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SYNERGIST UPPER-LIMB RESISTANCE TRAINING REDUCES BLOOD PRESSURE IN YOUNG NORMOTENSIVE MEN: A PILOTY STUDY

[1]Eliézer Guimarães Moura, [2]Wilton Marlindo Santana Nunes, [3]Luan Oenning Col, [4]Ligia Antunes-Correa, [5]Heitor Moreno Jr. & [6]Bruno Rodrigues

ABSTRACT

Purpose: We aimed to verify the effects of 8 weeks of resistance training on the synergistic and non-synergistic routines on peripheral and central blood pressure, biochemical variables, and pulse wave behavior recreationally trained men.

Methods: A program of resistance training predominantly for the upper limbs was prescribed. Ten healthy young men participated in a routine synergistic, and 12 men performed a routine non-synergistic. Peripheral and central arterial pressures (oscillometric and applanation tonometry methods, respectively), as well as biochemical variables (lipid profile, glucose, hemoglobin, and noradrenaline) and arterial stiffness (pulse wave velocity by applanation tonometry), were evaluated.

Results: No differences between group were observed in biochemical variables, except a decrease in values of the hemoglobin concentration at the post compared to pre-condition in the non-synergistic group (p= 0.015). No differences between group were observed for tonometry applanation variables. However, an increase in peripheral and central diastolic blood pressures was detected in the non-synergistic group (p= 0.026 and 0.021, respectively). In the synergistic group, a reduction in diastolic blood (p= 0.041) and increased central pulse pressure (p= 0.046) were observed.

Conclusions: Thus, the resistance training performed predominantly with the upper limbs does not increase arterial stiffness but may increase diastolic blood pressures in healthy young men.

Keywords: Hypertension. Resistance Training. Blood Pressure. Arterial Stiffness.

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[1]Centro Universitário Adventista de São Paulo - UNASP, São Paulo, (Brasil). E-mail: eliezer.guimaraes@acad.unasp.edu.br Orcid id: https://orcid.org/0000-0002-2477-8242
[2]Centro Universitário Adventista de São Paulo - UNASP, São Paulo, (Brasil). E-mail: wmsnunes@terra.com.br Orcid id: https://orcid.org/0000-0003-0320-7851
[3]Centro Universitário Adventista de São Paulo - UNASP, São Paulo, (Brasil). E-mail: luanoenning@hotmail.com
[4]Universidade Estadual de Campinas - UNICAMP, São Paulo. (Brasil). E-mail: E-mail: ligiamac@unicamp.br Orcid id: https://orcid.org/0000-0002-5639-1325
[5]Universidade Estadual de Campinas - UNICAMP, São Paulo. (Brasil). E-mail: E-mail: hmoreno@uol.com.br Orcid id: https://orcid.org/0000-0001-6330-697X
[6]Centro Universitário Adventista de São Paulo - UNASP, São Paulo, (Brasil). E-mail: prof.brodrigues@gmail.com

INTRODUCTION

Resistance training (RT) has been widely recommended for several purposes, such as increasing muscle mass (Sabag et al., 2018), reducing body fat, as well as for preventing and treatment of chronic diseases (Montalvo et al., 2018). The manipulation of training variables, such as volume and load, are crucial factors for strength and muscle mass gains in well-trained individuals (Simão et al., 2012). Dividing the RT routine into body regions, i.e., alternating upper and lower-body training days, is recommended to maximize training volume within a training session and allow appropriate muscle recovery (Monteiro et al., 2009). Additionally, the training of each body region can be further divided into different training routines. In upper-body training, for example, the routine can be divided into pull-pull exercises (i.e., synergist muscles) on the same day or push-pull exercises (i.e., nonsynergist muscles) on the same day (Castanheira et al., 2017). These routines can have advantages and disadvantages, such as longer recovery time for muscle groups, maximizing training volume, or impairment of performance (Gentil et al., 2007; Ribeiro et al., 2015).

On the other hand, adverse changes in hemodynamic and blood vessel compliance in young people have recently reported in RT practitioners, mainly from a process of increased arterial stiffness have been reported (Townsend et al., 2015). Edwards et al. (2008) found that arterial stiffness occurs when exercises are performed with the upper limbs; however, such findings can be mitigated when lower limb training is conducted in the same training session. These data seem to be corroborated by Okamoto et al. (2009), assessing the pulse wave velocity (PWV) method. Increases in arterial stiffness were strongly correlated with higher circulating norepinephrine levels, increasing the vasoconstriction and directly influencing increased stiffness (Raastad et al., 2001).

