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Effects of Aging on Cardiac Autonomic Response during Resistance Exercise at Critical Load

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Abstract **Background:** Critical load (CL) indicates the transition from moderate dynamic exercise to intense exercise and can be useful as a parameter of exercise intolerance during resistance exercise. In this sense, this study aimed to assess and contrast the cardiac autonomic response by heart rate variability during resistance exercise at CL in elderly and young individuals. **Methods:** Twenty apparently healthy active men, were allocated into young group (n=10) and elderly group (n=10), who underwent: 1) one repetition maximum (1RM) test on the Leg Press at 45º; 2) constant load exercise tests (70%, 80% and 90% of 1RM and intermediate load) in order to calculate the CL; and 3) CL assessment with record of heart rate (HR) and R-R intervals (R-Ri) to heart rate variability assessment. **Results:** During CL, the elderly presented lower value of mean HR in relation to young group ($p<0.05$), and mean R-Ri, RMSSD and SD1 were higher in elderly compared to young ($p<0.05$). In addition, delta (exercise minus rest) mean HR, STDRR, RMSSD, RRtri, TINN, SD1, SD2 and correlation dimension were lower in elderly compared to young ($p<0.05$). **Conclusion:** Elderly presented lower response to vagal withdrawal and less complexity compared to the young people during resistance exercise at CL.

Keywords Aging, Autonomic Nervous System, Exercise, Muscle Fatigue, Muscle Strength

1. Introduction

Data from the World Health Organization show that the number and proportion of people aged 60 years and older in the population is increasing, and in 2019 this number was 1 billion [1]. Aging is considered a physiological process, characterized by metabolic and cellular alterations, which can vary according to genetic factors, lifestyle and chronic diseases; these alterations lead to a progressive loss of functional capacity, leading to greater vulnerability, strength and muscle efficiency reduced [2]. For this reason, resistance exercise has been widely used to neutralize these alterations related to advancing age, thus promoting muscle mass gain and improvement in functional mobility and quality of life [3,4].

In the last years, some studies [5-7] were conducted in order to introduce the critical load (CL) concept during dynamic resistance exercise. This model was derived from critical power [8], commonly used during dynamic aerobic exercise, and can be obtained by applying the mathematical model of linear regression, considering the relationship between the load performed versus limit of tolerance (Tlim) during resistance exercise [5]. This concept marks the transition from moderate dynamic exercise to intense exercise, and can be maintained for a long period without muscle fatigue [5], so it is possible to assume that this intensity may represent functionally significant indicators of exercise capacity and assist in prescription of physical training, bringing us more knowledge of fatigue and exercise intolerance during resistance exercise.

Several studies have been conducted to evaluate the relationship between load versus Tlim during aerobic exercises in young and elderly [9], cyclists [10], running [11] and chronic obstructive pulmonary disease [12]; however, when we talk about the CL concept applied in the resistance exercise, the information is scarce in the literature, especially with regard to the elderly population.

Concomitantly to loss of functional capacity, aging is accompanied by structural and functional modifications of the cardiovascular system [13], with consequent reduction in the heart rate variability (HRV) at rest, and a decline in vagal tone [14-16]. In view of these changes, through HRV analysis it is possible to identify potential alterations in indices related to vagal predominance, global HRV and complexity, which favors the identification of imbalance in cardiac regulation.

During physical exercise, some physiological mechanisms are activated to supply the new imposed metabolic demand, and to minimize changes in the internal environment, in order to preserve homeostasis; therefore, several hemodynamic adaptations are necessary, including those related to cardiovascular function [17]. Although several studies have evaluated HRV during resistance exercise in the elderly population [18-20], we are not aware of any study that evaluated cardiac autonomic control during CL in this population. In this sense, the analysis of these variables in elderly people during CL would be important in clinical practice, allowing for a better understanding of cardiac autonomic adjustments during resistance exercise performed in this intensity of effort.

Thus, the aim of the current investigation was to assess and contrast the cardiac autonomic response by HRV during resistance exercise at CL en elderly and young individuals. The hypothesis of the present study is that the HRV adjustments in the elderly during resistance exercise at CL would be impaired in relation to the young people.

