Acute effects of high-intensity interval training and moderate-intensity continuous training on linear and nonlinear heart rate variability measures in arterial hypertension

Efeitos agudos do treinamento intervalado de alta intensidade e do treinamento contínuo de intensidade moderada nas medidas lineares e não lineares da variabilidade da frequência cardíaca na hipertensão arterial

Efectos agudos del entrenamiento en intervalos de alta intensidad y el entrenamiento continuo de intensidad moderada sobre las medidas lineales y no lineales de la variabilidad de la frecuencia cardíaca en la hipertensión arterial

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Abstract
Introduction: Systemic arterial hypertension is a chronic disease worldwide. High-intensity interval training (HIIT) has been described as an effective alternative treatment. Objective: To evaluate the acute effects of one HIIT session versus one moderate-intensity continuous training (MICT) on linear and nonlinear heart rate variability (HRV) measures in hypertension patients. Methods: A preliminary cross-sectional study with 11 non-elderly (35 to 59 years) hypertensive patients using drug therapy from both sexes. They were assigned for cardiological evaluation, ergometric test, echocardiography, and cardiopulmonary exercise test. Patients performed cycling exercise in the conditions HIIT (10 bouts of 1-minute at 85% of the maximum power [P_{max}] interspersed with 2 minutes at 50% of P_{max}) and MICT (30 minutes at 50% of P_{max}). R-R intervals (RRi) of HRV were recorded in the supine position for 10 minutes before and after the two exercise conditions. Results: HIIT and MICT presented a significant reduction (P<0.01) for the RRi between baseline (pre-session) and post-session. All other linear indices presented similar results (P>0.05) between

moments. Significant differences (P<0.05) in the symbolic HRV analysis were identified only in the HIIT group for 0V, 2LV, and 2ULV indexes. 0V index increased 2.3-times from pre- to post-session while 2LV and 2ULV indexes reduced to near 50% and 35%, respectively. Conclusion: An increase in sympathetic modulation with a significant decrease in vagal modulation by nonlinear HRV measures was identified in patients with hypertension submitted to one HIIT session.

Keywords: Hypertension; Heart rate; Exercise; High-intensity interval training.

Resumo

Introdução: Hipertensão arterial sistêmica é uma doença crônica em todo o mundo. O treinamento intervalado de alta intensidade (HIIT) tem sido descrito como alternativa eficaz de tratamento. Objetivo: Avaliar os efeitos agudos de uma sessão de HIIT versus um treinamento contínuo de intensidade moderada (MICT) em medidas lineares e não lineares da variabilidade da frequência cardíaca (VFC) em pacientes com hipertensão. Métodos: Estudo transversal preliminar com 11 hipertensos não idosos (35 a 59 anos) de ambos os sexos em uso de terapia medicamentosa. Eles foram designados para avaliação cardiológica, teste ergométrico, ecocardiografia e teste cardiopulmonar de exercício. Os pacientes realizaram exercícios em cicloergômetro nas condições HIIT (10 séries de 1min a 85% da potência máxima [P_{max}] intercaladas com 2min a 50% da P_{max}) e MICT (30min a 50% da P_{max}). Os intervalos R-R (RRi) da VFC foram registrados na posição supina por 10 minutos antes e depois dos exercícios. Resultados: HIIT e MICT reduziram significativamente (P<0,01) o RRi entre os momentos pré e pós-sessão. Todos demais índices lineares apresentaram resultados semelhantes (P>0,05) entre os momentos. Somente no grupo HIIT diferenças significativas (P<0,05) foram identificadas na análise simbólica da VFC para os índices 0V, 2LV e 2ULV. 0V aumentou 2,3 vezes do início para o final da sessão, enquanto 2LV e 2ULV reduziram cerca de 50% e 35%, respectivamente. Conclusão: Foi identificado aumento da modulação simpática com redução significativa da modulação vagal avaliada por medidas não lineares da VFC em pacientes com hipertensão submetidos a uma sessão de HIIT.

Palavras-chave: Hipertensão; Frequência cardíaca; Exercício físico; Treinamento intervalado de alta intensidade.

