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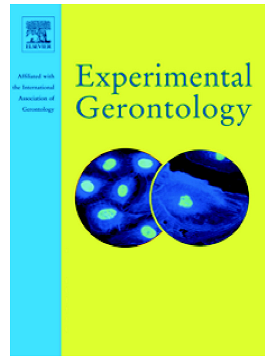

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Resistance but not elastic tubes training improves bioimpedance vector patterns and body composition in older women: a randomized trial

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Highlights

- Resistance training with weight machines may be a potent stimulus to improve bioimpedance vector patterns and handgrip strength in older women.
- Elastic tubes training offers a potential means for improving handgrip strength.
- Training using elastic tubes may maintain but not improve body composition in older women.

Abstract

The present study aimed to investigate the effects of traditional resistance training compared to elastic tubes training on bioimpedance vector patterns, body composition, and strength in older women. Thirty-eight older women (age 68.7 ± 6.9 years, body mass index 28.8 ± 7.2 kg/m^2) were randomly assigned to perform traditional resistance or elastic tubes training three times per week for 12 weeks. Body composition was assessed by dual energy X-ray absorptiometry and bioelectrical impedance ~~conventional and~~ vector analysis. In addition, handgrip strength was measured using a dynamometer. Only the participants who followed the 12-week traditional resistance training program significantly ($p < 0.05$) decreased fat mass (ES: -0.69) and extracellular water (ES: -1.06), and increased total body water (ES: 0.49), intracellular water (ES: 1.11), body cell mass (ES: 0.82), muscle mass (ES: 0.94), and phase angle (ES: 0.99), while no change occurred in the elastic tubes training group. Furthermore, a vector leftward displacement (ES: 1.11) into the resistance-reactance graph was found only after the traditional resistance training program. The handgrip strength increased for both traditional and elastic tubes training groups (ES: 0.64, ES: 0.71, respectively). Traditional resistance training improved body composition and strength in the older women group, while training using elastic tubes was effective only for the latter. The present outcomes encourage the use of systematic resistance training to counteract the effects of aging in older women.

Keywords

Bioelectric impedance analysis; BIVA; handgrip strength; muscle mass; fat mass; phase angle; older adults.

1. Introduction

Aging entails a decline in physiological functions and is influenced by genetic and environmental factors (Morris et al., 2019). Traditionally, researchers use ~~measures and~~ indicators based on people's chronological age, defining older persons as those aged 60 to 65 years or over (Campa et al., 2018; dos Santos et al., 2020; Dos Santos et al., 2020). According to the World Population Prospects 2019, by 2050 one out of six people will be over the age of 60, up from one in each eleven in 2019 (World Population Ageing, 2020). The changes in body composition that occur with aging continue to receive attention from researchers and clinicians, given their relationship with health status and physical functionality (Campa et al., 2018; Dos Santos et al., 2020). More in detail, ~~the~~ remodeling of ~~the~~ body mass involves gradual increases in fat mass, reductions in body fluids and minerals, and loss of muscle mass (Santanasto et al., 2017). An increase in adiposity, especially if localized in the abdominal area, is associated with established risk factors for a variety of chronic diseases (Santanasto et al., 2017), while a reduction in intracellular fluid contributes to the accumulation of cellular senescence induced by destructive stimuli from inside and outside the cell (Li et al., 2021). Lastly, the loss of muscle mass is a contributing factor to the loss of muscle strength, and the decline of both are key features in the diagnosis of sarcopenia (Bellieni et al., 2021; Cruz-Jentoft et al., 2019).

Among the methods used for assessing body composition, Bioelectrical Impedance Analysis (BIA) allows for a wide range of evaluations (Campa et al., 2021b; dos Santos et al., 2020; Francisco et al., 2020). In addition, BIA is non-invasive, portable, and user-friendly, as opposed to reference ~~and certainly most accurate but often unavailable~~ methods such as dilution techniques and magnetic resonance commonly used in laboratory routine assessments (Heymsfield et al., 2005). Bioimpedance-based predictive equations allows for monitoring changes in i) fat mass, ii) body fluids, including those that contribute to forming the body cell mass representing the metabolically active component of the human body, and iii) muscle mass (Campa et al., 2021b; Dittmar and Reber, 2004; Heymsfield et al., 2005). Furthermore, given the relationship between the bioelectrical properties and body composition, the evaluation of the raw bioimpedance parameters such as phase angle, resistance (R), and reactance (Xc) could allow for a qualitative assessment of body composition (Campa et al., 2021b; Francisco et al., 2020). Indeed, the phase angle represents the intracellular/extracellular water ratio (Francisco et al., 2020) and is considered a prognostic biomarker and an indicator of cellular integrity (Cruz-Jentoft et al., 2019; Gonzalez et al., 2016; Mattiello et al., 2020). Additionally, phase angle is associated with the tissue cellularity and cell size, representing the cell membrane integrity and permeability (Campa et al., 2021b). In this regard, it was shown that phase angle values increased after a 12-week progressive exercise program~~s~~ and its increase is associated with gains in strength and muscle mass (Lukaski et al., 2017). In addition, the interpretation of both R and Xc through the Bioelectrical Impedance Vector Analysis (BIVA) allows for a comparison of the bioelectrical properties within specific tolerance ellipses of ~~for~~ the reference population (Campa et al., 2021b; Piccoli et al., 1995).

