Cardiovascular Topics

Six months of resistance training improves heart rate variability in the elderly

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Abstract

Heart rate variability is a non-invasive method of assessing global health through the analysis of the autonomous central nervous system, including both the sympathetic and parasympathetic systems. The aim of this study was to evaluate the effect of resistance training on heart rate variability at rest in elderly individuals undergoing six months of resistance training with progressive loads. Training reduced the body fat percentage of the volunteers (pre: 39.39 ± 7.21 vs post: 34.97 ± 6.40%; $p = 0.0069$). There was also a significant reduction in the low-frequency index (pre: 69621.50 ± 9817.28 vs post: 54210.50 ± 14903.94; $p = 0.0322$) and a significant increase in the high-frequency index (pre: 30308.00 ± 9857.86 vs post: 45627.10 ± 14838.80; $p = 0.0326$). We concluded that six months of resistance training with progressive loads were beneficial for heart rate variability and reduced the body fat percentage in the elderly.

Keywords: resistance training, heart rate variability, elderly

Submitted 1/12/21; accepted 15/9/23
Cardiovasc J Afr 2023; 34: 00–00 www.cvja.co.za

DOI: 10.5830/CVJA-2023-050

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Global life expectancy has been increasing over the years, surpassing the birth rate, which has not increased at the same rate as the aging population. Therefore, an inversion of the worldwide proportion between the number of children (aged ≤ 5 years) and that of the elderly (aged ≥ 60 years) was predicted by the end of 2020.[1] Considering this change in the relative proportion of ages, older people can pose public health problems if there is a lack of support and planning that contributes to the maintenance of health. From this perspective, in addition to chronological time, sedentary lifestyle habits can contribute to the emergence of chronic degenerative diseases[2] and increased drug intake by the elderly,[3] consequently inducing harmful changes to the autonomic nervous system (ANS).[4]

ANS evaluation can be performed through the analysis of heart rate variability (HRV).[5] This is a non-invasive, low-cost method capable of assessing the predominant oscillations of the sympathetic and parasympathetic ANS, which in turn reflect an individual’s general health status (physical and psychological).[6] It is noteworthy that the continuous control of physiological parameters, such as HRV, blood pressure and blood glucose level, can contribute to the prevention, control and treatment of diseases that affect the elderly population, which are often due to autonomic dysfunctions associated with aging[5] or the pathophysiology of some diseases.

Regarding the health of the elderly population, improvements resulting from the systematic practice of physical exercises,[7] which must be measured according to the target audience and prescribed by exercise science experts, have been observed. In turn, one of the ways to monitor development, as well as establish the progression of training/sessions, is through HRV, evaluating the individual’s recovery, and is related to the time required for cardiac depolarisation and repolarisation. In other words, the branches of the sympathetic and parasympathetic innervations reach the heart, where they trigger a series of events related to atrial and ventricular depolarisation and repolarisation.

To observe such events, an electrocardiogram is used, in which we consider the appearance of PQRSTU waves.[8] Therefore, regarding HRV, evaluation of the difference between the R waves can be performed. In turn, the analysis of HRV can be performed through two different methods: a linear and non-linear method, both of which are used to evaluate the ANS.[9]

A healthy heart does not work like a metronome; that is, the variations in the time interval between one beat and another are not the same. It is known that physical exercise can induce autonomic modulation,[10] but studies on types of training (aerobic and anaerobic)[11] and load components (intensity, volume, frequency) and their influence on HRV are still controversial.[12,13] Furthermore, resistance training (RT) presents inconclusive data for modulation of HRV, and for the elderly population, there is an even greater lack of information.[14]

Medicated hypertensive patients can effectively control their blood pressure with the accessorial help of isometric exercises. Isometric contraction protocols using 30% of the maximum voluntary contraction was found to generate improvements in HRV by non-linear analysis[15] and frequency-domain analysis of HRV.[16] On the other hand, another study with a similar protocol to the one mentioned above did not improve HRV,[17] suggesting the need for more studies on this strategy.

The main objective of this study was to evaluate the effects of strength training on HRV of elderly volunteers after a six-month intervention programme.

Methods

In this before–after (pre–post) interventional study, the volunteers were recruited in a university extension project for the elderly. After explaining the aims and methodology of the research and clarifying any doubts, those who agreed to participate in the study signed the informed consent form.

