Elastic resistance training improved glycemic homeostasis, strength, and functionality in sarcopenic older adults: a pilot study

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The purpose of this study was to verify the effects of 12 weeks of elastic resistance training on the glucose homeostasis, strength and functionally in sarcopenic older adults. Seven sarcopenic subjects (age, 70.71 ± 8.0 years; body mass index, 22.75 ± 3.1 kg/m²) participated of training protocol with 12 weeks of elastic resistance training. The oral glucose tolerance test, handgrip strength, sit-to-stand test, 4-m walk test, and coordination test were measured at baseline and after training. According to the results, baseline values of area under the curve of glucose and homeostatic model assessment-insulin resistance were significantly lower than after 12 weeks, respectively (808.2 ± 185.0 mmol/L vs. 706.6 ± 114.8 mmol/L, $P = 0.049$; 1.44 ± 0.48 vs. 0.73 ± 0.32, $P = 0.040$). There were a significant improve of HGS (24.3 ± 5.7 kg vs. 27.3 ± 7.3 kg, $P = 0.01$), 4-m walking test (3.64 ± 0.4 sec vs. 3.23 ± 0.3 sec, $P = 0.04$), and STS (10.2 ± 2.3 sec vs. 9.0 ± 1.9 sec, $P = 0.04$) compared with baseline. In conclusion, these findings suggest that elastic resistance training improved glucose homeostasis, strength, and functionality in sarcopenic older adults.

Keywords: Sarcopenia, Exercise, Glucose tolerance test, Insulin resistance

INTRODUCTION

A marked reduction in muscle mass and strength associated with aging may result in sarcopenia (Bonnefoy and Gilbert, 2015), which is related with the development of certain diseases, such as insulin resistance (IR). It has been reported that IR may be one potential factor involving in muscle wasting by accelerates protein degradation. The link between the IR and reduction of skeletal muscle is based on the action of insulin in suppressing muscle protein degradation (Abdulla et al., 2016), once insulin signaling dysfunction leads suppression of phosphatidylinositol 3-kinase and Akt, increasing the activation of the ubiquitin-proteasome pathway (Wang et al., 2006). For this reason, maintain glucose homeostasis and insulin sensitivity is essential to prevent loss of skeletal muscle mass in sarcopenic condition (López Teros et al., 2015), mainly due low muscle mass is associated with mortality risk among older people (Ali et al., 2008; Levine and Crimmins, 2012).

The reduction of strength and functional capacity is also another characteristic in sarcopenic older adults, generating frailty, loss of autonomy, and higher risk of falls and fractures (Alley et al., 2014; Manini et al., 2007). A cohort study with examines the re-

lationship between handgrip strength (HGS) and fasting insulin levels showed a significant correlation between IR and weaker muscle strength in older persons, independently of confounders, suggesting that older with IR are more likely to achieve a reduction in strength (Lazarus et al., 1997). Supporting this, Kalyani et al. (2015) demonstrated that lower muscle strength were significantly associated with hyperglycemia with aging, demonstrating that glycemic control is important for muscle function (Kalyani et al., 2015). Additionally, it is also known that glucose levels can be higher in fragile patients when compared to healthy older adults, increasing the risk of type 2 diabetes for those patients (Goulet et al., 2010; Srikanthan et al., 2010).

On the other hand, resistance training is highly recommended for older. Studies have shown that resistance training generates beneficial effects on muscle function, acting in the prevention and treatment of sarcopenia (Papa et al., 2017; Smith et al., 2003). It is an effective tool in frailty syndromes, because it acts increasing strength, functional capacity, power, improving the capacity to perform tasks of daily living. In addition, resistance training is strongly recommended for improve insulin sensitivity as well as is an efficient training type to induce glycemic control (Winett and Carpinelli, 2001).

The effectivity of alternative tools for resistance training such as elastic resistance training (ERT) is highly important, because ERT can promote advantages for being simple to operate, portable, requiring less space and low cost compared to conventional resistance training. In addition, older adults in condition of frailty, rehabilitation program (i.e., hospitalized patients), dysfunction in motor control and musculoskeletal injury may not be able to perform traditional (machine or free weight exercise) resistance training at the gym, once ERT may be used for an alternative tool for these conditions. There currently exists a considerable body of research that suggests ERT to improve strength and functional capacity in older adults (Liao et al., 2017; Martins et al., 2015; Oesen et al., 2015). In addition, ERT was able to improve muscular performance in chronic obstructive pulmonary disease (COPD) (Silva et al., 2016), reduce fat mass in older woman with sarcopenic obesity (Huang et al., 2017) and increased lean body mass in sarcopenic obesity (Liao et al., 2017). Nevertheless, the behavior of glycemic homeostasis was not yet studied with elastic tubes.