Older women have lower levels of phase angle, muscle mass and strength, and body mineral density compared to ~~with~~ men, and may be more sensitive to the aging effects (Mattiello et al., 2020; Xu and Wu, 2018). To possibly counteract the age-related effects, resistance training was already shown to effectively increase phase angle, muscle mass, and strength in older people starting at ~~after~~ 12 weeks of intervention (Campa et al., 2021a; Dos Santos et al., 2016; Souza et al., 2017). Particularly, the handgrip strength was primarily associated with the diagnosis of sarcopenia and can be easily assessed in older people using a portable dynamometer (Cruz-Jentoft et al., 2019). An alternative to the traditional resistance training performed with dumbbells or weight machines is the use of elastic tubes. Older subjects could potentially benefit from elastic tubes training as it involves the use of low-cost tools and can be performed at home instead of in specialized sports centres. However, while the improvements in handgrip strength were shown to be similar in both traditional and elastic resistance training (Lopes et al., 2019), the changes in body composition after a resistance training program with elastic tubes are still unclear (Lopes et al., 2020). In this regard, the few studies available in older populations have shown contrasting results, reporting improvements (Liao et al., 2018) or absence of variation (Ramos et al., 2014) in body composition parameters. Therefore, the present study aimed to examine the effects of a traditional resistance versus elastic tubes training programs in older people. Body composition assessed by DXA, BIA, and BIVA was investigated, as well as the handgrip strength.

2. Materials and methods

2.1.Study design

The present investigation was designed as a longitudinal randomized interventional, two-group, two-time trial. An a priori power analysis was conducted to determine the sample size using a statistical software (G*Power v. 3.1.9.2, Stuttgart, Germany). Phase angle was selected as primary outcome, and we calculated the effect size from a previous study (dos Santos et al., 2020). There is evidence suggesting that phase angle decreases concomitantly with the decline in muscle mass, possibly reflecting sarcopenia (Di Vincenzo et al., 2020). A two-way repeated-measures analysis of variance (ANOVA) was selected as the F test of all the test family, inputting the following parameters: $\alpha = 0.05$; $(1-\beta) = 0.9$; Effect Size f = 0.25; correlation among repeated measures = 0.7, and the total sample size resulted in 28 subjects. To avoid a drop in statistical power due to possible drop out, we recruited 38 participants. The flow chart with a schematic representation of the participant allocation is shown in Figure 1.

Insert Figure 1 here

2.2.Participants

Thirty-eight post-menopausal older women ~~[age (traditional resistance group: 69.7 ± 8.2 years, body mass index 28.8 ± 6.3 kg/m^2; elastic tubes training: 70.1 ± 6.7 years, body mass index 29.1 ± 6.7 kg/m^2)]~~ voluntarily participated in the study. To participate in the study, the following inclusion criteria were met: i) not having chronic disabling and metabolic diseases, ii) not being bedridden institutionalized or hospitalized, iii) have their own mobility, iv) without assistance from people, even if they have the aid of devices such as crutches, walkers, etc. Additionally, the use of pacemakers and the presence of chronic and uncontrolled metabolic diseases were considered as exclusion criteria. After acceptance, the participants were included in the study only after being evaluated by a medical doctor and released without any restriction for participation in physical exercise programs. Subsequently, they were randomly allocated to each group following the study purpose: a group who performed a traditional resistance training program and another group who performed a resistance training program with tube elastic tools. The random allocation (random.org) was carried out by a blinded researcher. The food intake was assessed by the 24-h dietary recall method applied on two non-consecutive days of the week (dos Santos et al., 2020), and monitored in the first and last two weeks of the intervention period. The homemade measurements of the nutritional values of food were converted into grams and milliliters by an online software (Virtual Nutri Plus, Keeple®, Rio de Janeiro, Brazil) for diet analysis. The present procedures were approved by the local Ethics Committee and was conducted in accordance with the Declaration of Helsinki on research involving human beings. The study was registered at the Brazilian Registry of Clinical Trials (Trial nº RBR-2624R4). All participants, after being properly informed about the study proposal and procedures to which they were submitted, signed an informed consent form.

2.3.Procedures

All participants were tested to ensure a well-hydrated state using the urine specific gravity test (refractometer Urisys 1100; Roche Diagnostics), according to Armstrong et al. (Armstrong et al., 2010). A urine specific gravity value < 1.022 for the first urine was used to identify an euhydration state. To evaluate body composition, Dual energy X-ray Absorptiometry (DXA), BIA, and BIVA were assessed. To evaluate muscle strength, the handgrip strength was measured. The present investigation lasted a total of 15 weeks. During the first week, the baseline assessment was performed. During the second week, the participants were familiarized with the training interventions. The intervention lasted 12 weeks, from week-3 to week-14. The last week was dedicated to the post-training assessments. The participants were also instructed not to participate in any other type of training program during the study period. They were considered eligible to data analysis with a frequency higher than 75% in the training program.

