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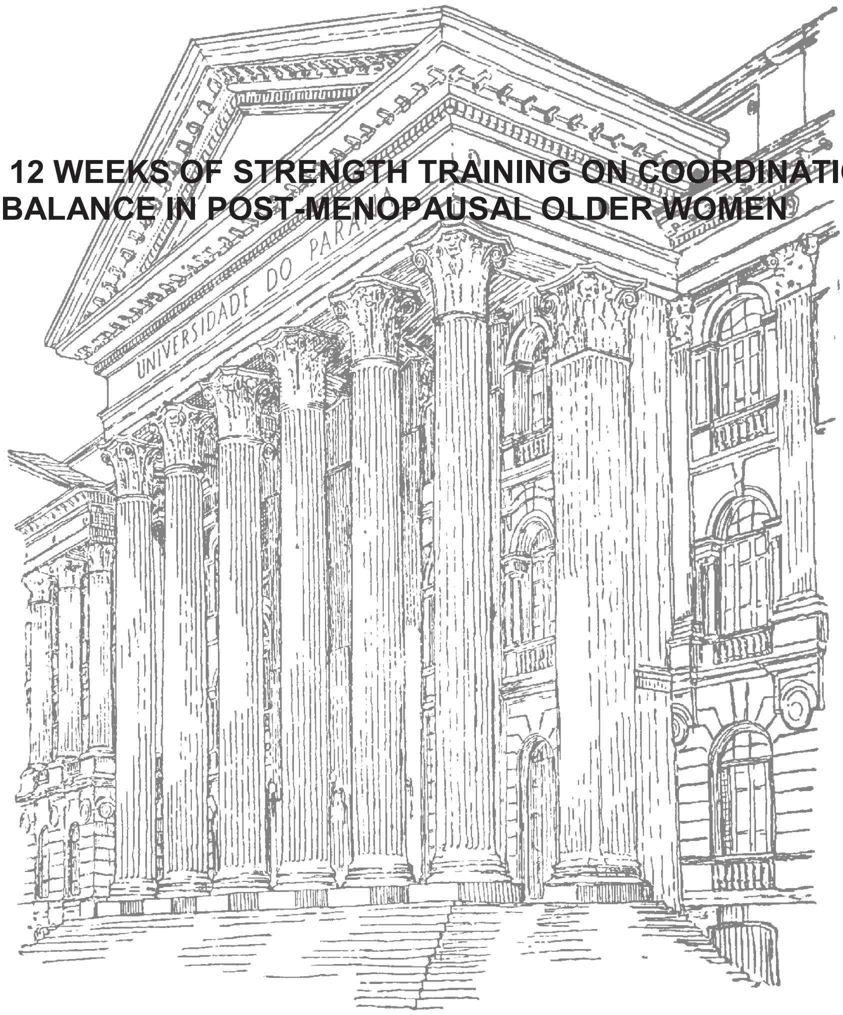
EFFECT OF 12 WEEKS OF STRENGTH TRAINING ON COORDINATION AND BALANCE IN POST-MENOPAUSAL OLDER WOMEN



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EFFECT OF 12 WEEKS OF STRENGTH TRAINING ON COORDINATION AND BALANCE IN POST-MENOPAUSAL OLDER WOMEN

Monografia apresentada pelo aluno Luis Henrique Boiko Ferreira como requisito parcial para a conclusão do Curso de Especialização em Treinamento de Força e Hipertrofia, Setor de Ciências Biológicas, Universidade Federal do Paraná orientado pelo Professor Dr. Tácito Pessoa de Souza Junior.

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Dedico este trabalho a todos os mestres e professores que fizeram parte desta jornada.