2. Materials and Methods

2.1. Research Design and Subjects

The current investigation is a retrospective, cross-sectional, comparative study which included a convenience sample of apparently healthy men, allocated to a young group (aged between 18 and 29 years) or elderly group according to the World Health Organization [1] (aged than 60 years). Subjects were invited to participate in study between June 2015 and March 2016. Exclusion criteria consisted of: 1) smokers, habitual drinkers and/or users of illicit drugs; 2) use of prescribed medications; 3) presence of anemias; 4) body mass index ≥ 30 kg/m^2; 5) neurological, musculoskeletal, cardiovascular and/or respiratory disorders; 6) complex cardiac arrhythmias or electrocardiogram alterations; 7) presence of diabetes mellitus and/or arterial hypertension (systolic blood pressure ≥ 130 and/or diastolic blood pressure ≥ 80 mmHg according to American College of Cardiology/American Heart Association Blood Pressure Guidelines) [21]; 8) a level of understanding that would limit the participation in the study.

2.2. Ethics Aspects

This study was approved by the Human Research Ethics Committee of the University (#794.638/2014). All subjects were informed about the study objectives and the experimental procedures, and were ensured about the confidentiality of personal data. All participants signed an informed consent statement prior to participation.

2.3. Experimental Procedures

All subjects were evaluated in the afternoon to avoid differing physiologic responses due to circadian variation. Protocols were carried out in a climate-controlled room (22-24ºC) with a relative air humidity of 40-60%. The subjects were instructed to abstain from caffeinated and alcoholic beverages, not to perform exercise on the day before data collection, to have a light meal at least 2h prior to the tests and not to speak unnecessarily during the assessments to avoid interfering with the acquisition of signals. All participants were familiarized with the experimental room environment and the protocol involved in the study, which was divided into five days (with an interval of 24 to 48 hours among evaluations). During all tests, monitoring consisted of 12-lead electrocardiogram (Ecafix TC 500, Sao Paulo, SP, Brazil) and blood pressure (BD, Sao Paulo, SP, Brazil); perception of effort was obtained using the modified Borg Scale [22].

Any of the tests should be interrupted if: 1) subjects were unable to perform the movement within the established mechanics, 2) increased systolic blood pressure > 200 mmHg, 3) increased heart rate (HR) ≥ 85% of maximum HR (220 - age x 0.85) and 4) presence of any alteration in the electrocardiogram [18].

2.3.1. First visit: Initial assessment and clinical evaluation

Subjects underwent an initial assessment consisting of anamnesis and physical examination. In addition, Baecke Questionnaire [23] was applied, in order to assess the subject's lifestyle. Subsequently, all underwent a clinical evaluation performed by a cardiologist, consisting of clinical cardiac examination, resting 12-lead electrocardiogram and maximal standard exercise test on a cycle ergometer (Corival Recumbent, Lode, Groningen, Netherlands). In addition, glycemia, hemoglobin, lipid profile, urea, creatinine, and uric acid were performed at the Clinical Analysis Laboratory, in order to confirm that all subjects were healthy.

2.3.2. Second visit: one repetition maximum (1RM) test

Based on a previous protocol for determining the 1RM [18], we apply a gradual increase in resistance until the volunteer succeeded in performing no more than one repetition of the exercise on the Leg Press at 45º (Vitally Convergent, Sao Paulo, SP, Brazil).

2.3.3. Third and fourth visit: constant load exercise tests with different percentages of 1RM

On two separate days, each subject undertook a series of four different constant load exercise tests, being two tests each day with an interval of 20 minutes between them. In the thirty visit the intensities applied consisted of 70%, and 90% of 1RM, and in the fourth visit applied an intermediate load and 80% of 1RM; the intermediate load was calculated by linear regression of the points found in the graph from the loads by time Tlim, using the two loads previously performed - 70% and 90% of 1RM (a previous CL calculation using only the first two tests). Initially to protocol, the subjects performed an adaptation on the equipment to establish the correct biomechanics of the movement. The protocol exercise was then initiated, with each repetition performed in 3 seconds (1.5 second eccentric phase and 1.5 second concentric phase) with the rhythm controlled by verbal commands. The effort was performed until Tlim, this is, inability to perform the movement within the established mechanics due to leg fatigue or difficulty to maintain the cadence and/or movement amplitude. From these protocols, we find parameters to calculate the CL.

