UNIVERSIDADE DE BRASÍLIA-UnB
FACULDADE DE CEILÂNDIA-FCE
CURSO DE FISIOTERAPIA

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EFFECTS OF ELASTIC RESISTANCE TRAINING ON MUSCLE STRENGTH AND FUNCTIONAL PERFORMANCE IN HEALTH ADULTS: A SYSTEMATIC REVIEW AND META-ANALYSIS.

BRASÍLIA
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Trabalho de Conclusão de Curso apresentado à Universidade de Brasília – UnB – Faculdade de Ceilândia como requisito parcial para obtenção do título de bacharel em Fisioterapia.
Orientador: Prof. Dr. Wagner Rodrigues Martins

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Brasília,___/___/_____

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Dedicatória

Ao meu filho Kaio, mesmo com sua pouca idade, tantas vezes compreendeu minha ausência, me doando carinho e seu sorriso aquecedor. Mamãe te ama!

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Por isso mesmo, empenhem-se para acrescentar à sua fé a virtude; à virtude o conhecimento; com o conhecimento, o domínio próprio; com o domínio próprio, a perseverança; com a perseverança, a piedade; com a piedade, a fraternidade; com a fraternidade o amor (2Pedro 1:5 -7).

ABSTRACT

OLIVEIRA, Poliana A., Martins, Wagner R. Effects of Elastic Resistance Training on muscle strength and functional performance in healthy adults: A Systematic Review and Meta-Analysis. 2016. 39f. Monograph (Graduation) - University of Brasilia, undergraduate course of Physiotherapy, Faculty of Ceilândia. Brasília, 2016.

Background: Elastic Resistance training (ERT) has already demonstrated its effectiveness in older adults and, when combined with the resistance generated by fixed loads, in adults. This article analyzes the effectiveness of ERT performed as isolated method on muscle strength and functional performance in healthy adults. **Methods:** A computerized literature research was performed in relevant databases to identify controlled clinical trials without date restriction and restricted to the English language. The mean difference (MD) with 95% confidence intervals (CIs) and overall effect size were calculated for all comparisons. The PEDro scale was used to demonstrate the quality of the included studies. **Results:** From the 93 articles identified by the search strategy, 5 articles met the inclusion criteria. Meta-analyses showed that the effects of ERT were superior when compared to passive control on functional performance and muscle strength. When compared to active controls, the effect of ERT was inferior on function performance and with similar effect on muscle strength. **Conclusion:** ERT are effective to improve functional performance and muscle strength when compared to no interventions in health adults. ERT are not superior to other methods of resistance training to improve functional performance and muscle strength in health adults.

Keywords: elastic bands, strength training, effect size.

SUMÁRIO

1-LISTA DE ABREVIATURAS

CG	Control Group
CI	Confidence Interval
EG	Elastic Group
e.g.	EXEMPLI GRATIA
ERT	Elastic Resistance Training
F	Female
i.g	ID EST.
M	Male
MD	Mean Difference
MVIC	Maximal Voluntary Isometric Contraction
1RM	One repetition maximum
OD	Other Device
OMNI - RES	OMNI – Resistance Exercise Scale
PEDro	Physiotherapy Evidence Database
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
PuBMed	Public/Publisher Medline
RCTs	Randomized Controlled Trials
repts	Repetitions
RET	Resistance Exercise Training
SD	Standart Deviation
SE	Standart Error
vs.	Versus

2-LISTA DE TABELAS E FIGURAS

1. Introduction

Resistance exercise training (RET) is an exercise that leads muscles to work against an applied force1. Since muscle strength is an indicative of disability and fitness, RET could be used as an effective model of exercise to directly improve muscle functions in adults2,3 and older adults4–7.

Many types of equipment can be used to improve muscular strength in RET. One of the guidelines related to this topic recommends the use of free weights, weights/pneumatic machines and resistance bands for developing and maintaining musculoskeletal fitness3. However, analyzing the guidelines evidence statement to improve muscle strength for novice to intermediate health adults and also for older adults, there is a strong and specific recommendation (evidence category A) for the use of free-weight and machine exercises in progression models of RET1. Nowadays weight machines are popular to scientific and professional use is considered safe, easy to motor learning, and allow performance of some exercises that may be less practical for doing with free weights (e.g. knee extension). Unlike machines, free weights may increase patterns of intermuscular coordination, which simulates some movements required in activities of daily living.

Considering that RET with machines and free weights are currently considered the gold standard for increased strength muscle, studies are investigating whether alternative and complementary methods are also effective. From this point of view, different studies have employed elastic resistance training (ERT) as a model of RTE on older adults to improve muscular strength8–12. It is also important to note that ERT devices in older adults seems to significant increases muscle strength supported by systematic reviews2,13. Historically, elastic bands have been used in the medical and physiotherapist scene such as hospitals for rehabilitation conditioning14. However, nowadays it is also widely used in fitness and sports training on health adults due to its practicality15 and ease of controlling the resistance intensity16,17.

Regarding the use of ERT on adults population, there is emerging evidence on how this type of RET allows muscle strength in trained and untrained adults. In a first systematic review, long term (> 7 weeks) variable resistance training using chains or elastic bands attached to the barbell in bench press or back squat exercise emerged as an effective method to improving muscle strength in athletes and untrained subjects18. Unfortunately, this evidence was provided to the use of ERT only combined with the resistance generated by fixed loads (e.g. barbell and discs) and only to 1RM test as outcome of muscle strength. Considering this context a rises the following question: Is there evidence to support the use of ERT performed as isolated method to increase muscle strength across different outcomes in health adults?

The aim of this current systematic review and meta-analysis was to analyze the effectiveness of ERT on muscle strength and functional performance in healthy adults and compare them to passive and active control groups in randomized clinical trials (RCTs).

2. Materials and Methods

2.1 Preliminary settings

This review was registered in PROSPERO under the number: CRD42015027002 (http://www.crd.york.ac.uk/PROSPERO/). We performed the checklist document according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) available at http://www.prisma-statement.org.