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RESUMO

Objetivo: Analisar o efeito de 12 semanas de treinamento de força no desempenho de força, coordenação e equilíbrio em mulheres idosas. Métodos: O efeito do treinamento resistido na força, coordenação e desempenho do equilíbrio foi avaliado em um total de 49 mulheres idosas na pós-menopausa (idade 71 ± 9 anos) que foram selecionadas para participar do estudo. A amostra foi randomizada em dois grupos: um grupo intervenção (GI; n = 29) e um grupo controle (GC; n = 20). O protocolo de treinamento resistido foi realizado três vezes por semana para os grupos musculares superior e inferior do corpo. A flexibilidade foi testada usando um Well's Bench. O equilíbrio dinâmico foi analisado usando um circuito que foi realizado antes do início da intervenção e no final do período de estudo de 12 semanas. O teste de coordenação foi realizado usando uma tarefa complexa misturada com um circuito. Resultados: A endurance nos membros superiores melhorou estatisticamente entre o GC e o GI (11,40 ± 2,87 vs 19,50 ± 1,52) semelhante à dos membros inferiores (14,90 ± 3,10 vs 26,56 ± 3,17, p = 0,001). Em relação ao equilíbrio dinâmico, o GI apresentou uma diminuição no tempo para completar a tarefa em relação ao GC (14,62s ± 1,83s vs 12,71s ± 0,62s, p <0,05). Não houve diferenças na coordenação entre GC e IG. Conclusão: Os benefícios relacionados ao desenvolvimento de força utilizando treinamento resistido estão de acordo com a literatura atual, entretanto, em oposição à literatura atual, encontramos que o treinamento resistido é efetivo no desenvolvimento do equilíbrio dinâmico.

Palavras-chave: treino de força, coordenação, equilíbrio, idosas.

ABSTRACT

Purpose: To analyze the effect of 12 weeks of resistance training on strength, coordination, and balance performance in elderly women. Methods: The effect of resistance training on strength, coordination, and balance performance was assessed in a total of 49 postmenopausal elderly women (age 71 ± 9 yrs) who were selected to participate in the study. The sample was randomized into two groups: an intervention group (IG; n=29) and a control group (CG; n=20). The resistance training protocol was carried out three times a week for both upper and lower body muscle groups. Flexibility was tested using a Well's Bench. Dynamic balance was analyzed using a circuit that was performed before onset of the intervention and at the end of the 12 week study period. The coordination test was performed using a complex task mixed with a circuit. Results: The endurance in upper limbs statistically improved between CG and IG (11.40 ± 2.87 vs 19.50 ± 1.52) similar that in the lower limbs (14.90 ± 3.10 vs 26.56 ± 3.17, $p=0.001$). Regarding dynamic balance, the IG presented a decrease in the time to complete the task compared to the CG (14.62s ± 1.83s vs 12.71s ± 0.62s, $p<0.05$). There were no differences in the coordination between GC and IG. Conclusion: The benefits related to strength development using resistance training are in accordance with the present literature, however, in opposition to the present literature, we found that resistance training is effective in developing dynamic balance.

Keywords: Resistance training, coordination, balance, elderly women.

LISTA DE FIGURAS

LISTA DE TABELAS

SUMÁRIO

INTRODUCTION

The aging process is characterized by a set of organic and functional modifications (Monti *et al.*, 1992). These changes usually result in alterations in anthropometric components (i.e. muscle mass, bone mass density, fat mass) and neuromuscular patterns (i.e. muscle strength, balance, motor control) (Aagaard *et al.*, 2002; Mitchell *et al.*, 2012; Walston, 2012; Montero-Fernandez e Serra-Rexach, 2013; Nilwik *et al.*, 2013; Scanlon *et al.*, 2014; Tudorascu *et al.*, 2014). The significant reductions identified in some of these components indicates a direct association between aging and reductions in functional autonomy levels (Chodzko-Zajko *et al.*, 2009; Martins *et al.*, 2015).

Impairments in balance and coordination are positively associated with strength declines and the incidence of falls in elderly individuals (Rubenstein, 2006; Granacher *et al.*, 2013). Reductions in balance and coordination combine to discourage an active lifestyle (Horak, 2006; Chodzko-Zajko *et al.*, 2009). Deleterious physiological and morphological alterations are seen throughout the neuromuscular system after short periods of inactivity (Buchner *et al.*, 1997; Clark e Manini, 2012). The term "dynapenia" has been coined to describe the significant decrease in strength observed with advancing age and its onset predisposes those afflicted to an increased risk of functional limitations (Clark e Manini, 2012; Tudorascu *et al.*, 2014). Reductions of strength in the lower limbs have a negative effect on gait and balance, impairing mobility in this population. In conjunction with strength reductions, a high incidence of muscle atrophy can be observed, mainly caused by a reduction in the number and size of muscle fibers; a condition known as sarcopenia (Clark e Manini, 2012; Walston, 2012; Nilwik *et al.*, 2013).

