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Research article

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

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Abstract
The objectives of the study were to compare the effects of resistance training using either a low cost and portable elastic tubing or conventional weight machines on muscle force, functional exercise capacity, and health-related quality of life (HRQOL) in middle-aged to older healthy adults. In this clinical trial twenty-nine middle-aged to older healthy adults were randomly assigned to one of the three groups a priori defined: resistance training with elastic tubing (ETG; n = 10), conventional resistance training (weight machines) (CTG; n = 9) and control group (CG, n = 10). Both ETG and CTG followed a 12-week resistance training (3x/week - upper and lower limbs). Muscle force, functional exercise capacity and HRQOL were evaluated at baseline, 6 and 12 weeks. CG underwent the three evaluations with no formal intervention or activity counseling provided. ETG and CTG increased similarly and significantly muscle force (Δ16-44% in ETG and Δ25-46% in CTG, $p < 0.05$ for both), functional exercise capacity (ETG Δ4 ± 4% and CTG Δ6±8%; $p < 0.05$ for both). Improvement on "pain" domain of HRQOL could only be observed in the CTG (Δ21 ± 26% $p = 0.037$). CG showed no statistical improvement in any of the variables investigated. Resistance training using elastic tubing (a low cost and portable tool) and conventional resistance training using weight machines promoted similar positive effects on peripheral muscle force and functional exercise capacity in middle-aged to older healthy adults.

Key words: Exercise, muscle strength, functional exercise capacity.

Introduction

There is compeling evidence linking resistance training (RT) to health. Benefits span across a broad range of outcomes with primary effects observed on muscle force and power (American College of Sports, 2009; Geirsdottir et al., 2012). Secondary effects are observed on metabolic control (e.g controling the risk factors related to metabolic syndromes, increase sensitivity to insulin and glucose tolerance (Hotamisligil, 2006)), improved systemic inflammatory response (Calle and Fernandez, 2010), and increased functional exercise capacity with consequent improvement in health-related quality of life (American College of Sports, 2009; Geirsdottir et al., 2012).

The American College of Sports Medicine recommends RT with a frequency of 2-3 days/week with intensities of 60-70% of one repetition maximum (RM) for 8-12 repetitions to maximize muscular strength (American College of Sports, 2009). Commonly, RT is delivered using dumbbells, barbells and weight machines. The elevated costs associated with the large space requirements of such equipments limit its availability (Ramos et al., 2014).

In the last few years, modalities have been proposed as alternative to deliver RT. The use of elastic resistance (ER) is a method that uses elastic bands / tubes as resistive load (American College of Sports Medicine, 2011; Ramos et al., 2014; Simoneau et al., 2001). Muscle activation measured by electromyography was found similar to both upper and lower limbs during isotonic contractions with the advantage of permiting greater range of motion compared to weight machines (American College of Sports Medicine, 2011; Andersen et al., 2010; Brandt et al., 2013). Aboodarda et al. (2016) performed a meta-analysis of 18 articles with 35 different measures of activation and observed that ER provides similar prime mover, antagonist, stabilizer and assistant movers activation as isoinertial resistance. There is also the advantage to use it in places with limited space including home environment, since the equipaments used on elastic resistance are relatively inexpensive and more portable than weight machines.

Likewise conventional RT, benefits of elastic resistance training are observed on muscle force and exercise capacity in healthy older adults and individuals with different diseases (Martins et al., 2013; Mikesky et al., 1994; Motalebi and Loke, 2014; Ramos et al., 2014; Singnoy et al., 2017; Turban et al., 2014). Behm (1991) conducted the first randomized trial comparing elastic resistance to traditional machine and hydraulic resistance machine during a 10-week training program in young women and concluded that the three training methods were equally effective in promoting strength gains. Similarly, Colado et al. (2010) compared the resistance training using Thera-Band® elastic tubes with conventional resistance training in young women and described comparable gains in isometric force in both groups. In middle-aged sedentary women, Colado and Triplett (2008) compared elastic resistance training to conventional RT and found similar benefits in functional exercise capacity and body composition in both groups. Furthermore, Webber and Porter (2010) observed similar improvement in

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strength and muscle power between ER and conventional RT in mobility-impaired older women.

