

Resistance Training and Autonomic Modulation in the Elderly

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ABSTRACT

We performed a review of acute and chronic effects of resistance training on the heart rate and cardiac autonomic regulation in the elderly. A systematic review of the literature was performed in June 2015 using MEDLINE, COCHRANE LIBRARY and PUBMED databases. The following combination of keywords, followed by the Clinical Trial filters, Humans, English, and Age \geq 45 years were used for search of relevant manuscripts: Heart rate variability and exercise (259 articles); Heart rate variability and exercise and elderly (259 articles); Heart rate and Resistance training and elderly (170 articles); Heart rate variability and Resistance training (22 articles); Heart rate variability and Resistance training and elderly (22 articles); Cardiac autonomic modulation and Resistance training and elderly (8 articles). We reported that although some results did not point to benefic chronic effects of resistance exercise on HRV, others presented different data.

Key words: Exercise; Autonomic nervous system; Cardiovascular system; Cardiovascular physiology; Aged

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INTRODUCTION

In 2010 people over 65 years of age accounted for 8% of the world population, and by 2050 it is expected that this percentage will increase to 16%^[1]. As a result, hospitalizations for people over 65 have become more frequent and the bed occupancy time has become longer when compared to other age groups. As a result, the aging population is becoming a greater burden on the health care system with increasing use of health services^[2].

The biological theories of aging examine the matter from the perspective of degeneration of the structure and function of organ systems and cells. In general, it can be classified into two categories: genetic-developmental and stochastic. The first theory assumes that aging occurs in the context of a genetically controlled continuum, while the latter theory is based on the hypothesis that the aging process depends mainly on the accumulation of environmental insults. There are also frequent allusions to physical exercise as an intervention strategy that could have positive influences on the aging process, slowing some of the common disorders in old age^[3,4].

Despite the evidence accumulated in recent years regarding the beneficial effects of regular physical exercise on chronic non-communicable diseases as well as reduction of the risk of premature death^[5-8], health professionals continue to strongly diverge on the specific type, standard, quantity and intensity of exercise that can provide measurable health benefits^[9]. This is due to the wide range of combinations that the exercise overload prescription parameters present in the face of different health conditions of the population served.

Among the modalities of exercise, resistance training has received special attention recently and has been prescribed in different health conditions^[10,11], including the risk factors and cardiovascular disease^[8].

A decrease in vagal modulation, sympathetic and sympathovagal ratio has been observed with increasing age, regardless of the presence of pathological conditions^[12-15]. However, research on the effects of exercise on cardiac autonomic modulation (CAM) are rare and inconclusive.

One method that has been extensively used to investigate the cardiac autonomic regulation is heart rate variability (HRV). In addition to the reproducibility and low cost, this technique allows us to identify changes even in the subclinical stage and has a high prognostic value. As a result, the indices derived from this method have been used as health and disease biomarkers, as well as indicators of the effects of therapeutic interventions in several diseases, among them cardiovascular^[16,17], metabolic^[18-20] and autonomic^[21,22] disorders.

Given the above, we conducted a review of acute and chronic effects of resistance training on the heart rate and cardiac autonomic regulation in the elderly.

METHOD

A systematic review of the literature was performed in June 2015 using MEDLINE, COCHRANE LIBRARY and PUBMED databases. The following combination of keywords, followed by the Clinical Trial filters, Humans, English, and Age \geq 45 years were used for search of relevant manuscripts: Heart rate variability and exercise (259 articles); Heart rate variability and exercise and elderly (259 articles); Heart rate and Resistance training and elderly (170 articles); Heart rate variability and Resistance training (22 articles); Heart rate variability and Resistance training and elderly (22 articles); Cardiac autonomic modulation and Resistance training and elderly (8 articles).

Two researchers read the titles and abstracts for selection of items including studies of clinical trials in humans with age \geq 60 years of both sexes, focused on the use of resistance exercises, acute or chronic, on cardiac autonomic modulation, and heart rate variability indices.

Articles presenting detailed description of sample characteristics and resistance exercise protocol were included, whether acute or chronic, including the number of sets and repetitions, intervention

time, overload intensity and rest periods. No studies were included that: (1) had no control group, (2) had intervention time of less than 12 sessions for involving intervention; (3) had a weekly frequency of less than twice; (4) included a sample with pathological conditions. However, in studies involving a group of healthy elderly and a comparison group of unhealthy individuals, the results related to the healthy individuals were used and the study was included in the review. After reading the articles we included 10 articles that analyzed the chronic effect, and 6 articles that analyzed the acute effects of exercise. Figure 1 illustrates the process performed and the quantity of studies found, included and excluded from this study.