Resistance training (RT) significantly diminishes sarcopenia and dynapenia (Maltais *et al.*, 2016). Studies report RT-induced gains of 5 to 10% in muscle cross sectional area and increases of 20 to 100% in muscle strength depending on the exercise/muscle group (Galvao *et al.*, 2005; Silva *et al.*, 2014). This highlights the importance of RT as a viable strategy to combat these debilitating conditions. It has been speculated that resistance exercise requires a continuous activation of anti-gravitational muscles and these activation stimulates increases in motor coordination, thus producing beneficial effects regarding to balance (Berthelsen *et al.*, 2014). The positive effects of RT on muscular strength is well-established, however, its interdependence with balance remains controversial (Orr *et al.*, 2008). Therefore, the aim of the study was investigate the effects of 12 weeks of RT on balance, muscle endurance, and motor coordination in elderly women.

METHODS

The study employed a quasi-experimental control design with repeated measurements aiming to analyze the effect of 12 weeks of RT on elderly women (Anderson-Cook, 2005). The independent variable was RT with three dependent variables which were strength levels, balance, and coordination. The control variables adopted were a food intake recall, age, rate and frequency of physical activity and body mass index.

Subjects

Forty nine physically active elderly women (BMI: 25.1 ± 5.0 kg/m^2; age: 63.7 ± 3.5 years; body mass: 61.3 ±15.1 kg) agreed to participate in the study (Blair e Morris, 2009). Participants were recruited by convenience method, which was developed in three stages: (1) mapping of possible locations where the target population could be found; (2) the establishment of inclusion and exclusion criteria; (3) visits to community groups, explaining the research procedures and possible benefits which was followed by an invitation to volunteer in the study. The study was approved by the Ethics Committee with the protocol number, CAAE: 03763312.7.0000.0117. A power analysis employing an alpha level of 0.05 and a power level of 0.80 determined that 41 participants were required for participation and the effect size (ES) was in accordance with (Cohen, 1992), where values lower than 0.41 represent a small ES, 0.41-0.70 a moderate ES, and greater than 0.70 a large ES.

Inclusion and Exclusion criteria

All participants had to meet the following criteria. Inclusion: a) postmenopausal; b) classified as physically active by IPAQ questionnaire (Benedetti *et al.*, 2007); c) answer in the negative to all items of the PAR-Q (Physical Activity Readiness Questionnaire). Exclusion: a) presence of joint, neurological, cardiovascular or respiratory issues that impair strength training performance; b) use of medications that affect exercise responses; c) self-report of contraindication to high intensity physical exercise, based on medical examinations performed within twelve months prior to the beginning of the evaluations. All participants signed an informed consent.