Therefore, although literature seems decisive about the benefits of ER, the comparability of a resistance training protocol using elastic tubing to conventional resistance training in middle-aged to older healthy adults including men and women, remains to be investigated.

This study compared the effects of resistance training using elastic tubing to conventional resistance training using weight machines on muscle force, functional exercise capacity, and health-related life quality. We hypothesized that RT using elastic tubing promotes similar positive effects to those found in conventional RT in middle-aged to older healthy adults.

Methods

Participants

In this quasi-randomized controlled trial, middle-aged to older healthy adults (mean age 58 years) were included between March and December 2015. The study was conducted in a university-based, outpatient, physical therapy clinic. Subjects were considered eligible if were older than 45 years old without any underlying cardiac, musculoskeletal or pulmonary disease and were not engaged in regular physical activity program during the last 6 months. Individuals would be excluded if they had low adherence to training (less than 75% of all sessions). All procedures were approved by the Research Ethics Committee (CAAE: 16606213.4.0000.5402) and followed the resolution #466/12 of the National Health Council, Brazil. Written informed consent was obtained from all patients. This study was registered in the Brazilian clinical trials registration (#RBR-4tswsq).

Study design

Subjects included in the study followed an initial assessment including medical consultation (including physical fitness test: cardiopulmonary exercise test), identification and assessment of medical history, anthropometric measurements and vital signs, physical activity levels (International Physical Activity Questionnaire - IPAQ questionnaire) (Pardini et al., 2001), health-related quality of life (Medical Outcomes Study 36-Item Short Form Health Survey, SF-36) (Ciconelli et al., 1999), functional exercise capacity (six minute walk test, 6MWT) (Holland et al., 2014), muscle force of upper limbs (UL) and lower (LL) (dynamometry) (Ramos et al., 2014).

After the initial assessment, subjects were allocated into one of three *a priori* defined groups (ETG = elastic tubing group; CG = control group; CTG = conventional training group). Allocation of the first three individuals occurred via sealed opaque envelopes. All subsequent subjects included in the study were allocated following the sequence of these three individuals (quasi-randomization, sequence: ETG, CG, CTG) (Figure 1).

Individuals in the control group did not receive physical training or formal activity counseling, but were instructed to mantain their daily activities. Patients in ETG and CTG groups performed resistance exercise training for 12 weeks (3x/week) with recuperative intervals of 48 to 72 hours between sessions. After six and 12 weeks of training, patients had their muscle force, functional exercise capacity and health-related quality of life reassessed. Details on muscle force measurements, load progression during the sessions and composition of exercise programs are described below.

