Area (cm^2)	1.10 (0.41–4.81)	0.96 (0.38–2.33)	0.04	-36.19

Note: Normally distributed data, expressed as average ± standard deviation. Data with non-normal distribution, expressed as median (minimum and maximum). % of variation= difference between pre and post data. AP: anteroposterior; ML: lateral medium; sec: seconds; W: watt; cm: centimeters; Ampl: Amplitude; Speed: speed; Freq: frequency; Vel: velocity.

Maximum strength test

Table 3 presents the loads, p-value and percentage of variation achieved by the elderly during the maximum strength test in situations before and after the ST period.

After 12 weeks of training, there was an increase in the 1-RM prediction test for anterior pull (p=0.01), triceps (p=0.01), bench press (p=0.01), sitting row (p=0.01), extensor chair (p=0.01) and flexor chair (p=0.01) (Table 03). Only the 1-RM load on the biceps curl did not change after intervention.

Table 3. 1-RM prediction test before and after training period.

Exercise	Pre (Kg)	Post (Kg)	P Value	Variation (%)
Anterior pull	46.25 ± 16.63	59.50 ± 16.31	0.01	+36.87
Triceps	40.0 (26.5–66.5)	51.50 (31.0–79.0)	0.01	+28.5
Bench Press	40.0 (20.0–80.0)	54.25 (27.5–95.5)	0.01	+35.62
Biceps Curl	10.76 ± 3.18	11.22 ± 2.52	0.42	+6.07
Sitting row	73.25 ± 16.84	76.66 ± 18.15	0.01	+6.01
Extension chair	73.25 ± 18.44	89.91 ± 26.24	0.01	+30.07
Flexion chair	69.50 ± 16.67	83.56 ± 25.19	0.01	+16.78

Note: Normally distributed data, expressed as average ± standard deviation. Data with non-normal distribution, expressed as median, minimum, and maximum. % of variation= difference between pre and post data.

DISCUSSION

Improvements in variables related to static balance were observed in the elderly after 12 weeks of progressive intensity ST. In relation to the beginning of the study, the AMP-AP, the VEL-AP and the total area displaced on the force plate presented comparatively smaller values, reaffirming the benefits of the ST to improve postural control. It is also possible to observe that ST was effective in increasing the maximum strength, evidencing the efficiency of high intensity progressive strength training.

Corroborating the findings of this study, Hauser et al.[19] evaluated dynamic balance, recoverable balance and static balance in the elderly. In addition, the strength of the lower limbs was evaluated and a positive relationship was found between it and balance. Still in this regard, Morais et al.[20] reported an increase in strength and balance in the elderly after four months of performing ST. Furthermore, Drozdova-Statkeviciene et al.[5] showed a decrease in AMP-AP and improvement in AMP-ML after acute ST in healthy adults. Despite the difference in the training program between the studies, the result was expected due to the similar profile of the populations studied in terms of age and the absence of previous diseases[5].

Recent reviews also corroborate the findings of this study. The systematic review by Keating et al.[10] evaluated randomized controlled trials, whose ST interventions measured at least one variable related to gait and/or balance in elderly and also showed improvements in this parameter. The mean duration of interventions was 12 weeks, similar to the study in question. The review by Papalia et al.[1] evaluated the effects of physical exercise on static and dynamic balance, as well as on the number of falls in the elderly, finding improvements in the data. Finally, Carlini et al.[21] evaluated the benefits of the practice of ST in the prevention of falls in the elderly, showing gains in strength, speed/gait length and stationary and dynamic balance. Overall, these studies suggest that ST programs of various durations (i.e., 5 to 24 weeks) are effective in promoting strength gains in older adults.

Bellew et al.[22] did not observe changes in balance after ST in the elderly who trained for three months. The workouts were performed at low or moderate intensity, starting at 40% of 1-RM with an increase of up to 60%. The training program did not involve performing exercises in the orthostatic position, which may have been responsible for the results. In addition, training intensity may also have limited the positive effect of ST on improving balance. According to Silva, et al.[23] ST for the elderly should involve intensity above 60% of 1RM since certain physiological adaptations induced by resistance training are determined by the intensity of the training stimulus[24]. Still in that regard, Motalebi et al.[2] studied the effect of progressive elastic resistance training on lower limb muscle strength and balance in institutionalized elderly. After the intervention, the changes were not significant, what can be explained by the lower control of the progression of load using elastic bands and also by the rate of falls, which is higher among the institutionalized elderly, limiting the extent of these results to an elderly population living in the community[25].

Similarly, Chen et al.[9] evaluated the effects of a three-month ST intervention on static posturography measures among patients with Parkinson's disease, showing no significant improvement in balance variables. This difference can be explained by the greater variability of the CoP in this disease compared to healthy elderly. Furthermore, the increase in workload occurred subjectively and it may have underestimated the training load[9]. Finally, in their meta-analysis, Manãs et al.[24] evaluated the effects of home resistance training to improve health-related outcomes in the elderly and found a small beneficial effect of training on static balance. The smaller effect evidenced may be due to adherence rates relatively poor in in the absence of supervision. In addition, most home interventions used light to moderate exercise intensities without load adjustment and has been observed a proportional relationship between high training intensities and benefits[24].

Regarding the training of upper limbs included in this study, the literature corroborates that posture and balance have dependent relationships, as the antigravity muscles are able to provide powerful adaptation in the face of balance disturbances with little range of motion[4]. Bankoff et al.[4] studied the postural deviations and asymmetries with body balance and CoP oscillations in a group aged 29 to 51 years. The study found that, although correct posture is essential for good balance, incorrect posture doesn't necessarily imply a balance disorder, which can be maintained at the expense of greater oscillations through adaptations of the organism. However, the elderly population in general has greater compensatory challenges, due to sensory and motor dysfunctions that impair the quality of the response to disturbances[2-4]. Thus, strengthening the antigravity muscles would act to provide an improvement in body biodynamics and less need for compensation to maintain balance.

Limitations of the study were the absence of a control group as a parameter of comparison and not considering differences between genders. In addition, participants were free to perform recreational and daily life activities, however it was found that they did not perform any other systematic and high-performance physical activity. Furthermore, although the adjustment of training intensity via repetition of the RM test was not performed due to its disturbing and harmful component to study adherence, the progression of training loads occurred, even if less accurately.

CONCLUSION

ST can improve parameters of static balance in the elderly. In addition, improvements in strength were observed. It may allow greater autonomy and independence to perform activities of daily living as age advances. Considering the consistent relationship between balance and falls, ST should be a fundamental component to be introduced in training programs for the elderly.

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COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee – Federal University of Ouro Preto and the protocol (no. 82376117.3.0000.5150) 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 the experiments: MIC, LKB, ECO, DBC. Performed the experiments: MIC, DBC. Analyzed the data: MIC, ECO, DBC. Contributed materials/analysis tools: LKB, ECO, DBC. Wrote the paper: MIC, ISC, PMS, ACS, ICR, JBFJ, DBC.

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