Effects of Resistance Training With Machines and Elastic Tubes on Functional Capacity and Muscle Strength in Community-Living Older Women: A Randomized Clinical Trial

Article *in* Journal of Aging and Physical Activity · January 2020

DOI: 10.1123/japa.2020-0018

11 authors, including:

Marisete Peralta Safons
University of Brasília

Milene Soares Nogueira de Lima
University of Brasília

Alexandre Lima de Araújo Ribeiro
University of Brasília

Clarissa Paz
University of Brasília

Journal of Aging and Physical Activity, 2021, 29, 959-967
https://doi.org/10.1123/japa.2020-0018

Human Kinetics
ORIGINAL RESEARCH

Effects of Resistance Training With Machines and Elastic Tubes on Functional Capacity and Muscle Strength in Community-Living Older Women: A Randomized Clinical Trial

Marisete P. Safons, Milene S.N. de Lima, Karina F.L. Gonçalves, Gerson A. de Souza Junior, Tito L.C. Barreto, Anderson José S. Oliveira, Alexandre L.A. Ribeiro, Clarissa C. dos Santos Couto Paz, Paulo Gentil, Martim Bottaro, and Wagner R. Martins

The aim of the present study is to compare the effects of 12 weeks of resistance training with machines and elastic tubes on functional capacity and muscular strength in older women aged 60 years or over. The participants were randomized into two groups: a machine group ($n = 23$) and an elastic group ($n = 20$). They performed 12 weeks of progressive resistance training, twice a week, with similar exercises. Outcomes were assessed at three time points: baseline, postintervention, and 8 weeks after the end of the training. A significant intragroup effect was demonstrated for both groups at postintervention on functional tests and muscle strength. For the functional reach test and elbow flexion strength (180°/s), only the machine group demonstrated significant intragroup differences. No differences were observed between groups for any outcome. At the 8-week follow-up, functional capacity outcome values were maintained. The muscle strength outcome values decreased to baseline scores, without differences between groups.

Keywords*:* aged, balance, detraining, hand strength

Older adults experience age-related declines in skeletal muscle strength and functional capacity (Baker et al., 2020). Neural and morphological factors, as well as their interaction, are responsible for age-related declines (Aagaard, Suetta, Caserotti, Magnusson, & Kjær, 2010). In addition, there is a strong relationship between a decrease in muscle strength and worsening physical performance and level of disability in older adults (Borde, Hortobágyi, & Granacher, 2015b). Engagements in exercise can slow the negative effects of aging, and in recent decades, guidelines and systematic reviews have been developed for exercise recommendations (Borde et al., 2015b; Di Lorito et al., 2020; Fiogbé, Carnavale, & Takahashi, 2019). Resistance training (RT) is a commonly used strategy for improving muscle strength and functional capacity in older adults (Kneffel, Murlasits, Reed, & Krieger, 2021).

According to the latest position of the American College of Sports Medicine on the progression of RT for older adults, an RT program performed with machines and free weights is recommended for older adult beginners (Chodzko-zajko et al., 2009). Recently, pneumatic machines have also been used as a device for RT, whereby the body mass represents the only inertia that must be overcome to perform the movement, supposedly reducing the risk of injury (Frost, Cronin, & Newton, 2010; Peltonen, Häkkinen, & Avela, 2013). The RT dose–response relationship to improve muscle strength and physical functioning in healthy older adults has recently been developed (Borde et al., 2015b; Kneffel et al., 2021). Resistance exercises are safe and considered effective to improve muscle force in healthy and functionally limited older adults (Fiogbé et al., 2019).

The RT programs, including variable resistance, such as elastic bands or elastic tubes, have gained popularity over the past few years. Elastic RT is a method that uses elastic devices as resistance and has been shown to promote an increase in muscle strength in older adults (Fritz et al., 2018; Souza et al., 2019). The use of elastic resistance in older populations is also supported by systematic reviews, which have demonstrated different positive effects on older adults, such as improvements in strength, flexibility, and balance (Martins et al., 2013; Yeun, 2017). The effects of elastic training compared with traditional isoinertial exercises have also been investigated by other systematic reviews, which have demonstrated similar effects on neuromuscular adaptations between devices (de Oliveira et al., 2016; Nilo dos Santos, Gentil, Lima de Araújo Ribeiro, Vieira, & Martins, 2018; Soria-Gila, Chirosa, Bautista, Baena, & Chirosa, 2015).

Although the effects of elastic training have been studied for many years, one of the most important limitations cited in many studies is the method for controlling training intensity since, unlike free weights or weight machines, elastic devices do not provide an objective value of strength. The main methods of controlling the intensity in such studies are the number of repetitions and rate of perceived exertion in the active muscles, as described by Colado et al. (2010, 2018) and Colado and Triplett (2008). More recently, different acute studies have been designed to demonstrate the muscle activity during strengthening exercises using free weights and elastic resistance, and the method proposed and used to standardize the loads in exercises with elastic bands was the multiple-repetition maximum (RM) test (Aboodarda, Page, & Behm, 2016; Andersen et al., 2016; Iversen, Mork, Vasseljen, Bergquist, & Fimland, 2017; Jakobsen, Sundstrup, Andersen, Aagaard, & Andersen, 2013; Saeterbakken, Andersen, Kolnes, & Fimland, 2014). The multiple-RM test can be performed based

Safons, de Lima, Gonçalves, de Souza Junior, Ribeiro, and Bottaro are with the Faculty of Physical Education, Campus Darcy Ribeiro, University of Brasília, Brasília, DF, Brazil. Barreto, Oliveira, dos Santos Couto Paz, and Martins are with the Faculty of Physical Therapy, Campus Ceilândia, University of Brasília, Brasília, DF, Brazil. Gentil is with the Faculty of Physical Education and Dance, Federal University of Goiás, Goiânia, GO, Brazil. Oliveira (oliveira.jsanderson@gmail.com) is corresponding author.