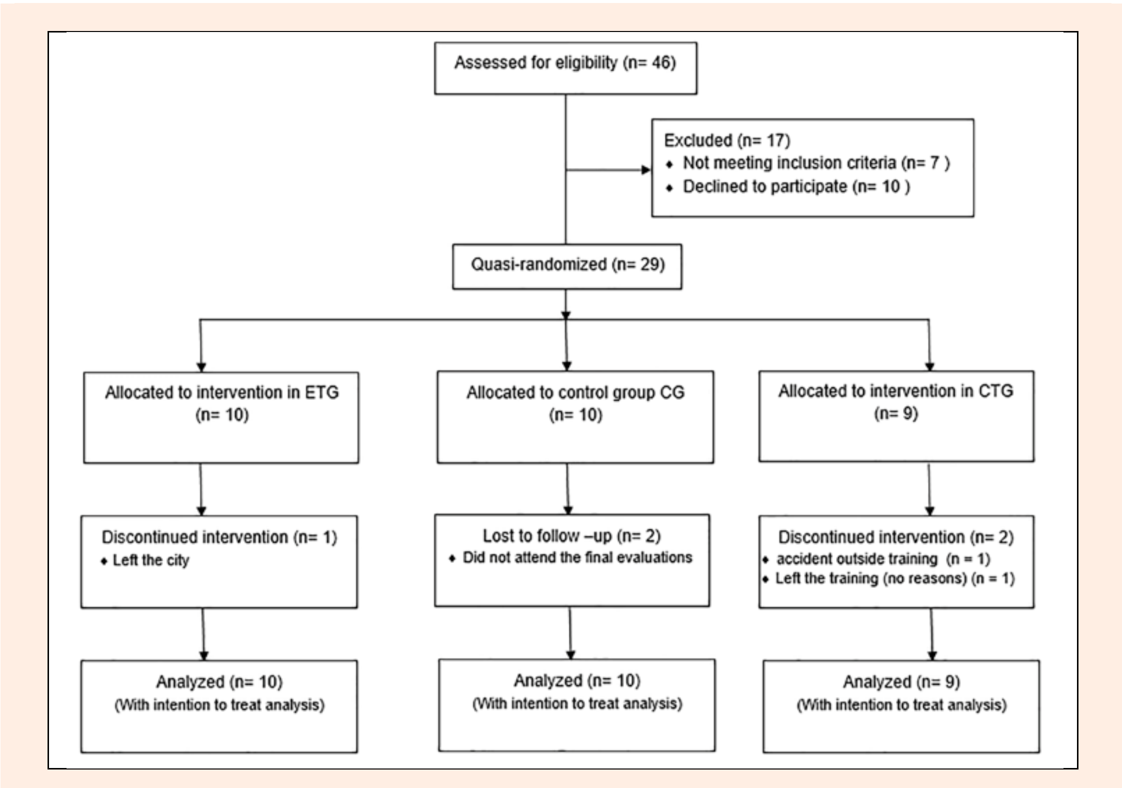

Figure 1. Flow chart of the study. GTE = Elastic tubing group; CG = Control group; CTG = Conventional training group.

Evaluation of muscle force and load increment over the sessions

The measurement of muscle force was performed using a digital dynamometer (Force Gauge®, model FG-100kg, USA) in the dominant UL and LL and the results were expressed in Newtons (N) (Ramos et al., 2014). Tested muscle groups were knee extensors, knee flexors, shoulder flexors, shoulder abductors and elbow flexors. Recent data confirms validity and reliability of the elastic resistance for muscle testing. (Andersen et al., 2017)

The criterion to increase workload was based on the number-of-repetitions test (NR) performed at the beginning of each session. Participants performed the NR to verify the maximum number of repetitions they could perform with a given load. The load would be maintained for that session when the maximum number of repetitions performed was 15 ± 2, it would be otherwise adjusted to achieve the expected number of repetitions. The increment in the ETG was done by changing the diameter of the tubes and/or adding extra tubes. Increases in the workload for subjects in CTG followed the same criterion of ETG with changes in the weights of the machine.

Training programs offered at ETG and CTG

The duration of each exercise session varied between 40 and 60 minutes and included the resistance training as well as global stretching exercises and the verification of vital signs. Prior to the start of the training, participants were familiarized with the exercises, equipment and elastic tubing. The movements were performed in the following order: shoulder abduction, elbow flexion, shoulders flexion, knee extension and knee flexion. Exercises were conducted under a periodized and progressive design starting with 2x15 NR (weeks 1 – 3), 3x15 NR (weeks 4 – 6), 3x10 NR (weeks 7 – 9) and finally 4x6 NR (weeks 10 – 12) with 2-minute interval between sets. More details of the adopted training protocols can be found in the literature (Silva et al., 2016).

