Resistance Training With Elastic Tubing Improves Muscle Strength, Exercise Capacity, and Post-Exercise Creatine Kinase Clearance in Subjects With COPD

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BACKGROUND: Among the types of physical exercise, resistance exercises have been gaining significant attention in the COPD population. The aim of this study was to compare effects of conventional resistance training and of training by using elastic tubes on muscle strength, exercise capacity, and creatine kinase clearance in subjects with COPD. METHODS: Twenty-eight subjects with COPD were randomized into the following: resistance training with the elastic tubing group and resistance training with the weight-machine training group (conventional resistance group), performed 3 times a week for 12 weeks. The subjects were submitted to spirometry, functional exercise capacity (the 6-min walk test), muscle strength (dynamometry), and the repetition maximum test. Differences between the initial and final evaluations (Δ) and the (final - initial evaluations)/initial evaluations ×100 (Δ%) of each group were expressed as mean [95% CI]. RESULTS: Nineteen subjects (FEV_1 % predicted, 52 ± 18; years, 65 ± 8) completed the training program. Similar improvements were observed in both modalities on muscle strength (knee extension, Δ%18 [6 to 29]; knee flexion, Δ%35 [17 to 54]; elbow flexion, Δ%28 [9 to 48]; shoulder abduction, Δ%41 [25 to 58] and shoulder flexion, Δ%31 [11 to 51] in the weight-machine training group (conventional resistance group); knee extension, Δ%15 [8 to 21]; knee flexion, Δ%28 [15 to 41]; elbow flexion, Δ%36 [22 to 51]; and shoulder abduction, Δ%43 [32 to 55] and shoulder flexion, Δ%43 [25 to 61] in the elastic tubing group, *P* < .05 for intra-group analysis and *P* > .05 for between groups analysis), 6-min walk test (baseline 493 ± 67m vs 12 weeks 526 ± 78 in the weight-machine training group (*P* = .10); baseline 493 ± 71 vs 12 weeks 524 ± 68 in the elastic tubing group (*P* < .01), *P* = .88 between groups). The elastic tubing group had lower accumulated creatine kinase levels between 24 and 72 h ((Δ%−24 [−31 to 16] than subjects in the weight-machine training group Δ%3 [−21 to 28], *P* = .042 between the groups. CONCLUSIONS: Training with elastic resistance provided similar changes in muscle strength and exercise capacity to conventional resistance group in the subjects with COPD. The elastic tubing group had faster creatine kinase clearance after a training session than the weight-machine training group (conventional resistance group). The ease of its application associated with similar training benefits to conventional training supported its application in clinical routine. *Key words: COPD; rehabilitation; exercise training; elastic resistance; muscle strength; creatine kinase.* [Respir Care 2019;64(7):835–843. © 2019 Daedalus Enterprises]

Introduction

COPD is primarily a lung disease that features extrapulmonary consequences, such as reduced physical activity, increased symptoms in daily life, reduced health-related quality of life, and muscle dysfunction.[1-3] The dysfunction of the peripheral muscles is seen as an important cause of

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reduced strength, endurance, and muscle mass, which makes the practice of exercise training an essential component of pulmonary rehabilitation programs.[4] Exercise training, if sufficiently intense, leads to a significant immune response in healthy individuals mediated by inflammatory cells, hormones, cytokines, and neural factors.[5] In high-intensity conditions, exercise alters cell membrane permeability and progressively releases creatine kinase (CK) to the circulation, reaching peak levels ~24 h after the exercise acute session and gradually returning in the and gradually returning in the following hours/day.[6] A better clearance time of CK after exercise is also related to better body adaptation to the exercise stimulus.[7]

Among the types of physical exercise, resistance exercises have been gaining significant attention in the COPD population[8] because the effects go beyond those provided by aerobic exercises[9] Resistance exercises can be performed in several ways, including conventional resistance training, and training with bands and elastic tubing.[10] In conventional resistance training, dumbbells, barbells, and weight machine training are generally used.[11] However, weight machine training is usually expensive, difficult to transport, and requires a considerably large physical space. Elastic tubing is safe, easy to use, portable, and relatively inexpensive.[12] In addition, these have the ability to increase tension linearly from the start of the contraction until the end of the movement, being less harmful to the joints.[11] Despite the advantages of elastic resistance compared with conventional resistance training, little is known about the effectiveness of the former in subjects with COPD.[13-15]