2.3.4. Fifth visit: Critical load (CL) assessment

To determine the CL, calculation applied was based on previous study [5]. The CL was determined by percentage of the four loads carried out (70%, 80%, 90% of 1RM and intermediate load) x reciprocal time on each load (time Tlim), as shown in **Figure 1**. In this test, maximum repetition capacity tolerated by the volunteer was evaluated, i.e., the highest sustainable work rate determined as CL. Prior to the execution of test, subjects remained at rest on the equipment for 10 min, and then the resistance exercise protocol was initiated at CL, being performed until Tlim; then a 10-minute passive recovery phase was realized. At rest and during the test, the R-R intervals (R-Ri) were recorded with a digital telemetry system (Polar® S810i, Kempele, Oulu, Finland).

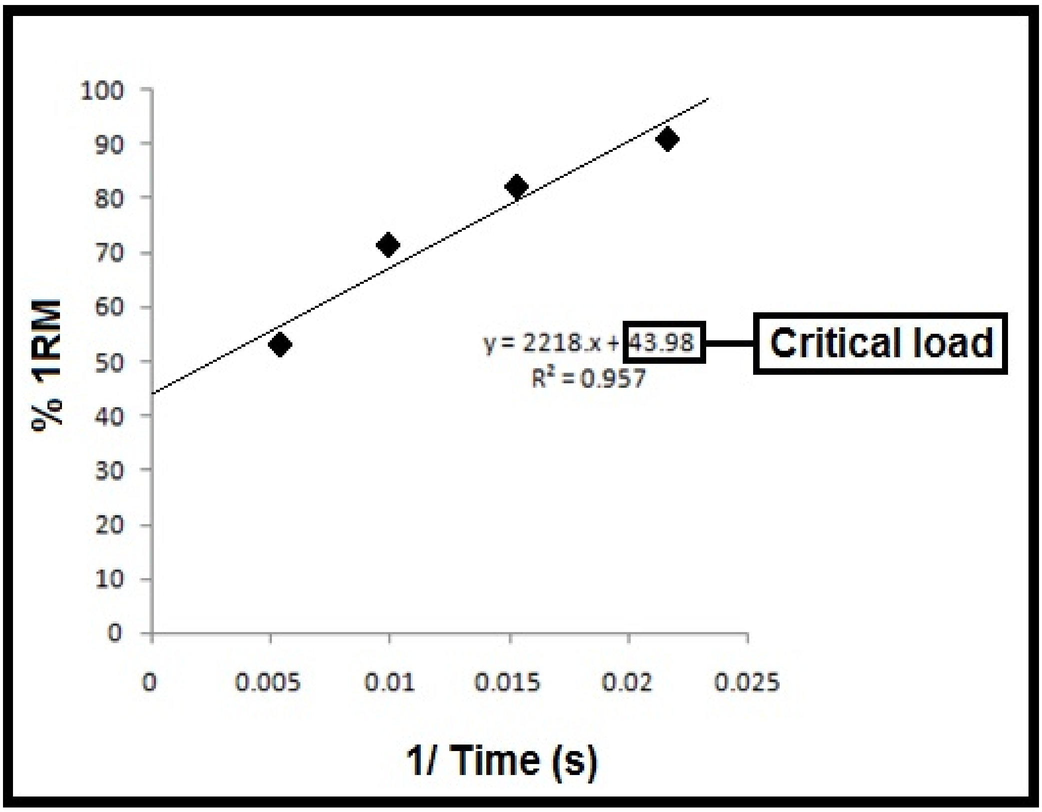

Figure 1. Illustration of the determination of critical load calculated by linear regression (loads by execution times) obtained in relation to the intensities of the exercises performed (70, 80 and 90% of 1RM and intermediate load). Critical load obtained = 43.98% of 1RM.