Resistance training with elastic tubing

Five models of elastic tubing were used (#200, #201, #202, #203 and #204) (Lemgruber, Brazil). The estimated cost of the elastic tubing per patient is US$20. Higher numbers indicate larger tube diameters. Tubes #200 (internal/external diameter: 3.0/5.5mm), #201 (internal/external diameter: 4.0/5.5mm), #202 (internal/external diameter:4.0/8.0mm) and #203 (internal/external diameter: 6.0/9.0mm) were used for the upper limbs training. Tubes #203 and #204 (internal/external diameter: 6.0/11.5mm) were used for lower limbs training. All tubes were connected to a specific chair with length and position adjusted for each trained muscle group. Trained muscle groups were the same as evaluated during the assessments (i.e. knee flexors and extensors, shoulder flexors and abductors and elbow flexors). An example of the training execution using elastic tubes can be seen in Figure 2.

Conventional resistance training

Participants allocated to the CTG used a weight machine (Ipiranga®, Brazil) (Figure 3). A simple pulley equipment was used for the upper limb training. One-legged open chain knee extension/flexion exercises were conducted on a sated position.

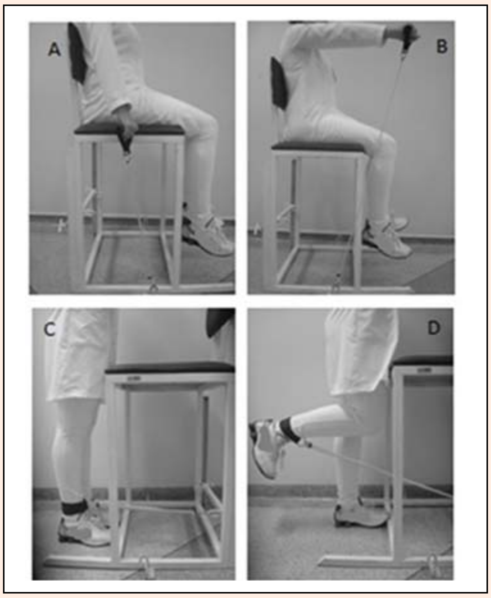

Figure 2. Execution of the exercise using elastic tubing. Upper quadrants: Elastic resistance training for Shoulder flexors from (A) resting position until (B) end of the movement. Lower quadrants: Elastic resistance training for the knee flexors from (C) resting position until (D) end of the movement.

Statistical analysis

Data analysis was conducted using SPSS v.22 (SPSS Inc., Chicago, USA) by a researcher (IBT) blinded for the subjects' allocation and training progression. Normality of data was checked using Shapiro-Wilk test. Results are reported as mean±standard deviation or median [interquartile range] according to the data distribution. We performed a priori the sample calculation based on previous study (Locks et al., 2012). To achieve an improvement of 51 m in the 6MWD (for the conventional and elastic tubing training modalities) with a standard deviation of 63 m it was necessary to include 9 subjects in each group. Considering 10% of sample loss the calculation was adjusted to 10 individuals each group to obtain 80% of power with a statistical significance of 5% (Z= 1.96). Categorical data was presented as frequency and compared using the chi-square test. One-way ANOVA or Kruskal-Wallis test for repeated measures was used to compare intra-group differences between baseline, 6 and 12 weeks. Two-way ANOVA was used to compare changes between 3 groups across 3 testing times. Magnitude of differences between group responses was also describe as effect size using Cohen's *d*. The effect size classes were defined according to calculated values d [small ($d \leq 0.2$), moderate ($d = 0.5$) or large ($d \geq 0.8$)] (Cohen, 1988). An intension-to-treat analysis was performed for variables with missing data in the final evaluation by the last observation carried forward (Elkins and Moseley, 2015).

Figure 3. Execution of the exercise using weight machine. Upper quadrants: Conventional resistance training for Shoulder flexors from (A) resting position until (B) end of the movement. Lower quadrants: Conventional resistance for the knee flexors from (C) resting position until (D) end of the movement.