Resumen

Introducción: La hipertensión arterial sistémica es una enfermedad crónica a nivel mundial. El entrenamiento en intervalos de alta intensidad (HIIT) se ha descrito como un tratamiento alternativo eficaz. Objetivo: Evaluar los efectos agudos de una sesión de HIIT versus un entrenamiento continuo de intensidad moderada (MICT) sobre las medidas lineales y no lineales de la variabilidad de la frecuencia cardíaca (VFC) en pacientes con hipertensión. Métodos: Estudio transversal preliminar con 11 pacientes hipertensos no ancianos (35 a 59 años) de ambos sexos que usaban farmacoterapia. Fueron asignados para evaluación cardiológica, prueba ergométrica, ecocardiografía y prueba de esfuerzo cardiopulmonar. Los pacientes realizaron ejercicio de ciclismo en las condiciones HIIT (10 series de 1min al 85% de la potencia máxima [P_{max}] intercaladas con 2min al 50% de la P_{max}) y MICT (30min al 50% de la P_{max}). Los intervalos R-R (RRi) de la VFC se registraron en posición supina durante 10 minutos antes y después de los ejercicios. Resultados: HIIT y MICT presentaron reducción significativa (P<0.01) para el RRi entre pre y post-sesión. Todos los demás índices lineales presentaron resultados similares (P>0.05) entre momentos. Solo en el grupo HIIT se identificaron diferencias significativas (P<0.05) en el análisis simbólico de la VFC para los índices 0V, 2LV y 2ULV. 0V aumentó 2,3 veces desde el principio hasta el final de la sesión, mientras que 2LV y 2ULV disminuyeron en un 50% y 35%, respectivamente. Conclusión: Se identificó un aumento en la modulación simpática con una reducción significativa en la modulación vagal evaluada por medidas no lineales de VFC en pacientes con hipertensión sometidos a una sesión de HIIT.

Palabras clave: Hipertensión; Frecuencia cardíaca; Ejercicio físico; Entrenamiento de intervalos de alta intensidad.

1. Introduction

Systemic arterial hypertension (SAH) is a multifactorial clinical condition characterized by high and sustained blood pressure (BP) levels (Costa et al., 2020; Vital, Silva & Paz, 2020). When not treated early, SAH can affect target organs such as the heart, brain, kidneys, and blood vessels (Queiroz et al., 2020). The treatment for SAH is carried out through medication, dietary behavior change, and physical exercise (Santos et al., 2020; Santana et al., 2020). Physical training is an effective non-pharmacological method in reducing BP levels (Polegato & Paiva, 2018).

In this context, high-intensity interval training (HIIT) has been described in the literature as an alternative method to conventional physical practice in various clinical conditions in patients with risk factors for cardiovascular disease (Abreu et al., 2019; Bourne et al., 2019; Cuddy et al., 2019; De Nardi et al., 2018). This training consists of a period between 1 to 4 minutes of high intensity interspersed with active or passive recovery intervals (Paula et al., 2020; Souza et al., 2020).

HIIT is efficient in improving cardiorespiratory fitness, maximum oxygen consumption (VO_{2max}), cardiovascular

health, and BP levels (Souza et al., 2020). However, the acute effects of a single HIIT exercise session on the autonomic control of heart rate (HR) studied by heart rate variability (HRV) have not been completed described; there is a study in healthy people (Andrade et al., 2020) but not in SAH.

In this context, the present study aims to evaluate and compare the acute effect of one session of HIIT versus moderate-intensity continuous training (MICT) on linear and nonlinear HRV measures in patients with hypertension.

2. Methodology

2.1 Experimental design, sampling methods, and procedures

This is a preliminary cross-sectional study conducted in the Laboratório de Pesquisas em Desempenho Humano (LAPEDH) from the Universidade de Pernambuco (UPE) and in the Laborarório de Fisiologia do Exercício from Universidade Federal do Vale do São Francisco (UNIVASF). The research was approved by the Research Ethics Committee of UPE (CAAE: 69902817.5.0000.5207) and complied the Resolution 466/2012 of the Brazilian National Health Council (CNS).

This is a within-subject design with a non-probabilistic sample by convenience included non-elderly hypertensive patients from both sexes, aged between 35 and 59 years old, using optimized drug therapy and clinical follow-up for at least twelve months, with BP levels controlled by antihypertensive drugs (systolic BP < 140 mmHg and diastolic BP < 90 mmHg), without a change in medication for at least three months and limitations on physical efforts, such as osteoarticular problems, cachexia or cardiovascular limitations (ischemic heart disease and/or important changes in the electrocardiogram during the ergometric test).

Those who decided to abandon the follow-up or had limitations on physical efforts, such as osteoarticular problems, cachexia, or cardiovascular limitations (ischemic heart disease and/or important changes in the electrocardiogram during the ergometric test), diabetics, frequent drinkers, pregnant women, or patients who practiced physical activity regularly in the three months before the study were excluded. Besides, patients who were not using medications on the days of the tests were also excluded.

The patients were summoned to the outpatient clinic of the University Hospital from UNIVASF (HU-UNIVASF) to be examined by a cardiologist, where they underwent the ergometric test, echocardiogram, and blood test to verify that they were clinically stable for the performance of assessment and exercise protocols. The next step was carried out at the Laboratories of UPE and UNIVASF where the patients underwent cardiopulmonary exercise tests and the assessments of HR and BP.

Then, randomization was performed by which type of exercise would be performed first to avoid interference. All patients underwent a session of HIIT and MICT, on different days, with an interval of at least 72 hours. The allocation sequence was performed by a researcher who was not involved in recruiting participants using random numbers from Microsoft Excel (Microsoft Corporation, Redmond, WA, United States, Release 12.0.6662, 2012). Data from allocation was placed in sequentially numbered opaque sealed envelopes.