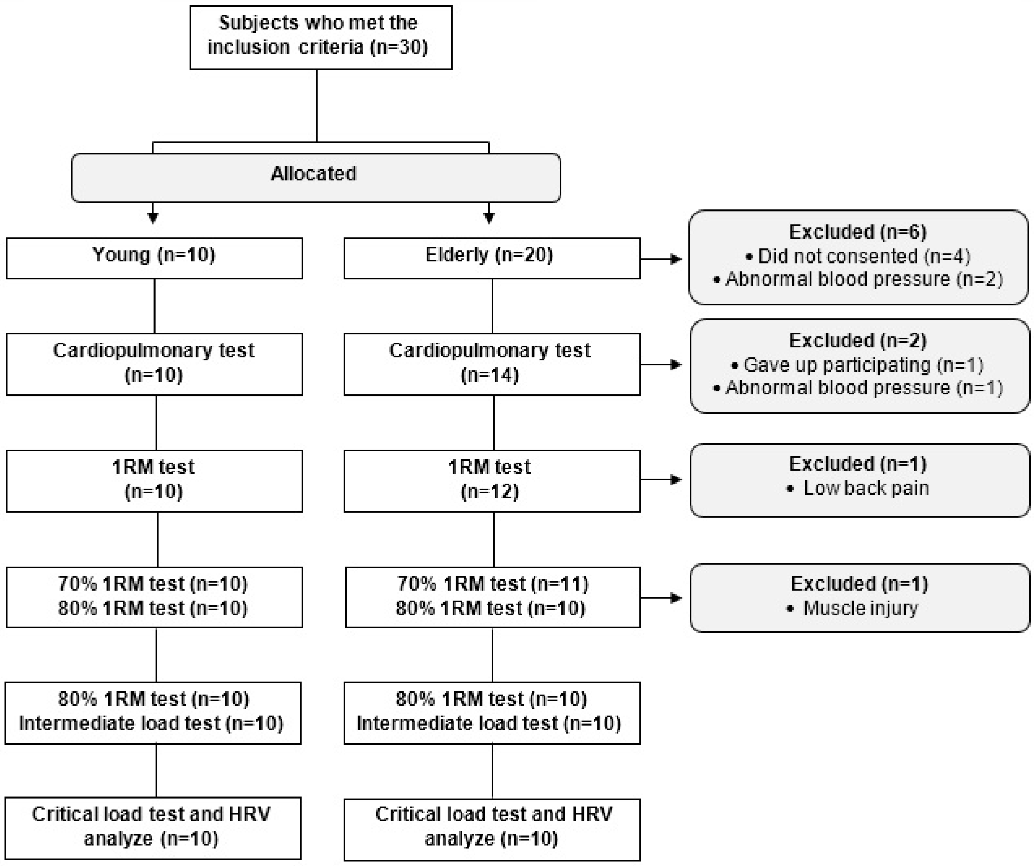

Figure 2. Flowchart showing subjects' participation in the study. n: number of subjects; 1RM: one repetition maximum; HRV: heart rate variability.

2.3.5. Heart rate variability (HRV) analysis

The R-Ri recordings were reviewed by visual inspection using the Polar Precision Performance SW (version 4.03.040, Kempele, Finland). A series containing sequential 300 R-Ri of rest and exercise phase was analyzed using Kubios® HRV analysis software 2.0 for Windows (MATLAB, version 2 beta, Kuopio, Finland); in the exercise phase, the initial 30 s of signal were excluded from each tachogram.

HRV was analyzed by time domain and through nonlinear statistical measures. Mean of R-Ri (RR), Mean of HR, standard deviation of the mean of all normal R-Ri (STDRR), square root of the difference in the sum of squares between R-Ri on the record, divided by the determined time minus one (RMSSD), total number of R-Ri divided by the height of the histogram of all R-Ri (RRtri) and width of the R-Ri triangle distribution (TINN) were computed as time domain measures [24]. In addition, nonlinear statistical measures were calculated by standard deviation of Poincaré plot perpendicular to the line-of-identity (SD1), standard deviation of the Poincaré plot along the line-of-identity (SD2) [25], approximate entropy (ApEn) [26,27], sample entropy (SampEn) [27] and correlation dimension (CD) [28].

HRV indexes at CL were presented in the following ways: 1) during the exercise phase with its absolute values; and 2) absolute delta (exercise minus rest) and normalized delta by the maximum load obtained at CL (kg).

2.4. Statistical Analysis

Based on pilot study, the sample size was calculated using RMSSD index; thus was necessary a sample of 10 subjects in each group to promote sufficient statistical power (80%) at an α-level of 0.05 (GPower software package, version 3.1.6, Kiel, Schleswig–Holstein, Germany). The magnitude of differences in the delta (exercise-baseline) of HRV indices between the groups was examined using Cohen's d effect size analysis [29], also showing the confidence interval; the Cohen's d effect size results were qualitatively interpreted using the following thresholds: <0.2 (trivial), 0.2-0.5 (small), 0.5-0.8 (medium) or 0.8 or higher (large) [29,30]. Due to normal distribution of the data (verified by the Shapiro–Wilk test), and to homogeneity of variance (verified by Levene´s test) the data were expressed in mean ± SD or SE. Unpaired Student's t-test was used for all inter-groups comparisons (young vs. elderly) and Paired Student's t-test was used for all intra-groups comparisons (resistance exercise vs. rest and delta). All statistical analyses were carried out using the Statistica for Windows software release 5.1 (StatSoft, Inc, Tulsa, OK, USA) and the significance level used was $p<0.05$.