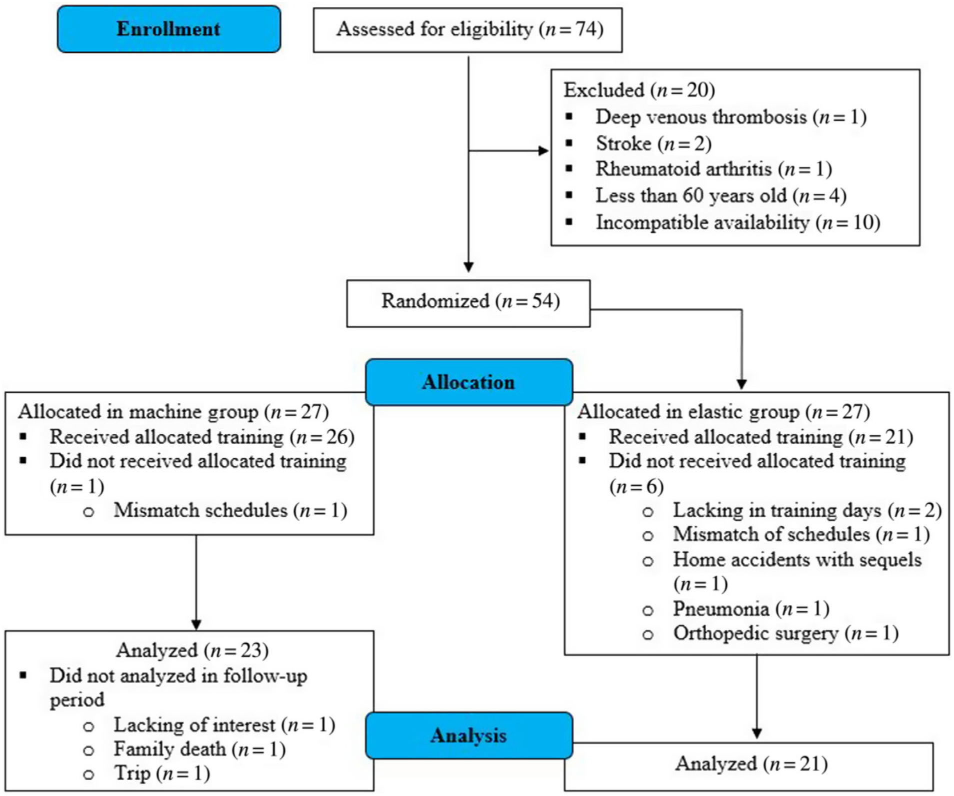

Figure 1 — Participants selection and study progress.

on goal repetitions, thereby eliminating computations or estimations. For example, a prescription of 6RM may be described as a strength training goal (American College of Sports Medicine, 2010; Baechle, Earle, & Wathen, 2000).

Considering that the multiple-RM test for elastic bands has been used and supported by many neuromuscular acute studies, its use in a longitudinal study should be a viable alternative for determining training loads. Thus, the aim of the present study is to compare the effects of two RT protocols on muscle strength and functional performance in community-living older women. Our hypothesis was that the elastic training program would demonstrate similar effects to machines by controlling the training loads using the multiple-RM test.

Methods

Study Design and Ethical Aspects

The study was approved by the Research Ethics Committee of the Faculty of Health Sciences of the University of Brasília, under protocol 081/11 and registered at the clinical trials database (www.clinicaltrials.gov) under number NCT 02253615. All individuals who agreed to participate in the study signed the informed consent form.

Participants

The study participants were recruited by nonprobabilistic sampling with the support of the coordination of care in Primary Health Care of Ceilândia (Distrito Federal, Brazil), which allowed the distribution of booklets and some lectures to be given at Primary Care Centers that present health programs for older people. Individuals interested in participating in the study contacted the researchers by phone, at which time a face-to-face interview was scheduled to provide further details of the project objectives and apply the eligibility criteria for participant selection.

The eligibility criteria of the present study were (a) subjects of at least 60 years of age, (b) residing in Distrito Federal (Brazil), and (c) presenting medical clearance to practice RT. The exclusion criteria were (a) chronic degenerative diseases (metabolic, cardiovascular, mental, vascular, and rheumatology); (b) locomotor surgeries in the previous 6 months; (c) the use of locomotion aid devices; (d) restriction in the range of motion in the limbs that would make it impossible to perform the movements in the exercises; (e) the use of prostheses or orthoses in upper or lower limbs; and (f) practice of RT within the previous 6 months. The researcher who determined if a subject was eligible for inclusion in the study was unaware of which group the participant would be allocated to (Figure 1).

Instruments

Functional capacity assessments. Four tests were used to evaluate functional capacity: (a) 30-s elbow flexion test (EFT)—to evaluate upper limb strength through the number of complete repetitions performed in this time period holding 2 kg (Rikli & Jones, 2008); (b) 30-s sit to stand test (SST)—to assess lower limb strength through the number of complete repetitions performed by volunteers in the determined time (Rikli & Jones, 1999; Safons & Pereira, 2007); (c) timed up and go test (TUG)—to evaluate functional mobility, the TUG was used as a practical and quick test as it does not require special equipment; and (d) functional reach test (FRT)—to evaluate functional balance, the FRT was used to verify the stability and balance limits with a dynamic measure during the displacement of the center of gravity within the support base. All procedures were carried out based on a published protocol (Rikli & Jones, 1999).

Muscle strength assessments. An isokinetic dynamometer (Byodex Medical System, Model IV, Shirley, NY) was used to assess the knee extensor and elbow flexor muscle strength of the dominant side. To define the dominant side, the subjects were asked, "with which leg would you kick a ball?" and "with which hand would you sign a document?" (Martins, Santos, Diniz, Lima, & Bottaro, 2015).

The movements analyzed were (a) concentric elbow flexion peak torque at 60°/s and 180°/s and (b) concentric knee extension peak torque at 60°/s and 180°/s. The volume (two sets of four repetitions at each speed) and rest interval (1 min) between sets of the isokinetic protocol for two speeds were based on a previous study (Bottaro, Russo, & Jaco De Oliveira, 2005; Martins et al., 2015). The speed (60°/s or 180°/s) and limb (elbow or knee) order for all participant assessments were decided through simple randomization using coin tossing. The rest interval between speeds (60°/s and 180°/s) was set at 2 min and between limbs (elbow and knee) as the time necessary to adapt the equipment to the next corporal segment. Two examples of the randomized protocol are as follows: (1) an elbow protocol—(a) warm-up series with 10 repetitions at 300°/s, (b) two sets of four repetitions at 60°/s, and (c) two sets of four repetitions at 180°/s; and (2) a knee protocol—(a) warm-up series with 10 repetitions at 300°/s, (b) two sets of four repetitions at 60°/s, and (c) two sets of four repetitions at 180°/s.

In order to minimize the movement artifacts, the subjects were asked to sit on the dynamometer chair in a comfortable position, and seat belts were used to stabilize the trunk, hips, and thighs. To align the knee and elbow rotation axis with the dynamometer rotation axis, the lateral epicondyle of the femur and humerus were set as the bone references. The position allowed free and comfortable knee and elbow flexion and extension, with a range of motion set at 80° and 140° measured from the maximum knee and elbow flexion, respectively. Chair height and position, backrest adjustment, dynamometer position, and resistance arm adjustment were recorded to standardize each subject's individual position. Correction for gravity was performed by measuring the torque exerted by the resistance arm and the subject's leg at full knee and elbow extension. Verbal stimuli and Biodex visual feedback were used to promote maximum effort. The verbal stimulus was standardized and given by the same investigator. The highest peak torque at each speed (pre- and postintervention and follow-up) was recorded for statistical analysis.