QUICK LOOK

Current knowledge

Peripheral muscle dysfunction is seen as an important cause of reduced muscle strength, impaired creatine kinase function, and functionality in COPD, which makes the practice of resistance training an essential component of pulmonary rehabilitation. However, it is estimated that only 5% of patients with COPD who could benefit from pulmonary rehabilitation have access to programs.

What this paper contributes to our knowledge

We demonstrated that elastic tubing was a viable, low-cost alternative tool for resistance training in COPD, with similar improvements in muscle strength and exercise capacity to weight machines. In addition, subjects who exercised with elastic resistance had lower accumulation of muscle stress after a training session.

Our group recently compared the effectiveness of both conventional and elastic resistance training in this population. A potential limitation of the study was the lack of controlled training progression and intensity between the 2 groups.[15] A study that investigates training effectiveness of elastic resistance (with elastic tubes) compared with conventional resistance training with similar intensity is required. Furthermore, there is no information on whether different approaches of resistance training have a unique impact on CK clearance time. The present study aimed to evaluate the muscle strength, CK clearance, and functional exercise capacity of subjects with COPD submitted to either resistance training with elastic tubing or with weight-machine training. We hypothesized that the resistance training protocol with elastic tubing would improve peripheral muscle strength and functional exercise capacity similarly to resistance training by using weight machines while inducing less muscle stress.

Methods

The subjects who were clinically stable with moderate-to-severe COPD classified according to internationally accepted criteria[1] underwent a 12-week program in a specialized rehabilitation center. Knee extension force was a priori defined as the primary end point. Sample-size calculation was done based on equivalence of training. Twenty subjects (10 per group) were needed to achieve a power of 80%, expecting a difference of 45 N between groups with a SD of 36 N and taking into account a typical dropout rate of 20%. Patients were excluded if they were

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The authors have disclosed no conflicts of interest.

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active smokers or presented with unstable cardiac disease or musculoskeletal disorders that would prevent implementing the experimental protocol. Patients were also excluded if they had an exacerbation or complications that hindered the continuity of the treatment.

All the individuals were informed beforehand of the objectives and procedures of the study and provided informed written consent to participate in the study. All procedures were approved by the local ethics committee, São Paulo State University (UNESP), Presidente Prudente, São Paulo, Brazil (CAAE 12492113.5.0000.5402) and followed Resolution 466/12 of the Brazilian National Health Council. Recruitment and follow-up of individuals was conducted between 2014 and 2015 in a rehabilitation center in Presidente Prudente, São Paulo, Brazil. This radomized trial is registered with the Brazilian Registry of Clinical Trials (Universal Trial RBR-7kcr2p).

Study Design

Individuals were randomized by strata as follows: first, the subjects were classified into quartiles according to individual relative strength of the lower limbs (maximum voluntary isometric contraction of the knee extension).[16] Next, individuals in each quartile were randomized by numbered brown envelopes by an individual who was not related to the study, into one of the two groups a priori defined as follows: (1) either to perform resistance training with elastic tubing (ET group) or (2) to perform conventional resistance training (CR group). Although the therapists (BS, FL and GA) and subjects were not blinded to the interventions, data analysis was performed by an individual who was not involved with the data collection. The subjects were submitted to an initial evaluation, which included measurements of expired carbon monoxide,[17] lung function (spirometry),[1,18-20] functional exercise capacity (the 6-min walk test [6MWT]), muscle strength of the upper and lower limbs (dynamometry), and the number-of-repetitions test by using conventional weight-machine training in the CR group and elastic tubing in the ET group. On completion of the 12-week training period, the same evaluation was repeated to verify the training effects. Finally, muscle stress (via serum levels of CK)[21] was assessed at baseline and in the final week.