Table 1. Age, anthropometry and baseline hemodynamic variables of both groups

	Young (n=10)	Elderly (n=10)	p value
Age, years	25 ± 4	68 ± 4	<0.001
Antropometry			
Weight, kg	78.9 ± 8.1	76.7 ± 13.1	0.971
Height, m	1.78 ± 0.07	1.72 ± 0.10	0.133
BMI, kg/m²	24.6 ± 1.3	26.1 ± 4.14	0.164
Hemodinamic variables			
SBP, mmHg	115.8 ± 12.5	132.0 ± 10.4	<0.01
DBP, mmHg	78.5 ± 10.2	88.6 ± 6.2	0.022
HR, bpm	77.5 ± 5.7	75.4 ± 9.2	0.558

Values are mean ± SD. BMI: body mass index; DBP: diastolic blood pressure; HR: heart rate; n: number of subjects; SBP: systolic blood pressure

Table 2. Variables of constant load exercise tests and at critical load, load of one repetition maximum test and percentage of one repetition maximum reached in the critical load of both groups

	Young			Elderly		
% in relation to 1RM	Load, kg	Tlim, s	No. repetitions	Load, kg	Tlim, s	No. repetitions
70%	178 ± 40	102 ± 32	34 ±7	176 ± 33.8	51 ± 18*	17 ± 6*
80%	203 ± 45	54 ± 22	18 ± 8	201 ± 37	36 ± 15*	12 ± 4*
90%	229 ± 51	33 ± 10	11 ± 3	226 ± 44	18 ± 12*	6 ± 4*
Intermediate	147 ± 29	144 ± 57	48 ± 20	146 ± 25	102 ± 47	34 ± 15
CL	133 ± 26	165 ± 63	55 ± 20	131 ± 52	141 ± 74	47 ± 28
	Young			Elderly		
1RM, kg	254 ± 56			251 ± 5		
CL, % 1RM	54 ± 8			52 ± 9		

Values are mean ± SD. 1RM: one repetition maximum; CL: critical load; No.: number; Tlim: limit of tolerance; Intermediate: calculated by linear regression of the points found in the graph from the loads by Tlim, using the two loads previously performed - 70% and 90% of one repetition maximum; *Significant differences between groups ($p<0.05$).

3. Results

Initially, 30 subjects were considered eligible, being 10 in the young group and 20 in the elderly group, but 10 elderly were excluded during the protocol due to several factors; in this way, the final sample was composed of 10 young and 10 elderly (**Figure 2**), all being considered physically active according to the Baecke Questionnaire [23]. Age, anthropometry and baseline hemodynamic variables of groups are summarized in **Table 1**; as expected, there was difference in age between groups, and the elderly group presented higher values of systolic and diastolic blood pressure compared to the young. With respect to constant load exercise tests with different percentages of 1RM and CL, although they reached loads were similar between groups, the elderly presented lower values for Tlim and number of repetitions performed at 70%, 80% and 90% of 1RM in relation to young. Furthermore, the groups were similar in relation to the load obtained in the 1RM test and percentage of 1RM reached in the CL (**Table 2**).

Table 3 shows the comparison of HRV indexes analyzed by time domain and through nonlinear statistical measures during rest and resistance exercise at CL, beyond the delta of these variables to both groups. In the rest, STDRR, RMSSD, RRtri, TINN, SD1, SD2 and CD indexes were lower in the elderly group compared to the young group. Regarding resistance exercise at CL, the elderly group presented lower value for mean HR in relation to the young group, and the mean RR, RMSSD and SD1 were higher in the elderly compared to young. When HRV indexes obtained during resistance exercise at CL were compared with those obtained at rest, we observe that to young group the exercise induced an increase in the mean HR and decrease in the mean RR, STDRR, RMSSD, RRtri, TINN, SD1, SD2, ApEn, SampEn and CD; while for the elderly group, the exercise induced only an increase in the mean HR and decrease in the mean RR, ApEn and SampEn. In addition, delta HRV indexes were obtained to show the behavior of vagal withdraw, and was observed that the elderly presented lower response of mean HR, STDRR, RMSSD, RRtri, TINN, SD1, SD2 and CD when compared to young (**Table 3**).