The study started with 24 physically active elderly individuals who met the following inclusion criteria: age 60 years or older, absence of diseases to ensure a smooth practice of strength training, and absence of fractures in the upper and lower limbs in the six months prior to the study. Smokers were excluded, as well as those who did not reach a cut-off percentage of frequency in the training programme (≥ 70%) or those who prematurely ended their participation of their own volition.

All procedures were submitted and approved by the Research Ethics Committee of the Federal University of Ouro Preto (UFOP) under protocol number: 06687019.6.0000.5150. This research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki.

Body composition was measured by bioelectrical impedance (Biodynamics® 450, Seattle, WA, USA), and the percentage of lean and fat mass was expressed in kilograms. The participants were weighed on a Filizola® portable scale, and height was measured using a WISO® portable stadiometer. Subsequently, the body mass index (BMI) was calculated using the predictive equation: weight (kg)/height^2 (m).

The first and second week of intervention were aimed at familiarising the volunteers with the exercises to be performed. During this period, the weight adjusted on the machines was low, and the focus was on the correct execution of the movements, respecting the individualities of each volunteer, so that they could later safely perform the one-repetition maximum test (1-RM), which was used to assign the load used by each volunteer.

The training programme was an adaptation of a methodology previously described for strength training of the elderly.[18,19] The selection of exercises and apparatus included the following:

- Alternate biceps curl: an exercise that targets the anterior muscles of the arms, such as the brachialis and biceps brachii. In this exercise, the volunteer held a dumbbell in each hand and alternately performed elbow flexion with each arm.
- Triceps pushdowns: an exercise that targets the triceps brachii (lateral, long and medial head) muscle located in the back of the arms. In this exercise, the volunteer held a straight bar attached to a high pulley located above their head and exerted a counterforce to extend the elbows, projecting the hands towards the ground.
- Bench press: an exercise that primarily targeted the pectorals with secondary emphasis on the triceps, anterior deltoids, serratus and coracobrachialis. It was performed in a supine position with a barbell.
- Lats pulldowns: an exercise that targets the latissimus dorsi muscle. In this exercise, the volunteer remained seated on the equipment, holding a bar attached to a high pulley located above the head, and exerted a pulling force on the bar towards the chest after performing a slight trunk incline, favouring the back muscles.
- Seated rows: an exercise that targets the posterior muscles of the back, mainly the trapezius, rhomboids and latissimus dorsi. In this exercise, the volunteer remained seated on the equipment, holding a bar located in front of them, and performed the motion of pulling the bar towards their abdomen using the back muscles.
- Sit ups: an exercise that focuses on the rectus abdominis and works the obliquus externus abdominis and hip flexors.
- Leg extensions chair: an exercise that targets the muscles of the anterior thigh, mainly the rectus femoris, vastus intermedius, vastus lateralis and vastus medialis. In this exercise, the volunteer remained seated on the equipment and performed knee extensions against a resistance located in front of the ankles.
- Seated leg curls: an exercise that targets the muscles of the posterior leg, including biceps femoris, semimembranosus, semitendinosus and gastrocnemius. The volunteer remained seated on the equipment and performed knee flexions against a resistance located behind the ankles.
- Squats: an exercise that targets the quadriceps femoris, gluteus medius and gluteus maximus muscles. The volunteer holds dumbbells laterally to the body and performs hip and knee flexion and extension movements.
- Seated calf raises: an exercise that works the triceps surae and focuses on the soleus. The volunteer remained seated on the equipment and performed dorsiflexion and plantarflexion against a resistance located above the thighs.

The names of the exercises and other details are in the book cited here.[20]

The estimated 1-RM test was conducted with up to three attempts, spaced five minutes apart, following a warm-up period on the equipment, using an estimated load of 50% of everyone's maximum load. The tests were performed on all the equipment used in the training programme, with the volunteer aiming to complete a minimum of nine and a maximum of 11 full repetitions, allowing for an incomplete repetition if necessary. In each attempt, the load was adjusted by instructors based on the volunteer's effort, aiming for approximately 10 repetitions per set. The 1-RM was calculated using the approved equation:[21]

$$\text{1-RM} = \frac{100 \times \text{load}}{102.78 - (2.78 \times \text{number of repetitions performed})}$$

Based on the obtained results, each subject received loads representing 60, 70, 80 and 85% of their 1-RM, progressively increasing every two weeks of training before the new 1-RM test. This new test took place after the eighth week of the training programme, generating new loads to which the volunteers would be subjected until the end of the study. The overall duration of exercise training protocol was six months.