The methodological quality of studies was assessed through PEDro scale^[23], which is based on the Delphi list^[24]. It has 11 questions, however, ten are punctuated with a range from zero to ten. The criteria are scored according to presence or absence of a specific item. Items not found in the articles were not scored. The final score was obtained by adding the positive answers. Studies with scores equal to or greater than 50% (5/10) of the maximum possible score were considered as high quality, according to Verhagen *et al.*^[24]. Due to the impossibility of achieving certain conditions such as blinding of evaluators or subjects in intervention studies^[23], the maximum score that could be achieved by a study would be 8/10. In this sense, for this review all studies with higher scores than or equal to 4 (4/8) were considered high methodological quality studies, and the study excluded those studies which did not reach this score. Studies were independently assessed by two reviewers. If there was disagreement, a third reviewer was consulted. The results of the evaluation of methodological quality by the PEDro scale are presented in Table 1 for studies that analyzed the chronic effect and Table 2 for studies that evaluated the acute effect.

RESULTS

Studies on the acute and chronic effects of resistance exercise on the autonomic nervous system are presented in Tables 3 and 4.

In relation to the acute effect, previous studies^[25-27] showed that training with resistance exercise increased heart rate, and the increase

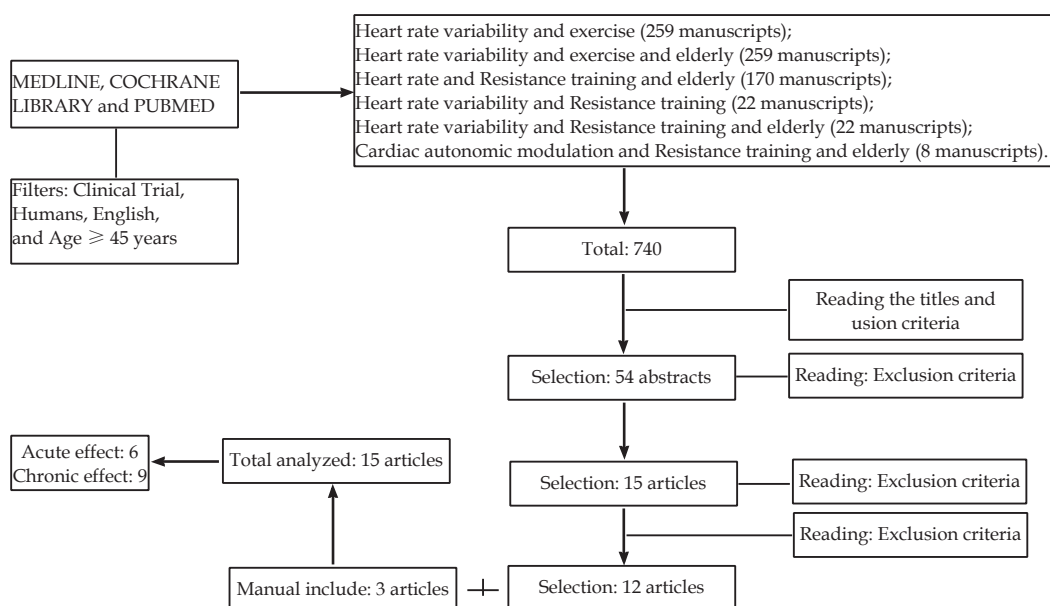


Figure 1 Schematic illustration of the method used to conduct the review.

Table 1 Methodological classification assessed by PEDro scale for the study that analyzed the chronic effect on HRV and HR.

Manuscript	Criteria / Questions											TOTAL
	1	2	3	4	5	6	7	8	9	10	11	
Gerage <i>et al</i> (2013)	1	1	0	1	0	0	0	1	1	1	1	6
Wanderley <i>et al</i> (2013)	1	1	0	1	0	0	0	1	1	1	1	6
Wieser & haber (2007)	1	1	0	1	0	0	0	0	1	1	1	5
Maddene <i>et al</i> (2006)	1	1	0	1	0	0	0	1	1	1	1	6
Melo <i>et al</i> (2008)	1	0	0	1	0	0	0	1	0	1	1	4
Wood <i>et al</i> (2001)	1	1	0	1	0	0	0	1	1	1	1	6
Vicent <i>et al</i> (2003)	1	1	0	1	0	0	0	1	1	1	1	6
Lovell <i>et al</i> (2009)	1	1	0	1	0	0	0	1	1	1	1	6
Hunter <i>et al</i> (2001)	1	1	0	1	0	0	0	1	1	1	1	6