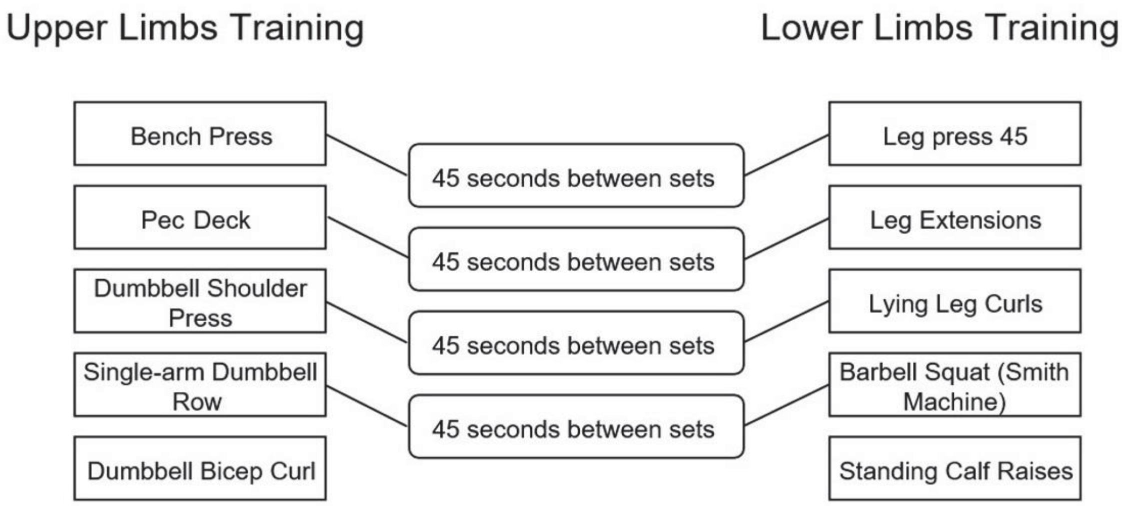
Experimental Design

Initially, all participants completed an anthropometric evaluation in the Physiology Laboratory of Universidade Federal do Paraná (UFPR). In a subsequent visit, participants were tested for baseline flexibility, balance, and motor coordination. After completing these analyses, participants were familiarized with the RT protocol, which consisted of five exercises for the lower limbs and five exercises for the upper limbs. Following familiarization, a 10 repetition maximum test was conducted for all exercises to determine the intensity of the training. Participants then were randomly divided into two groups: an intervention group (IG; n=29) that performed a regimented RT program or a non-training control group (CG; n=20). A 3-week acclimation period using 30% of 1RM was provided for IG. Thereafter, the IG performed twelve weeks of RT using intensities of 60% of 1RM three/four days a week with a 24 hour recovery interval between each training session. Small adjustments in the workload were made every four weeks in order to avoid problems related to adjustments to the load. Following the 12 week training period, participants repeated the initial testing protocol. All tests, as well as, interventions were performed at the same time of day (morning: 9:00 A.M) to avoid the potential influence of circadian variations.

RT Protocol

RT was carried out for 12 weeks with training segmented into two protocols: one for the upper limbs and one for the lower limbs. Participants performed three sets of ten repetitions for each of the 10 total exercises (five exercises for upper limbs and five exercises for the lower limbs), with a rest interval of 45 seconds provided between sets and 90 seconds afforded between exercises (Smolarek Ade *et al.*, 2016). A 24 hour recovery period was provided between each training session. Figure 1 depicts the specifics of the training program.

Figure 1. Training protocol for upper and lower limbs



Instruments and Procedures

Anthropometric Components

In the first visit to the lab, we assessed participants' body weight and percent body fat (BF) using a tetra-polar bioelectrical impedance analysis (BIA) device (Model TFB-310, Tanita Corporation, Tokyo, Japan). Height was measured with a stadiometer (Holtain Harpen ®) fixed in the wall following a standardized protocol (Aroom *et al.*, 2009). BMI was then calculated as the body mass divided by the square of the body height.

10 RM Test

The first training session was relegated to estimate the 1RM using the 10 RM test values, as per the protocol by Haff and Triplett (2015). The protocol was employed in each one of the exercises proposed by the strength training intervention, which followed an intensity of 60% of 1RM during the training sessions. Every four weeks, a new evaluation was conducted to estimate the 1RM values, aiming to avoid issues related to adjustments to the weight.

Upper Limb Endurance

Upper limb strength was assessed by the 30-second arm flexion test (Rikli e Jones, 1999). After being advised about the testing procedures, participants were instructed to sit in a chair with no backrest, hold a halter (2.27 kg) with their dominant arm and hand, and assume a semi-pronated position. Movement comprised complete elbow flexion and extension while supinating the hand as fast as possible in 30 seconds (TIMEX® timer). Three attempts were made with a one minute rest interval between trials; the trial with the greatest number of repetitions performed was accepted as the final value.

Lower Limb Endurance

Lower limb strength was assessed though a sit-up test, which had a 30 seconds limit to reach the highest number of repetitions (Rikli e Jones, 1999). Participants were positioned with the arms crossed in the chest line in a chair without the backrest, and their feet fully resting on the floor. Participants performed the complete movement of getting up and sitting on the chair in the predicted time of 30 seconds. Following the protocol for upper limbs, three attempts were made for the sit-up test, with an interval of one minute. The best result among the three tests was taken as the final value.

Flexibility Test

Flexibility (FLEX) was assessed by the sit-and-reach test (SRT) in a Wells bench. Participants placed their hands on top of one another and slowly slid their hands over the ruler as far as possible without flexing the knees and holding the final position for at least two seconds. One test session was performed with three trials used to evaluate flexibility. The best of the three trials was taken as the final result.

Balance Test

To perform the dynamic balance test, participants placed their feet on an X marked on the floor. From the center of the X, a point was demarcated 1.10m to the left side (Y), 0.80m backwards (Z), 1.10m to the right side (R) and finally 0.80m ahead from the starting point (H). The area was well lit, the floor flat and not slippery. In the test, participants had to perform some specific movements in the lines aiming to reach the specific point (i.e.: with the right leg positioned in the X, the sample has to perform specific movements to reach Z, R, H and Y with the opposite leg) in the minimum amount of time possible (Bloem *et al.*, 2003), and therefore, analyze the balance level presented by them (Figure 2).