In this context, the use of elastic resistance can be an accessible way for any public or private health care, as well as in the home environment. Characteristics that may positively imply in more access to treatment may also decrease hospitalizations, public spending and increased patient survival. Thus, the aim of this study was to verify the effects of 12 weeks resistance training with elastic tubes on the glucose homeostasis, strength and functionality in sarcopenic older adults.

MATERIALS AND METHODS

Subjects and design

This study was conducted in the city of Presidente Prudente, São Paulo, Brazil (approximately 210,000 inhabitants). The participants were chosen through convenience sampling. The study was advertised in the local media, and the individuals voluntarily presented themselves at the institution. The inclusion criteria were: to be aged 60 years or older and to have lived in Presidente Prudente (São Paulo) for at least 2 years. The exclusion criteria were: an inability to walk, being bedridden, using pacemakers, and having incomplete personal data in the database.

Initially, for the classification of the sarcopenic older adults, appendicular muscle mass was determined by a Lunar Dual-Energy X-Ray Absorptiometry (General Electric Healthcare model, Lunar DPX-NT, version 4.7, Madison, WI, USA), using the three-compartment model (lean body mass, fat mass, and mineral mass). The sum of fat and bone free mass of upper and lower limbs was used to indicate appendicular lean soft tissue (ALST). ALST index was calculated as the ratio of ALST and height to the square (ALSTi). Muscle strength, in kg, was measured with a CAMRY hydraulic hand dynamometer (EH101 Camry, Guangdong, China). Gait speed, in m/sec, was recorded in a 4-m test. After screening measurements, the European Working Group on Sarcopenic in Older People proposal for sarcopenia diagnosis was applied.

From 307 older adults who attended the invitation, 15 were classified as sarcopenic and agreed to participate in the 12 weeks of resistance training with elastic tubes program, and seven subjects (age, 70.7 ± 8.0 years; body weight, 61.2 ± 12.9 kg; body mass index, 22.7 ± 3.1 kg/m^2, three males and four females) completed all procedures in this study. The participants were informed regarding the study objectives and data collection methodology, and also that they were free to drop out of the study at any time. Only those who signed an informed consent form were allowed to join the study. All protocols were reviewed and approved by the Research Ethics Committee of the São Paulo State University (Process nº 16792013. 1.0000.5402). Clinical trial number - RBR-5cc79w.

Resistance training program

The sarcopenic older adults were involved in 12 weeks of resistance training with elastic tubes program consisted of 75-min

training sessions performed three times per week. Each session consisted of a warm-up at the beginning and general stretching at the end. The exercises used in the program were: knee extension and flexion, shoulder abduction, elbow flexion and extension, chest press, and seated row were performed using seven different elastic tubes (Lemgruber brand, Rio de Janeiro, Brazil) sizes, ranging from internal diameters of 2,5 mm to 12 mm and external diameters of 5 mm to 18.5 mm.

Individuals were trained after assessing the individual's elastic tube size, as determined by repeated administration of the fatigue resistance test with 1-min rest intervals. The fatigue resistance test aimed to provoke task failure owing to fatigue after 12–15 repetitions for each movement execution, in a specific elastic tubing size. During the test, the patients were instructed to perform each movement with a full range of motion for the maximum number of repetitions. The test was interrupted in the case of fatigue, significant reduction in the range of motion or muscle compensation.

Training program consisted of three progressive phases: phase 1 (1st to 2nd weeks: 2 sets of 15 repetitions; 60 sec of interval recovery between sets); phase 2 (3rd to 6th weeks: 3 sets of 15 repetitions; 90 sec of interval recovery between sets); phase 3 (6th to 12th weeks: 3 sets of 8 to 12 repetitions; 90 sec of interval recovery between sets). The sets were executed until momentary exhaustion, (i.e., when the participants performed the training with repetitions varying from 8 to 12 repetition maximum (RM), they were always encouraged to execute at least 8 and no more than 12 RM). In the case of the participants executing more repetitions, the elastic tubing size was increased in order to keep within the training zone (Silva et al., 2016).