* The score of the first item, if related to external validity is not considered in the score (Moseley *et al*⁽⁴⁰⁾). Question 1: The eligibility criteria were specified; Question 2: The subjects were randomly assigned to group; Question 3: The distribution of the subjects was blind; Question 4: Initially, the groups were similar with respect to most important prognostic indicators; Question 5: All subjects participated in a blinded fashion in the study; Question 6: All therapists who administered the therapy did so blindly; Question 7: All assessors who measured at least one key outcome did so blindly; Question 8: Measurements of at least one key results were obtained in over 85% of subjects initially distributed between the groups; Question 9: All subjects from which results of performed measurements, received the treatment or control condition according to the distribution, or made analyzing the data for at least one of the key results of "intention to treat"; Question 10: The results of statistical comparisons between groups were reported for at least one key outcome; Question 11: The study presents both accurately measures as measures of variability for at least one key outcome.

Table 2 Methodological classification assessed by PEDro scale for the study that analyzed the acute effect on HRV and HR.

Manuscript	Criteria / Questions											TOTAL
	1	2	3	4	5	6	7	8	9	10	11	
Simões <i>et al</i> 2013	1	0	0	1	0	0	0	1	1	1	1	5
Queiroz <i>et al</i> 2012	1	1	0	1	1	0	0	1	1	1	1	7
Vieira <i>et al</i> 2013	1	0	0	0	0	0	0	1	1	1	1	4
Quitério <i>et al</i> 2011	1	1	0	1	0	0	0	1	1	1	1	6
Simões <i>et al</i> 2010	1	0	0	1	0	0	0	1	1	1	1	5
Huggett <i>et al</i> 2004	1	1	0	1	0	0	0	1	1	1	1	6

* The score of the first item, if related to external validity is not considered in the score (Moseley *et al*⁽⁴⁰⁾). Question 1: The eligibility criteria were specified; Question 2: The subjects were randomly assigned to group; Question 3: The distribution of the subjects was blind; Question 4: Initially, the groups were similar with respect to most important prognostic indicators; Question 5: All subjects participated in a blinded fashion in the study; Question 6: All therapists who administered the therapy did so blindly; Question 7: All assessors who measured at least one key outcome did so blindly; Question 8: Measurements of at least one key results were obtained in over 85% of subjects initially distributed between the groups; Question 9: All subjects from which results of performed measurements, received the treatment or control condition according to the distribution, or made analyzing the data for at least one of the key results of "intention to treat"; Question 10: The results of statistical comparisons between groups were reported for at least one key outcome; Question 11: The study presents both accurately measures as measures of variability for at least one key outcome.

Table 3 Studies have found that the acute effect of autonomic modulation and / or heart rate in elderly individuals performing resistance exercise.

Authors	Sample (n; age)	Protocol	HR	HRV
Huggett <i>et al</i> (2004)	ER (n = 20; 74.2 ± 5)	3 sets of 10 repetitions: ISOM; ISO / EX(knee extension)	Isometric = ↑HR Eccentric Isokinetic = ↑HR	Not evaluated
Simões <i>et al</i> (2010)	ER (n = 10; 64 ± 4)	1RM; submaximal ISOT (started with 10% of 1RM comprogressão 10% up to 30%. After this point the progression was 5% closing with exhaustion)(legpress 45)	1RM = ↑ HR Submaximal = ↑ HR	1RM = Not analyzed Submaximal = ↓ SD1, SD1/SD2, RMSSD, RMSM. ↔ SD2
Quitério <i>et al</i> (2011)	ER (n = 12; 61.5 ± 1.6)	3 sets from 5 to 8 repetitions: ISO/EX and ISO/CON at 60°/s and 120°/s. 3 CVM series: ISOM(extension and knee flexion)	ISO/EX = ↑HR ISO/CON = ↑HR ISOM = ↑HR	Not evaluated
Simões <i>et al</i> (2013)	ER (n = 14; 70 ± 4)	1RM; Submaximal ISOT (started with 10% 1RM comprogressão 10% until exhaustion) (legpress 45°)	1RM = ↑ HR Submaximal = ↑ HR	1RM = Not evaluated Submaximal = ↓ SD1, RMSSD, RMSM
Queiroz <i>et al</i> (2012)	SE; SC (n = 16; 63 ± 1.0)	A training session with 9 exercises; 3 sets of 8RM.	SE = ↑ HR SC = ↓ HR	SE ↔ HF (nu), LF (ms ²), HF (nu) ↑ LF(nu), LF/HF SC ↔ HF (nu), LF (ms ²), HF (nu) e LF/HF. ↑HF(ms ²)
Vieira <i>et al</i> (2013)	GER1 (n = 15; 30 ± 3) GER2 (n = 12; 66 ± 7)	1RM elbow flexion (biceps curl); Submaximal (30% de 1RM), 3 minutes of execution with and without local blood flow restriction (ERC and ERS). Method in crossover and random.	GER1 ERC = ↑ HR ERS = ↑ HR ERC x ERS = ERC >HR GER2 ERC = ↑ HR ERS = ↑ HR ERC x ERS = ERC >HR	Not evaluated