Results

Characteristics of the subjects included in the study are shown in Table 1. As expected, none of the individuals presented cardiac, respiratory or musculoskeletal disease. All subjects were irregularly active (i.e. subjects performed physical activity but not enough to be classified as active, according to IPAQ) (Matsudo et al., 2002) and no statistically significant difference was observed between the three groups at baseline. Five individuals (ETG, n = 1; CG, n = 2; and CTG, n = 2) had their data of functional exercise capacity, muscle force and health-related quality of life repeated in the final assessment (intention-to-treat analysis) due to discontinued intervention or lost to follow-up.

Changes in muscle force from baseline (Table 2) were observed in ETG and CTG for all the trained muscle groups (Δ16% to 44% for ETG and Δ25% to 46% for CTG, $p < 0.05$ for all movements at least one of the groups). No significant differences were observed in the control group. Observed effect size was large for all trained groups in ETG (0.86 to 1.62) and CTG (0.94 to 1.29). Only small to moderate (0.14 to 0.58) effect size was observed between ETG and CTG training responses.

Effects on functional exercise capacity are described in Table 3. Significant improvements from baseline were observed on walked distance in both ETG (Δ+4.5 ± 4.3%, $p < 0.05$**)** and CTG (Δ+6.5 ± 8.1% $p < 0.05$) (Cohen's d = 0.99 for both).

Changes on domains of health-related quality of life (Table 4) were only observed in the CTG for "pain" (Δ21 ± 26 points $p = 0.037$). No significant differences between groups were observed for changes in none of the domains of the questionnaire.

Table 1. Characteristics of all subjects according to group allocation. Data expressed as frequency and mean ± standard deviation.

	ETG	CTG	CG
Gender (F/M)	6/4	4/5	7/3
IPAQ (irregularly active A/B)	4/6	2/7	3/7
Age (years)	62 (8)	56 (8)	54 (6)
BMI (kg/m^2)	27 (3)	29 (3)	25 (3)
6MWT (%Predicted/ Baseline)	123 (11)	112 (12)	111 (9)

ETG: Elastic tubing group; CTG: Conventional training group; CG: Control group; F: female; M: male; IPAQ: International Physical Activity Questionnaire; Irregularly active A/B: A is related to a higher level of physical activity compared to irregularly active B; BMI: body mass index; kg: kilogram; m: meter; cm: centimeters; 6MWT: 6-minute walk test; %Predicted: Percentage of predicted.

Discussion

This study confirms the effects of a conventional resistance training on muscle force and add that a RT program using elastic tubing resistance of equal duration and intensity was able to promote similar effects in irregularly active middle-aged to older healthy adults. The two training regimens also showed similar improvements in functional exercise capacity.

Table 2. Muscle force of the three groups for the different testing moments. Expressed as median and interquartile range (25-75%). Δ% 0-12 weeks presented as mean and confidence interval of 95%.

	Muscle force (N)	Baseline	6 Weeks	12 Weeks	Δ%0-12 Weeks	p-value Moments	p-value Groups
Elbow flexion	ETG	77 (64-111)	109 (76-147)*	119 (76-152)*	+34 (17-50)†	<.0001	.089
	CTG	83 (68-130)	121 (71-145)	123 [80-152)	+30 (7-52)†	.348	
	CG	68 (48-117)	56 (48-87)	59 [53-78)	-6 (-25-12)	.151	
Shoulder abduction	ETG	48 (38-73)	69 (48-101)	71 (50-93)*	+16 (7-25)	.023	.143
	CTG	62 (36-81)	75 (41-94)	75(47-94)*	+31 (5-56)†	.004	
	CG	47 (30-74)	35 (33-60)	43 (36-55)*	-4 (-27-18)	.192	
Shoulder flexion	ETG	53 (37-83)	70 (44-92)	68 (42-88)*	+36 (12-60)†	.001	.145
	CTG	58 (34-83)	66 (54-86)*	66 (51-92)	+26 (-1,8-53)	.004	
	CG	45 (37-75)	38 (32-52)	42 (38-66)	-5 (-25-15)	.197	
Knee flexion	ETG	110 (63-136)	141 (107-175)*	131 (108-175)*	+44 (15-73)†	<.0001	.777
	CTG	100 (71-122)	104 (88-141)	125 (101-155)*	+36 (12-58)	.002	
	CG	92 (66-121)	97 (67-120)	99 (66-131)	-7 (-35-22)	.315	
Knee extension	ETG	214 (175-291)	287 (226-343)*†	259 (233-398)*†	+35 (8-61)	.003	.024
	CTG	203 (156-251)	246 (209-309)*†	253 (221-321)†	+46 (-4-97)†	.023	
	CG	164 (135-259)	143 (118-234)	152 (125-229)	-9 (-21-2)	.053	