Training Devices

The machine group (MG) trained with pneumatic equipment (EN-Dynamic, Enraf Nonius, Rotterdam, The Netherlands). The elastic group (EG) trained with elastic tubes, 50 cm in length (ELASTOS, Rio de Janeiro, RJ, Brazil). The tubes are arranged on a color-based scale with seven levels of resistance, represented by the colors: yellow, red, green, blue, black, purple, and gold (weakest to strongest). Intensity is adjusted by changing from the current tube to the next color presented on the scale (e.g., from a green to a blue tube). When a subject reached the level of resistance gold (strongest), another elastic tube was added while always respecting the progression scale, that is, gold plus yellow. As variations in tube length (percentage of elongation) can affect exercise intensity, to control tube elongation, an adhesive tape was placed on the ground (reference) to standardize the maximum elongation in each exercise.

Multiple-RM Test

The control of training intensity in both groups was performed using the multiple-RM test based on repetitions range. For example, if a professional decides that a subject should perform 10 repetitions of the bench press exercise in the training, the multiple-RM testing protocol should include the subject performing the exercise with a load that will result in 10 repetitions, that is, 10RM. The multiple-RM test was performed after a global muscle warm-up. The initial load was proposed by the examiner. After each attempt to achieve the maximal target repetitions, the participant was allowed a 5-min rest, and the test was interrupted when the volunteer failed to achieve the complete goal repetition. At that time, the final load lifted was defined as the maximum load (Baechle et al., 2000) for machine equipment. For elastic bands, as it is impossible to determine the load, the number and color of elastics used at the end of the test were registered.

Procedures

The assessments at baseline, 12-week postintervention, and after 8-week follow-up were performed in the morning and in the same order, in the following sequence: Day 1—muscle strength: isokinetic elbow or knee measurements (simple randomization); and Day 2—functional capacity measurements: FRT, TUG, EFT, and SST (in this order). To categorize the sample, body mass and height measurements were performed only at baseline. After 12 weeks, postintervention tests were performed by the same examiners 48 hr after the final training session. The examiners were not blinded to the group. As all outcomes were evaluated using objective measurements and considering that the examiners have wide experience of the tests and perform the procedures in a standardized manner, a low risk of bias of outcome assessment was incorporated.

The intervention was performed for 12 weeks, twice a week on alternate days, with each session lasting 60 min. The participants were familiarized with the exercises for 2 weeks prior to training by performing two sets of 15–20 repetitions of the prescribed exercises, with a 1-min rest interval between sets, and at low intensity, measured by the rate of perceived exertion (OMNI-Resistance Exercise Scale:1–4 in scale; Colado & Triplett, 2008; Martins et al., 2015a). After this period, 12RM tests were performed for each exercise to determine the load for each participant to begin training. The training program was divided into three mesocycles, composed of 4 weeks each. The RT progressed with load increments and a reduction in the number of repetitions performed, according to Table 1. For the MG, the load increment was performed directly on the machine's display, and for the EG, the increment occurred through the combination of elastic tubes using specific numbers and colors.

The exercise program was composed of nine exercises: four for the upper limbs (bench press, high pull, triceps, and row) and five for the lower limbs (knee flexion, knee extension, hip abduction [two exercises], and hip extension). The exercises performed were structured by adapting previous studies (Colado et al., 2010; Colado & Triplett, 2008; Martins et al., 2015b) and following the recommendations of the American College of Sports Medicine statement (American College of Sports Medicine et al., 2009). All exercises were carried out at the pace of 4 s for each repetition

Table 1 Description of Training Program Mesocycles, Volume, and Rest Period Length Assignments

Mesocycle	Week	Sets	Maximal repetitions	Rest period length (min)
I	1–4	3	12	1
II	5–8	3	10	1–1.5
III	9–12	3	08	2

Table 2 Demographic Characteristics of Participants

Characteristics	MG ($n = 23$) Mean ± *SD*	EG ($n = 21$) Mean ± *SD*
Age (years)	67.5 ± 5.18	66.1 ± 4.72
Height (cm)	151 ± 6.5	154 ± 7.3
Body mass (kg)	67.02 ± 11.24	68.44 ± 10.14
BMI (kg/m^2)	29.35 ± 4.42	28.71 ± 3.48

Note. MG = machine group; EG = elastic group; BMI = body mass index.

(eccentric phase: 2 s and concentric phase: 2 s; Colado et al., 2010). All upper limb exercises were performed standing by the EG and sitting by the MG. Regarding the lower limbs, in the MG, the abductor chair exercise was performed seated, and the EG performed the hip abduction exercise in the standing position and in sequence through lateral gait dislocation with the elastic device attached at the ankle level. As the tube length variations (percentage of elongation) can affect exercise intensity, an adhesive tape was placed on the ground (reference) to demonstrate the maximum elongation for all exercises. The exercise was then standardized and performed at 150% of tube elongation.

Training was conducted in the Therapeutic Gymnasium of the undergraduate course in Physical Therapy at the University of Brasilia (Brasília, Brazil). The participants were instructed not to perform any other type of exercise during the training period. The researchers informed the participants of possible adverse effects, and all training sessions were supervised by both a physiotherapist and a physical education teacher (Steele et al., 2017).

Statistical Analysis

The sample size was calculated considering: (a) two-way analysis of variance (ANOVA, repeated measures, within–between interaction); (b) two groups; (c) Type I error = 5%; (d) Type II error = 20%; (e) the power of the statistical test = 80%; and (f) effect size (ES) = 0.20. With these parameters, G*Power software (version 3.1.9.2; Düsseldorf, Germany) calculated a total sample size of 52 individuals (26 per group).

Mean and *SD* were used for descriptive statistics. The Shapiro–Wilk test was used to test data normality and Bartlett's test for homoscedasticity. Considering these assumptions, every dependent variable was analyzed using 2 × 2 mixed-model (Group [TG and CG] × Time [pre and post]) ANOVA, utilizing the Bonferroni post hoc method when a statistically significant difference was found. To fulfill the condition of sphericity of the data, Greenhouse–Geisser correction analysis was used. Data were analyzed using Prism 6 software (GraphPad Software, San Diego, CA), and a significance level of $p \leq .05$ was adopted for all variables.