When we normalize the HRV absolute values by the individual load obtained during the exercise in the CL, RMSSD and SD1 indexes once again were higher in the elderly in relation to young, i.e. RMSSD/load (ms/kg): 0.16 ± 0.04 vs. 0.03 ± 0.01 ($p<0.01$), and SD1/load (ms/kg): 0.11 ± 0.03 vs. 0.03 ± 0.01 ($p<0.01$). Additionally, when we observe the behavior of HRV derived from absolute delta (exercise minus rest) normalized by the maximum load reached (kg) of each subject at CL, it is possible to verify that the elderly group presented smaller variations during exercise compared to young people in the following indexes: delta RMSSD/load, delta TINN/load, delta SD1/load and delta CD/load (**Figure 3**).

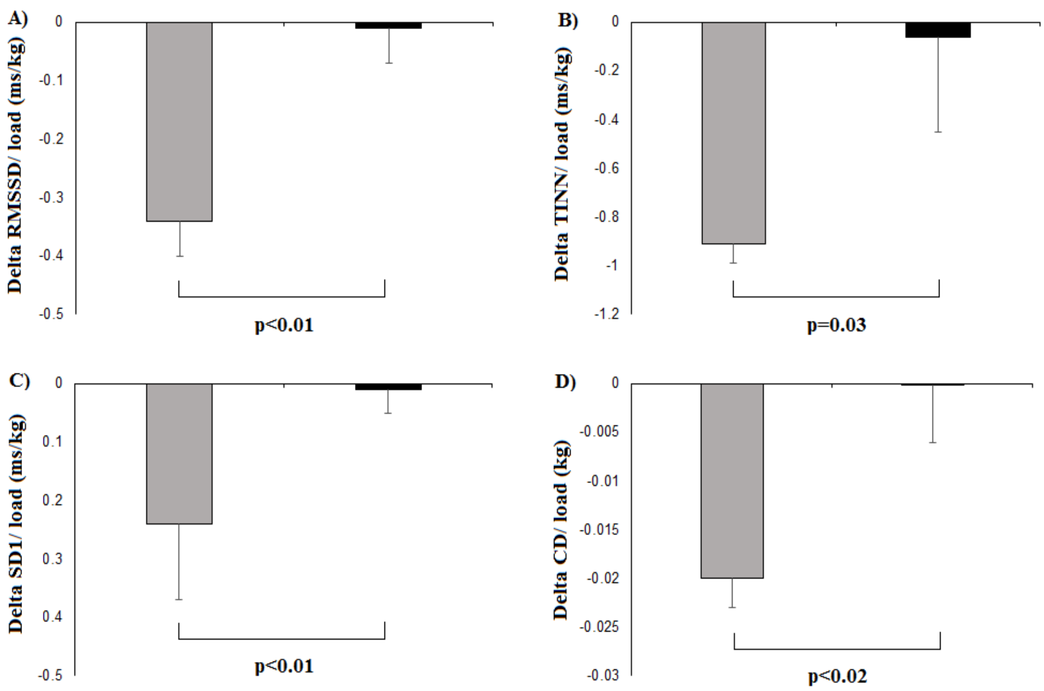

Figure 3. Delta of heart rate variability indexes normalized by the maximum load reached (kg) of each subject during resistance exercise at critical load of both groups. **A)** RMSSD/load; **B)** TINN/load; **C)** SD1/load; **D)** CD/load. Values are mean ± SE. Delta: exercise minus rest; RMSSD: square root of the difference in the sum of squares between R-Ri on the record, divided by the determined time minus one; TINN: width of the R-Ri triangle distribution measures; SD1: standard deviation of Poincaré plot perpendicular to the line-of-identity; CD: correlation dimension. Cohen's d effect size and difference delta 95% confidence interval, respectively: Delta RMSSD/load (0.64; 0.16-0.50); Delta TINN/load (0.51; 0.10-1.60); Delta SD1/load (0.15; 0.14-0.31); Delta CD/load (0.50; 0.01-0.02). Young group: in gray; Elderly group: in black.