Figure 2. Balance Test with four distal points.

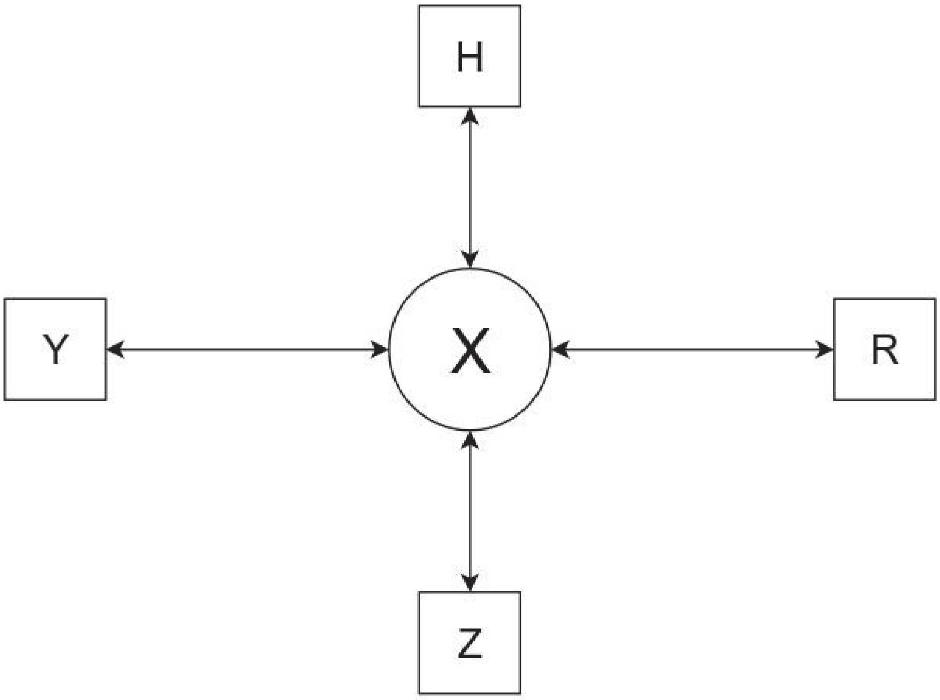


Figure adapted from Bloem et al., 2003

Motor Control Test

The coordination test was performed on a flat surface, with a piece of 76.2 cm long adhesive tape attached to the floor. Six marks were made on the tape. The marks were 12.7 cm equidistant from each other with the first and last mark 6.35 cm away from the ends of the tape. In each of the six marks, another piece of adhesive tape 7.6 cm in length was affixed perpendicular to the initial piece of tape. If the dominant hand of the sample was the right, one can of refrigerant was placed in position 1, the other in position 3, and the third can was positioned at 5, creating an average distance of 25.4 cm between points 1-3 and 3 - 5. The right hand was placed in the can which was in positioned at 1, with the thumb up and the elbow being flexed at an angle of 100 to 120 degrees. When the evaluator gave the signal, the participant rolled the can, reversing the base of support at points 1-3-5 as fast as possible (Rikli e Jones, 1999).

Statistical Analysis

All data were reported as mean and standard deviation (SD). Descriptive statistics were used to elucidate measures of central tendency and variability for the characterization of study participants. The normality of the data distribution was assessed by the Shapiro-Wilk test. A one-way analysis of variance (ANOVA) was employed to compare the means of the dependent variables at different times and between the groups, and the Bonferroni multiple comparison test was used to identify any possible differences. To analyze the Cohen's D effect size (ES) was accessed, using the scale proposed by Rhea (2004) and the statistical significance was established at $p \leq 0.05$.

RESULTS

Results related to the anthropometric components between intervention group (IG) and control group (CG) are presented in Table 1.

TABLE 1. Anthropometric components between CG and IG before 12 weeks of strength training (N=49). Values are reported as mean ± standard deviation.