Based on the above, this study aimed to verify the effects of 8 weeks of RT on the synergistic (SN, pectoralis, and triceps muscles in the same session, and back and biceps muscles in the same session) and non-synergistic (NSN, pectoralis and biceps muscles in the same session, and back and triceps muscles in the same session) routines on peripheral and central blood pressure, biochemical variables and pulse wave behavior in recreationally trained men. We hypothesized that the SN and NSN groups did not show significant differences in arterial stiffness.

MATERIAL AND METHODS

Subjects

Thirty-one male volunteers, ranging from 18 to 25 years, were screened for this descriptive and randomized study. All subjects had previously performed resistance training (RT) for at least six months without interruption. They were excluded if they had any history of neuromuscular, metabolic, hormonal, or cardiovascular diseases. The exclusion criteria were also extended if they had taken any drug that could influence hormonal function or neuromuscular performance.

Study design

After twelve hours of fasting, blood samples were collected during the first visit. A Physical Activity Readiness Questionnaire (PAR-Q) was applied. Then, the participants were assessed for body weight, height, and office blood pressure. Applanation tonometry evaluated noninvasive central hemodynamic variables (SphygmoCor CPV system, AtCor Medical, USA). 24 hours later, subjects performed one maximum repetition test (1RM) that was repeated 48 hours later in the second visit. Subjects participated in the randomized (made after the pre-evaluations through a draw in paper numbers) stage of the protocol, where they were allocated to the two resistance training (RT) programs (8 weeks), i.e., synergistic routine (SN) and non-synergistic (NSN) routine. After 48 hours of least RT session, blood samples were collected, and hemodynamic variables were also measured.

Biochemical analyses

Blood samples were collected by venipuncture in heparinized vacutainers after 12 hours of fasting and immediately centrifuged at 4000 rpm for 5 min to separate plasma. The colorimetric method through the BIOCLIN® kit was used for the biochemical analysis of glucose, total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-c), and hemoglobin. To determine low-density lipoprotein cholesterol (LDL-c) values, Friedewald et al. (1972) procedure was used. The device used to verify the optical density of the samples was the Micro processed Digital Spectrophotometer, model V-M5 (Bel Photonics®). Noradrenalin concentrations were determined in peripheral blood using the enzyme-linked immunosorbent assay (ELISA) technique using a high detection sensitivity kit (Elabsience, USA) with ranges between 0.313-20ng/mL.

Office blood pressure measurement

Office BP was measured using a certified digital sphygmomanometer (HEM-907 XL OMRON Healthcare Inc., Bannockburn, IL, USA) by a trained health professional. Office BP was assessed to calibrate the tonometer, which was used to determine central blood pressure and pulse wave velocity (PWV).

Central blood pressure and pulse wave assessment

Applanation tonometry was performed to assess noninvasive central hemodynamic variables and pulse wave velocity using the SphygmoCor system (AtCor Medical, Sydney, Australia). Consecutive measurements of the carotid and femoral artery pulse waves were electrocardiogram gated. The distance between the two sites was measured on the body surface to determine aortic PWV in meters/second (m/s). The total distance between the carotid and femoral arteries was used for measurement. The average sizes throughout 8 s (9-10 cardiac cycles) were calculated after excluding extreme values (above or below four standard deviations).

After 20 sequential waveforms were acquired and averaged, a validated generalized mathematical transfer function was used to synthesize the corresponding central aortic pressure wave.

The Augmentation Index (AIx), defined by the ratio between the pressure exerted by the reflected wave and the ejection wave, was evaluated (de Andrade Barboza et al., 2021). This index is expressed as a percentage of the Central Pulse Pressure (AIx = BP/central pulse pressure (cPP) × 100%). Since AIx is influenced by heart rate, an index normalized for 75 bpm was used too. The patients were required to abstain from smoking and consuming alcohol or coffee 24-h before the procedure.