2.2 Literature Search Strategy

A computerized literature search was conduced using four databases: PubMed, The Cochrane Library, PEDro and ISI Web of Knowledge. The literature review was performed last time in March 12, 2016. The descriptors were obtained from the Medical Subject Headings of the National Library of Medicine. As the descriptors “elastic bands” or “elastic tubes” is not registered in Medical Subject Headings of the National Library of Medicine, the search used the most prevalent descriptors in the titles of articles on this scientific field. The following key words in the English language were combined (by a maximum of two descriptors) for the search:(“elastic bands” OR “elastic resistance” OR “elastic tubing” OR “elastic band exercise” OR “elastic band resistance”) AND (“resistance” OR “strength” OR “resistance training” OR “strength training” OR “muscle strength” OR “exercise movement techniques” OR “exercise therapy” OR “exercise programs”). Limits were used when appropriate: RCT, clinical trial, human trials, written in English. The PRISMA flow diagram is presented as Figure 1.

2.3 Study Inclusion and Exclusion Criteria

Only RCTs in the English language and available online were included in order to investigate the effects of RET with elastic resistance on outcomes of muscle strength and functional performance. The inclusion criteria were: (I) health subjects aged between 18-59 years old; (II) direct (e.g. one repetition maximum [1RM], multiples repetition maximum, maximal voluntary isometric contraction [MVIC], isokinetic peak torque) or indirect (e.g., functional tests like: knee push up test, 60 squat test, 30 second sit to stand test, abdominal crunch) measures. It was considered resistance training the exercises that require muscle to exert a force against some form of resistance, being a combination of static and dynamic contractions involving shortening and lengthening of skeletal muscle (available at http://www.ncbi.nlm.nih.gov/mesh/). In the present study all types of elastic devices (bands or tubes) was considered as load to produce responses in resistance training. The following exclusion criteria were considered: (I) studies in which individual had a history of surgical intervention at the musculoskeletal system; (II) individuals with rheumatoid arthritis, fractures, malignancies, any kind of systematic diseases; (III) athletes subjects (IV) interventions in which the ERT was used in combination with other methods of resistance training (e.g., ERT plus free weights vs. free weights).

2.4 Selection of studies

Two authors independently screened titles and abstracts of the results identified by the search strategy and a full text read was done to the potentially eligible studies. The reference list of the selected articles was consulted to obtain possible additional studies. Disagreements were resolved by consensus between two reviewers.

2.5 Methodological Quality Assessment

The methodological quality of the identified RCTs was scored using the PEDro scale. The PEDro scale consists of 11 criteria (random allocation; concealed allocation; baseline comparability; blind subjects; blind therapists; blind assessor; adequate follow up; intention-to-treat-analysis; between groups comparisons; point estimates and variability), which receives either a “yes”, or “no” rating. As criteria 1 is not used in the calculation, the maximum PEDro score is 10 points. Trials with a PEDro score ≥ 6 points were classified as of high-quality, while trials with a PEDro score < 6 points were classified as low-quality. The studies selected were assessed according to Brazilian-Portuguese version of the PEDro scale19.

2.6 Types of comparisons

Studies with any active (e.g., weight machines, free weights, aquatic resistance devices) or passive (e.g., no intervention, waiting list) comparisons group were considered to perform the meta-analysis procedure. So, in all comparisons, the experimental groups (i.e. ERT) were compared to active and passive groups separately. In addition, other decisions were made to meta-analysis procedure: (I) analyze separately the outcomes of muscle strength (e.g. maximal voluntary isometric contraction [MVIC]) and functional performance (e.g. knee push up test); (II) analyze separately the body regions in which the measure was applied (i.e. upper, lower and trunk). According to these decisions, the forest plots were generated considering an overall and subgroup meta-analysis.

Additionally, for the meta-analysis, we considered the outcome measures closest to the last time point measurement, even if studies used various time point measurements (e.g. follow ups), so the first post intervention measurement was chosen to the analysis.

2.7 Statistical Analysis

Considering that the included studies employed similar outcomes measurements (units and scales), the Mean Difference (measures the absolute difference between the mean values in two groups in a clinical trial) and 95% of the Confidence Intervals were considered in meta-analysis procedure20.

Data required for calculating the Mean Difference (MD) for continuous outcomes were: (I) Mean change in variable x, from baseline to follow up; (II) Standard deviation (SD) of the mean difference in variable x; (III) Number in each comparison group (n) at post intervention moment. To calculate the mean change in a variable from baseline to follow up was used: Mean difference = mean at follow up minus mean at baseline. The same process was used to calculate the mean difference in the experimental and control group. Unfortunately sometimes the SD values of the mean difference have not been calculated in the source papers. The authors who didn't publish the SD difference were tried to contact to find out more information, but when this procedure was not successful attempt, the variance of all articles was estimated on the basis of the information available. For this purpose, the formula below was used to calculate the SD difference when the SD was presented for comparing groups at baseline and follow up.

Standard error (SE) difference = □ [SD1 2/n1 + SD2 2/n2]; where: SD1 is the SD at baseline; n1 is the number at follow up; SD2 is the SD at follow up; n2 is the number at baseline. To calculate the SD difference from the SE difference: SE = SD □n. So: SD difference = SE difference X □n. If the means and SD of the outcome measures were not listed in a table or mentioned in the text, the data were extracted from their plots using Adobe Photoshop v. 17.020.

In cases of the presence of statistical heterogeneity (Chi-squared method set at $p < 0.05$) across analysis, we checked the results using only random-effects mode. The heterogeneity of the studies was also assessed by the statistic I2 and 95% CI. The statistical analysis was performed using the Review Manager21.