Pulmonary Function

Spirometry was performed by using a digital spirometer (Medical International Research (MIR)-Spirobank version 3.6, Roma, Italy) according to guidelines for pulmonary function tests.[20] The interpretation was performed by using recommendations of the American Thoracic Society and the European Respiratory Society,[18] and the results were compared with normative data of a Brazilian population.[19] The spirometric criterion for air-flow limitation was a postbronchodilator fixed ratio FEV_1/FVC of <0.70. Classification of COPD severity followed the Global Initiative for Chronic Obstructive Lung Disease.[1]

Analysis of Muscle Stress

CK activity was assessed at the following moments: week 0 (before the training session) and weeks 12 (24, 48, and 72 h after the last training session) from a blood sample collected from the tip of the index finger of the individual. A 30-μL sample of fresh blood was collected in a heparinized capillary tube and then immediately pipetted onto the CK test strip directly from the capillary tube. The analysis was performed by using a colorimetric assay procedure with Reflotron (Boehringer, Mannheim, Germany); the unit of measurement was U/L.[21]

Functional Exercise Capacity

The functional exercise capacity was evaluated by using the 6MWT according to the guidelines of the European Respiratory Society/American Thoracic Society.[22]

Muscle Strength and Load Increment Over the Sessions

The measurement of strength was performed on the dominant side, at baseline, and after 6 weeks and 12 weeks of training by using a digital dynamometer (Force Gauge, model FG-5100, Shanghai, China), with results expressed in newtons (N). The following muscle groups were evaluated: knee flexors and extensors, shoulder flexors and abductors, and elbow flexors.[10]

The criterion to increase work load was based on the number-of-repetitions test (NR) performed at the beginning of each session. Participants performed the number-of-repetitions test to verify the maximum number of repetitions that 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; otherwise, it would be adjusted to achieve the expected number of repetitions.[16] The increment in the ET group was done by changing the diameter of the tubes and/or by adding extra tubes. Increases in the work load for subjects in the CR group followed the same criterion of the ET group with changes in the weights of the machine. The measurement of the load in the ET group was performed according to a previous study.[23]

Training Protocol Programs Offered to the ET and CR Groups

Both groups followed the training programs for 12 weeks (3 times per week), which totaled 36 training sessions of

~60-min durations. At the beginning and at the end of each session, the vital signs were verified and stretching of the trained muscle groups was carried out. Before the start of the training, the participants were familiarized with the exercises, equipment, and elastic tubing. The movements were performed in the following order: shoulder abduction, elbow flexion, shoulder flexion, knee extension, and knee flexion. Thus, the muscles trained were deltoid, coracobrachial, pectoralis major, supraspinatus, brachialis, biceps brachialis, brachioradialis, biceps femoris, semimembranosus, semitendinosus, and quadriceps femoris. Exercises were conducted by using specific time frames and a progressive design starting with 2 × 15 NR (weeks 1–3), 3 × 15 NR (weeks 4–6), 3 × 10 NR (weeks 7–9), and 4 × 6 NR (weeks 10–12) with a 2-min interval between sets. The training program was developed in our study center, and more details of the adopted training protocols can be found in the literature.[24]

Resistance Training With Elastic Tubing

Elastic tubing was used for the training in the ET group. Different tubes with progressive resistance were used. The higher the reference number, the higher the diameter (resistance) of the tube (nos. 200, 201, 202, 203, and 204; Lemgruber, Rio de Janeiro, Brazil). Exercises were performed by using a specific chair that had an elastic tubing support fitting for each trained muscle group.[12,24] In addition, metal rings and beams (plastic cable ties) were used for fixating the elastic tubing to the rings. Based on a pilot study (unpublished data), we defined the initial selection of a tube diameter for each movement by using subjects' dynamometry. The initial lengths for the tubing were determined according to each individual's distance from the upper or lower limb to the hook (fixed point) on the chair. Thus, the length of the tubing used for each subject was unique and remained the same in all sessions. Trained muscle groups were the same as those evaluated during dynamometry (see the supplementary material at http://www.rcjournal.com).