Resistance training

All subjects performed seven exercises for the upper body, four times a week, for eight weeks. The SN group trained in the same session: pectorals (straight bench press, incline bench press, peck deck, and crucifix); and the triceps (triceps on the straight bar and rope). In subsequent session: back (pronated pull on the upper pulley, supine pull on the upper pulley, reverse peck deck and open row) and biceps (barbell and Scott thread). The NSN group trained in the same session: pectorals and biceps, and in the subsequent session: back and triceps. All exercises consisted of 4 sets of 8-12 repetitions, with 240 repetitions per session. 60-90 seconds were adopted as the rest between series. The maintenance of lower body training in both groups occurred as follows: 15-20% of the total volume of the upper body, training the knee extensor musculature (extension chair) unilaterally.

Statistical analysis

Statistical analysis and graphing performed using the GraphPad Prism 8.3 software. Data normality was tested using the Shapiro-Wilk test. To complete the paired comparison between pre- and post-moments in all variables, including age, BMI, and RT experience, the Unpaired T-Test (when normal distribution) and the Mann-Whitney test (when not observed normal distribution) for analysis of deltas (Δ post-pre) of all variables. A Mixed-effects analysis was used to compare intragroup and intergroup hemodynamic and arterial stiffness variables. Repeated measures ANOVA cannot handle missing values. Therefore, we analyzed the data instead by fitting a mixed model as implemented in GraphPad Prism 8.0. This mixed model uses a compound symmetry covariance matrix and is fit using Restricted Maximum Likelihood (REML). In the absence of missing values, this method gives the same P values and multiple comparisons tests as repeated measures ANOVA. In the presence of missing values (missing completely at random), the results can be interpreted like repeated measures ANOVA. An ANOVA two-way was used to compare the values of biochemical variables since the N of participants was similar. When necessary, a Tukey posthoc was used to perform all multiple comparisons. The significance level adopted was $p \leq 0.05$.

RESULTS

Thirty-one participants started the study; however, 4 interrupted the program due to changes in their work schedule, three due to injuries not associated with this study, and two due to lack of motivation. Thus, 22 subjects completed the RT program (10 in the SN group and 12 in the NSN group). Two subjects of the NSN group were unable to participate in one of the blood collections, and they were excluded from this analysis, remaining in all the others (Figure 1).

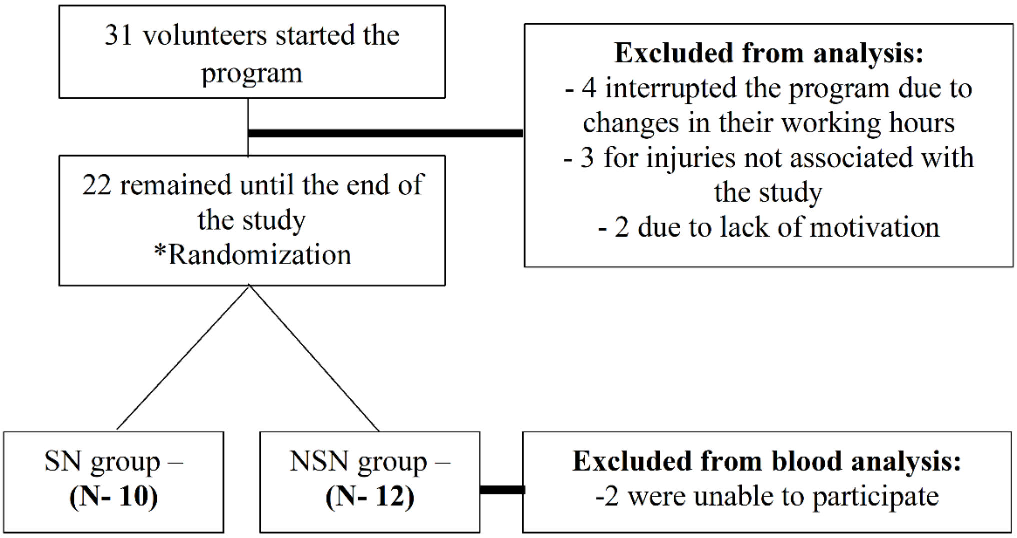

Fig. 1 Flowchart of participant's enrolment and randomization for the SN (RT synergist routine) and NSN (RT non-synergist routine) groups.