ISOM: Isometric; ISO/EX: eccentric isokinetic; ISO/CON: concentric isokinetic; IT: isotonic; RM: repetition maximum; HR and HRV (↓: decreased; ↑: rose; ↔: no change); ER: resistance exercise; SE: exercise session; SC: session control; HF: high frequency; LF: low frequency; RMSSD: square root of the square average of the differences between normal R-Ri in a time interval; RMSM: the square root of the square sum of differences in individual values in relation to the average value divided by the number of iR-R in a given time SD1: standard deviation of the distances of the points to the diagonal y = x Plot of Poincare It is associated with short term variability; SD2: standard deviation of the distances of points to the line y = -x + RRmdo Plot of Poincare.

Table 4 Studies have found that the acute effect of autonomic modulation and / or heart rate in elderly individuals performing resistance exercise.

Authors	Sample (n, age)	Strength evaluation	Change	Progression	Weekly frequency and duration	HR (rep/exe)	HRV
Vicent <i>et al.</i> (2003)	ERB (n = 22; 67.6 ± 6.0) ERA (n = 24; 66.6 ± 7.0) CON (n = 16; 71.0 ± 5.0)	1 RM	13 exe. (Lower and upper limbs) ERB: 13 rep. 50% RM ERA: 8 rep. 80% RM CON: Without Exercise	(> 5% if Borg < 18)	3x/week 6 months	Rep. ↔ ERB: ↔ ERA: ↔ CON: ↔	Not evaluated
Hunter <i>et al.</i> (2001)	ERV (n = 14; 65.9 ± 4.3) ERA (n = 14; 67.3 ± 4.7); CON (n = 8; 65.9 ± 4)	1 RM Isometric (elbow flexion)	ERV: 50, 65 e 80% RM ERA: 80% RM 2 sets of 10 repetitions CON: Without Exercise	Every session and MRI every 25 days.	3x/weeks 25 weeks	Exe. ↔ ERV: ↑ ERA: ↑ CON: ↔	Not evaluated
Lovell <i>et al.</i> (2009)	CON (n = 12; 73.5 ± 3.3) ER (n = 12; 74.1 ± 2.7)	1 RM	ER: 3 sets of 8 repetitions at 50% RM (weeks 1 and 2) 3 sets of 6 to 10 repetitions 70 to 90% of the MR 3 to 16 weeks CON: Without Exercise	RM each 4 weeks	3x/week 16 weeks	Exe. ↔ ER: ↑ CON: ↔	Not evaluated
Wood <i>et al.</i> (2001)	CON (n = 6; 68.0 ± 5.4) ER (n = 11; 69.8 ± 6.0)	5 RM	ER: 12 a 15 repetitions at 75%RM CON: with no exercise	Increment: 5 a 10% até 8-12 repetitions of RM	3x/week 12 weeks	Rep. ↔ ER: ↑ CON: ↔	Not evaluated
Gerage <i>et al.</i> (2013)	CON (n = 14; 66.2 ± 4.1) ER (n = 15; 65.5 ± 5.0)	1 RM	ER: 8 exercise in 2 sets of 10 to 15 repetitions with CON: stretching exercises 25 – 30 min.	Increments when 2 sets of 15 rep.: 2 to 5% for MS 5 to 10% for MI	ER: 3x/week 12 weeks CON: 2x/ week 12 weeks	Rep. ↔ ER ↔ CON: ↔	Rep. ER e CON: HF; LF; HF; RMSSD SDNN; R-R (ms); SD1; SD2: ↔
Wanderley <i>et al.</i> (2013)	ER (n = 11; 67.3 ± 4.9) CON (n = 19; 67.8 ± 5.5)	1 RM	ER: Weeks (1 to 4), 2 sets 50 to 60% IRM; Other weeks: 2 sets to 80% of IRM. CON: sem exercício	Revaluation of IRM every 2 months.	3x/week 8 months	Rep. ↔ ER: ↔ CON: ↑	ER: SDRR; HF (m2): ↔ CON: SDRR; HF (m2): ↔ ER x CON: ↔
Wieser & haber (2007)	ER (n = 14; 76.1 ± 2.9) CON (n = 10; 76.6 ± 3.2)	Not informed	ER: 8 exercises 10-15 repetitions in charge to take fatigue CON: without exercise	1st to 4th week: 2 weekly series; 5th to 8th week: 3 weekly series; 8th and 12th week: 4 weekly series.	2x/week 12 weeks	Exe. ↔ ER: ↔ CON: ↔	Not evaluated
James <i>et al.</i> (1989)	ER (n = 19; 72 ± 3) CON (n = 13; 72 ± 3)		1 set of 8-12 repetitions light loads / moderate (first 13 sessions) to exhaustion (Last 13 sessions)	Progression when they reached 12 repetitions without difficulty.	3x/week 26 weeks	Exe. ↔ ER: ↔ CON: ↔	Not evaluated
Madden <i>et al.</i> (2006)	ER: (n = 15; 69.8 ± 1.5) CON: (n = 15; 71.8 ± 1.2)		ER: 10 exercises 3 sets of 8 to 12 repetitions. CON: Without Exercise		5x/week. 6 months	Exe. ↔ ER: ↑ CON: ↓	Rep. (ER e CON) %RR50, RMSSD, SD, SDANN, SDNN, HF, LF e PT: ↔ PT Rep. RMSSD, PT, LF e HF (ms2): ↔
Melo <i>et al.</i> (2008)	ER (n = 9; 62 ± 2)	CVM: isokinetic	ER: isokinetic, eccentric, 2 to 4 sets of 8 to 12 repetitions, 75 to 80% Peak Torque	2x/week. 12 weeks		Rep. ↔ ER: ↔	LF (um): ↑ HF (um): ↓ LF/HF: ↑