Conventional Resistance Training

The duration of conventional resistance training and the progression were similar to the method offered to the ET group. A weight machine (Ipiranga-model Executive (adapted), Rio de Janeiro, Brazil) was used for the conventional resistance training. Simple pulley equipment was used for the upper-limb training, whereas open-chain single-legged flexion-extension exercises were performed for the lower limbs.[12]

Statistical Analysis

A statistical package (SPSS 22, SPSS, Chicago, Illinois) was used for data analysis. Normality of the data was assessed by using the Shapiro-Wilk test, and results were described as mean ± SD or as median (25–75% interquartile range) according to the data distribution. Differences between the initial and final evaluations (Δ) and the (final − initial evaluations)/initial evaluations × 100 (Δ%) of each group were expressed as mean (95% CI). Analysis of variance for repeated measures model in a 2-factor scheme was performed for each group to compare training effects on the different time points (week 0, weeks 6, and weeks 12). Data used for the repeated measurements were checked for violation of sphericity by using the Mauchly test. The Greenhouse-Geisser correction was used when the sphericity was violated. For intragroup analysis of the moments (baseline, 6 weeks, and 12 weeks), the Bonferroni posttest was used for parametric distribution or the Dunnet posttest for nonparametric distribution. The comparison of the initial moments and percentage variations in gains between the groups at baseline and 12 weeks moments was performed by using the Student *t* test for parametric distributions or the Mann-Whitney test for nonparametric distributions. Categorical variables were analyzed by using the chi-square test. The level of significance was set at $P < .05$.

Results

A complete overview of the study can be seen in Figure 1. Twenty-eight subjects with COPD were included and allocated into one of the two groups. Five subjects discontinued the training after commencing the program, and one was excluded from final analysis because the subject returned to smoking. Randomization according to individual relative muscle strength assured similarity in baseline strength levels between the training groups (ET group, 242 ± 46 N; CR group, 247 ± 62 N; $P = .40$). Subject characteristics are presented in Table 1. No significant differences were found between the groups.

The progression of the training load in the 12 weeks of training in the 2 groups is presented in Figure 2. Although the progression of training load in both groups was based on the same criteria (ie, number-of-repetitions test), the subjects in the ET group managed greater work load progression in elbow flexion and in knee flexion-extension exercises than the subjects did in the CR group from weeks 6–7 onward (elbow flexion [$P = .035$], knee flexion [$P = .045$], and knee extention [$P = .01$]). Training effects on muscle function can be seen in Table 2. No statistical differences were observed between the groups at baseline. A significant increase in strength can be observed in all movements analyzed in both groups. In ad-