Cohen's *d* coefficient (*d*) intragroup ESs were calculated as follows: ES = (preintervention − postintervention score)/preintervention *SD*. An ES for untrained individuals <0.5 was considered as trivial, 0.50–1.25 small, >1.25–1.9 moderate, and ≥2.0 large (Rhea, 2004). This scale is a specific approach for determining the magnitude of ES in strength training research. We adopted the untrained category for analysis, considering participants who had not been consistently training for 1 year (Rhea, 2004).

Adverse Events

There were no adverse events associated with training program participation. In addition, progression was well tolerated by all participants.

Results

Of 74 subjects who expressed interest, 10 (13.5%) were excluded due to deep venous thrombosis ($n = 1$), RT practitioner ($n = 1$), heart failure ($n = 1$), stroke ($n = 2$), rheumatoid arthritis ($n = 1$), and aged less than 60 years ($n = 4$). Another 10 subjects (13.5%) withdrew due to time incompatibility and study location. Thus, 54 older women were recruited who met the eligibility criteria and were randomized by simple randomization to one of two groups, using a list of random numbers generated by a computer. To conceal the allocation, sequentially numbered, opaque, sealed envelopes were used. This process was performed by a person who did not know the study design.

During the RT period, of the 54 participants, six volunteers (11.1%) from the EG did not complete the training protocol because of low attendance ($n = 2$), mismatch of schedules ($n = 1$), home accidents with sequels ($n = 1$), pneumonia ($n = 1$), and orthopedic surgery ($n = 1$). Only one person (1.8%) was excluded from the MG due to a mismatch of schedules. Therefore, the RT training period finished with 47 volunteers (MG = 26 and EG = 21). To be included in the final analyses, participants were required to attend ≥80% of all training sessions (≥19 of 24 sessions; Gentil & Bottaro, 2013). At the 8-week follow-up, one person from the EG (1.8%) was excluded due to gallbladder extraction surgery, and three (5.5%) were excluded from the MG due to lack of interest ($n = 1$), death of a family member ($n = 1$), and going on a trip ($n = 1$). Finally, the sample of this study was composed of 43 older women (MG, $n = 23$; EG, $n = 20$).

The demographic characteristics of participants are presented in Table 2. The ANOVA demonstrated that there were no statistical differences between groups at baseline for age, height, body mass, or any other outcome investigated.

After 12 weeks of RT, the ANOVA showed a statistically significant time interaction in both groups for functional capacity and muscle strength, without statistically significant group by time interactions. After a detraining period of 8 weeks, the EG presented similar values to those at the posttraining assessment. In contrast, overall muscle strength decreased after the detraining period when compared with the posttraining assessment. There were no significant differences between the groups in functional capacity and muscle strength after the detraining period. The data with respect to functional capacity are presented in Table 3 and muscle strength in Table 4.

Regarding functional capacity, the MG and EG demonstrated improvements in the TUG (MG, 14.6%, ES = 1.22, $p < .001$; EG, 15.1%, ES = 1.00, $p < .001$), EFT (MG, 31.8%, ES = 3.29, $p < .001$; EG, 37.5%, ES = 2.54, $p < .001$), and SST performances (MG, 23.6%, ES = 2.11, $p < .001$; EG, 30.8%, ES = 2.31, $p < .001$). In the FRT, only the MG presented increased values (4.5%, ES = 0.44, $p = .038$). Considering the magnitude of the treatment effect, "large" effects were obtained in the EFT and SST for both groups.

Table 3 Changes on Functional Capacity After 12-Week Training and 8-Week Follow-Up Assessment

		Mean ± SD		Effect			Follow-up vs. POST assessments		
Variables	Group	PRE	POST	ES (within group)	Time	Group × Time	Follow-up Mean ± SD	Time	Group × Time
TUG (s)	MG	6.36 ± 0.76	5.43 ± 0.56	1.22 (small)	<0.001*	0.901	5.55 ± 0.58	0.437	0.359
	EG	6.42 ± 0.97	5.45 ± 0.60	1.00 (small)	<0.001*		5.33 ± 0.74	0.428	
FRT (cm)	MG	36.15 ± 3.90	37.88 ± 3.24	0.44 (trivial)	0.038*	0.437	37.88 ± 3.31	1.000	0.455
	EG	37.96 ± 4.20	38.93 ± 4.16	0.23 (trivial)	0.297		38.71 ± 2.67	0.874	
EFT (rep)	MG	16.88 ± 2.39	24.76 ± 3.77	3.29 (large)	<0.001*	0.133	26.24 ± 5.32	0.342	0.249
	EG	16.79 ± 3.96	26.86 ± 3.74	2.54 (large)	<0.001*		24.21 ± 3.96	0.001*	
SST (rep)	MG	12.71 ± 1.86	16.65 ± 2.12	2.11 (large)	<0.001*	0.146	17.24 ± 2.25	0.154	0.104
	EG	12.5 ± 2.41	18.07 ± 3.17	2.31 (large)	<0.001*		19.07 ± 3.77	0.095	

Note. MG = machine group; EG = elastic group; PRE = preintervention evaluation; POST = postintervention evaluation; TUG = timed up and go; FRT = functional reach test; EFT = elbow flexion test of 30 s; SST = sit to stand test of 30 s; ES = effect size; rep = repetition.
*$p < .05$.

Table 4 Changes on Muscle Strength After 12-Week Training and 8-Week Follow-Up Assessment

		Mean ± SD		Effect			Follow-up vs. POST assessments		
Variables	Group	PRE	POST	ES (within group)	Time	Group × Time	Follow up Mean ± SD	Time	Group × Time
EPT 60°/s (N·m)	MG	22.35 ± 5.40	26.04 ± 4.52	0.68 (trivial)	0.003*	0.129	24.48 ± 6.60	0.113	0.568
	EG	25.97 ± 8.00	29.13 ± 6.47	0.39 (trivial)	0.050*		25.69 ± 4.64	0.004*	
EPT 180°/s (N·m)	MG	19.82 ± 4.49	23.65 ± 4.07	0.85 (trivial)	0.004*	0.306	20.81 ± 4.83	0.003*	0.475
	EG	23.51 ± 8.35	25.48 ± 5.71	0.23 (trivial)	0.297		22.05 ± 4.67	<0.001*	
KPT 60°/s (N·m)	MG	85.36 ± 19.37	97.97 ± 18.07	0.65 (trivial)	<0.001*	0.463	91.74 ± 19.33	0.002*	0.584
	EG	92.85 ± 14.64	102.7 ± 17.01	0.67 (small)	0.002*		95.35 ± 16.40	<0.001*	
KPT 180°/s (N·m)	MG	57.07 ± 12.43	65.41 ± 14.01	0.67 (small)	<0.001*	0.651	60.49 ± 14.29	<0.001*	0.553
	EG	60.85 ± 9.51	67.50 ± 10.85	0.69 (small)	0.001*		63.31 ± 11.29	0.001*	

Note. MG = machine group; EG = elastic group; PRE = preintervention evaluation; POST = postintervention evaluation; EPT = elbow peak torque; KPT = knee peak torque; ES = effect size.
*$p < .05$.