2.4. Body composition and handgrip strength assessments

Fat mass, fat-free mass, and bone mineral content were assessed using a lunar DXA scanner (model DPX-MD, software 4.7, General Electric Healthcare - Lunar DPX-NT; England). The scanner was calibrated daily against the standard supplied by the manufacturer to avoid possible baseline drift. All scanning and analyses were performed by the same operator to ensure consistency (Coratella et al., 2018).

The impedance measurements were performed with a phase-sensitive bioimpedance analyzer (Bia Vitality, Harrisville, USA) at a frequency of 50 kHz. Bioimpedance parameters [Resistance (R) and reactance (Xc)] were analyzed according to the BIVA procedures (Piccoli et al., 1995). Phase angle was calculated as the arctangent of $Xc/R*180°/\pi$. Total, intra and extracellular water, body cell and muscle mass were estimated using specific bioimpedance-derived equations (Dittmar and Reber, 2004; Looijaard et al., 2020; Sergi et al., 1994; Sun et al., 2003).

The handgrip strength was measured using a manual dynamometer (EH101, Camry, Guangdong Province, China) for wrist flexion. Each participant was evaluated by keeping the dynamometer at a

90-degree flexion of their elbow, in a sitting position for a maximum of three attempts for each hand (Toselli et al., 2020).

2.5.Intervention programs

The participants underwent two different resistance training programs carried out in three weekly 75-min sessions, on alternate days consisting of specific exercises for conventional training and with elastic tubes, as experimented in previous studies conducted by our research group (de Alencar Silva et al., 2018; de Freitas et al., 2019). Each session of both resistance programs consisted of a warm-up at the beginning and general stretching at the end. Both training programs consisted of three progressive phases: phase 1 (1st to 2nd weeks: 2 sets of 15 repetitions; 60 sec of interval recovery between sets); phase 2 (3rd to 6th weeks: 3 sets of 12 to 15 repetitions; 90 sec of interval recovery between sets); phase 3 (6th to 12th weeks: 3 sets of 8 to 12 repetitions; 90 sec of interval recovery between sets). The exercises used in the traditional resistance training program were: chest press, leg press 45°, front pulldown, knee extension, arm curl, leg curl, triceps pushdown, and calf raises, performed on dynamic constant external load machines (Ipiranga Equipamentos, Presidente Prudente, Brazil). After assessing the 20-RM for each exercise, the external load was 20-RM in the first and second phase, while it was increased to 15-RM in the third phase. Such non-exhaustive loads were used to avoid extreme fatigue and increase the adherence to the training. The exercises used in the elastic tubes training program were: knee extension and flexion, shoulder abduction, elbow flexion and extension, chest press, and seated row, performed using seven different elastic tubes (Lemgruber brand, Rio de Janeiro, Brazil) sizes, ranging from internal diameters of 2.5 mm to 12 mm and external diameters of 5 mm to 18.5 mm. The external resistance was progressively increased to match the number of repetitions performed by the resistance training group. An operator who personally supervised all training sessions to ensure safety and adherence to the training protocols.

2.6. Statistical analysis

Data were analyzed with SPSS v. 27.0 (SPSS, IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to check the normal distribution of data. A two-way repeated-measures ANOVA was performed to determine the changes over time in body composition and bioimpedance parameters, and handgrip strength. Where F-value was significant ($p<0.05$), multiple comparisons were performed to examine changes across the 12 weeks of intervention, using the Bonferroni correction. The paired, one-sample Hotelling's T^2 test was performed to determine if the changes in the mean group vectors were significantly different from zero (null vector). Hedges's d effect size (d) was calculated for the pairwise comparisons. Mahalanobis distance (D^2) was calculated to determine the magnitude of the changes in the mean group vectors. Threshold values were identified for d or $D^2 < 0.5$ as small, for $0.5 \leq$ d or $D^2 < 0.8$ as medium, and for d or $D^2 \geq 0.8$ as large effect.

3. Results

The demographics are shown in Table 1.

Insert Table 1 here

There was a significant ($p<0.05$) group by time interaction for bioelectrical reactance, phase angle, fat mass, intracellular and extracellular water, body cell mass, and muscle mass, as shown in Table 1. Decrements in R/H and increments in Xc/H after the traditional training program (Table 2) were found. Similarly, phase angle only increased in participants who followed the traditional resistance training. Fat mass and extracellular water decreased, while total body and intracellular water, body cell mass, and muscle mass increased in participants who followed the traditional resistance training program, as shown in Table 2 and Figure 2. The dominant handgrip strength increased after both traditional and elastic tubes training programs (Table 2).

Insert Table 2 here

Insert Figure 2 here

The present population had reference BIVA vectors about the 50th percentile of the tolerance ellipses of the female healthy population (Figure 3). The bioelectrical vector showed a significant displacement from the right to the left side of the R-Xc graph for the traditional resistance training group, while any vector change was assessed in the participants who performed the 12-week elastic tubes training program (Figure 3).