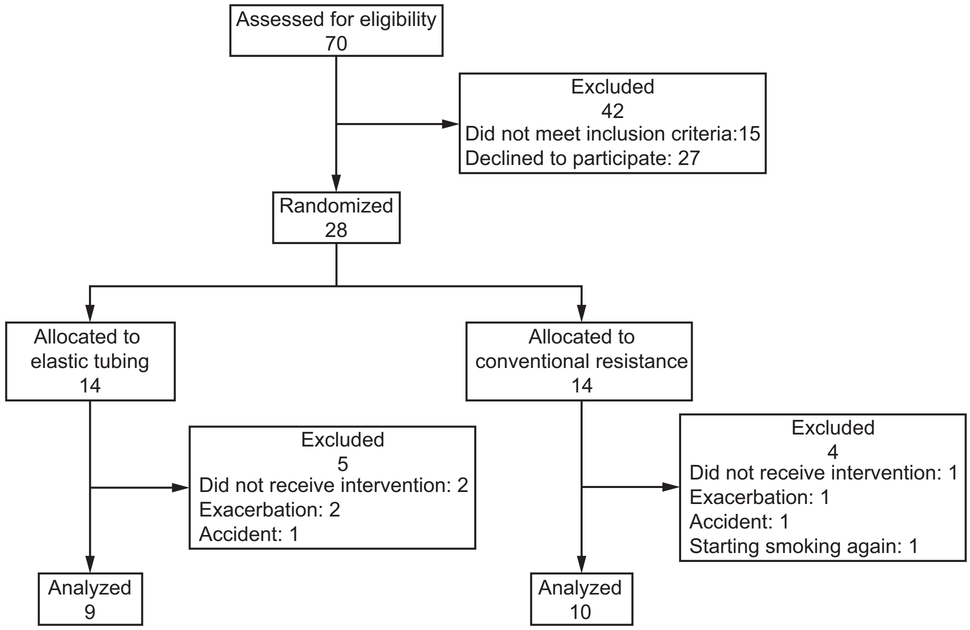

Fig. 1. Flow chart.

Table 1. Baseline Characteristics of the Subjects by Group. Data Expressed in Mean SD or Median (IQR)

Characteristic	CR Group (n = 14)	ET Group (n = 14)	P
Age, mean ± SD y	65 ± 8	63 ± 9	.40
Males, n (%)	10 (71)	9 (64)	.69
BMI, median (IQR) kg/m^2	28 (23–32)	27 (22–33)	.75
FVC%, median (IQR)	78 (73–85)	66 (50–86)	.14
FEV$_1$%, median (IQR)	59 (42–71)	37 (35–64)	.12
GOLD II/III/IV	06/07/01	04/08/02	.67
CO, median (IQR) ppm	0 (0–3)	2 (0–3)	.28
HbCO, median (IQR) %Hb	0 (0–3)	0.32 (0–0.52)	.28

CR = conventional resistance
ET = elastic tubing
BMI = Body mass index
IQR = 25–75% interquartile range
GOLD = Global Initiative for Chronic Obstructive Lung Disease
CO = Carbon monoxide
ppm = parts per million
HbCO = carboxyhemoglobin
Hb = hemoglobin

dition, no differences were observed on the magnitude of 6MWT changes in the evaluated groups. However, when analyzed individually, the ET group had slightly larger improvements than the CR group in the 6MWT from baseline.

The behavior of the serum levels of CK from baseline to the measurements at 72 h is depicted in Figure 3. There was an effect between moments (baseline and 24, 48, and 72 h) (P = .02, effect size = 0.18). Both groups had similar increases in CK levels from baseline to 24 h (Δ%33 [−5 to 71] for the ET group and Δ%32 [14–50] for the CR group, P = .96 between the ET and CR group). Differences between CK measured at baseline and 72 h were not significant between the groups (P = .15, ET group, Δ%2 [−31 to 37]; CR group, Δ%39 [−3 to 81]). However, the subjects in the ET group had a faster reduction of CK levels between 24 and 72 h (Δ%−24 [−31 to 16] for the ET group and Δ%3 [−21 to 28] for the CR group; P = .042 between the groups).

Discussion

The main findings of the present study demonstrated that both training regimens improved peripheral muscle strength and functional exercise capacity similarly. In addition, the subjects in the ET group showed a faster reduction of the muscle stress after a training session at the end of the 12 weeks of training. Elastic resistance training is commonly used by athletes due to its highly adaptable characteristics with the additional advantage of inducing reduced levels of muscle stress (preventing overtraining). As a consequence, it renders better individual performance and training effects.[25] It is also relatively inexpensive and easy to use, which increases its dissemination and its use in clinical practice. Despite the benefits, it is not widely used in pulmonary rehabilitation programs.

Previous work describes modest benefits of elastic resistance training using elastic bands (Theraband, Akron, Ohio, EUA) on muscle strength in subjects with COPD after a partially supervised domiciliary training program of 12 weeks.[14] Nyberg et al[13] showed benefits of elastic resis-