	CG (n=20)	IG (n=29)
Age (years)	63.7 ± 3.5	64.3 ± 4.7
Height (cm)	152.1 ± 2.0	154 ± 1.5
Body mass (kg)	61.3 ± 15.1	65.8 ± 13.2
BMI (kg/m^2)	26.5 ± 5.2	27.7 ± 4.7
WC (cm)	89.2 ± 10.6	93.0 ± 9.7

*= $p \leq 0,05$
†=Shapiro Wilk
WC: waist circumference

Table 2 describes the results regarding coordination, balance and strength levels between CG and IG before 12 weeks of strength training.

TABLE 2. Autonomy characteristics represented by coordination, balance and strength between CG and IC. (N=49). Values are reported as mean ± standard deviation.

	CG (n=20)	IG (n=29)
Coordination (s)	5.9 ± 1.3	5.9 ± 1.5
Balance (s)	14.6 ±1.8	14.4 ± 1.8
ULS (rep)	11.4 ± 2.8	12.5 ± 3.4
LLS (rep)	14.9 ± 3.1	16.3 ± 2.0

*= $p \leq 0.05$
†=Shapiro Wilk
ULS: Upper Limb Strength
LLS: Lower Limb Strength

The results related to balance, coordination and strength on both, upper and lower limbs are indicated in Table 3, comparing the results between CG and IG pre and post 12 weeks of strength training.

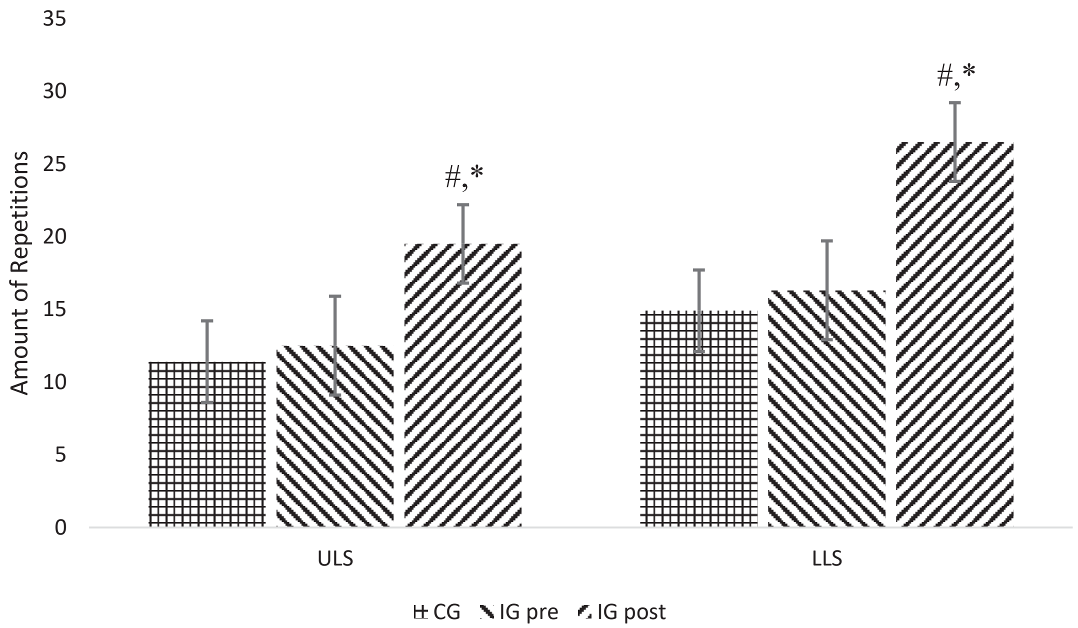
Table 3. Difference in coordination, balance and strength levels between CG and IG pre and post intervention (N=49). Values are reported as mean ± standard deviation.

	CG (n=20)	IG pre (n=29)	IG post (n=29)	*F*	*Effect Size (ES)*
Coordination (s)	5.9 ±1.3	5.6 ±1.5	5.1 ± 1.5	2.24	0.27
Balance (s)	14.6 ±1.8	14.4 ±1.8	12.7^{bc} ± 1.2	7.92*	0.52
ULS (rep)	11.4 ±2.8	12.5 ±3.4	19.5^{bc} ± 2.7	34.17*	0.82
LLS (rep)	14.9 ±3.1	16.3 ±2.0	26.5^{bc} ± 3.7	66.72*	0.86

* = P ≤ 0.05. b = significant difference between CG and IG post. c = significant difference between IG pre and IG post. ULS = upper limb strength. LLS = lower limb strength.