Insert Figure 3 here

4. Discussion

The present randomized trial was conducted to evaluate the effectiveness of a 12-week resistance training program using weight machines in comparison to ~~as compared with~~ resistance training with elastic tubes, in improving BIVA patterns, body composition, and strength in older women. BIVA vector showed a displacement along the minor axis of the tolerance ellipses, reflecting a simultaneous change in R/H and Xc/H ~~only~~ after the 12-week traditional resistance training by a large magnitude. In addition, only the participants who followed the traditional resistance training program decreased ~~the~~ fat mass and extracellular water by a medium and large magnitude respectively and increased ~~the~~ total body water by a small magnitude, and intracellular water, body cell and muscle mass by a large magnitude. Both resistance training programs were effective in increasing the handgrip strength by a medium magnitude. Although no improvement in body composition occurred after the elastic tubes training program, this could be used to counteract the possible age-related decline in strength.

An innovative approach for assessing body composition is represented by the evaluation of the raw bioimpedance parameters (Campa et al., 2021b). The phase angle results from the ratio between Xc and R, and accurately reflects the intracellular/extracellular water ratio (Francisco et al., 2020;

Gonzalez et al., 2016). More importantly, phase angle is now considered ~~as~~ a biomarker for cellular integrity (Cruz-Jentoft et al., 2019; dos Santos et al., 2020). In addition to the phase angle evaluation, R and Xc can be simultaneously considered in ~~the~~ BIVA as a vector within a graph. ~~This graph, called~~ The R-Xc graph, allows for the evaluation of ~~to evaluate~~ the position of the BIVA vector in comparison with the tolerance ellipses built on the reference percentiles of the older population (Reljic et al., 2020). A rightward vector displacement is interpreted as a worsening in muscle quantity and a reduction in phase angle, and vice versa (Piccoli et al., 1995). Additionally, a vector shortening represents an increase in body fluids and vice versa (Piccoli et al., 1995). A concurrent decline in phase angle and vector rightward displacement have been related to ~~the~~ aging, being interpreted as a decline in muscle quantity and cellular integrity (Cruz-Jentoft et al., 2019; Souza et al., 2017). In the current study, the elastic tubes training program did not lead to any change in BIVA patterns, while the traditional resistance training was able to increase the phase angle and induced a leftward vector displacement in~~to~~ the R-Xc graph. Our results are in line with previous studies that showed ~~that~~ resistance training improved both phase angle and vector position (Campa et al., 2018; dos Santos et al., 2020; Dos Santos et al., 2016; Souza et al., 2017), while no direct comparison can be made for the elastic tubes training group.

The current outcomes showed that fat mass decreased only in the traditional resistance training group, while the fat-free mass and its component related to the bone mineral content remained unchanged. After a period equal to or slightly higher than 12 weeks without any training, fat mass showed no ~~did not~~ change (Campa et al., 2018; Souza et al., 2017) or increased (dos Santos et al., 2020; Dos Santos et al., 2020) in older women. An increment in fat mass is associated with an increase in cardiovascular and metabolic risk factors (Dos Santos et al., 2020), so that traditional resistance training can be used to reduce such a risk, as reported in previous studies (Campa et al., 2018; dos Santos et al., 2020; Dos Santos et al., 2016; Souza et al., 2017). In addition, a non-training period was sufficient to induce reductions in fat-free mass and bone mineral content in older people (Campa et al., 2018; dos Santos et al., 2020; Turcotte et al., 2020). An active lifestyle in older female populations should therefore ~~promote to~~ counteract ~~the~~ age-related decline.

Intriguingly, although the fat-free mass did not change after 12 weeks, the remodeling of the body mass encompasses changes in several components, such as the intracellular and extracellular water. Here, the extracellular water decreased, and the intracellular water increased in the participants who followed the traditional but not the elastic tubes resistance training program. The intracellular water is included in the metabolic active component of the body who constitute the body mass cell, and its increment is associated with healthier status (Dittmar and Reber, 2004). Furthermore, the intracellular water also represents the amount of muscle cells and its reduction may be associated with age-related sarcopenia (Cruz-Jentoft et al., 2019). On the contrary, an increase in extracellular water could be associated with a fluid retention and an inflammation status (Dos Santos et al., 2020). Previous results confirmed the effectiveness of traditional resistance training in improving fluid~~s~~ component distribution in older women (dos Santos et al., 2020; Dos Santos et al., 2016; Souza et al., 2017). In contrast, the studies that have assessed the changes in fat-free mass failed to report the changes in intracellular and extracellular water (Lopes et al., 2020; Ramos et al., 2014), therefore ~~so~~ a direct comparison cannot be made. However, the present results showed that resistance training with elastic tubes is not sufficient enough to induce any change.

Sarcopenia is nowadays defined as a geriatric syndrome and ~~it~~ is associated with lower muscle mass and strength, decreasing quality of life and increasing mortality (Cruz-Jentoft et al., 2019). A sedentary lifestyle was shown to decrease muscle mass (Cruz-Jentoft et al., 2019, 2010), and resistance training is considered the best method to fight such a~~s~~ decline (Souza et al., 2017). Our results showed that only the traditional resistance training program was effective in increasing muscle mass, although the elastic tubes training program was sufficient to avoid the decline. Interestingly, muscle mass was shown to increase in an age-matched population after a 12-week intervention using elastic resistance (Liao et al., 2018). However, the participants involved in that study (Liao et al., 2018) were sarcopenic, and it is possible that they were more sensitive to the training compared to ~~with~~ the present healthy participants.