For the TUG, the result was categorized as "small" ES and for the FRT as "trivial" ES.

Regarding muscle strength, both the MG and EG demonstrated improved knee peak torque at 60°/s (MG, 12.9%, ES = 0.65, $p < .001$; EG, 9.6%, ES = 0.67, $p = .002$) and at 180°/s (MG, +12.7%, ES = 0.67, $p < .001$; EG, 9.8%, ES = 0.69, $p = .001$), and elbow peak torque (EPT) at 60°/s (MG, 14.2%, ES = 0.69, $p = .003$; EG, 10.8%, ES = 0.39, $p = .05$). Only the MG presented improvement in EPT at 180°/s (16.2%, ES = 0.85, $p = .004$). Considering the magnitude of the treatment effect, in contrast with functional capacity, the strength values presented only "trivial" and "small" ES.

After the 8-week period of detraining, for functional outcomes, the ANOVA showed that only the EFT (–9.8%, $p = .001$) presented a significant decrease in values compared with the 12-week post-training assessment. The other functional variables demonstrated the same values as those obtained after 12 weeks of training for both groups: (a) TUG (MG, +2.1%, $p = .437$; EG, –2.2%, $p = .428$); (b) FRT (MG, 0%, $p = 1.000$; EG, –0.5%, $p = .874$); and (c) SST (MG, +3.4%, $p = .154$; EG, +5.2%, $p = .095$).

With respect to muscle strength, only the EPT at 60°/s in the MG showed the same values obtained in the 12-week posttraining assessment (–6%, $p = .113$). For all other strength variables, both groups presented significantly reduced values: (a) knee peak torque at 180°/s (MG, −12%, $p = .003$; EG, −13.4%, $p < .001$); (b) knee peak torque at 60°/s (MG, –6.3%, $p = .002$; EG, –7.1%, $p < .001$); and (c) EPT at 180°/s (MG, –7.5%, $p < .001$; EG, –6.2%, $p = .001$).

Discussion

The present study compared the effectiveness of 12 weeks of RT with machines versus elastics tubes on functional capacity and muscular strength in older women. The results showed that the RT programs performed significantly improved functional capacity and muscular strength in older women, without significant differences between groups and with a "larger" magnitude of treatment effect for two functional tests: the EFT and SST, for both groups. The functional outcome values after 8 weeks of follow-up were statistically the same as obtained after the 12-week RT for both groups and without between-group differences. For muscle strength, the 8-week follow-up values significantly decreased when compared with the 12-week posttraining assessments, demonstrating decreases in muscle strength. The overall similar effects between groups demonstrate that a simple device such as elastic tubes (easy to use and low-cost equipment) could lead to similar effects when compared with traditional RT performed with machines. Thus, when machine exercises cannot be employed, elastic tube devices are a real alternative for performing RT. Although machines are commonly used devices among adults, many older adults may not have easy access to this equipment due to lack of facilities or financial resources.

With respect to dose–response relationships, the assumptions of our two RT protocols were in accordance with previous recommendations for training in older adults (Silva, Oliveira, Fleck, Leon, & Farinatti, 2014) regarding frequency (Borde, Hortobágyi, & Granacher, 2015a), intensity, and volume (American College of Sports Medicine et al., 2009). Considering these issues together, our study confirms the hypothesis that an elastic training program with adequate control of intensity can produce similar effects to machine exercises in a longitudinal study. Thus, the use of elastic tubes with the multiple-RM should be considered by health professionals. Moreover, from a practical perspective, compared with conventional RT (weight machines and free weights), elastic tubes present more accessibility, high portability, and very low cost, which can reduce some barriers to the adherence to traditional RT programs.

Recently, the study of Irversen et al. (2017) showed that elastic resistance exercises can also present similar muscle activation compared with free-weight exercises in multiple-joint resistance exercises, adding support to the use of elastics due to their similarity to one of the most commonly used devices in gyms for lower limb muscle strengthening and hypertrophy. Historically, the first randomized controlled trial to explore the comparative effects on body mass, muscle strength, and functional performance between machines and elastic tubes was performed by Colado and Triplett (2008), in which improvements in functional performance (28% increase measured by squat test and 30% increase measured by knee push-up test) were demonstrated in sedentary middle-aged postmenopausal women (mean age = 54.14 [±2.87] years), without significance between devices. The program was performed for 10 weeks, twice a week, with six exercises, controlled by monitoring the target number of repetitions and rating of perceived exertion in active muscles. In another study with postmenopausal women (mean age = 54.14 [±0.63] years), Colado et al. (2012) reported significant increases of 30.62%, 16.27%, and 27.4% in the number of push-ups, crunches, and squats, respectively, without difference between devices (elastic and machines). Even considering the differences between populations and tests employed, for functional outcomes, our results were similar when compared with the Colado et al.'s study, as within-group (EG) results of 15.1%, 37.5%, and 30.8% were observed for the TUG, EFT, and SST, respectively.

With respect to comparisons between elastic tubes and machines in older populations, few studies have been published. The first, by Webber and Porter (2010), showed in a particular context that high-velocity/low-load elastic band training improved dorsiflexion and plantar flexion strength (peak torque at 30°/s and peak power at 90°/s) after 12 weeks of RT, which were not statistically different when compared with weight training. The authors suggest that elastic bands could be incorporated in resistance programs designed for older adults with mobility limitations. The change in dorsiflexion peak torque after training was 25% for the weight group and 16% for the elastic band group, and the change in plantar flexion peak torque after training was 17% for the weight group and 11% for the elastic band group. More recently, in the field of dynamometry for muscle strength (isometric digital dynamometer; Force Gauge®, model FG-100kg), de Lima et al. (2018) demonstrated that changes in muscle force from baseline were observed in both the EG and conventional training group for all muscles trained (16–44% for EG and 25–46% for conventional training group). The observed ES was large for both the EG (0.86–1.62) and conventional training group (0.94–1.29). The results of the present study demonstrated changes in isokinetic knee assessments of 12.9% and 12.7% (MG at 60°/s and 180°/s, respectively), and 9.6% and 9.8% (EG at 60°/s and 180°/s, respectively). For isokinetic elbow assessments, our study demonstrated changes of 14.2% and 16.2% (MG at 60°/s and 180°/s, respectively), and 10.6% and 1.1% (EG at 60°/s and 180°/s, respectively). In general, these results presented lower changes than de Lima et al. (2018) for muscle strength, and this difference could be attributed to the methods of strength assessment used (isometric vs. isokinetic), which are very distinct regarding the type of contraction. The study of de Lima et al. (2018) also demonstrated significant improvements from baseline in the walked distance in both the EG (4.3%, $p < .05$) and conventional training group (8.1%, $p < .05$; Cohen's $d = 0.99$ for both). All improvements regarding functional outcomes in the present study presented superior scores (15.1% = TUG, 37.5% = EFT, and 30.8% = SST) when compared with the study of de Lima et al. (2018).