RM: repetition maximum test; HR (↓: worsened; ↑: improved; ↔: no change; exe: exercise; rep: rest); HRV (↓: decreased; ↑: rose; ↔: no change); ERB: resistance exercise of low intensity; ERA: high intensity resistance exercise; CON: control; ERV: variable resistance exercise; MS: upper limb; EA: aerobic exercise; HF: high frequency; LF: low frequency; PT: Total Power; RMSSD: square root of the square average of the differences between normal R-Ri in a time interval; SD: standard deviation; SDNN: standard deviation of all normal R-Ri recorded at an interval of time; SD1: standard deviation of the distances of the points to the diagonal y = x Plot of Poincare, is related to short-term variability; SD2: standard deviation of the distances of points to the line y = -x + RRmido Plot of Poincare.

in intensity and number series produced greater increase. In the study of Hugget *et al.*^[25], performing 3 sets of 10 repetitions maximum of knee extension, produced 13% of HR increases for the isometric exercise and 12% for the eccentric exercise. Moreover, Quitério *et al.*^[26], also using the knee extension exercise and 3 sets but with 5-8 maximum repetitions, observed an average increase of 36% HR in eccentric and concentric exercise. Simões *et al.*^[27], when performing 5 sets of 12 repetitions on the leg press exercise, observed an increase of 58% HR compared to resting conditions. Even after 60 minutes of resistance training with 9 exercises performed in 3 sets of 8 repetitions maximum, Queiroz *et al.*^[28] observed HR values 5% higher than the resting values.

Regarding HRV, Simões *et al.*^[27] found 70% reductions in RMSSD index, 37% of RMSM and 73% of the SD1. Similarly, Queiroz *et al.*^[28] found that even after 60 minutes of completing the resistance training the values of the spectral indices of HRV were altered in relation to resting values, with 31% reduction of high frequency indices (HF) and an increase of 29% and 15% of the low frequency content (LF) and LF/HF ratio, respectively.

With respect to the chronic effect, most studies found no significant adaptations of resting HR to resistance training^[29-33]. Chronic reductions in resting HR were observed only by Wood *et al.*^[34], and HR during submaximal exercise by Hunter *et al.*^[35,36], but all with low percentage of variation (2 to 6%).

Regarding the chronic effect of resistance exercise on the cardiac sympathetic and / or parasympathetic modulation the results are not as conclusive. Previous studies have found changes in HRV indices according to Gerage *et al.*^[32] (HF, LF, LF / HF, RMSSD, SDNN, SD1 and SD2); Wanderley *et al.*^[33] (HF and SDRR); Madden *et al.*^[30] (% RR50, RMSSD, SD, SDANN and SDNN); Melo *et al.*^[31] (RMSSD, TP, LF and HF). However, Madden *et al.*^[30] observed a significant increase of the total variance and Melo *et al.*^[31] found an increase in LF values in standard and LF/HF units, also decrease in HF values in normalized units.