The HRV data were collected after a previous appointment informing the volunteers that the collections would always be conducted in the morning, that stimulant foods (containing caffeine) and physical exercise before collection (12 hours) were prohibited, and that the consumption of alcoholic beverages should be discontinued for at least 48 hours before HRV collection. For this purpose, a heart rate monitor (Polar RS800®; Polar Electro Oy) was used with the time units fixed at 1 ms, and the samples of the RR intervals were collected at a sampling frequency of 1 000 Hz.

Analysis of HRV was conducted using linear (frequency and time domain) and non-linear (Poincaré plot) methods. The parameters used in this study were: LF = low frequency; HF = high frequency; SDNN = standard deviation of R-R intervals; RMSSD = square root of the mean squares of the difference between the R-R intervals; NN50 = number of R-R intervals with variation greater than 50 ms; pNN50 = percentage of R-R intervals with variation greater than 50 ms; SD1 = standard deviation 1; SD2 = standard deviation 2; and SD1/SD2 = ratio between short and long duration of R-R intervals.[9,22,23]

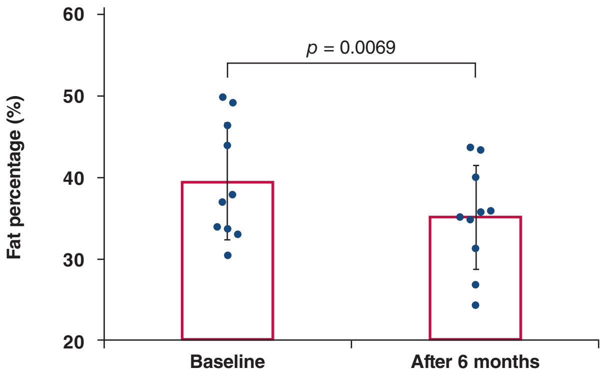

Fig. 1. Fat percentage after six months of RT. $t_9 = 3.481$; data presented a normal distribution and were subject to the paired *t*-test (*p*-values indicated in the graph); values are expressed as mean ± standard deviation.

The data obtained by the heart rate monitor were transferred to a computer using the Polar Pro Trainer 5® software, through an interface with an infrared device. This database was then exported as text, and the R-R interval signals were processed to calculate HRV using Kubios HRV Analysis software® (MATLAB, version 2 beta, Kuopio, Finland).

The records were entered when the volunteer had been at rest for five minutes and 30 seconds. In the analysis section, we excluded the initial 10 seconds and the final 20 seconds. During the entire recording time, standardised neutral photos were displayed to minimise possible intrinsic influences.[24]

Statistical analysis

The raw data were analysed to verify the existence of outliers, which, when identified, were removed. Then, data normality was verified using the Shapiro–Wilk test. Data that exhibited a normal distribution were analysed using the paired *t*-test and values are expressed as mean ± standard deviation. Data without a normal distribution were analysed using the Wilcoxon paired test and are presented as median and 25 and 75% percentiles.

Results

Having satisfied the inclusion criteria, 10 volunteers who agreed to undergo the intervention completed the study. Of these volunteers, two had both hypertension and diabetes, four had hypertension, and one had diabetes, leaving three individuals without any known disease.

The mean age of the volunteers who completed the RT was 65 ± 4.98 years, their mean body mass was 77.76 ± 11.00 kg, their height was 1.62 ± 0.10 m, body mass index (BMI) was 29.65 ± 3.59 kg/m^2 and percentage fat was 37.39 ± 5.81%. After six months of intervention, the volunteers showed an improvement in body composition, resulting in a reduction in the percentage of fat (Fig. 1).

Analysing HRV from the perspective of the frequency domain, we found that the low-frequency component, which represents the predominance of sympathetic ANS activity, decreased after six months of RT (Fig. 2A). On the other hand,