Another question to be highlighted in the results of the present study is that although statistical significance was observed for functional capacity and muscle strength, the magnitude of treatment effect demonstrated that a "larger" ES was obtained for two functional tests: EFT and SST for both groups. In general, systematic reviews describing the effects of progressive RT in older adults provide evidence for improving physical functioning (De Labra, Guimaraes-Pinheiro, Maseda, Lorenzo, & Millán-Calenti, 2015; Guizelini, de Aguiar, Denadai, Caputo, & Greco, 2018; Latham, Anderson, Bennett, & Stretton, 2003; Liu & Latham, 2011), and the only systematic review to explore the magnitude of treatment effects (ES) between strength and functional gains showed similar improvements: (a) moderate to large effects for getting out of a chair (11 trials, 384 participants, standardized mean difference [SMD] = 0.94) and (b) a large effect on muscle strength (73 trials, 3,059 participants, SMD = 0.84; Guizelini et al., 2018). With respect to ES computation, we employed a strict analysis of the magnitude of treatment effect specifically for RT studies (Rhea, 2004), and not three (conventional) but four categories (more rigorous) were used to classify the effects.

The superior ES results in functional outcomes in the present study were probably responsible for the adaptions being maintained in the 8-week follow-up assessment. In contrast, muscle strength at the 8-week follow-up decreased to values similar to those obtained at the baseline assessments in both groups. Corroborating with these findings, the study of Correa et al. (2013) showed that 12 weeks of detraining can reduce both strength and muscle mass in older people, returning to baseline values. The study of Padilha et al. (2015) evaluated older volunteers after 12 weeks of detraining and found that they presented less muscle strength when compared with the end of the intervention performed with machines and free weights, while improvements in muscle strength remained higher than preintervention values only in the upper limbs, but returned to preintervention values in the lower limbs.

Trivial ES in functional outcomes, for both groups, was shown for the FRT (a clinical measure of balance), and only the MG presented a statistical within-group significance. Concerning this topic, there is weak evidence that some types of exercises are moderately effective, immediately postintervention, in improving clinical balance outcomes in older people (Howe, Rochester, Jackson, Banks, & Blair, 2007). Motalebi and Loke (2014) assessed the effects of 12 weeks of progressive resistance tube training on lower limb muscle strength (five times SST), dynamic balance (FRT), and functional mobility (TUG) in older people (noncontrolled study). The results revealed significant increases in lower limb strength (30.3%), dynamic balance (29.6%), and functional mobility (27.1%). Sousa and Sampaio (2005) also demonstrated significant differences in the FRT, with a 13% increase after a progressive strength training program in healthy older subjects. Similarly, Granacher, Gruber, and Gollhofer (2009) obtained a positive effect (11%) in the FRT after 13 weeks of high-intensity RT. Finally, a systematic review with meta-analysis that included 66 articles (3,783 participants) reported that it is not clear whether RT presents significant benefits in the balance of older adults, as some authors found improvement in balance after the training while others reported that the training did not promote a statistically significant improvement in balance (Latham et al., 2003).

The present study contains two main limitations: (a) as elastic equipment does not provide the loads through metric scales, it was not possible to compare the intensity (workloads) between the RT programs; and (b) the absence of control of nutrition and physical activity during the study. However, the participants were strongly advised to maintain their nutritional and physical activity habits.

Conclusions

The evidence from this study suggests that RT using elastic tubes with the control of training intensity through the multiple-RM test promotes similar effects on functional capacity and muscle strength in older adults when compared with conventional RT with machines after a 12-week training period. The effects observed in functional outcomes were maintained at the 8-week follow-up assessment; however, a significant decrease in muscle strength was observed for both groups at the 8-week follow-up.

Acknowledgment

To the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for financial support to the Lima's Master Degree. The authors have no conflicts of interest to disclose.

References

Aagaard, P., Suetta, C., Caserotti, P., Magnusson, S.P., & Kjær, M. (2010). Role of the nervous system in sarcopenia and muscle atrophy with aging: Strength training as a countermeasure. *Scandinavian Journal of Medicine and Science in Sports, 20,* 49–64.

Aboodarda, S.J., Page, P.A., & Behm, D.G. (2016). Muscle activation comparisons between elastic and isoinertial resistance: A meta-analysis. *Clinical Biomechanics, 39,* 52–61

American College of Sports Medicine. (2010). ACSM guidelines for exercise testing and prescription. In *Medicine & Science in Sports & Exercise* (8th ed., Vol. 37). https://doi.org/9781609136055

American College of Sports Medicine, Chodzko-Zajko, W.J., Proctor, D.N., Fiatarone Singh, M.A., Minson, C.T., Nigg, C.R., . . . Skinner, J.S. (2009). American College of Sports Medicine position stand. Exercise and physical activity for older adults. *Medicine & Science in Sports & Exercise, 41*(7), 1510–30. doi:10.1249/MSS.0b013e3181a0c95c

Andersen, V., Fimland, M.S., Kolnes, M.K., Jensen, S., Laume, M., & Saeterbakken, A.H. (2016). Electromyographic comparison of squats using constant or variable resistance. *Journal of Strength and Conditioning Research, 30*. doi:10.1519/JSC.0000000000001451

Baechle, T., Earle, R., & Wathen, D. (2000). *Essentials of strength and conditioning*. Champaign, IL: Human Kinetics.