N = Newtons; ETG: Elastic tubing group; CTG: Conventional training group; CG: Control group *: different from baseline; † $p < 0.05$ compared to CG.

Table 3. Changes on functional exercise capacity. Data are expressed as mean (± standard deviation).

6MWT	Baseline	6 Weeks	12 Weeks	p-value Groups	Δ 0-6 weeks (m)	p-value	Δ 0-12 Weeks (m)	p-value
ETG	611 (71)	634 (70)	638 (74) *	.451	23 (25)	.266	27 (24)	.043
CTG	571 (75)	597 (75)	606 (67) *		25 (31)		34 (40)	
CG	622 (56)	627 (43)	619 (47)		4 (36)		-3 (32)	

6MWT: 6-minute walk test; m: meters; ETG: Elastic tubing group; CTG: Conventional training group; CG: Control group; *: different from baseline.

Table 4. Changes in the SF-36 domains.

SF-36	Group	Baseline	6 weeks	12 weeks
Functional Capacity	ETG	95 (85-96)	95 (77–96)	95 (86-100)
	CTG	95 (75-97)	95 (80–97)	95 (70-97)
	CG	85 (65-91)	80 (66-91)	82 (68–90)
Physical Aspects	ETG	100 (68-100)	100 (75-100)	87 (75-100)
	CTG	75 (62-100)	75 (75–100)	100 (75-100)
	CG	100 (75-100)	100 (37-100)	100 (37–100)
Pain	ETG	72 (51-100)	72 (67–80)	73 (61-88)
	CTG	62 (56-79)	74 (67–100)	74 (67–100) *
	CG	59 (48-72)	56 (38–88)	61 (51-88)
General State	ETG	75 (57-89)	82 (70–87)	82 (7-87)
	CTG	67 (54-84)	62 (52–84)	67 (52-96)
	CG	84 (65-92)	84 (64–92)	84 (70-92)
Vitality	ETG	71 (62-76)	73 (65–87)	79 (65-91)
	CTG	65 (52-85)	80 (67-85)	80 (67-92)
	CG	70 (53-77)	65 (57-80)	70 (65-80)
Social Aspects	ETG	84 (59-100)	85 (71-100)	94 (68-100)
	CTG	100 (81-100)	100 (87-100)	100 (87-100)
	CG	87 (87-100)	87 (75-100)	87 (75-100)
Emotional Aspects	ETG	83 (50-100)	100 (100-100)	100 (66-100)
	CTG	100 (66-100)	100 (83-100)	100 (83–100)
	CG	83 (24-100)	100 (100-100)	100 (66-100)
Mental Health	ETG	80 (65-93)	80 (78-85)	84 (76-94)
	CTG	72 (66-78)	88 (64–94)	88 (74-98)
	CG	72 (55-88)	76 (65–88)	72 (65-86)

SF-36: Medical Outcomes Study 36-Item Short Form Health Survey; ETG: Elastic tubing group; CTG: Conventional training group; CG: Control group. * $p < 0.05$.

The force curve of elastic tubing is not as simple as a linear increase in force and the differences in load applied may not be that different between ER and conventional RT (Aboodarda et al., 2016). The similar level of exercise resistance between ER and conventional RT support the similarity in gains in the investigated sample in the present study.

Evidence exist on the effects of elastic RT. Colado et al. (2010) found similar increases of isometric muscle force comparing a training program using Thera-Band® elastic tubing to RT with weight machines and free weights in a sample of physically active young women.