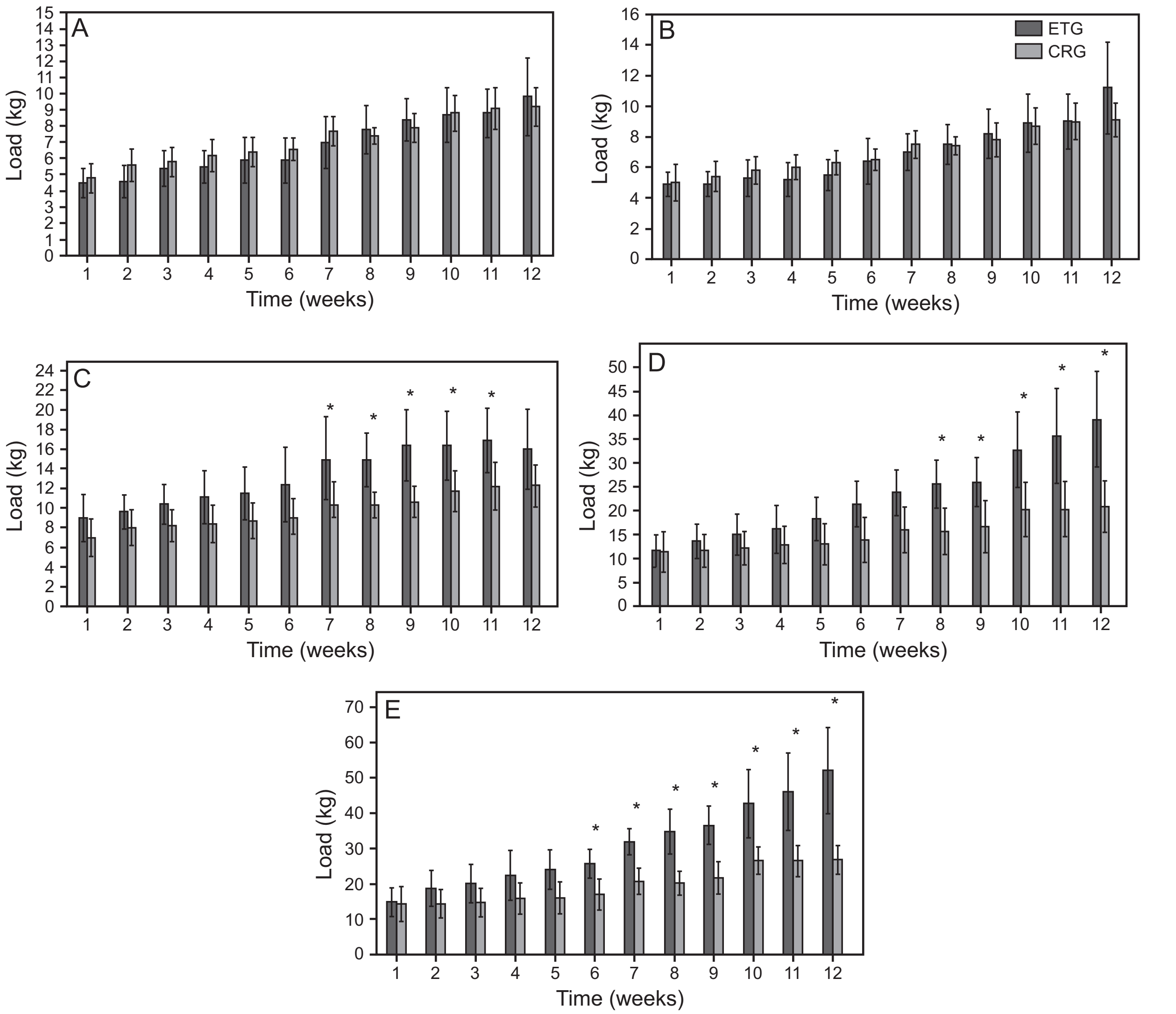

Fig. 2. Training progression during the 12 weeks of training in both groups. Bars show mean ± SD. A: Shoulder abduction; B: shoulder flexion; C: elbow flexion; D: knee flexion; E: knee extension. ET: elastic tubing resistance training group; CR: conventional weight machine resistance training group. *Significant difference between groups.