Baker, B.S., Weitzel, K.J., Royse, L.A., Miller, K., Guess, T.M., Ball, S.D., & Duren, D.L. (2020). Efficacy of an 8-week resistance training program in older adults: A randomized controlled trial. *Journal of Aging and Physical Activity, 29*(1), 121–129. doi:10.1123/japa.2020-0078

Borde, R., Hortobágyi, T., & Granacher, U. (2015a). Dose-response relationships of resistance training in healthy old adults: A systematic review and meta-analysis. *Sports Medicine, 45*(12), 1693–1720. doi:10.1007/s40279-015-0385-9

Borde, R., Hortobágyi, T., & Granacher, U. (2015b). Dose–response relationships of resistance training in healthy old adults: A systematic review and meta-analysis. *Sports Medicine, 45*(12), 1693–1720. doi:10.1007/s40279-015-0385-9

Bottaro, M., Russo, A., & Jacó De Oliveira, R. (2005). The effects of rest interval on quadriceps torque during an isokinetic testing protocol in elderly. *Journal of Sports Science and Medicine, 4*(3), 285–290. PubMed ID: 24453533

Chodzko-Zajko, W.J., Proctor, D.N., Fiatarone Singh, M.A., Minson, C.T., Nigg, C.R., Salem, G.J., & Skinner, J.S. (2009). Exercise and physical activity for older adults. *Medicine & Science in Sports & Exercise,*(7), 1510–1530. doi:10.1249/MSS.0b013e3181a0c95c

Colado, J.C., Garcia-Masso, X., Pellicer, M., Alakhdar, Y., Benavent, J., & Cabeza-Ruiz, R. (2010). A comparison of elastic tubing and isotonic resistance exercises. *International Journal of Sports Medicine, 31*(11), 810–817. PubMed ID: 20703977 doi:10.1055/s-0030-1262808

Colado, J.C., Garcia-Masso, X., Rogers, M.E., Tella, V., Benavent, J., & Dantas, E.H. (2012). Effects of aquatic and dry land resistance training devices on body composition and physical capacity in postmenopausal women. *Journal of Human Kinetics, 32,* 185–195. doi:10.2478/v10078-012-0035-3

Colado, J.C., Pedrosa, F.M., Juesas, A., Gargallo, P., Carrasco, J.J., Flandez, J., . . . Naclerio, F. (2018). Concurrent validation of the OMNI-Resistance Exercise Scale of perceived exertion with elastic bands in the elderly. *Experimental Gerontology, 103,* 11–16.

Colado, J.C., & Triplett, N.T. (2008). Effects of a short-term resistance program using elastic bands versus weight machines for sedentary middle-aged women. *Journal of Strength and Conditioning Research/National Strength & Conditioning Association, 22*(5), 1441–1448. doi:10.1519/JSC.0b013e31817ae67a

Correa, C.S., Baroni, B.M., Radaelli, R., Lanferdini, F.J., Dos Santos Cunha, G., Reischak-Oliveira, Á., . . . Pinto, R.S. (2013). Effects of strength training and detraining on knee extensor strength, muscle volume and muscle quality in elderly women. *Age, 35*(5), 1899–1904. PubMed ID: 23014987 doi:10.1007/s11357-012-9478-7

De Labra, C., Guimaraes-Pinheiro, C., Maseda, A., Lorenzo, T., & Millán-Calenti, J.C. (2015). Effects of physical exercise interventions in frail older adults: A systematic review of randomized controlled trials physical functioning, physical health and activity. *BMC Geriatrics, 15,* 154. doi:10.1186/s12877-015-0155-4

de Lima, F.F., Camillo, C.A., Gobbo, L.A., Trevisan, I.B., do Nascimento, W.B.B.M., Silva, B.S.de A., . . . Ramos, E.M.C. (2018). Resistance training using low cost elastic tubing is equally effective to conventional weight machines in middle-aged to older healthy adults: A quasi-randomized controlled clinical trial. *Journal of Sports Science and Medicine, 17,* 153–160.

de Oliveira, P.A., Blasczyk, J.C., Lagoa, K.F., Soares, M., de Oliveira, R.J., Filho, P.J.B.G., . . . Martins, W.R. (2016). Effects of elastic resistance training on muscle strength and functional performance in healthy adults: A systematic review and meta-analysis. *Journal of Physical Activity and Health,14*(4), 317–327. doi:10.1123/jpah.2016-0415.

Di Lorito, C., Long, A., Byrne, A., Harwood, R.H., Gladman, J.R.F., Schneider, S., … van der Wardt, V. (2020). Exercise interventions for older adults: A systematic review of meta-analyses. *Journal of Sport and Health Science, 10*(1), 29–47. doi:10.1016/j.jshs.2020.06.003

Fiogbé, E., Carnavale, B.F., & Takahashi, A.C.de M. (2019). Exercise training in older adults, what effects on muscle force control? A systematic review of randomized clinical trials. *Archives of Gerontology and Geriatrics, 83,* 138–150. PubMed ID: 31026723 doi:10.1016/j.archger.2019.04.005

Fritz, N.B., Juesas, Á., Gargallo, P., Calatayud, J., Fernández-Garrido, J., Rogers, M.E., & Colado, J.C. (2018). Positive effects of a short-term intense elastic resistance training program on body composition and physical functioning in overweight older women. *Biological Research for Nursing, 20,* 321–334. doi:10.1177/1099800418757676

Frost, D.M., Cronin, J., & Newton, R.U. (2010). A biomechanical evaluation of resistance fundamental concepts for training and sports performance. *Sports Medicine, 40*(4), 303–326. PubMed ID: 20364875 doi:10.2165/11319420-000000000-00000

Gentil, P., & Bottaro, M. (2013). Effects of training attendance on muscle strength of young men after 11 weeks of resistance training. *Asian Journal of Sports Medicine, 4,* 101–106. doi:10.5812/asjsm.34489

Granacher, U., Gruber, M., & Gollhofer, A. (2009). Resistance training and neuromuscular performance in seniors. *International Journal of Sports Medicine, 30*(9), 652–657. PubMed ID: 19569007 doi:10.1055/s-0029-1224178

Guizelini, P.C., de Aguiar, R.A., Denadai, B.S., Caputo, F., & Greco, C.C. (2018). Effect of resistance training on muscle strength and rate of force development in healthy older adults: A systematic review and meta-analysis. *Experimental Gerontology, 102*, 51–58. doi:10.1016/j.exger.2017.11.020

Howe, T.E., Rochester, L., Jackson, A., Banks, P.M.H., & Blair, V.A. (2007). Exercise for improving balance in older people. *Cochrane Database of Systematic Reviews, 9,* CD004963. doi:10.1002/14651858.CD004963

Iversen, V.M., Mork, P.J., Vasseljen, O., Bergquist, R., & Fimland, M.S. (2017). Multiple-joint exercises using elastic resistance bands vs. conventional resistance-training equipment: A cross-over study. *European Journal of Sport Science, 17,* 1–10. doi:10.1080/17461391.2017.1337229

Jakobsen, M.D., Sundstrup, E., Andersen, C.H., Aagaard, P., & Andersen, L.L. (2013). Muscle activity during leg strengthening exercise using free weights and elastic resistance: Effects of ballistic vs controlled contractions. *Human Movement Science, 32,* 65–78. doi:10.1016/j.humov.2012.07.002