DISCUSSION

Both aging and the physical exercise cause adjustments in the autonomic nervous system. The studies of HRV are useful to assist the body of evidence on the sympathetic and parasympathetic modulation and interaction of health and disease in this population.

Acute effect of resistance exercise (EFR) on the HR and the Autonomic Modulation

It is well established that the autonomic nervous system (ANS), through central and peripheral mechanisms, plays a critical role in mediating the settings of the cardiovascular system to meet the demands of active skeletal muscle during exercise^[37-41].

In the first ten seconds of muscle contraction, there is a fast initial response of HR^[25,26,39], attributed to inhibition of vagal modulation of the sinus node that happens based on the type of contraction, joint angle or muscle groups submitted to exercise. The faster the acceleration of HR at this phase, the greater the preservation of the vagal autonomic component^[26,39,41]; individuals with impaired vagal modulation tend to have reduced variation of HR in response to this effort^[41-44].

After ten seconds, vagal recovery and the interrelationship between vagal and sympathetic regulation of the FC that is organized in a reciprocal manner is observed, i.e., late increase in sympathetic activity is accompanied by decreased cardiac vagal activity^[45,46]. In this context, it has been found that during exercise heart rate increases

and HRV decreases, especially indices related to parasympathetic modulation, as the intensity of effort increase^[46].

Increased sympathetic activity in response to the increased intensity of exercise stimulates the production of catecholamines, resulting in increased blood glucose levels and consequently lactate^[47], whose blood concentration is stable until the anaerobic threshold (AT), at which time the production capacity exceeds that of removing it from the body^[48]. During resistance exercise, this point usually occurs at moderate intensities, approximately 30% of 1RM for both active individuals, and for sedentary^[49]. These findings have contributed to new approaches with prognostic purposes and/or therapeutic with such an exercise.

It has been observed in the elderly that reducing the vagal component during resistance exercise (RE) reaches a plateau at the transition point between aerobic and anaerobic metabolism (LA)^[27,50,51]. This point in resistance exercise occurs around 30% of maximum voluntary contraction^[27,49,51], suggesting that from this charge, hypoxia caused by muscle contraction stimulates glycolysis and accelerates the increase in lactate production. From the anaerobic threshold then there is a reduction of the pH in muscles that stimulates metabolic receptors, causing increased sympathetic activity on the cardiovascular system, raising the HR.

The bradycardia observed in the recovery period after exercise seems to depend on a joint action of the sympathetic and parasympathetic branches of the ANS^[41,52]. After the physical exertion, there is a fast vagal reactivation, and in individuals with better resting parasympathetic modulation this recovery is done faster and more efficient^[53-55]. Instead, the sympathetic nervous system seems to have more time to return to baseline after cessation of exercise, resulting in lasting hyperactivity disorder^[54]. These responses can be explained by an increase in baro-reflex control, which is an attempt to keep blood pressure in levels considered "normal"^[28,56]. The recovery time for the basal levels has also been shown to be proportional to the size of the muscle group and energy expenditure involved during exercise^[55].

Chronic effect of resistance exercise (EFR) on HR and HRV

Most studies that examined the effects of resistance training (RT) on HRV indices did not include the elderly, both for investigating the acute effect^[39,56,57] or the chronic effects^[58-64]. However, conventional resistance training seems to have no deleterious or positive effect on cardiac autonomic modulation in adults, regardless of age. However, it is not clear if the resistance training does or does not improve the autonomic modulation in individuals with autonomic dysfunction.

There were no differences in the structures of resistance training programs that explain different behavior of the HR in the study of Wood *et al.*^[34], Hunter *et al.*^[35] and Lovell *et al.*^[36], leading us to believe that resistance training does not produce significant effect on resting HR or submaximal exercise, or that the effect can be associated with the variability of the sample and the initial levels.

Some studies have reported smaller HR values after resistance training, both at rest and during submaximal exercise in similar overloads^[29,33,36]. However, these studies did not analyze HRV and the results can not be attributed to changes in the autonomic control of the heart.

Regarding the effect of resistance training on cardiac SNA, some studies have found changes that pointed to significant improvements on the HRV indices^[30-33,65]. However, Madden *et al.*^[30] observed a significant increase over the total variance and Melo *et al.*^[31] observed increased LFnu values and LF/HF, with a reduction in HFnu values.