Glucose tolerance test

The homeostasis model assessment was performed by oral glucose tolerance test (OGTT) before and posttraining, and venous blood samples were collected at times 0, 15, 30, 45, 60, 90 and 120 min after oral administration 75 g of glucose in 0.3 L of water, after 12 hr of fasting. The differences in glucose and insulin levels before and after administration of glucose were used to calculate the area under the curve (AUC). In addition, the homeostatic model assessment-IR (HOMA-IR) was calculated. Glucose levels in plasma was analyzed by a colorimetric method, obtained from Labtest, Brazil. Insulin was assessed using enzyme-linked immunosorbent assay commercial kits (Monobind Inc., Lake Forest, CA, USA). To eliminate interassay variance, all samples were analyzed in identical runs resulting in an intraassay variance of <7%.

Handgrip strength

The HGS was estimated by electronic dynamometer (Power Din Standard, CEFISE, São Paulo, Brazil). Each test was performed twice with an interval of 1 min. The largest values obtained were recorded for analysis purposes. The subjects remained seated with the dominant member on the table and angle of elbow flexion between 120° and 150°. Peak force values were measured.

Functionality

The sit-to-stand test (STS) was applied, in which subjects kept their arms crossed over chest, and, at a signal from the evaluator, stood up and sat down in the chair as quickly as possible, 5 times without pause. Those who failed to perform this task in less than 60 sec were disqualified from the test (Guralnik et al., 1994).

A 4-m walk test was used to assess the gait speed. Subjects were instructed to walk naturally, and the lower time (in sec) obtained between two walks was recorded (Guralnik et al., 1994).

The coordination test was taken from the American Alliance for Health, Physical Education, Recreation and Dance. The equipment for soda pop coordination test consisted of three unopened (360 g) cans of soda pop, a stopwatch, masking tape, a table, and a chair. Two test trials were given to a subject after two practice trials to allow him or her to understand test instructions and procedures. The time for each trial was measured with the unit of 0.1 sec. The best trial was recorded as the score (Yaguchi and Furutani, 1998).

Data analysis

A 2×7 repeated measures analysis of variance (RMANOVA) with the Bonferroni adjustment for multiple comparisons was used to compare OGTT and insulin. When a significant difference or interaction was observed, a Bonferroni *post hoc* test was conducted. For all measured variables, the estimated sphericity was verified according to Mauchly W test and the Greenhouse–Geisser correction was used when necessary. The effect size (ES) was calculated. Statistical significance was set at $P < 0.05$. The comparison of HGS and functionality at baseline and 12 weeks after resistance training protocol was performed using the Student *t*-test for parametric distributions or the Mann–Whitney test for nonparametric distributions. The data were analyzed using SPSS ver. 17.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

There was an increase of HGS with significant difference between baseline and after 12 weeks of training ($P = 0.01$). For functional-

Table 1. Comparison between moments on handgrip strength and functionality

Variable	Baseline	12 Weeks	Δ	ES	P-value
HGS (kg)	24.3±5.7	27.3±7.3	3.0	0.46	0.01
4-m walk test (sec)	3.64±0.4	3.23±0.3	-0.4	1.13	0.04
STS (sec)	10.2±2.3	9.0±1.9	-1.2	0.57	0.04
Coordination test (sec)	15.9±3.6	11.7±1.4	4.2	1.68	0.08