tance on functional exercise capacity and muscle function in subjects with moderate-to-severe COPD when compared with a control group. In a recent study, our group demonstrated benefits of an 8-week training protocol when using elastic tubing compared with using a weight machine in subjects with COPD.[15] A point of criticism of the latter was the limited comparability of the delivered work load during training protocols. In the present study, we confirmed these findings by using a 12-week program with comparable training progression and expanded the results by also describing benefits on serum levels of muscle stress in subjects with COPD.[15]

Although the progression of the training load in both groups was based on the same criteria, subjects in the ET group progressed more than subjects in the CR group from weeks 6–7 onward, especially in the lower limbs. This result was not expected, but we speculated that the higher activation of muscle units promoted by elastic resistance compared with weight-machine resistance[11] may have contributed. The possible higher recruitment of muscle fibers in the ET group may have influenced the subjects' effort perception in relation to the training loads, in which higher loads could be supported even with effort perception similar to the CR group. This higher recruitment of muscle fibers can be related to the property of elastic resistance to increase tension linearly from the start of the contraction until the end of the movement.[11] Muscle strength was significantly improved in both groups after 12 weeks of training with effects mostly observed in the first 6 weeks of training. This was in line with a recent meta-analysis that demonstrated a minimum of 4 weeks of training as necessary to promote clinically important gains in functional exercise capacity and health-related quality of life.[26]

Table 2. Muscle Strength and Functional Exercise Capacity of the Groups Subjected to the Elastic Tubing and Conventional Training at the Evaluated Moments

Factor	Baseline	6 Weeks	12 Weeks	*P**	Effect Size	Δ%0–12 Weeks	*P*†
Muscle strength							
CR group	248 ± 69‡	282 ± 78	288 ± 75§		0.56	18 (6 to 29)	
Knee extension, N				< .001			.91
ET group	243 ± 56‡	261 ± 56‖	277 ± 56§		0.61	15 (8 to 21)	
CR group	137 (113–165)‡	176 (151–212)	180 (153–216)§		1.11	35 (17 to 54)	
Knee flexion, N				< .001			.47
ET group	127 (111–157)‡	174 (150–190)	173 (146–193)§		1.16	28 (15 to 41)	
CR group	53 (40–67)‡	64 (52–79)‖	70 (58–87)§		1.00	41 (25 to 58)	
Shoulder abduction, N				< .001			.82
ET group	49 (44–69)‡	70 (64–84)	73 (67–92)§		1.44	43 (32 to 55)	
CR group	63 ± 20‡	74 ± 18‖	78 ± 18§		0.79	31 (11 to 51)	
Shoulder flexion, N				< .001			.13
ET group	65 ± 19‡	79 ± 21‖	90 ± 17§		1.39	43 (25 to 61)	
CR group	102 ± 33‡	114 ± 35‖	125 ± 32§		0.71	28 (9 to 48)	
Elbow flexion, N				< .001			.32
ET group	94 ± 35‡	113 ± 33‖	123 ± 37§		0.81	36 (22 to 51)	
Functional exercise capacity							
CR group	493 ± 67	ND	526 ± 78	.10	0.46	7 (-3 to 18)	
6MWD, m							.88
ET group	493 ± 71	ND	524 ± 68	< .001	0.45	7 (4 to 9)	

Data are expressed as mean ± SD, median, and median (25–75% interquartile range) for baseline, 6 Wk and 12 Wk columns and for Δ% 0–12 Wk column mean [95% confidence interval].
* For muscle strength data, analysis of variance for a repeated measures model in a 2-factor scheme was carried out for each group, and, for 6MWT data, paired Student t test (or the Wilcoxon test for nonparametric data) was used.
† Student *t* test for parametric distributions or the Mann-Whitney test for nonparametric distribution.
‡ Difference between baseline and 6 wk moments.
§ Difference between baseline and 12 wk moments.
‖ Difference between 6 wk and 12 wk moments.
Δ%0–12 wk = difference between (final minus initial evaluations)/initial evaluations × 100.
CR group = conventional weight machine training resistance training group
N = newtons
ET group = elastic tubing resistance training group
6MWD = 6-min walk distance
ND = no data