In addition to the remodeling in body composition, aging is characterized by a reduction in strength, especially that of the handgrip (Campa et al., 2021a, 2018). The handgrip strength is a marker used to diagnose sarcopenia (Cruz-Jentoft et al., 2019). Recent studies have shown the effectiveness of both traditional and elastic tubes training programs in improving the handgrip strength in older adults (Colado and Triplett, 2008; Lopes et al., 2019; Ramos et al., 2014). In line with these studies, similar increases in the handgrip strength for both resistance training groups were found in the present investigation. Interestingly, the increase in handgrip strength in absence of any change in muscle mass for the elastic tubes training group confirms previous findings in which a lack of relationship between the changes in muscle mass and strength was reported (Li et al., 2018). Despite their questionable relationships, both muscle mass and handgrip strength should be maintained and developed in older people to contrast their age-related decline (Bellieni et al., 2021; Cruz-Jentoft et al., 2019).

Some strengths of the present study are: i) the older female population involved, often underrepresented in ~~the~~ scientific literature, and less involved in the training practice; ii) the use of a portable and easy-friendly tool for assessing body composition; iii) the application of BIVA, which represents a more sensitive approach to detect qualitative changes in body composition; iv) the use of the elastic tubes, which could be utilized in a home-based context. The present investigation has also some limitations. First, our results are related to an older female population, and are not generalizable to different subjects. Second, a control group was not included, and it would have reinforced the study design. Third, matching a-priori the overall training volume of the two groups was not possible, given the intrinsic characteristics of the elastic tubes. However, these are used in the practice with older people, so we believe that the present information may be useful for practitioners. Finally, our results cannot be compared with those obtained from bioimpedance measurements performed using different technology and sampling frequency than the ones used here.

5. Conclusions

A number of perspectives come from the present study. While it is known that aging implies a worsening in body composition and strength, older people should be encouraged to take part in systematic resistance training programs to improve their quality of life. However, should ~~not be~~ this be impossible, the use of elastic tubes in a home-based training context might still minimize the age-related decline. Noteworthy, people should maintain an active lifelong style to face the aging effects. In this regard, a regular body composition assessment using BIA and BIVA could help exercise specialists in tailoring the training programs.

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Declaration of interest statement

The authors have no conflicts of interest to declare.

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Figure captions

Figure 1. Flow chart showing the randomization process and participants involvement in exercise programs.

Figure 2. Schematic representation of the changes in body composition from baseline (pre) to after (post) 12 weeks of traditional resistance training according to different organization levels. FM: fat mass, FFM: fat-free mass, TBW: total body water, BMC: bone mineral content, ICW: intracellular water, ECW: extracellular water, BCM: body cell mass, ECM: extracellular mass, MM: muscle mass.

Figure 3. R-Xc and paired graphs for the multivariate changes in bioelectrical parameters are shown. On the left panels, bioimpedance data are plotted on the tolerance ellipses of the reference population. On the right panels, mean vector displacements with 95% confidence ellipses and results of the Hotelling's T^2 test are shown.