Table 3. Comparison of heart rate variability indexes at rest, during resistance exercise at critical load and delta (exercise – rest) of both groups

	Rest		Resistance exercise at CL		Delta (CL - rest)		Cohen's d	Difference delta
	Young	Elderly	Young	Elderly	Young	Elderly	effect size	95% CI
Time domain								
Mean RR, ms	868.7 ± 38.7	882.5 ± 33.9	460.5 ± 15.1*	583.4 ± 23.2*+	-408 ± 40.3	-299.1 ± 34.9	0.82 (large)	(1.79-216.20)
Mean HR, bpm	70.8 ± 2.9	68.8 ± 2.6	132.0 ± 4.1*	104.3 ± 3.9*+	61.2 ± 4.9	35.4 ± 4.1+	0.94 (large)	(12.92-38.67)
STDRR, ms	72.7 ± 12.6	30.3 ± 7.3+	28.1 ± 3.7*	23.4 ± 5.7	-44.6 ± 8.6	-6.9 ± 7.6+	0.91 (large)	(1.50-60.79)
RMSSD, ms	49.2 ± 6.8	20.2 ± 4.6+	5.4 ± 1.7*	19.3 ± 4.4+	-43.8 ± 6.3	-0.9 ± 5.9+	0.96 (large)	(25.58-60.22)
RRtri	12.9 ± 1.4	7.1 ± 1.1+	6.0 ± 0.4*	4.4 ± 0.9	-6.9 ± 1.1	-2.7 ± 1.2+	0.87 (large)	(0.86-7.48)
TINN, ms	236.5 ± 17.9	126.2 ± 22.7+	112.0 ± 12.3*	123.7 ± 31.2	-124.5 ± 15.5	-2.5 ± 39.2+	0.89 (large)	(41.37-202-63)
Non-linear								
SD1, ms	34.8 ± 4.8	14.4 ± 3.3+	3.8 ± 1.2*	13.8 ± 3.1+	-31.0 ± 4.4	-0.6 ± 4.3+	0.96 (large)	(18.11-42-74)
SD2, ms	95.8 ± 16.6	46.7 ± 10.4+	39.3 ± 5.2*	42.6 ± 5.5	-56.5 ± 11.8	-4.1 ± 12.9+	0.90 (large)	(17.70-87.08)
ApEn	1.02 ± 0.06	0.90 ± 0.05	0.41 ± 0.06*	0.45 ± 0.06*	-0.61 ± 0.06	-0.45 ± 0.01	0.88 (large)	(-0.03-0.33)
SampEn	1.39 ± 0.15	1.44 ± 0.09	0.37 ± 0.06*	0.57 ± 0.17*	-1.02 ± 0.14	-0.86 ± 0.23	0.38 (small)	(-037-0.68)
CD	2.78 ± 0.39	0.80 ± 0.38+	0.57 ± 0.10*	0.89 ± 0.30	-2.2 ± 0.40	0.08 ± 0.56+	0.94 (large)	(0.94-3.63)

Values are mean ± SE. ApEn: approximate entropy; CD: correlation dimension; CL: critical load; Delta: exercise minus rest; CI: confidence interval; HR: heart rate; RMSSD: square root of the difference in the sum of squares between R-R intervals on the record, divided by the determined time minus one; RR: R-R intervals; RRtri: total number of R-Ri divided by the height of the histogram of all R-R intervals; SampEn: sample entropy; SD1: standard deviation of Poincaré plot perpendicular to the line-of-identity; SD2: standard deviation of the Poincaré plot along the line-of-identity; STDRR: standard deviation of the mean of all normal R-R intervals; TINN: width of the R-Ri triangle distribution measures. *Significant difference between resistance exercise at CL and rest ($p<0.05$); +Significant differences between groups in the same situation ($p<0.05$).

4. Discussion

The present study evaluated and contrasted cardiac autonomic response by HRV during resistance exercise at CL in elderly and young individuals. The main finding of this study was that elderly presented an attenuated response of vagal withdrawal compared to young during resistance exercise at CL, represented both by absolute values of HRV and normalized by the load.

To our knowledge, this is the first study to evaluate the cardiac autonomic nervous system responses in elderly during resistance exercise at CL. A previous study [7] evaluated the metabolic and cardiovascular responses during dynamic lower limbs resistance exercise at CL in elderly and young, but without assessment of cardiac autonomic control, in which can add more methodological evidence for therapeutic interventions, reinforcing the need for preventive measures and adequate aging control, especially during exercise.