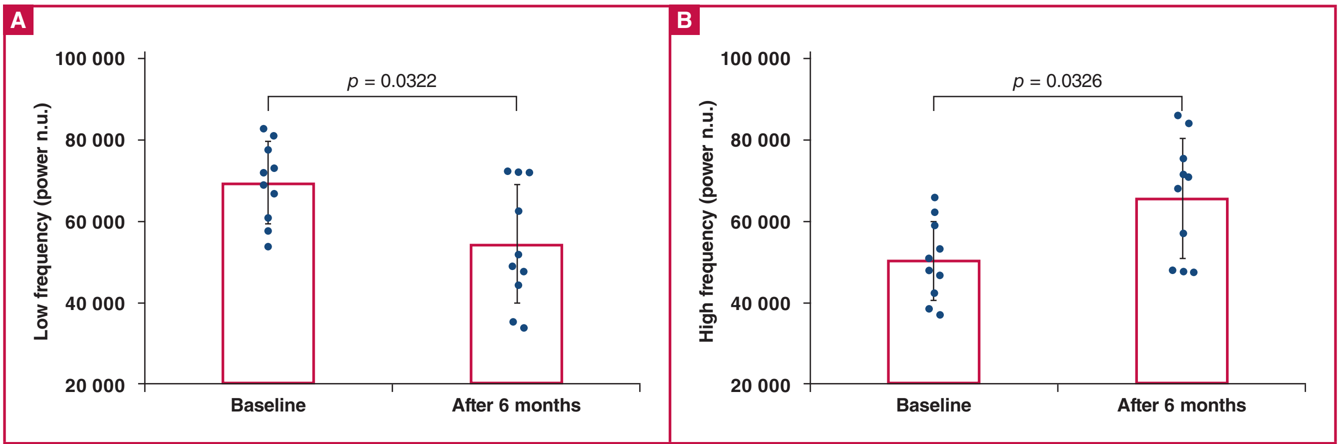

Fig. 2. HRV expressed in the frequency domain before and after six months of RT. (A) Low frequency ($t_9 = 2.530$); (B) High frequency ($t_9 = 2.524$). Values obtained after a fast fourier transform (FFT). Data presented a normal distribution and were subject to the paired *t*-test (*p*-values indicated in the graph); values are expressed as mean ± standard deviation.

Table 1. HRV expressed in the time domain and in a non-linear way, before and after six months of RT

Parameter	*Median (25/75% percentile)*	*95% CI*	*CV (%)*	*Wilcoxon*
Time domain				
SDNN (ms), B	23323 (14622/35077)	35351	52.30	0.4316
SDNN (ms), 6M	29134 (12648/56696)	72239	74.92	
RMSSD (ms), B	25295 (13135/30911)	35182	51.39	0.4258
RMSSD (ms), 6M	27622 (11537/67235)	67882	78.28	
NN50 (beats), B	1 (0/10)	10	163.1	0.3750
NN50 (beats), 6M	0.5 (0 / 24,25)	31	208.5	
pNN50 (%), B	0.22 (0 / 0,25)	0.57	113.7	0.1875
pNN50 (%), 6M	0.25 (0/64519)	95225	134.0	
Poincaré plot				
SD1 (ms), B	29935 (18405/86177)	91612	73.18	0.9219
SD1 (ms), 6M	47610 (20622/77064)	77682	58.55	
SD2 (ms), B	29393 (22780/44570)	46325	48.38	0.8203
SD2 (ms), 6M	33426 (14884/46696)	54600	72.74	
SD1/SD2, B	19095 (16981/24885)	25843	31.75	0.4922
SD1/SD2, 6M	17909 (15152/20572)	22795	24.30	

SDNN = standard deviation of R-R intervals; RMSSD = square root of the mean squares of the differences between the R-R intervals; NN50 = number of R-R intervals with variation greater than 50 ms; pNN50 = percentage of R-R intervals with variation greater than 50 ms; SD1 = standard deviation of the instantaneous beat-to-beat variability; SD2 = long-term standard deviation of continuous R-R intervals; SD1/SD2 = ratio between short and long duration of R-R intervals; CI = confidence interval; CV = coefficient of variation; B = baseline; 6M = after six months. Data were without normal distribution.

the high-frequency component, representing parasympathetic predominance, increased after six months of RT (Fig. 2B).

When considering the linear analysis of the HRV for the time-domain components, it was observed that none of the evaluated components changed after the intervention of six months of RT. The same was seen for the Poincaré plot, which is a non-linear HRV method (Table 1).

Discussion

At the end of the study, the elderly volunteers showed a decrease in the low-frequency component, the main representative of the sympathetic nervous system, and an increase in the high-frequency component, representative of the parasympathetic nervous system (PNS) under the high- and low-frequency indexes, respectively. This finding provides evidence for a better general health status, as it is expected that a healthy young adult in a resting state would have his/her health regulated by the activation of the PNS.[25]

This study contributes to the investigation of the influence of RT on HRV, since little has been reported about the benefits of such training in autonomic modulation in the elderly. Current findings show a greater response to RT in individuals with an associated pathology.[14] However, in addition to the presence of diseases, age and lifestyle also influence autonomic modulation; hence, young people and physically active individuals have better HRV (parasympathetic components) compared with older and sedentary individuals.[6] In our results, we found that six months of training were enough to positively modulate vagal activity, despite the age and health conditions of the volunteers, which could have been decisive in HRV change.