Figure 1

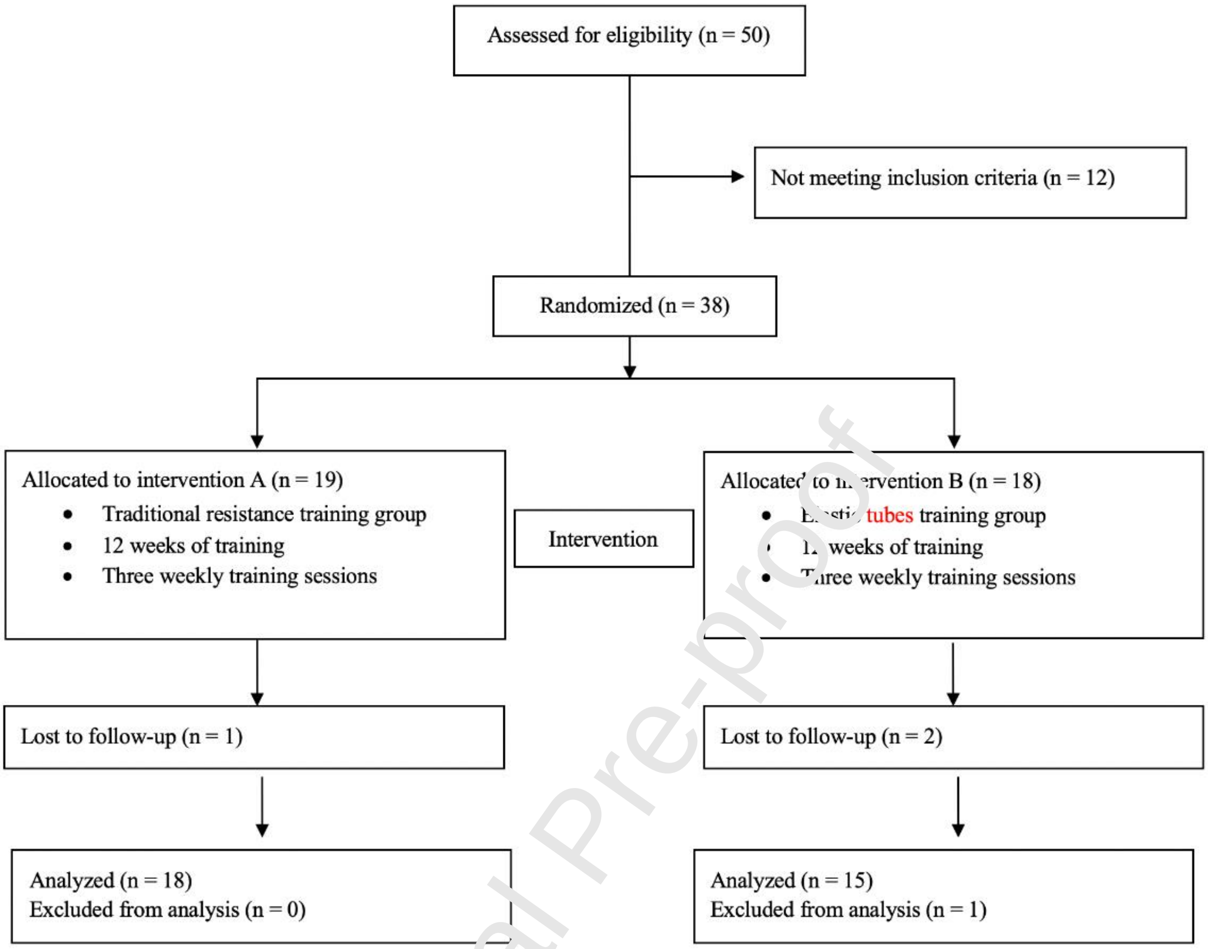
Assessed for eligibility (n = 50)
Not meeting inclusion criteria (n = 12)
Randomized (n = 38)
Allocated to intervention A (n = 19)
Traditional resistance training group
12 weeks of training
Three weekly training sessions
Intervention
Allocated to intervention B (n = 18)
Elastic tubes training group
12 weeks of training
Three weekly training sessions
Lost to follow-up (n = 1)
Lost to follow-up (n = 2)
Analyzed (n = 18)
Excluded from analysis (n = 0)
Analyzed (n = 15)
Excluded from analysis (n = 1)

Figure 2

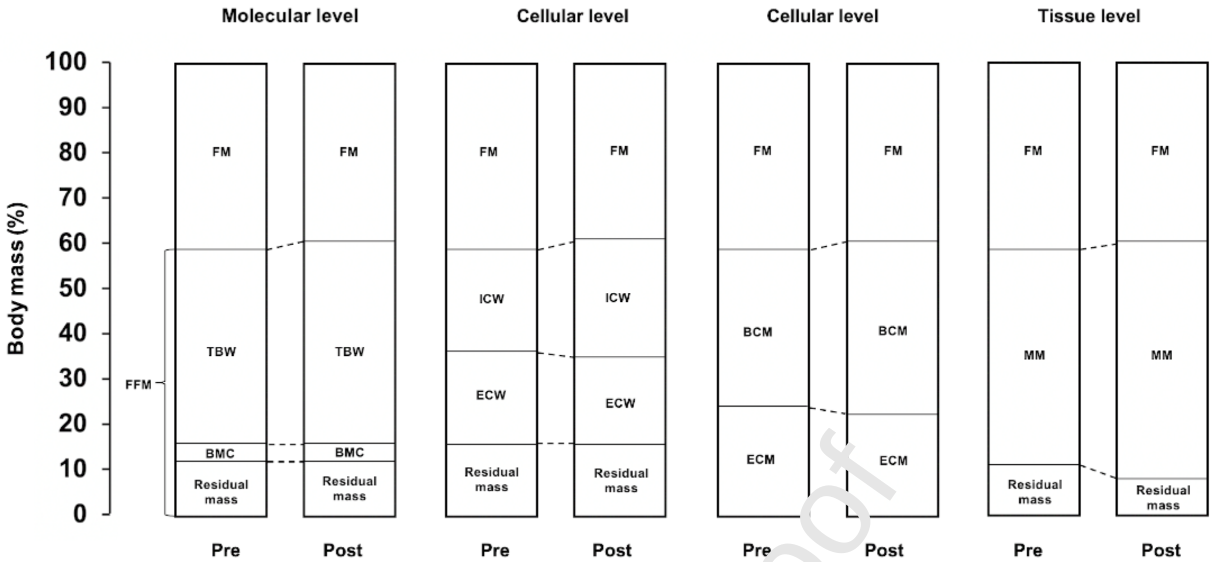
Molecular level
Cellular level
Cellular level
Tissue level
Body mass (%)
100
90
80
70
60
50
40
30
20
10
0
FFM
FM
TBW
BMC
Residual mass
ICW
ECW
BCM
ECM
MM
Pre
Post