3. Results

The search strategy identified 93 studies. Reviewers judged 19 of the, to be relevant. Out of these, 10 were excluded after reviewing their abstracts and/or full text based on the inclusion criteria. Finally, 5 studies met the inclusion criteria and an overview of the characteristics of the studies included is provided in Table 1. Figure 1 presents the flowchart of selection process based on study criteria and Table 2 presents the results of PEDro scale. The methodological quality of the included studies varied from 6 to 7 points on the PEDro scale. Three studies scored by 7 points and the other two scored 6 points, so the all five studies were considered of high quality.

3.1 Study and subjects Characteristics

The 5 articles included, were published between 2006 - 2012. They are RCTs and designed to investigate the effectiveness of ERT in increasing muscle strength and/or functional performance. The experimental design of the studies presented: (I) only one comparison group using another overload device (bodyblade and weight machines) [SUGIMOTO, 2006; COLADO, 2008]; (II) studies with two comparison groups: overload device (water devices, weight machines, free weights) and no intervention [COLADO, 2009; COLADO, 2010; COLADO, 2012].

The 5 studies included in this review enrolled a total of 229 participants, with an average age ranging from 21-54 years. The sample size ranged from 40 to 62 participants and the number of participants per group ranged from 10 to 21 individuals. Only one study included men and women allocated in the same group, with a sample of 40 participants [SUGIMOTO 2006]. The other four studies were performed only with women, totaling 189 participants [COLADO, 2008; COLADO, 2009; COLADO, 2010; COLADO, 2012].

In all studies, individuals were identified as "healthy" because they were functionally independent; free of orthopedic disabilities and others associated morbidities.

3.2 Training and tests characteristics

To measure the muscle strength, the following body regions and parameters were used: (I) MVIC of upper limbs using a isokinetic dynamometer on internal and external shoulder rotation [SUGIMOTO, 2006] and a load cell in MVIC on vertical rowing [COLADO, 2010]; (II) MVIC of lower limbs using a load cell on squat [COLADO, 2010]; (III) MVIC of trunk using a load cell on back extension [COLADO, 2010].

To measure functional performance, the following body regions and parameters were used: (I) upper limbs using the number of repetitions on knee push-up test [COLADO, 2008; COLADO, 2009; COLADO, 2012]; (II) lower limbs using the number of repetitions on squat test [COLADO, 2008; COLADO, 2009; COLADO, 2012]; (III) trunk using the number of repetitions on crunch abdominal test [COLADO, 2009; COLADO, 2012].

The duration of the intervention ranged from 8 to 24 weeks with a frequency of 2 to 4 times a week. The number of exercises ranged from 6 to 15 exercises, the number of sets and repetitions per exercise was (I) 3 sets of 10-20 repetitions (2 exercises) [SUGIMOTO, 2006]; (II) one set of 20 maximum repetitions (10 exercises) [COLADO, 2008]; (III) one set of 20-30 maximum repetitions (10 exercises) [COLADO, 2009]; (IV) one set of 8-15 maximum repetitions (15 exercises) [COLADO, 2010]; (V) one set of 20 maximum repetitions (12 exercises) [COLADO, 2012]. The rest interval between exercises in the included studies ranged from 30s to 90s.

3.3 ERT versus passive control

The mean strength gain observed in ERT group was greater when compared to passive control group on function performance (MD = 7.34 repetitions; 95% CI: 5.17 to

9.51; Z = 6.63; P < 0.00001). All subgroups analysis showed the same direction of significant effect in favors to ERT: (I) knee push up test (MD = 6.1 repetitions; 95% CI: 2.98 to 9.26; Z = 3.38; P = 0.0001), squat test (MD = 7.4 repetitions; 95% CI: 4.03 to 11.06; Z = 4.21; P < 0.0001) and abdominal test (MD = 10.9 repetitions; 95% CI: 5.17 to 16.78; Z = 3.70; P = 0.0002). The general and subgroups analysis are show in Figure 2.

The mean strength gain observed in ERT group was greater when compared to passive control group on direct measure of muscle strength (MD = 1.89 Kg; 95% CI: 0.44 to 3.45; Z = 2.55; P = 0.01). Two subgroups analysis showed the same direction of significant effects in favors to ERT: MVIC lower limb (MD = 15.25 Kg; 95% CI: 7.14 to 23.38; Z = 3.68; P = 0.0002) and MVIC trunk (MD = 1.89 Kg; 95% CI: 0.44 to 3.35; Z = 2.35; P = 0.01). The MVIC upper limb subgroup analysis showed no differences between ERT and passive (MD = 1.07 Kg in favors to ERT; 95% CI: 0.19 to 2.34; Z = 1.66; P = 0.10). The general and subgroups analysis are show in Figure 3.

3.4 ERT versus active control

The mean strength gain observed in active control groups (other methods of training) was greater when compared to ERT on functional performance (MD = 3.1 repetitions; 95% CI: 5.27 to 0.93; Z = 2.79; P = 0.005). Two subgroups analysis showed the same direction of significant effects in favors to active control: knee push up test (MD = 5.1 repetitions; 95% CI: 7.57 to 2.80; Z = 4.26; P < 0.0001) and abdominal test (MD = 3.7 repetitions; 95% CI: 6.20 to 1.32; Z = 3.02; P = 0.003). The squat test subgroup analysis showed no differences between active control and ERT (MD = 1.0 repetitions in favors to active control; 95% CI: 3.79 to 1.60; Z = 0.79; P = 0.43). The general and subgroups analysis are show in Figure 4.

Regarding comparisons between ERT and active control groups on muscle strength, there were no statistical differences on mean strength gain (MD = 0.11 Kg in favor to ERT; 95% CI: 0.29 to 0.51; Z = 0.54; P = 0.59). Two subgroups analysis showed the same results of absence in-group differences: MVIC upper limb (MD = 0.12 Kg in favors to ERT; 95% CI: 0.28 to 0.52; Z = 0.61; P = 0.54) and MVIC trunk (MD = 0.46 Kg; 95% CI: 3.17 to 4.09; Z = 0.25; P = 0.80). The MVIC lower limb subgroup analysis showed that mean strength gain observed in active control group was greater when compared to ERT group (MD = 9 Kg; 95% CI: 17.89 to 0.11; Z = 1.99; P = 0.05). The general and subgroups analysis are show in Figure 5.