Table 1 shows that the mean age of the SN group was 22.1 ± 3.2 years, and the NSN group 20.2 ± 2.4, and had performed RT for 33.2 ± 16.4 and 29.1 ± 19.0 months, respectively, not show significant differences between them. Also, it shows the values of the biochemical analyses, peripheral and central blood pressure, and pulse wave behavior pre, and post-RT. No intra- and inter-group differences resulting from RT were observed in biochemical variables, except a decrease in the mean values of the hemoglobin concentration at the post compared to pre-condition in the NSN group (p= 0,015). Also, we did not observe differences between pre- and post-RT for tonometry applanation variables. However, an increase in peripheral (pDBP) and central (cDBP) diastolic blood pressures were detected in the NSN group (p= 0.026 and 0.021, respectively). In the SN group, a reduction in cDBP (p= 0.041) and increased central pulse pressure (cPP, p= 0.046) were observed.

Table 1. Biochemical, peripheral, and central blood pressure, and pulse wave behavior in SN and NSN groups.

	SN (n=10)		NSN (n=12)		#*P* value
	PRE	POST	PRE	POST	
Age (years)	22.1±3.2	22.1±3.2	20.2±2,4	20.2±2,4	0.1177
BMI (Kg/m²)	26.3 ± 4.1	26.6 ± 4.4	23.1 ± 2.9	23.5 ± 3.2	0.4655
RT experience (months)	33.2±16.4	-	29.1±19.0	-	0.6354
Biochemical Variables					
Glucose (mg/dL)	87.5 ± 10.8	85.6 ± 4.6	88.0 ± 5.1	87.3 ± 9.6	0.8210
Cholesterol Total (mg/dL)	149.3 ± 15.3	138.9 ± 18.9	134.4 ± 27.1	144.6 ± 30.5	0.1236
Triglycerides (mg/dL)	62.2 ± 19.4	57.7 ± 22.1	71.2 ± 6.1	72.8 ± 19.9	0.5361
HDLc (mg/dL)	42.2 ± 4.6	37.7 ± 7.5	43.3 ± 6.5	40.4 ± 5.4	0.5172
LDLc (mg/dL)	94.7 ± 15.0	89.7 ± 19.2	76.8 ± 23.6	89.7 ± 28.4	0.1572
Hemoglobin (g/dL)	15.8 ± 1.0	14.7 ± 2.6	15.8 ± 1.1	13.9 ± 2.3*	**0.0231**
Norepinephrine (ng/mL)	5.1 ± 2.3	5.2 ± 3.3	4.1 ± 2.5	4.0 ± 2.4	0.7714
Hemodynamic Variables					
pSBP (mmHg)	121.3 ± 11.0	124.9 ± 6.6	122.4 ± 8.6	123.1 ± 6.7	0.5047
pDBP (mmHg)	74.6 ± 6.1	69.5 ± 6.1	68.4 ± 3.4	73.4 ± 6.2*	**0.0043**
cSBP (mmHg)	104.3 ± 9.0	105.4 ± 6.7	103.0 ± 6.5	104.3 ± 5.4	0.8088
cDBP (mmHg)	75.1 ± 6.0	70.1 ± 6.0*	68.9 ± 3.5	74.0 ± 6.1*	**0.0034**
pPP (mmHg)	47.0 ± 7.6	55.4 ± 7.0	54.0 ± 9.0	49.7 ± 9.9	**0.0052**
cPP (mmHg)	29.2 ± 4.6	35.3 ± 4.6*	34.1 ± 6.3	30.3 ± 6.6	**0.0046**
HR (bpm)	62.5 ± 10.1	59.4 ± 5.1	61.1 ± 7.4	63.0 ± 5.3	0.2344
Pulse Wave Behavior					
Period (ms)	980.4 ± 152.5	1013.4 ± 86.9	993.5 ± 108.3	960.3 ± 86.3	0.3437
Ejection Duration (ms)	329.0 ± 17.7	328.6 ± 11.0	326.8 ± 16.8	317.6 ± 15.1	0.2494
AIx (mmHg)	1.3 ± 2.3	2.3 ± 1.8	1.1 ± 4.2	1.3 ± 2.1	0.5694
Aortic AIx AP/PP % (mmHg)	4.1 ± 7.7	6.3 ± 4.2	2.8 ± 11.8	3.8 ± 5.5	0.7716
AIx 75bpm (mmHg)	-1.9 ± 6.0	-1.1 ± 4.0	-3.8 ± 12.3	-2.1 ± 6.3	0.8163
PWV (m/s)	5.5 ± 1.4	5.28 ± 0.5	5.1 ± 0.8	5.5 ± 0.6	0.1965