Several strategies that aim to increase HRV have been studied. These include different training methodologies, such as isometric exercise at 30% of maximum contraction in hypertensive individuals,[17] eight-week aerobic exercise in individuals over 70 years of age,[26] and strength training under a protocol with eight exercises of 15–20 repetitions at 50% of RM.[27]

Moreover, aerobic training, when compared to RT, showed better results for autonomic modulation.[11] However, when analysing only RT, it was possible to notice that this training can improve HRV, even in individuals affected by diseases such as obstructive pulmonary disease,[28] chronic heart failure[29] and hypertension.[27] These findings suggest that physical exercise, approached using different methods, can cause changes in the central nervous system.

In addition to health status, chronological age and type of training, intervention intensity can also influence HRV. Protocols with low loads and high repetitions can increase cardiovascular stress, causing an adverse effect on the hypertensive individual, and therefore, being ineffective in controlling autonomic modulation.[13] A previous study showed that high-intensity RT for the elderly promotes an increase in muscle mass and strength gain, but not necessarily bringing benefit to autonomic modulation.[30]

HRV is expected to change with advancing age, producing a reduction in the PNS.[31] Despite the expected decrease, this study demonstrates an inversion of these values in the elderly population that practiced RT. With physical exercise, it was shown that the elderly volunteers had a predominance of the PNS at rest, which was not expected for the elderly population.

Body composition (body mass, BMI, waist and hip circumference, fat percentage, among others) can impact on HRV. Studies have shown that worse anthropometric indicators, such as greater waist circumference, visceral fat area and BMI, can be negatively associated with HRV components, that is, individuals with worse indicators of anthropometric composition have reduced parasympathetic activity.[32,33] We emphasise that the above RT protocol, in addition to providing an improvement in autonomic activity (sympathetic reduction and parasympathetic increase), improved the anthropometric composition (reduction in the fat percentage) of the elderly volunteers.

HRV is a classic marker of physical and emotional health. Considering that RT was able to improve HRV in our study, exercise becomes an important practice to be incorporated into Brazilian public healthcare policies, and/or even used as a non-pharmacological HRV-improvement practice for the elderly population.

Possible limitations of this study include adherence of the volunteers to the intervention, since few volunteers remained until the end of the research, showing the difficulty in maintaining intensive training among the elderly population. In addition, the atypical circumstances of the pandemic that we experienced made it impossible to recruit new volunteers. Furthermore, there was no respiratory rate control during HRV collection. Therefore, more studies are needed to contribute to this body of knowledge and reduce the scarcity of information on autonomic modulation in elderly people undergoing strength training.

Finally, considering the unprecedented situation brought on by the COVID-19 pandemic to our generation, strategies that improve the general health of individuals, for example, RT positively impacting on HRV (which is a marker of general health), as shown in this study, can be seen as a mechanism to protect the health of the elderly, one of the pandemic's most impacted upon groups.

Conclusion

Despite the advanced age of the volunteers, the six-month RT programme contributed to an increase in parasympathetic activity and a reduction in sympathetic activity in the elderly in a resting state.

We acknowledge the Pro-Rectory of Research, Postgraduate and Innovation of the Federal University of Ouro Preto (Pró-Reitoria de Pesquisa, Pós-Graduação e Inovação da UFOP: PROPPI-UFOP), the Postgraduate Program in Health and Nutrition (PPGSN), and the Exercise Physiology Laboratory (LABFE), Physical Education Department, Nutrition School and Physical Education School of the Federal University of Ouro Preto.

Funding was obtained from the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico: CNPq), Coordination and Improvement of Superior Education Staff (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior: CAPES), Minas Gerais State Research Support Foundation (Fundação de Amparo à Pesquisa do Estado de Minas Gerais: FAPEMIG), and Pro-Rectory of Research, Postgraduate and Innovation of the Federal University of Ouro Preto (Pró-Reitoria de Pesquisa, Pós-Graduação e Inovação da UFOP: PROPPI-UFOP - 23109.000928/2020-33).

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