3.5 Heterogeneity

In this review it was compiled four forest plots that report the I2 statistic (total [95% CI]) due the heterogeneity of the continuous data. In two analyses there is no evidence of heterogeneity (I2 = 0%): (I) ERT versus passive control on functional performance; (II) ERT versus active control on muscle strength.

In two analyses there was high evidence of heterogeneity: (I) ERT versus active group on functional performance (I2 = 89%); (II) ERT versus passive control on muscle strength (I2 = 85%) in the ERT versus passive control direct measures.

4. Discussion

The objective of the present systematic review was to establish the effectiveness of elastic resistance training to improve muscle strength and functional performance in healthy adults. To our knowledge, the meta-analysis procedure applied in this study is the first one to identify the isolated effects of ERT on different outcomes across different body regions. The analysis showed that the effects of ERT were superior when compared to passive control on functional performance and muscle strength. But when compared to active controls, the effect was inferior on function performance and similar on muscle strength.

The overall results in favors to ERT when compared to passive control on functional outcomes were demonstrated across all of three subgroups analysis (upper limb, lower limb and trunk), with the major results from the abdominal crunch test (10.9 repetitions). These results were provided from three studies [COLADO, 2008; COLADO, 2009; COLADO, 2012], all of them only with women's participants, using similar exercises and with identical methods in order to equalize de intensity of elastic exercises. The effects of ERT on functional outcomes were more expressive in 24 weeks [COLADO, 2009] than in 10 weeks [COLADO, 2008; COLADO, 2012]. There is no heterogeneity between these comparisons according the I2 statistics.

On muscle strength outcome, the overall results in favors to ERT when compared to passive control could be particularly attributed to two subgroups analysis (lower limbs and trunk), with the major results from MVIC of lower limbs (15.2 Kg). However for these subgroups only one study was analyzed in meta-analysis [COLADO, 2010]. In contrast, the similar results between ERT and passive control on MVIC upper limb subgroup were provided from two studies, one only with women's [COLADO, 2010] and other with men's and women's [SUGIMOTO, 2006]. Only the study of Colado et al. [COLADO, 2010] presents significant strength gains. Besides these two studies employed 8 weeks of elastic resistance training, Sugimoto et al. [SUGIMOTO, 2006] performed only resisted shoulder internal and external exercises and Colado et al. [COLADO, 2010] performed inclined standing rowing, horizontal bench press, military press, vertical rowing, lateral raise, horizontal abduction, biceps curl and horizontal

French press. The I2 statistics demonstrated high evidence of heterogeneity on these comparisons.

Similar results were demonstrated in a systematic review conducted by Martins et al.13 (2013) when compared the effects of ERT versus passive control groups on muscle strength. The resistance training with elastic bands show large effects on muscle strength in healthy elderly (SMD = 1.30; 95% CI, 0.90, 1.71) and in participants with some functional incapacity (SMD = 1.01; 95% CI, 0.82, 1.19), and a moderate effect on muscle strength in elderly patients with pathology (SMD = 0.54; 95% CI, 0.12, 0.96), according to Cohen´s classification for Effects Sizes (ESs; < 0.41 = small; 0.41 – 0.70 = moderate; > 0.70 = large)22. In these systematic review13 the duration of the training ranged from 6 to 24 weeks at a frequency of 1 to 5 times per week. The number varied from 2 exercises to 11, the number of sets per exercise ranged from 1 to 3 and number of repetitions varied between 10 and 12. The American College of Sports Medicine´s position states that a participant in regular physical activity elicits a number of favorable responses that contributes to health23,24. Corroborating to this statements, many systematic reviews performed comparisons between physical exercise and no interventions or usual care. Accumulated evidence indicates that physical exercise in its strength form is fully recommended across different population25–30.

The overall results in favors to active control groups when compared to ERT on functional outcomes could be particularly attributed to two subgroups analysis (knee push up and abdominal crunch test), with the major results from the knee push up test (5.1 repetitions). These results were provided from three studies [COLADO, 2008; COLADO, 2009; COLADO, 2012] that used weights machines and aquatic devices that increase drag force to applied external overload. In this context, Colado et al. [COLADO, 2012] the last RCT published on this field, recommended the use of elastic bands as an economical alternative to the use of weights machines, as no significant differences between the two devices exists in terms of their effects on physical capacity in the short term. However, our findings demonstrated that only one subgroup analysis (squat test) had similar effects when comparing weights machines and aquatic devices versus ERT on functional outcomes. The I2 statistics demonstrated high evidence of heterogeneity on these comparisons.

Regarding to the muscle strength outcome, the overall similar results between ERT and active control groups could be particularly attributed to two subgroups analysis (MVIC of upper limb and trunk). These results were provided from two studies [COLADO, 2010; SUGIMOTO, 2006] that used weights machines and flexible shoulder devices to applied external overload. Only one subgroup analysis showed superior effects in favors to active control, which was MVIC of lower limbs (9 Kg). Colado et. al [COLADO, 2010], the last RCT with this design, indicate that resistance training using elastic tubing or weight machines/free weights has equivalent improvements in isometric force in short-term programs applied in fit young women. However, our findings demonstrated that only two subgroup analysis (MVIC of upper limb and trunk) had similar effects when comparing weight machines/free weights versus ERT on muscle strength. There is no heterogeneity between these comparisons according the I2 statistics.