These results further provoke more controversy because, Madden *et al.*^[30] conducted 24 weeks of resistance training with frequency of 5 times per week, 3 sets of 8 to 12 repetitions for 10 years, and Melo *et al.*^[31] conducted 12 weeks training with a frequency of 2 times a week for 2 to 4 series of 8 to 12 replicates for only 2 years.

Hu *et al.*^[63] reported improved cardiac autonomic modulation after resistance training, Wood *et al.*^[34] compared the effects of aerobic combined cardiovascular training (aerobic and strength) and insulated power and found minor HR responses indicating cardiac improvement in both studied protocols. Moreover, Hunter *et al.*^[35] studied two protocols called a high intensity (80% RM) and a variable resistance. The latter increased strength and showed a decrease in the HR response to stress during the tasks of daily living when compared to resistance training group and 80% of the RM.

By contrast, the study by LOVELL *et al.*^[36] showed that the reductions in cardiovascular response (HR, double product and systolic pressure) during submaximal exercise found in the study suggest that the resistance for lower limbs in the elderly may have benefits in reducing the likelihood of cardiovascular risk. According to the authors, the myocardial oxygen consumption indirectly evaluated by double product (FCxPAS) to the same submaximal exercise load after 16 weeks of RT reinforce the improvement of cardiac function and efficiency. The authors infer further that the reduction in HR to 50% of VO₂max between the pre TR (101 bpm) and after 16 weeks (95 bpm) during submaximal load of aerobic exercise test can be explained by a lower sympathetic modulation. The study evaluated the effect of detraining (4 weeks) and found the HR to be 94 bpm, indicating permanence of the benefit and suggesting that resistance can lower the risk of coronary heart disease installation. The authors also point out that evaluating the cardiovascular variables outside the submaximal exercise is more relevant than when evaluated at rest because most of the time the elderly are performing activities that are not at rest, and hence the importance of evaluating the cardiovascular variables in situations closest to the reality.

In the VICENT *et al.* study, resistance training with higher intensity (80% RM) afforded broader adaptation regarding cardiovascular response in comparison to the low-intensity (50% RM) in the elderly. The results showed significant improvements in cardiovascular function, maximum exercise capacity increase and decrease in cardiovascular responses for a given workload. The HR presented lower values for the group that trained with 80% of RM and also when compared to the control for submaximal exercise loads during the treadmill test. For the resistance training at 50% of RM under the same conditions, the group was different compared to the control and not only between pre and post. The authors also evaluated the HR recovery after exercise and both groups showed lower values when compared to the control post training and the resistance training to 80% of RM improved significantly intragroup. Thus, the resistance training is able to improve the recovery of HR when applied at 80% of the MR and this overcharge appears to present the best possible combination of exercise-induced chronic adaptations as increased muscle blood flow, improved systemic and local vasodilatation and increased release of Nitric oxide which contributes to better vasodilatation.

Wanderley^[33] found no changes in both HR and HRV, analyzed in the time domain and parasympathetic indices after 8 months and 3 times per week of resistance training. The authors did not discuss the possible implications of the results of these variables. In the study of Wieser and Haber^[66] despite the increase in cardiorespiratory fitness by 15% and the VO₂ at 12% with 12 weeks of resistance exercise

HR did not differ between the pre and post period and between the control group. The authors commented that the inconsistency between no change in HR and the significant increase in VO₂ can be explained by the increased metabolic active muscle mass. They did not associate the HR to cardiac autonomic behavior and intrinsic HR. The authors point out that the resistance training for the elderly is effective when performed with control and security, indicating that it is an important method in the treatment of atrophy in this population.

In this line, Madden *et al.*^[30] found improvement in autonomic response in the elderly after aerobic training and not in the trained group with resistance exercise. The authors justify the finding physiologically in arterial compliance explaining that this improvement with aerobic training and that the most distensible vessels have improved baro-reflex sensitivity and this condition is associated with an improvement in vagal behavior as measured from the HF index of HRV. By contrast, the resistance training promotes arterial stiffening reducing the baro-reflex sensitivity and decreasing the vagal participation. The authors suggested that interventions that improve the HRV measures related to the vagus nerve are protective against sudden cardiac death and that resistance training appears to have the greatest impact on HRV that the latter join modify other risk factors, but it does not provide an increase in HRV. The authors do not suggest that the resistance training has no value in preventing cardiac death in older women and suggest that aerobic and strength training should be used to complement each other.