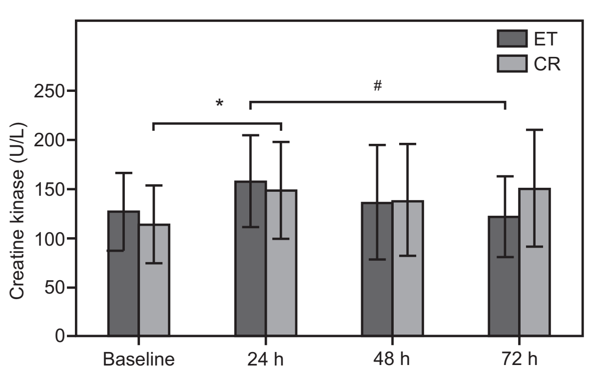

Fig. 3. Creatine kinase behavior in the evaluated training. ET = elastic tubing resistance training group; CR = conventional weight-machine resistance training group; *Significant difference between the baseline time and 24 h in CR group; #Significant difference between times 24 and 72 h in ET group.

Despite including a sample-size calculation, there was no statistical improvement in the 6MWT after conventional treatment, which was not expected. Commonly, resistance training induces positive changes in functional exercise capacity.[22,27] However, no differences were observed on the magnitude of 6MWT changes between the evaluated groups. Likewise, the changes in both groups exceeded, on average, values above those considered as minimally important differences in the test (30 m)[28] and the proportion of subjects in both groups that reached the minimally important differences of the test was similar (*P* = .59). This information supported the equivalence of both modalities on changes in the 6MWT. We could not exclude the possibility that the difference in training loads between the groups could have a positive effect on the intragroup improvement of the ET group compared with the CR group, but the equivalence of minimally important differences mentioned above added to the fact that there was no difference in the gains (Δ%) allowed us to speculate that the same results would be found in the CR group in a study that included a larger sample size (powered for this outcome).

CK is an enzyme that plays an important role in energy metabolism within muscles and is predominantly present in the muscle tissue.[29] When the intensity of exercise exceeds the metabolic capacity, there is a significant change in cell membrane permeability and CK is released from within cells to the circulation, with consequent elevation of its serum levels.[29] An increase of the serum levels of CK observed in both groups 24 h after the exercise session confirmed that, even at the final stages of the training (week 12), the delivered intensity was high enough to induce overload. This was in line with previous findings in COPD.[30]

Ideally, serum CK levels should quickly return to baseline and thus avoid accumulation in subsequent sessions.[7] Our results showed that, in comparison with peak values of CK (measured 24 h after a training session), CK clearance after 72 h was faster in the ET group. Of note, this phenomenon occurred despite the higher work loads at the last weeks of training in the ET groups. Elastic resistance tends to induce higher muscle activation in comparison with conventional muscle resistance,[11] and this greater activation decreases the risk of muscle damage because more fibers are recruited simultaneously. Therefore, it can be speculated that muscle damage is reduced, which justifies a faster CK clearance in the ET group. Because the investigation of causes related to increased clearance after the training modalities are out of the scope of the present investigation, this hypothesis remains to be confirmed in a future investigation.

Finally, it is important to note that this study was powered to find differences in muscle strength and was innovative in including the elastic tubing load measurement, which is not commonly performed in elastic resistance training and that facilitates the comparison of training tools. As limitations, despite the sample size calculation for the primary outcome (muscle strength), it was not possible to confirm whether the sample included in this study had enough power for the effects on any of the secondary outcomes. Therefore, the observed effects on functional exercise capacity and muscle stress need to be confirmed in a large study powered for these specific outcomes. In addition, we did not perform intention-to-treat analysis; nevertheless, the power of the study was not impaired because the subjects who completed this study followed our sample-size calculation.

Conclusions

Based on these results, we concluded that training with elastic resistance provided similar changes in muscle strength and exercise capacity to a conventional resistance training program in subjects with COPD. The subjects in the ET group had faster CK clearance after a training session than did the CR group. The ease of its application associated with similar training benefits to conventional training supports its application in clinical routine.

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