Soria et al.18 (2015) compared the effects of traditional versus variable resistance training on the adaptive response produced in terms of maximal strength. The results indicated that variable resistance training over at last 7 weeks leads to a significantly greater strength gain (1RM) than that produced by traditional strength training program. However a subgroup analysis according to training status, demonstrated that training individual had greater strength gain with variable resistance training than the traditional training and the strength gains observed for the non-trained did not vary significantly. These results could not be directly compared with the present study because the large differences between the tests of maximal strength employed (1RM versus MVIC), the study design (variable resistance training using chains or elastic bands attached to the barbell in bench press or back squat exercise versus elastic resistance training performed as isolated method) and the participants (untrained, with under 12 months experience in strength training versus no previously experience in a program of strength training). Besides this, for muscle strength we founded similar results, where the strength gains observed for the non-trained adults undertaking a variable resistance training program versus a traditional program did not vary significantly17.

A growing interest in developing more particle and effective training methods convenient for exercising at the different situations (workplace, hospitals, home, training field) has been emerging to be attractive31. According to this tendency, strength training using elastic resistance has shown to be equally effective in activating smaller muscles in the neck, shoulder, and arm when compared to similar training exercises performed isotonically with dumbbells32,33. On the same way, Jacobsen et al.34 demonstrated that in untrained individual knee extensions performed with elastic tubes induces similar pattern of electromyography activity than exercise performed in machine. Andersen et al.35 (2010) also demonstrated comparably high levels of muscle activation were obtained during resistance exercises with dumbbells and elastic tubing, indicating that therapists can choose either type in clinical practice.

Possible limitations of this study are the few studies included in the meta-analysis and the heterogeneity of compared studies. Besides the overall results at the four forest plots have at least 2/3 included studies, for two subgroups (MCVI of lower limb and trunk) the analysis was performed with one study. So the interpretation of our results needs to take account this limitation. In the same way, the heterogeneity according I2 statistics were high in two analysis (ERT versus active control on functional performance and ERT versus passive control on muscle strength), with suspected clinical and or methodological heterogeneity across compared studies. We have to point that the majority of participants were women's, so this fact compromises the external validity of the present study.

According to the limitations, we believe that it is extremely necessary a comparative analysis of the effectiveness of ERT as the isolated method of training in men's and with more outcomes of muscle strength and functional performance. It is necessary more studies with adulthood population, so we can have more power at these results and to state an ideal training protocol.

5. Conclusion

This systematic review showed that elastic resistance training is better than passive control groups to develop muscle strength and functional capacity in health adults. Elastic resistance training seems to produce worst results on functional performance and appears to be effective on muscle strength than other methods of resistance exercise.

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Trial registration: This review was registered in PROSPERO under the number: CRD42015027002 (http://www.crd.york.ac.uk/PROSPERO/).

Figure 1 – PRISMA flow diagram

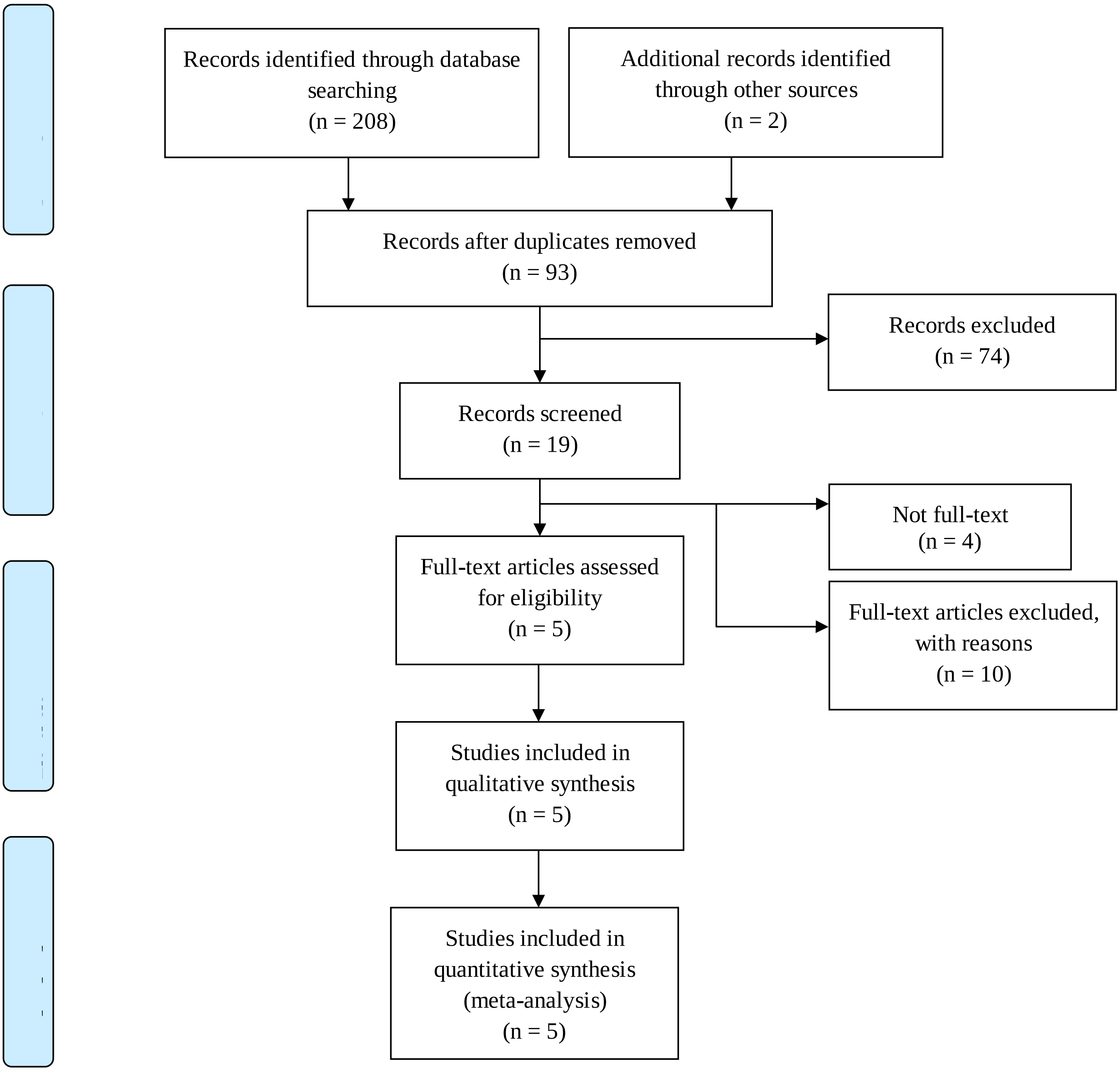


Table 1 - Characteristics of the studies.