Figure 3

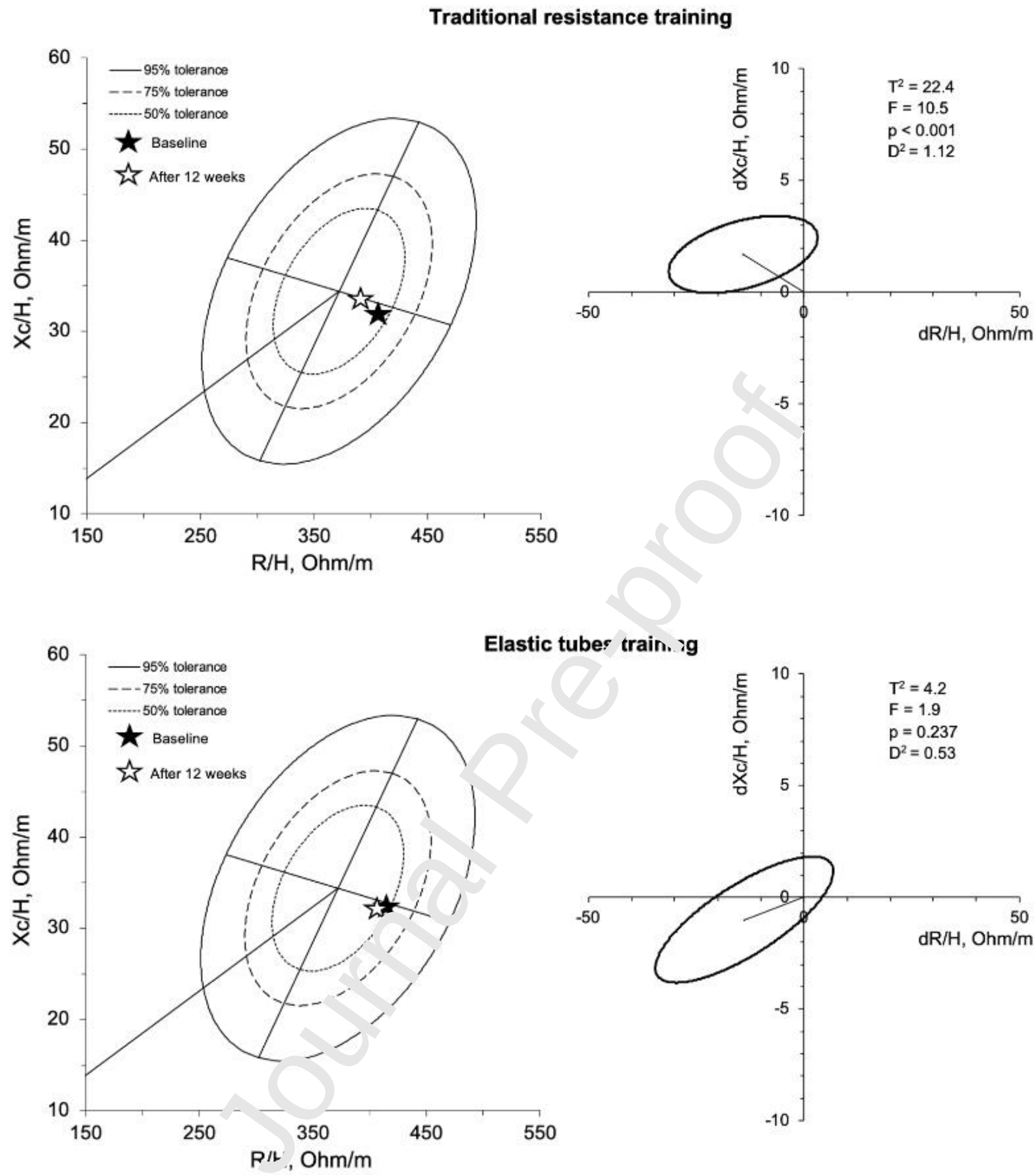
Traditional resistance training
95% tolerance
75% tolerance
50% tolerance
Baseline
After 12 weeks
Xc/H, Ohm/m
R/H, Ohm/m
dXc/H, Ohm/m
dR/H, Ohm/m
T² = 22.4
F = 10.5
p < 0.001
D² = 1.12
Elastic tubes training
95% tolerance
75% tolerance
50% tolerance
Baseline
After 12 weeks
Xc/H, Ohm/m
R/H, Ohm/m
dXc/H, Ohm/m
dR/H, Ohm/m
T² = 4.2
F = 1.9
p = 0.237
D² = 0.53

Table 1. General characteristics of the participants.

	Traditional resistance training group (N=19)	Elastic tubes training group (N=18)
Variable	Mean ± standard deviation	Mean ± standard deviation
Age (years)	69.7 ± 8.2	70.1 ± 6.7
Body mass index (kg/m^2)	28.8 ± 6.3	29.1 ± 6.7

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Table 2. The baseline (mean ± standard deviation) and post intervention (mean ± standard deviation) values of the dependent parameters are shown. The changes and the effect size (ES) are reported as mean with 95% confidence intervals (CI).