Values are presented as means±standard deviation.
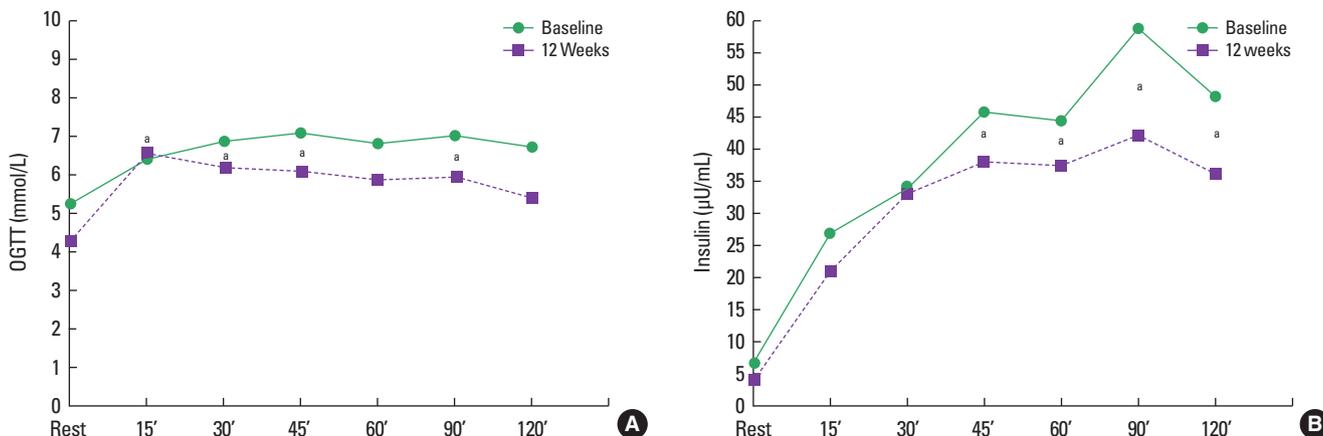HGS, handgrip strength maximum; STS, sit-to-stand test; Δ, 12 weeks minus baseline; ES, effect size.

Fig. 1. Difference on the oral glucose tolerance test (OGTT, mmol/L) (A) and insulin concentration (μU/mL) (B) between baseline and after 12 weeks of training. a, main effect of time with $P < 0.05$ compared to rest (Bonferroni *post hoc* test).
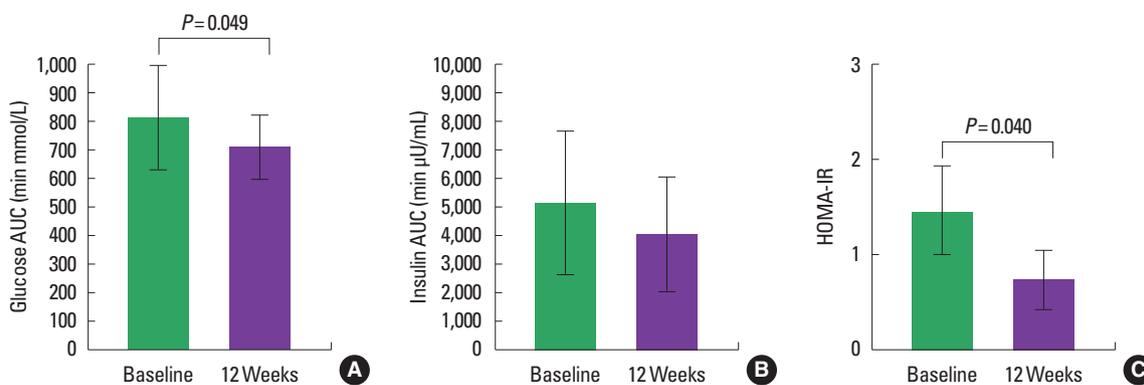

Fig. 2. Areas under the curve (AUC) for glucose (A), insulin (B), and homeostatic model assessment-insulin resistance (HOMA-IR) (C) during the 120 min following glucose ingestion. Results are presented as mean±standard deviation.

ity, there were an improvement of STS ($P = 0.04$) and 4-m walk test ($P = 0.04$) after training compared with baseline (Table 1).

When performing the comparison on OGTT (Fig. 1), there was main effects of time ($F = 3.32$, $P = 0.01$, ES = 0.36). OGTT increased post 15, 30, 45, 90 min compared to rest at baseline and after 12 weeks of training ($P < 0.05$). There was no statistical difference between baseline and after 12 weeks of training ($F = 5.16$, $P = 0.06$, ES = 0.46).

For insulin, there was main effects of time ($F = 4.80$, $P < 0.01$, ES = 0.44). Insulin increased post 45, 60, 90, 120 min compared to rest at baseline and after 12 weeks of training ($P < 0.05$). However, there was no statistical difference between baseline and after 12 weeks of training ($F = 3.16$, $P = 0.13$, ES = 0.35).

Baseline values of AUC of glucose ($P = 0.049$) and HOMA-IR ($P = 0.04$) (Fig. 2A, C) were significantly lower than after 12 weeks of ERT, respectively. Insulin values showed no significant

difference (Fig. 2B).