Author and year	Aim of the study	Sample size (n)	Age (years)	Gender	Groups	Duration (weeks)	Frequency	Intervention	Outcome measures	Author´s conclusion
Sugimoto, 2006	Compare strength gains on the shoulder after an exercise program using 'Bodyblade' and exercises with elastic bands	EG = 12 OD = 14 CG = 14	24.3 (5,0) 23,8 (5,1) 24,9 (5,2)	M = 13 F = 27	EG = elastic band OD = 'Bodyblade' CG = without intervention	08	Once a week	EG = 3 x 10-20 repts OD = 2 x 30s-60s CG = without intervention	Isometric, concentric, and eccentric muscle strength of the internal and external shoulder rotators was measured by a isokinetic dynamometer	The exercise program with OD no increased strength in external and internal rotators in the CG and EG. Since the EG obtained in isometric strength of internal and external rotators higher percentage than the OD group and CG
Colado, 2008	If a short-term supervised muscular endurance program, produces differences in muscle mass and functional capacity when using two different devices	EG = 21 OD = 14 CG = 10	54,14 (2,87) 51,07 (6,81) 53,9 (1,85)	M = 0 F = 45	EG = elastic bands OD = weight machines CG = without intervention	10	Twice a week	10 combined exercises with 20 repts in each exercise in all devices	Knee push-up test to check the resistance of the extensor muscles of the elbow and shoulder horizontal adductor, squat test for lower limbs	Resistance training with elastic bands produces similar adaptations to the other device used in the study, in the early stages of strength training
Colado, 2009	Effects of resistance training with aquatic resistance devices or elastic bands on markers of cardiovascular health and physical capacity	EG = 21 OD = 15 CG = 10	54,0 (2,8) 54,7 (2,0) 52,9 (1,9)	M = 0 F = 46	EG = elastic bands OD = aquatic resistance device CG = without intervention	24	Twice per week in first 12 weeks and three times per week for weeks 13–24	7 different types of routines, progressive, combining 8-10 exercises with 20-30 repts and 30s for rest	Physical capacity tests - sit and reach, knee push-up, squat and abdominal crunch	Both exercise groups improved physical capacity indicators tested, but only OD group, significantly improved resistance of the abdominal muscles when compared with the group of EG. When compared with the CG, both exercise groups were significantly improved physical capacity tests

Colado, 2010	Effects of a short resistance exercise program, on the strength in young women using weight machines and free weight or elastic tubing	EG = 12 OD = 11 CG = 13	21,41 (0,36) 21,73 (0,78) 22,23 (0,97)	M = 0 F = 36	EG = elastic tubing OD = weight machine/ free weight CG = without intervention	08	2 – 4 sessions per week	15 combined exercise in 3 different training sessions, with 15 repetitions during weeks 1-2, 10 repts weeks 3 - 4, 8 repts weeks 5 - 7, and 15 repts in the last week of training and 30s - 90s for rest, according to the week	The maximal isometric voluntary contraction in 3 different Conditions using load cell: vertical rowing, squat and back extension	The strength training using elastic tubing or weight machines and free weights lead to an equivalent increase of isometric strength in young and physically active women
Colado, 2012	Effects of a supervised strength training program on body composition and physical capacity of older women using three different devices	EG = 21 OD1 = 14 OD2 = 17 CG = 10	54,14 (0,63) 51,07 (1,82) 54,71 (0,45) 53,9 (0,59)	M = 0 F = 62	EG = elastic bands OD1 = weight machines OD2 = aquatic device CG = without intervention	10	Twice per week	12 combined exercises with 20 repts, during the week, with change of speed exercises performed in water and passive rest 30s	In assessing the physical capacity were carried out three tests: knee push-up, squat and abdominal crunch	There are minimal differences in the effectiveness of the use of OD2, EB or OD1 to improve physical capacity and body composition in postmenopausal women. The different resources for strength training that have been used in this study have shown the potential to cause improvements in the post-test compared to the pre-test

EG = elastic group; OD = other device; CG = control group; M = male; F= female; repts = repetitions.

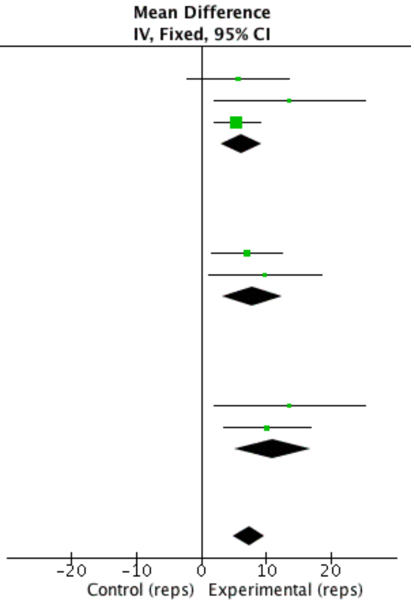
Table 2 - Assessment of the methodological quality of the studies included in the review analyzed by the PEDro scale.