Variable		Traditional resistance training (N=18)	Elastic tubes training (N=15)	Time effect	Group x time interaction
R/H (ohm/m)	Baseline	402.8 ± 66.5	414.9 ± 70.7	F=8.6, p=0.006	F=0.0, p=0.977
	After 12 weeks	388.7 ± 10.1*	401.2 ± 58.0		
	95% CI	-27.22 / -0.91	-29.2 / 1.67		
	ES (95% CI)	-0.53 (-0.99 / -0.03)	-0.48 (-0.99 / 0.05)		
Xc/H (ohm/m)	Baseline	32.0 ± 4.3	33.2 ± 2.9	F=0.3, p=0.535	F=5.6, p=0.023
	After 12 weeks	33.7 ± 5.1*	32.2 ± 4.7		
	95% CI	0.39 / 3.00	-3.19 / 1.12		
	ES (95% CI)	0.63 (0.13 / 1.12)	-0.25 (-0.75 / 0.25)		
Phase angle (degree)	Baseline	4.8 ± 0.6	4.6 ± 0.6	F=10.0, p=0.003	F=11.1, p=0.002
	After 12 weeks	5.1 ± 0.9*	4.6 ± 0.7		
	95% CI	0.23 / 0.67	-0.19 / 0.17		
	ES (95% CI)	0.99 (0.43 / 1.55)	-0.03 (-0.53 / 0.46)		
Fat mass (kg)	Baseline	28.8 ± 11.4	[illegible]1.5 ± 12.7	F=8.1, p=0.008	F=2.1, p=0.152
	After 12 weeks	27.3 ± 11.4*	[illegible]1.1 ± 12.1		
	95% CI	-2.42 / -0.42	-1.[illegible]7 / 0.25		
	ES (95% CI)	-0.69 (-1.19 / -0.18)	[illegible].4[illegible] (-0.99 / 0.19)		
Fat-free mass (kg)	Baseline	38.5 ± 7.5	40.9 ± 7.4	F=0.2, p=0.600	F=2.5, p=0.125
	After 12 weeks	39.2 ± 7.8	40.6 ± 7.8		
	95% CI	-0.31 / 1.83	-1.24 / 0.48		
	ES (95% CI)	0.35 (-0.13 / 0.[illegible])	-0.28 (-0.86 / 0.30)		
Total body water (kg)	Baseline	28.8 ± 4.9	27.0 ± 6.7	F=5.6, p=0.023	F=0.3, p=0.576
	After 12 weeks	29.5 ± 5.1*	27.5 ± 6.4		
	95% CI	0.01 / 1.32	-0.27 / 1.09		
	ES (95% CI)	0.49 (0.01 / 0.96)	0.32 (-0.19 / 0.82)		
Bone mineral content (kg)	Baseline	1.9 ± 0.9	1.9 ± 0.9	F=0.6, p=0.809	F=2.8, p=0.600
	After 12 weeks	1.8 ± 0.9	1.9 ± 0.9		
	95% CI	-0.55 / 0.32	-0.39 / 0.47		
	ES (95% CI)	-0.15 (-0.70 / 0.39)	0.05 (-0.44 / 0.54)		
Extracellular water (kg)	Baseline	14.2 ± 2.9	12.9 ± 3.9	F=5.3, p=0.027	F=8.6, p=0.006
	After 12 weeks	13.6 ± 2.9*	13.1 ± 3.9		
	95% CI	-0.93 / -0.34	-0.39 / 0.54		
	ES (95% CI)	-1.06 (-1.63 / -0.48)	0.09 (-0.44 / 0.62)		
Intracellular water (kg)	Baseline	14.6 ± 1.9	14.1 ± 2.4	F=8.6, p<0.001	F=5.5, p=0.026
	After 12 weeks	15.9 ± 2.4*	14.5 ± 2.1		
	95% CI	0.72 / 1.87	-0.17 / 0.95		
	ES (95% CI)	1.11 ± (0.51 / 1.68)	0.40 (-0.15 / 0.95)		
Body cell mass (kg)	Baseline	21.9 ± 1.9	22.1 ± 2.1	F=12.1, p=0.002	F=7.2, p=0.011
	After 12 weeks	23.0 ± 2.6*	22.2 ± 2.0		
	95% CI	0.42 / 1.62	-0.11 / 0.38		
	ES (95% CI)	0.82 (0.29 /1.34)	0.28 (-0.23 / 0.81)		
Muscle mass (kg)	Baseline	31.6 ± 8.1	29.9 ± 11.8	F=12.1, p=0.002	F=11.5, p=0.002
	After 12 weeks	34.1 ± 8.6*	29.9 ± 11.5		
	95% CI	1.21 / 3.79	-0.63 / 0.69		
	ES (95% CI)	0.94 (0.29 / 1.37)	0.02 (-0.47 / 0.52)		
Dominant handgrip strength (kg)	Baseline	22.8 ± 5.8	21.9 ± 4.7	F=16.0, p<0.001	F=0.6, p=0.423
	After 12 weeks	24.1 ± 5.7*	23.8 ± 4.9*		
	95% CI	0.26 / 2.22	0.42 / 3.32		
	ES (95% CI)	0.64 (0.12 / 1.14)	0.79 (0.14 / 1.41)		

Note: * p < 0.05 vs. baseline. R/H: resistance divided by body height, Xc/H: reactance divided by body height.