ANOVA two-way (for biochemical variables) and Mixed-effects analysis (for other analyzes) test. Data presented as mean ± standard deviation. SN = RT synergistic routine. NSN = RT non-synergistic routine. BMI = Body Mass Index. RT = resistance training. HDLc = High density lipoprotein cholesterol. LDLc = Low density lipoprotein cholesterol. pSBP = Peripheral Systolic Blood Pressure. pDBP = Peripheral Diastolic Blood Pressure. cSBP = Central Systolic Blood Pressure. cDBP = Central Diastolic Blood Pressure. pPP = Peripheral Pulse Pressure. cPP = Peripheral Pulse Pressure. HR = Heart Rate. AIx = Amplification Index. AIx 75bpm = Amplification Index adjusted to 75bmp; PWV = pulse wave velocity. #= Fixed Effects of the interaction. * = significant difference between intragroup post vs. pre-RT.

When comparing the deltas of hemodynamic variables, SN group displayed reduced values of pDBP (Figure 2a, SN, Δ=-4.8±5.7 vs. NSN, Δ=5.0±7.2, p=0.0005), cDBP (Figure 2b, SN, Δ=-5.3± 5.6 vs. NSN, Δ=5.0±7.1, p=0.0003), peripheral pulse pressure (pPP, Figure 2c) (SN, Δ= 8.4±7.3 vs. NSN, Δ=-4.3±10.6, p =0.0012), and cPP (Figure 2d, SN, Δ= 6.1±5.5 vs. NSN, Δ=-3.8± 7.6, p=0.0007) as compared with NSN group. Additionally, peripheral (Figure 2e) and central mean blood pressure (Figure 2f) values were increased in the NSN subjects (Δ=3.2± 5.2) as compared with the SN (Δ=-1.9±5.4) (p=0.0198, for both).