First author, year	1 Eligibility criteria*	2 Random allocation	3 Concealed allocation	4 Baseline Comparability	5 Blind subjects	6 Blind therapists	7 Blind assessor	8 < 15% of desistence	9 Intention to treat analysis	10 Between groups comparison	11 Point estimates and variability	Total
Sugimoto, 2006		1	1	1	0	0	0	1	1	1	1	**7**
Colado, 2008		1	1	1	0	0	0	1	1	1	1	**7**
Colado, 2009		1	1	1	0	0	0	0	1	1	1	**6**
Colado, 2010		1	1	1	0	0	0	1	1	1	1	**7**
Colado, 2012		1	1	1	0	0	0	0	1	1	1	**6**

***Criterion 1 is not considered for the final score because it is an item that assesses the external validity (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003).**

Figure 2 – ERT versus passive control on functional performance.

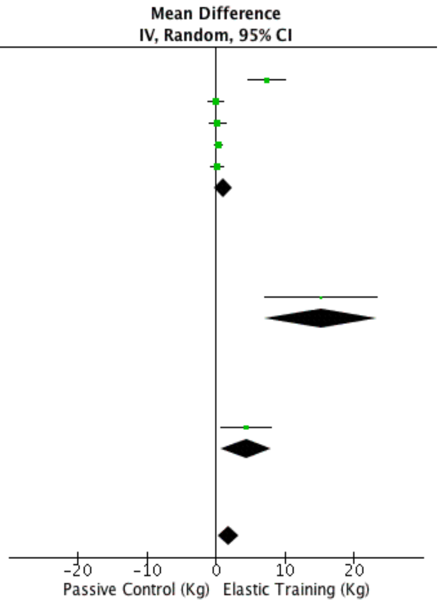
Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Fixed, 95% CI
6.1.1 Knee push up test								
Colado 2008 (a)	4.8	13.01	21	-0.9	9.12	10	8.9%	5.70 [-2.23, 13.63]
Colado 2009 (a)	8.1	16.01	21	-5.5	15.15	10	4.2%	13.60 [1.98, 25.22]
Colado 2012 (a)	5	2.69	21	-0.5	5.46	10	43.9%	5.50 [1.93, 9.07]
Subtotal (95% CI)			**63**			**30**	**57.0%**	**6.12 [2.98, 9.26]**
Heterogeneity: $Chi^2 = 1.72$, df = 2 (P = 0.42); $I^2 = 0\%$								
Test for overall effect: Z = 3.82 (P = 0.0001)								
6.1.2 Squat test								
Colado 2008 (b)	7.6	7.88	21	0.5	6.89	10	18.9%	7.10 [1.66, 12.54]
Colado 2009 (b)	12.8	7.7	21	3	12.93	10	7.5%	9.80 [1.14, 18.46]
Subtotal (95% CI)			**42**			**20**	**26.4%**	**7.86 [3.26, 12.47]**
Heterogeneity: $Chi^2 = 0.27$, df = 1 (P = 0.60); $I^2 = 0\%$								
Test for overall effect: Z = 3.35 (P = 0.0008)								
6.1.3 Abdominal crunch test								
Colado 2009 (a)	8.1	16.01	21	-5.5	15.15	10	4.2%	13.60 [1.98, 25.22]
Colado 2012 (c)	6.9	4.39	21	-3.2	10.39	10	12.5%	10.10 [3.39, 16.81]
Subtotal (95% CI)			**42**			**20**	**16.6%**	**10.97 [5.17, 16.78]**
Heterogeneity: $Chi^2 = 0.26$, df = 1 (P = 0.61); $I^2 = 0\%$								
Test for overall effect: Z = 3.70 (P = 0.0002)								
Total (95% CI)			**147**			**70**	**100.0%**	**7.39 [5.02, 9.76]**
Heterogeneity: $Chi^2 = 4.38$, df = 6 (P = 0.63); $I^2 = 0\%$								
Test for overall effect: Z = 6.11 (P < 0.00001)								
Test for subgroup differences: $Chi^2 = 2.13$, df = 2 (P = 0.34), $I^2 = 6.1\%$								



Forest plot of the results of the meta-analysis showing the mean difference in number of repetitions and 95% CI detected for the Knee push up test, Squat test and Abdominal crunch test. The last diamond represents the pooled mean difference (♦).

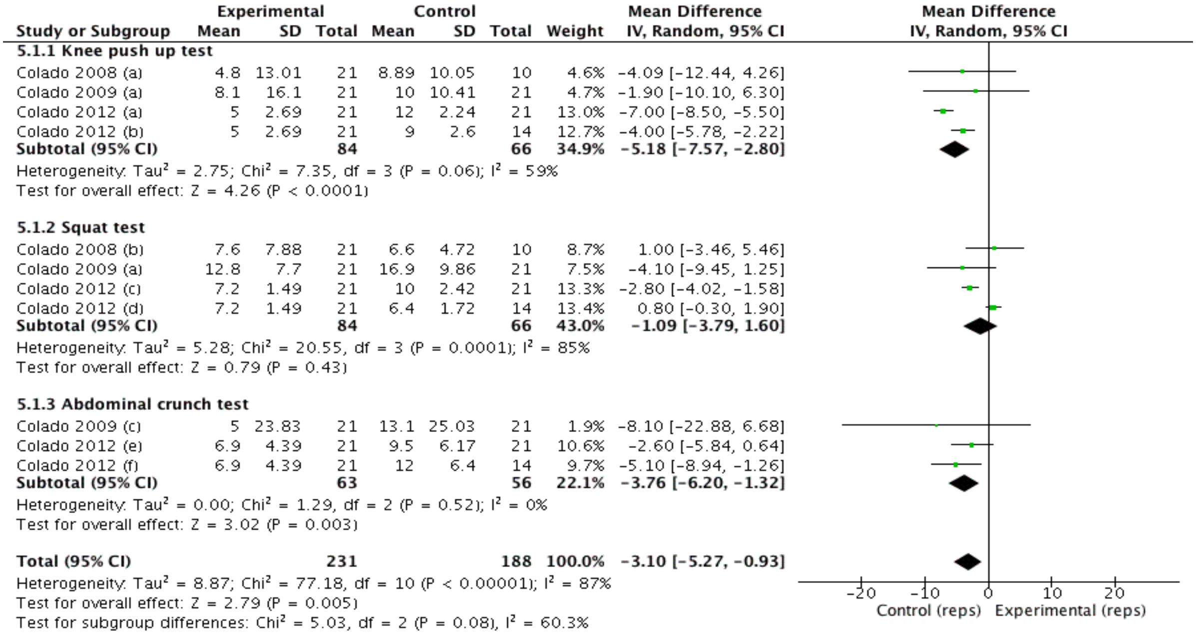
Figure 3 - ERT versus passive control on muscle strength.