In the present study, the mean value of the CL was between 52% and 54% of 1RM for the elderly and young, respectively, corroborating the previous findings of Arakelian et al. [6]; in addition, no differences were observed in relation to loads obtained during resistance exercise at CL (kg) between elderly (131 ± 52 kg) and young (133 ± 26 kg). Although aging is related to both the reduction of strength production and functional status, which can be accelerated by sedentary lifestyle [31], in the present study all elderly were considered physically active, therefore presented similar responses to young related to performance during CL.

As expected, the elderly presented lower vagal modulation at rest compared to young, even though our sample is composed of healthy active men, is already well established in the literature that rest cardiac vagal tone declines with age [14-16]. On the other hand, at the beginning of the exercise, in a physiological condition, HR tends to increase to meet the competing demands of working muscles; this rapid HR increase is primarily mediated by vagal withdrawal, while additional increases are sustained both due to reductions in cardiac vagal tone and increased sympathetic activity [32]. The mean RR and mean HR during CL presented higher and lower values respectively in elderly in relation to young; these findings do not seem to be related to the performance realized by the subjects, since the effort during the resistance exercise was similar between groups, i.e., the groups did not present differences in the reached load, % load in relation to 1RM, Tlim and number of repetitions during CL, as already mentioned. In that same sense, the elderly group showed higher vagal modulation (represented by the RMSSD and SD1 indexes) and consequently lower value of HR in relation to young during resistance exercise at CL; additionally the elderly presented an attenuated response of vagal withdrawal in the exercise in relation to rest compared to young, what could be observed through the absolute delta normalized by the load (RMSSD/load, SD1/load and TINN/load). A possible explanation for our results is that the aging cause alterations in the ability of produce cardiac autonomic adjustment during the physical effort, mainly related to vagal withdrawal, as already reported in previous studies with different exercise protocols [33,34]. Our findings corroborate those of Taylor et al. [34], which found smaller tachycardic response to isometric exercise in older due to an inability to decrease cardiac vagal tone from already low baseline levels; in our study, reduced vagal modulation at rest was observed in the elderly group, which also helps to explain our findings.

Furthermore, the absolute values of HRV indexes were normalized by the load (kg) reached by the subjects during the resistance exercise at CL. We observed that even after this normalization, this attenuated response of vagal withdrawal presented in elderly compared to young remained, supporting our previous and discarding the influence of the load carried.

In addition, we used others nonlinear statistical measures, like ApEn, SampEn and CD, in order to complement the HRV traditional assessments, since these indexes are related with the unpredictability, fractability and complexity of the signal [35]. Our results showed significant reduction of ApEn and SampEn both in the elderly and young groups in the resistance exercise at CL compared to rest; lower values reflect high degree of regularity and predictability of signal, that is, may reflect a worse cardiac autonomic function [26,27], and in this sense both groups showed similar response of these indexes, which was already expected with regard to effort. On the other hand, the elderly group presented lower value of CD in relation to young already in the rest condition, confirming previous findings that the aging alters the complexity of the system, i.e., the system is chaotic [28]; this reduced rest value present in the elderly, possibly limited their ability to produce critical autonomic adjustment to reduce the CD value during exercise, similar to RMSSD and SD1 results observed in our findings.

From a practical point of view, our findings may have a clinical potential to assessment of capacity exercise and, in that context, can assist in the resistance training prescription of elderly population, possibiliting the elaboration of strength and endurance training in which can be maintained for a long period. Additionally, this study extends our understanding of the importance of alterations in the regulation of cardiac autonomic control during this modality of exercise related to aging.

This investigation has some limitations, such as the lack of dosage of lactate, which could show us if there was an accumulation of that substance during exercise; however, we took all methodological care so that the subjects of this study carried out the load until Tlim. In addition, we did not include women in the sample, because the selected age range could include both women in the reprodutive period and postmenopausal women, which could affect our findings [36,37]; then, whether gender would influence the cardiac autonomic control during resistance exercise at CL remains unknown, needing future studies to elucidate this point.

5. Conclusions

In conclusion, our data showed less ability to adjust the cardiac autonomic modulation during resistance exercise at CL in elderly, with less response to vagal withdrawal and less complexity compared to young people. Although this deficiency related to the cardiac autonomic adjustments of the elderly has been observed, future studies involving physical training at CL can be carried out in this population, in order to verify the benefits in cardiac autonomic control.

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