Effects of training using elastic tubing can be found in studies with single group designs (Lubans et al., 2013) and only partially supervised protocol (Skelton et al., 1995). Using protocol similar to the present study, Ramos et al. (2014) described equal improvements of muscle force between conventional and elastic tubing RT.

Previous studies have found similar benefits when comparing ER and conventional RT with regards to functional exercise capacity and body composition of middle-aged adults (Colado and Triplett, 2008), and in strength and power muscle of older adults (Webber and Porter, 2010). However, these studies have included only women. Furthermore, the study of Webber and Porter (2010) included women with mobility-impairments. Our results confirm these findings in a sample composed of both men and women and show similar benefits of modalities on functional exercise capacity and health-related quality of life (further than muscle force) in a sample of irregularly active middle-aged to older healthy adults. This has important implications for this population, since it confirms the modality as an equally effective alternative option to the conventional resistance training. These tools are distinguished by their practicality because they require little space and especially the low cost compared to weight machines and even other elastic materials commonly used in clinical practice (Ramos et al., 2014).

Benefits were also observed on functional exercise capacity. As expected, CTG and ETG improved similarly after 12 weeks of training in both absolute values and magnitude of the effect size. However, an intriguing lack of significant differences between these two groups and CG was also observed. The construct of the 6MWT may, at least in part, explain this finding. 6MWT is a timed test with a well-described ceiling effect on populations with better muscle function (as the one in the present study) (Holland et al., 2014). In other words, the higher the baseline covered in the test, the lower the improvement expected on the test after an intervention. Baseline 6MWT in CG group was numerically higher than the other two intervention arms. Although it was expected that no changes would occur in the CG during the 12 weeks of the protocol, the extent of improvements of ETG and CTG were also not expected to surpass the values of CG at 12 weeks due to the already high values at baseline.

Effects of resistance training can also be seen on health-related quality of life specially in older subjects (American College of Sports Medicine, 2013; Damush and Damush, 1999; Vieira et al., 2012). Our sample consisted of irregularly active middle-aged to older healthy adults without any undelying disease. It could, therefore, be anticipated that participants had preserved health-related quality of life upon inclusion (Laguardia et al., 2013). Importantly, to those subjects with somewhat increased complains of pain (in CTG), resistance training was effective to improve symptoms and scores in the health-related quality of life questionnaire.

The findings of the present study must be interpreted under the context of some limitations. We did not control for the exact workload delivered during sessions in the ETG. Although this can be interpreted as a limitation, both initial workload and progression during sessions were based on subjects' tolerance (i.e. by the NR test), guaranteeing comparable training volume for both modalities. Although we performed a sample size calculation prior to the commencing of the study, the sample size is relatively small. In addition, the magnitudes of change for the different outcomes in ETG were similar to those observed in CTG, reinforcing the benefits of the modality. Future studies with larger and more heterogeneous sample of middle-aged to older healthy adults are needed to confirm the effectiveness of elastic resistance training to this group of subjects, mainly in outcomes not investigated yet. It would be interesting to study separating middle-aged of older healthy adults including men and women.

Conclusion

In conclusion, resistance training with elastic tubing is a viable alternative to deliver resistance training as it promoted similar positive effects on peripheral muscle force and functional exercise capacity in middle-aged to older healthy adults than conventional resistance training.

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Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study received approval from Human Research Ethics Committee (CAAE: 16606213.4.0000.5402) and all procedures were in compliance with Resolution 466/12 of the Brazilian National Health Board.

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Key points

- There is compeling evidence linking resistance training to health.
- Elastic resistance training improves the functionality of middle-aged to older healthy adults.
- Elastic resistance training was shown to be as effective as conventional resistence training in middle-aged to older healthy adults.

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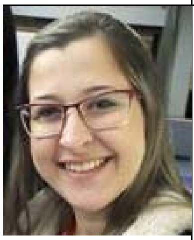

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