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
2.1.1 MVIC Upper Limb								
Colado 2010 (a)	6.74	3.89	12	-0.71	2.93	13	12.1%	7.45 [4.73, 10.17]
Sugimoto 2010 (a)	0.19	1.32	12	0.14	1.7	14	18.5%	0.05 [-1.11, 1.21]
Sugimoto 2010 (b)	0.3	1.5	12	0.04	1.84	14	18.1%	0.26 [-1.02, 1.54]
Sugimoto 2010 (c)	0.34	0.73	12	-0.04	0.65	14	20.4%	0.38 [-0.16, 0.92]
Sugimoto 2010 (d)	0.16	1.24	12	-0.01	1.38	14	19.1%	0.17 [-0.84, 1.18]
Subtotal (95% CI)			**60**			**69**	**88.3%**	**1.07 [-0.19, 2.34]**
Heterogeneity: $Tau^2 = 1.62$; $Chi^2 = 26.40$, df = 4 (P < 0.0001); $I^2 = 85\%$								
Test for overall effect: Z = 1.66 (P = 0.10)								
2.1.2 MVIC Lower Limb								
Colado 2010 (b)	12.16	11.09	12	-3.1	9.48	13	2.8%	15.26 [7.14, 23.38]
Subtotal (95% CI)			**12**			**13**	**2.8%**	**15.26 [7.14, 23.38]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 3.68 (P = 0.0002)								
2.1.3 MVIC Trunk								
Colado 2010 (c)	6.53	5.16	12	2.1	4.18	13	8.9%	4.43 [0.73, 8.13]
Subtotal (95% CI)			**12**			**13**	**8.9%**	**4.43 [0.73, 8.13]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 2.35 (P = 0.02)								
Total (95% CI)			**84**			**95**	**100.0%**	**1.89 [0.44, 3.35]**
Heterogeneity: $Tau^2 = 2.62$; $Chi^2 = 43.45$, df = 6 (P < 0.00001); $I^2 = 86\%$								
Test for overall effect: Z = 2.55 (P = 0.01)								
Test for subgroup differences: $Chi^2 = 13.75$, df = 2 (P = 0.001), $I^2 = 85.5\%$								



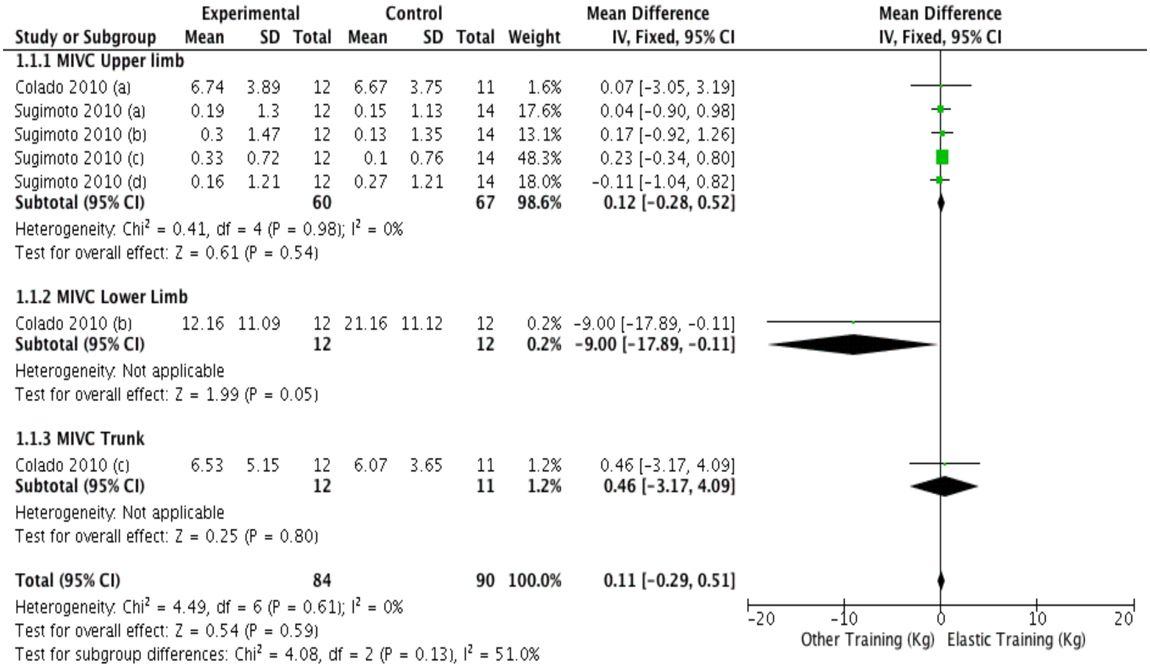
Forest plot of the results of the meta-analysis showing the mean difference in weight and 95% CI detected for the MVIC lower limb, MVIC trunk, MVIC upper limb. The last diamond represents the pooled mean difference (♦).

Figure 4 - ERT versus active control on functional performance.



Forest plot of the results of the meta-analysis showing the mean difference in number of repetitions and 95% CI detected for the Knee push up test, Squat test, Abdominal crunch test. The last diamond represents the pooled mean difference (♦).

Figure 5 - ERT versus active control on muscle strength.



Forest plot of the results of the meta-analysis showing the mean difference in weight and 95% CI detected for the MVIC lower limb, MVIC trunk, MVIC upper limb. The last diamond represents the pooled mean difference (♦)