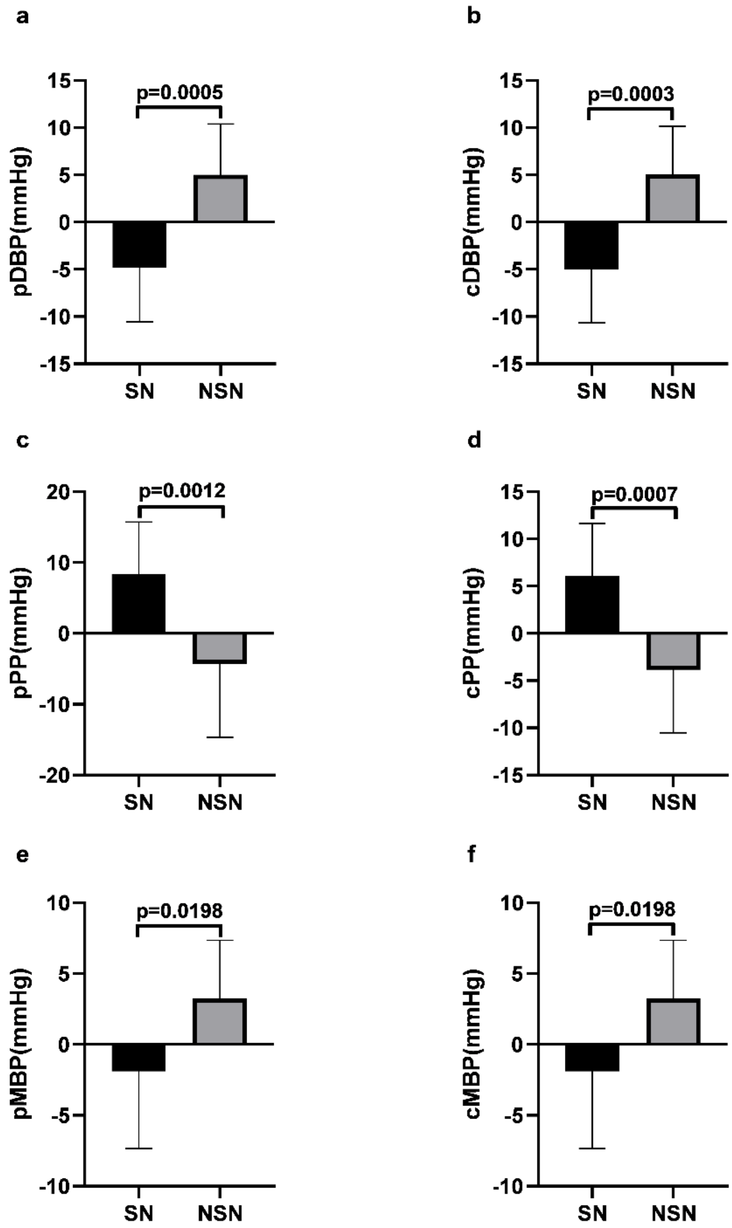

Fig. 2 Deltas of peripheral and central hemodynamic variables in synergistic routine (SN) and non-synergistic (NSN) routine. Unpaired T-Test (a, b, e, and f) and Mann-Whitney test (c and d). p: peripheral and c: central. DBP, SBP, PP, and MBP: diastolic, systolic, pulse, and mean blood pressure, respectively

Discussion

The main findings of the present study are: 1) synergistic RT routine reduced diastolic and mean blood pressure in normotensive trained men; 2) non-synergistic RT reduced the pulse blood pressure in young normotensive trained men; and 3) synergistic and non-synergistic RT routines did not change arterial stiffness.

It is well known that RT reduces systolic, diastolic, and mean blood pressure in prehypertensive and hypertensive patients, especially in the elderly (Ashor et al., 2015). However, the effects of RT in normotensive subjects are controversial. Recently, a meta-analysis showed that isometric RT reduced systolic, diastolic, and mean blood pressure in normotensive young adults (Loaiza-Betancur et al., 2020). Some evidence suggests that dynamic RT may reduce arterial blood pressure in normotensive subjects. However, the effects of dynamic RT in normotensive subjects are less studied and conclusive. Some authors hypothesize that dynamic RT improves endothelial function, which contributes to a reduction in peripheral vascular resistance and, in consequence, contributes to a decrease in blood pressure (Ashor et al., 2015).

In the present study, synergist and non-synergist RT did not reduce systolic blood pressure. However, we found a significant reduction in peripheral diastolic and mean blood pressure in subjects who performed the synergistic RT routine. Previous studies showed that blood pressure decreases after exercise training is associated with exercised muscle mass and exercise volume. Our study was a pioneer in evaluating the effects of synergistic and non-synergistic RT routines in upper limbs. In this context, our results suggest that synergistic RT routines may contribute significantly to reducing diastolic blood pressure. This finding has an important clinical implication since low diastolic blood pressure is associated with low cardiovascular risk (Flint et al., 2019). In addition, non-synergistic RT routines reduced the pulse blood pressure, suggesting that periodization and combining both RT routines may improve hemodynamic variables. More studies about this issue need to be performed.

Arterial stiffness has proven to be an independent risk factor for cardiovascular disease and mortality. The effects of RT on arterial stiffness in healthy people are not entirely understood. Heffernan et al. (2006) verified that the RT performed with a single leg caused reductions in arterial stiffness of the exercised limb. In contrast, Okamoto et al. (2006) found that the RT performed with a single upper limb caused an increase in systemic arterial stiffness. Recently, Figueroa and colleagues, in a meta-analysis, showed that low-intensity RT decreases systemic arterial stiffness in young, healthy adults but does not affect arterial stiffness in middle-aged and older adults (Figueroa et al., 2019). In another meta-analysis, Zhang and colleagues showed that low-to-moderate-intensity significantly decreased pulse wave velocity (PWV) in young and middle-aged adults. At the same time, the high intensity did not affect both age groups (Zhang et al., 2021). In the present study, such as in previous trials, RT did not change arterial stiffness in young normotensive subjects. However, all current study subjects had performed RT for at least six months before starting the study protocol. Usually, healthy young people do not show structural vascular changes (Townsend et al., 2015). This is a significant limitation of our study.

CONCLUSION

In conclusion, the present study's findings suggest that a synergistic RT routine reduces diastolic and mean blood pressure in young normotensive trained men. In addition, non-synergistic RT reduced the pulse blood pressure in young normotensive trained men. Combining both RT routines may augment blood pressure reduction in young men. Synergistic and non-synergistic RT routines did not change arterial stiffness in this set of subjects.

Declaration of competing interest

The authors declare that they do not have any potential conflict of interest.

Ethical standards

This protocol was approved by the Ethical in Research Committee of the University Adventist Center of São Paulo (UNASP/HT, São Paulo-SP, Brazil) and performed following the amended Declaration of Helsinki of 1964 and its subsequent changes. All participants signed a written consent form before being included in the study (approval no.4.622.465).

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