Gerage *et al.*^[32] studied menopausal women and found that HRV did not change after 12 weeks of resistance training. This corroborates the studies of Madden *et al.*^[30] and Wanderey *et al.*^[33], suggesting that resistance training can improve muscle strength, without causing a reduction in HRV. A possible explanation for the maintenance of HRV after training may be characteristic of the protocol applied for the short period of performing exercise, because according to authors, resistance training sessions were probably not enough to promote autonomic changes in the sample investigated. Changes in HRV at rest are observed especially after exercise training with longer sessions^[30]. Based on the above discussion, it is possible to assume that the effects of resistance training on HRV may depend on the type of training and the study population, and these differences should be investigated. In this sense, the authors suggest that a resistance training program supervised for 12 weeks can improve muscle strength and reduce the systolic and diastolic blood pressure without affecting HRV in hypertensive, untrained, elderly and postmenopausal women.

In the study of Melo *et al.*^[31] resistance training promoted effects on cardiovascular variables among them the HR and HRV in the elderly, however, negatively. They showed an increase in LF/HF ratio. They emphasized that this type of training is recommended for use in the cardiovascular rehabilitation. Regarding the type of muscular action, the excentric is pointed by the authors as the most appropriate since it favors a greater strength gain and lower cardiovascular demand hence the choice of this type of exercise for the study. Nevertheless, there was no change in HR at rest and after training HRV showed opposite results than expected, i.e. a worsening in vagal modulation and increased sympathetic modulation. The results do not agree with Madden *et al.*^[30] which showed an influence of increased arterial stiffness, developed by resistance training, a greater sympathetic stimulation and parasympathetic inhibition. The authors discuss that systolic blood pressure decreased after training and it has important relationship with the stiffness of the arterial wall in the elderly. The authors attributed the change of HRV to increased

catecholamines related to increased sympathetic participation in post training. However, the basal HR has not changed and this fact may be associated with a reduction of beta adrenergic response. The authors did not measure catecholamines and did not have control group (untrained), it only allows assumptions of the possible mechanisms involved in autonomic modulation.

Although studies of apparently healthy elderly indicated disagreement, cardiac autonomic changes (improvement, deterioration or no change) studies involving similar age profile but with diagnostic pathology bring different results. Taylor *et al*^[67] and Selig *et al*^[68] investigated patients with chronic heart failure while Caruso *et al*^[69] with coronary artery disease and the results of the studies reported a positive effect of resistance training on cardiac autonomic modulation pointing out that resistance training can contribute positively to cardiac autonomic modulation among the elderly when pathological conditions are present.

Taylor *et al*^[67] found increased amounts of HF and reduced variability in blood pressure for LF and increase in HF and LF/HF, after 8 weeks of isometric exercise (handgrip) performed 2 times a week with 4 sets of 2 minutes contraction compared to the control group without training. Selig *et al*^[68] after 12 weeks of resistance training, performed in 3 weekly sessions with six exercises performed in isokinetic equipment for 30 to 120 seconds to reach maximum HR, observed a significant reduction of LFnu and increased HFnu and LF / HF ratio in the control group. Caruso *et al*^[69] observed significant increases in RMSSD values and SD1 in the trained group compared to the control group, after the completion of 8 weeks of resistance training with exercise Leg Press, held in two sessions per week for 3 sets of 10 repetitions for 2 minutes each series and pause of 5 minutes between sets.

An important point to be mentioned is the brain-heart axis, which is crucially involved in heart rate. The anatomy and functions of the connections between the heart and brain is well explored in the literature. The role of brainstem areas surrounding the fourth cerebral ventricle in cardiovascular reflex was reported in the literature^[70,71]. Among the areas relevant to cardiovascular regulation we may include the solitary tract, which is an area that receives projection from baroreceptors. The solitary tract receives glutamergic and GABAergic projections in order to control blood pressure^[72].

In this review we focused on HRV as a non-invasive method that analysis. It is worth to mention that there are several methods of HRV data acquisition, including electrocardiogram (ECG), heart rate monitor, digital-to-analog converter, Holter monitoring for instance^[16]. In this context, very important details should also be considered for HRV analysis such as stationary or non-stationary data, the specific method of digital and manual filtering, criteria for artefacts and ectopic beats exclusion.

CONCLUDING REMARKS

The unique role of the ANS in the control of bodily functions, particularly on cardiac adjustments to the exercise is well established; however, we found few studies related to this theme. Although the results presented here do not allow us to state that the resistance training has an apparently positive impact on the cardiac autonomic regulation in healthy elderly, we are unable to exclude the possible effect of exercise mode on the autonomic modulation. This is because a positive effect was reported in studies that assessed the effects of resistance training on the HRV in the elderly in pathological conditions.

CONFLICT OF INTERESTS

There are no conflicts of interest with regard to the present study.

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