Balance was significantly improved after 12 weeks of strength training compared to CG and IG pre (p = 0.03) with a moderate ES (0.52). In Figure 1 indicated analyses of the difference in muscular endurance levels between CG and IG pre and post intervention, presenting significant differences in upper limb endurance between GC and IG post and IG pre and IG post respectively (11.4 ± 2.8 to 19.5 ± 2.7 with p = 0.001 and 12.5 ± 3.4 to 19.5 ± 2.7, with p = 0.006).

Figure 3. Comparison between upper and lower limb endurance during CG, IG pre and IG post intervention. (N=49)



P ≤ 0.05 between CG and IG post. * P ≤ 0.05 between IG pre and IG post. ULS = upper limb endurance. LLS = lower limb endurance.

DISCUSSION

Our findings failed to confirm the hypothesis that increased strength enhances muscle coordination, improving the extent of neural activity within the central nervous system (CNS) (Carroll *et al.*, 2001). The early RT-induced increases in strength may be associated with neural adjustments (Silva *et al.*, 2014), such as alterations in muscle fiber recruitment and neural coordination (Carroll *et al.*, 2001). In the present study, subjects did not show significant improvements in coordination after twelve weeks of RT, even though strength was significantly enhanced. Coordination development may arise due to improvements in strength and/or as result from the motor learning process (Rutherford e Jones, 1986). The learning process results in the establishment of new neural pathways in the central nervous system; however, it affects mostly gross coordination patterns (Rutherford e Jones, 1986; Anderson *et al.*, 2016). Therefore, due to the specificity of the task used to analyze the coordination, a predominance of fine motor skills may have affected the results.

Regarding balance, other researchers have found balance-related improvements following regimented strength training (Hess e Woollacott, 2005; Orr *et al.*, 2008), consistent with the findings of the present study. Conversely, some studies show that RT does not significantly improve markers of either static or dynamic balance in adult and elderly populations (Wolfson *et al.*, 1996; Schlicht *et al.*, 2001). Nevertheless, it is important to note that both studies used subjective criteria to determine the intensity of the workout session, and therefore may underestimate or overestimate the correct intensity from the workload.

Another possible explanation for discrepancies in the literature may be related to the duration of the training interventions (Orr *et al.*, 2008). Studies showing significant improvements in balance lasted at least twelve weeks (Hess e Woollacott, 2005; Orr *et al.*, 2006) while those with shorter durations had null findings (Ferrucci *et al.*, 1997) (Schlicht *et al.*, 2001). Moreover, one of these studies did not present significant improvements on strength, thus justifying the lack of improvement in balance. It also is important to highlight that participants only performed lower limb exercises, but the strength capacity was assessed by upper limbs tests, making the lack of similarity between training and testing a potential confounder in determining the real benefits of strength training (Jaric, 2002).

The present study observed a significant increase in strength and endurance capacity of both the upper and lower limbs. Other studies (Palmieri *et al.*, 2002; Granacher *et al.*, 2013), found that strength and endurance of lower limbs are directly related to balance conditions, which is fundamental for the performance of daily activities. Aagaard and colleagues (2002) demonstrated that RT significantly heightens neuromuscular activation, which is purported to be a primary mechanism responsible for increases in balance (Anderson *et al.*, 2016). When a moment of imbalance occurs between an individual's center of gravity and base of support, the CNS send signals requesting a greater amount of muscular recruitment through efferent responses (Rogers *et al.*, 2013). Therefore, a greater ability to activate motor units is proposed as a possible justification for improvements in balance through RT (Aagaard *et al.*, 2002; Anderson *et al.*, 2016).

A potential limitation of the present study is that fact that, although nutritional intake was analyzed prior to the beginning of the study, subjects did not follow a standardized dietary protocol during the training intervention. However, it should be noted that no significant changes were observed in reported caloric intake between IG and CG throughout the study period.

CONCLUSION

Twelve weeks of RT significantly increased markers of strength and balance in postmenopausal elderly women. Alternatively, no significant changes in motor coordination were seen, conceivably because of the specificity of the applied testing protocol. These data reinforce the importance of including resistance exercises in an elderly population to counteract the detrimental effects of aging on functional performance. Future studies should investigate the effect of RT on coordination using specific tasks to provide a better understanding of this parameter.

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