DISCUSSION

The main finding of this study was that 12 weeks of ERT was able to improve glucose homeostasis in sarcopenic older adults by decreasing AUC for glucose as well as IR. In addition, our results showed that ERT increased HGS and functionality.

The link between the IR and reduction of skeletal muscle is based on the action of insulin in suppressing muscle protein degradation (Abdulla et al., 2016). Specificity, insulin can stimulate the PI3lK/Akt signaling pathway in muscle cells, leading inhibition of ubiquitin-proteasome system (Wang et al., 2006). In fact, the increases of IR can accelerate loss of muscle mass in aged subjects, mainly due the inefficient action of insulin to inhibit muscle protein degradation. Human evidence demonstrated that hyperinsulinemia, a marker of IR, is associated with the loss of appendicular skeletal muscle mass in older (López Teros et al., 2015). Based these findings, it seems reasonable to speculate that increase insulin sensitivity is essential to prevent or increase muscle mass in older.

There currently exists a considerable body of research demonstrating increases of insulin sensitivity using traditional resistance training (Irvine and Taylor, 2009; Tresierras and Balady, 2009). However, the influence of ERT on IR in sarcopenic older adults is unknown in the literature. Our study demonstrated that AUC of glucose and HOMA-IR were lower than after 12 weeks of ERT. Supporting our results, Jin et al. (2015) found that 12 weeks of ERT using elastic band (twice a week) reduced the mean value of blood glucose levels from 122.2 to 103.1 (mg/dL) in older women with hyperglycemia (Jin et al., 2015). Thus, according with our study and Jin et al. (2015) it is considerable the prescription of ERT to improve glucose homeostasis in older adults. These findings have a great clinical application, once older adults in condition of fragility, rehabilitation program (i.e., hospitalized patients), dysfunction in motor control and musculoskeletal injury may not be able to go at the gym, however, elastic tubes is portable, requiring less space and low cost compared to conventional resistance training, and can be an accessible way for any public or private health care, as well as in the home environment.

Furthermore, older with IR are more likely to achieve a reduction in strength, which there is a relationship between lower HGS with higher fasting insulin levels, suggesting that IR may be one potential factor involving weaker muscle strength in older persons (López Teros et al., 2015). Corroborating with this finding, Kaly-

ani et al. (2015) demonstrated that lower muscle strength were significantly associated with hyperglycemia with aging. Corroborating with these findings, our results also showed that ERT increased HGS as well as functionality, once the improvement of insulin sensitivity as demonstrated in our results may be one possible factor that the subjects improved skeletal muscle function.

Corroborating with our findings, Liao et al. (2017) investigated the effects of ERT on body composition and functional capacity in older women with sarcopenic obesity. The program lasted 12 weeks with three training sessions weekly, each exercise was performed with three sets of 10 repetitions and the intensity was monitored by rate of perceived exertion. The results showed that ERT increased total fat-free mass, HGS and improved functional capacity (time up-and-go, single-leg stance, gait speed and timed chair stand) (Liao et al., 2017). In addition, training with elastic resistance has already been used, and showed functional benefits in healthy older adults (Turban et al., 2014), cardiovascular disease (Martins et al., 2013) and COPD (Silva et al., 2016). Thus, ERT may be an effective tool in frailty syndromes, increasing autonomy and reduces the risk of falls and fractures. In addition, it is very important to keep the practice of resistance training for sarcopenic older adults, once regular practice of resistance training has the potential to significantly reduce all-cause mortality in older adults (Kraschnewski et al., 2016), thus, elastic tube is one alternative to increase adherence of resistance training in this population.

Despite the importance of our data, some limitations need to be considered, such as the lack of a control group, body composition assessment and small sample size. However, from the results, there is a direction for the use of the elastic tubes in this population, mainly for the glycemic control. Other studies should be developed to analyze more effects of exercise training on sarcopenic people, where as this procedure is involved in decreased mortality and risk factors for severe disease, which may reflects decreases in hospitalizations, public spending and better quality of life for these patients.

In conclusion, ERT improved glucose homeostasis by increasing insulin sensitivity in sarcopenic older adults. Moreover, ERT enhanced strength and functionality in this population. Based on the study results, elastic tubes may be an accessible way to improve glucose homeostasis, strength and functionality in any public or private health care, as well as in the home environment.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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