Kneffel, Z., Murlasits, Z., Reed, J., & Krieger, J. (2021). A meta-regression of the effects of resistance training frequency on muscular strength and hypertrophy in adults over 60 years of age. *Journal of Sports Sciences, 39*(3), 351–358. doi:10.1080/02640414.2020.1822595

Latham, N., Anderson, C., Bennett, D., & Stretton, C. (2003). Progressive resistance strength training for physical disability in older people. *Cochrane Database System Revision, 89*(2), 1–144. PubMed ID: 12804434 doi:10.1002/14651858.CD002759

Liu, C.J., & Latham, N. (2011). Can progressive resistance strength training reduce physical disability in older adults? A meta-analysis study. *Disability and Rehabilitation, 33,* 87–97. doi:10.3109/09638288.2010.487145

Martins, W.R., de Oliveira, R.J., Carvalho, R.S., de Oliveira Damasceno, V., da Silva, V.Z.M., & Silva, M.S. (2013). Elastic resistance training to increase muscle strength in elderly: A systematic review with meta-analysis. *Archives of Gerontology and Geriatrics, 57,* 8–15. doi:10.1016/j.archger.2013.03.002

Martins, W.R., Safons, M.P., Bottaro, M., Blasczyk, J.C., Diniz, L.R., Fonseca, R.M.C., … de Oliveira, R.J. (2015a). Effects of short term elastic resistance training on muscle mass and strength in untrained older adults: A randomized clinical trial. *BMC Geriatrics, 15*(1), 99. doi:10.1186/s12877-015-0101-5

Martins, W.R., Safons, M.P., Bottaro, M., Blasczyk, J.C., Diniz, L.R., Fonseca, R.M.C., … De Oliveira, R.J. (2015b). Effects of short term elastic resistance training on muscle mass and strength in untrained older adults: A randomized clinical trial. *BMC Geriatrics, 15,* 99.

Martins, W.R., Santos, T., Diniz, L.R., Lima, R.M., & Bottaro, M. (2015). Avaliação da força de extensão do joelho em indivíduos idosos: confiabilidade de um protocolo de teste isocinético [Assessment of knee extension strength in older adults: Reliability of an isokinetic testing protocol]. *Brazilian Journal of Physical Activity and Health, 20*(4), 435–444. doi:10.12820/rbafs.v.20n4p435

Motalebi, S.A., & Loke, S.C. (2014). Efficacy of progressive resistance tube training in community dwelling older adults: A pilot study. *International Journal of Gerontology, 8*(4), 213–218. doi:10.1016/j.ijge.2013.12.007

Nilo dos Santos, W.D., Gentil, P., Lima de Araújo Ribeiro, A., Vieira, C.A., & Martins, W.R. (2018). Effects of variable resistance training on maximal strength. *Journal of Strength and Conditioning Research, 32*(11), e52–e55. PubMed ID: 30540285 doi:10.1519/JSC.0000000000002836

Padilha, C.S., Ribeiro, A.S., Fleck, S.J., Nascimento, M.A., Pina, F.L.C., Okino, A.M., … Cyrino, E.S. (2015). Effect of resistance training with different frequencies and detraining on muscular strength and oxidative stress biomarkers in older women. *Age, 37*(5), 104. doi:10.1007/s11357-015-9841-6

Peltonen, H., Häkkinen, K., & Avela, J. (2013). Neuromuscular responses to different resistance loading protocols using pneumatic and weight stack devices. *Journal of Electromyography and Kinesiology, 23*(1), 118–124. PubMed ID: 23021603 doi:10.1016/j.jelekin.2012.08.017

Rhea, M.R. (2004). Determining the magnitude of treatment effects in strength training research through the use of the effect size. *Journal of Strength and Conditioning Research, 18,* 918–920. doi:10.1519/14403.1

Rikli, R.E., & Jones, C.J. (1999). Development and validation of a functional fitness teste for community-residing older adults. *Journal of Aging and Physical Activity, 7*(2), 129–161. doi:10.1123/japa.7.2.129

Rikli, R.E., & Jones, C.J. (2008). *Senior fitness test* (Manole). São Paulo, Brazil: Human Kinetics.

Saeterbakken, A.H., Andersen, V., Kolnes, M.K., & Fimland, M.S. (2014). Effects of replacing free weights with elastic band resistance in squats on trunk muscle activation. *Journal of Strength and Conditioning Research, 28,* 3056–3062. doi:10.1519/JSC.0000000000000516

Safons, M.P., & Pereira, M. (2007). *Princípios metodológicos da atividade física para idosos*. Brasília, Brazil: CREF7.

Silva, N.L., Oliveira, R.B., Fleck, S.J., Leon, A. C.M.P., & Farinatti, P. (2014). Influence of strength training variables on strength gains in adults over 55 years-old: A meta-analysis of dose-response relationships. *Journal of Science and Medicine in Sport, 17*(3), 337–344. PubMed ID: 23806877 doi:10.1016/j.jsams.2013.05.009

Soria-Gila, M.A., Chirosa, I.J., Bautista, I.J., Baena, S., & Chirosa, L.J. (2015). Effects of variable resistance training on maximal strength: A meta-analysis. *Journal of Strength and Conditioning Research, 29,* 3260–3270. doi:10.1519/JSC.0000000000000971

Sousa, N., & Sampaio, J. (2005). Effects of progressive strength training on the performance of the functional reach test and the timed get-up-and-go test in an elderly population from the rural north of Portugal. *American Journal of Human Biology, 17*(6), 746–751. PubMed ID: 16254902 doi:10.1002/ajhb.20446

Souza, D., Barbalho, M., Vieira, C.A., Martins, W.R., Cadore, E.L., & Gentil, P. (2019). Minimal dose resistance training with elastic tubes promotes functional and cardiovascular benefits to older women. *Experimental Gerontology, 115,* 132–138. PubMed ID: 30550762 doi:10.1016/j.exger.2018.12.001

Steele, J., Raubold, K., Kemmler, W., Fisher, J., Gentil, P., & Giessing, J. (2017). The effects of 6 months of progressive high effort resistance training methods upon strength, body composition, function, and wellbeing of elderly adults. *BioMed Research International, 2017,* 2541090. doi:10.1155/2017/2541090

Webber, S.C., & Porter, M.M. (2010). Effects of ankle power training on movement time in mobility-impaired older women. *Medicine & Science in Sports & Exercise, 42,* 1233–1240.

Yeun, Y.R. (2017). Effectiveness of resistance exercise using elastic bands on flexibility and balance among the elderly people living in the community: A systematic review and meta-analysis. *Journal of Physical Therapy Science, 29*(9), 1695–1699. doi:10.1589/jpts.29.1695