The evaluations and session pieces of training were carried out only in the morning, with a controlled temperature of 22 ± 1 ºC, relative humidity of approximately 55%, and control of people entering the room at the training time. Before the tests and exercises, all subjects were instructed to avoid alcoholic drinks and caffeine and not perform any strenuous exercise on the day and one day before the protocols. In addition, light diets at least 2 hours before the evaluations and tests and before the experimental protocols were strongly recommended and emphasized.

2.2 Cardiopulmonary exercise test (CPET)

The exercise protocols and the CPET were performed on the Biotec 2100 mechanical cycle ergometer (Cefise

Biotecnologia Esportiva Ltda., Nova Odessa, SP, Brazil). All patients underwent a progressive CPET to determine VO_{2max} and maximum power (P_{max}).

Test day intervention, the patient was instructed to remain seated in a chair at rest for 5 minutes for the HR to enter the baseline. Then, the patient was instructed to sit on the cycle ergometer bench and start the exercise at 60 revolutions per minute (rpm) for 2 minutes, with a load of 30 Watts. After this period, stages with 15 Watts of load increase were added every 2 minutes until reaching the patient's volitional exhaustion. The last load was considered when the participant completed at least 51% of the total stage time. Throughout the test period until volitional exhaustion or test interruption, the pulmonary ventilation and oxygen uptake, and carbon dioxide production were measured breath-by-breath using a Fitmate PRO Compact Ergospirometer (COSMED Srl, Rome, Italy). HR and BP were also monitored and recorded continuously by the combined electrocardiogram (ECG) Holter and ambulatory blood pressure monitoring recorder and software analysis system (CARDIOS, São Paulo, Brazil). The peak oxygen consumption (VO_{2peak}) was considered as the highest value reached of the maximum load maintained in the final 20 seconds of the exercise. Finally, after the test was interrupted, the patient was instructed to sit in the chair and remain for at least 5 minutes at rest, or until HR and BP returned to their baseline values.

2.3 Interventions

The HIIT session consisted of 30 minutes of exercise performed in a protocol with an effort of 1 minute at 85% of the P_{max} interspersed with 2 minutes of active recovery at 50% of the P_{max}. The MICT session was performed for the same 30 minutes but continuously with intensity maintained at 50% of P_{max}. Both interventions were based on the recommendations from the American College of Sports Medicine (Campbell et al., 2019).

Both protocols were performed on the mechanical cycle ergometer (Cefise Biotecnologia Esportiva Ltda.) at 60 rpm. Continuous HR recording and BP measurement were performed before, during, and after the exercise with the help of ECG Holter and ambulatory blood pressure monitoring recorder CardioMapa (CARDIOS).

2.4 HRV assessment

The volunteers remained at rest for 10 minutes before the start HRV assessment. To perform this test, all of them had to present respiratory rates within the high-frequency band range (from 0.15 to 0.50 Hz) that is higher than 9 breaths per minute. Then, the R-R intervals (RRi) were recorded for 10 minutes in the supine position before and after each session training. ECG acquisition was carried out at a sampling ratio of 250 Hz with a digital electrocardiograph (Micromed Biotecnologia, Guará, DF, Brazil). The Wincardio software (Micromed Biotecnologia, Release 4.4a) was used to automatically generate the RRi series from a selected ECG lead (Dantas et al., 2010).

The sequence with 256 highest stability RRi was selected for each subject. This sequence was used for linear and non-linear analyzes. Furthermore, the RR means, and variances were also calculated according to the Catai checklist (Catai et al., 2020).

The HRV analysis in the frequency domain (spectral analysis) was performed using an autoregressive model (Malliani et al., 1991; Pagani et al., 1988), and the low-frequency bands (LF – from 0.04 to 0.15 Hz) and high frequency (HF – from 0.15 to 0.40 Hz) were obtained. These spectral components were expressed in normalized units (LFnu and HFnu) (Task Force, 1996). The normalization of the indices consisted of dividing a given power of each spectral component (LFnu and HFnu) by the total power minus the very low frequency (< 0.04 Hz) and then multiplying the ratio by 100 (Task Force, 1996).

After this, the RRi series was distributed in levels from 0 to 5 and transformed into a sequence of patterns with 3 symbols, which were decoded into whole numbers. Then, the patterns of a sequence of 3 beats were determined and the distribution was calculated using Shannon's entropy (SE). This index describes the pattern distribution. SE is high if the

distribution is flat (all patterns are distributed identically, and the series carries as much information as possible). On the other hand, SE is low if a subset of patterns is more common, while other patterns are absent or infrequent (Guzzetti et al., 2005).

All patterns were grouped into four families as follows: (a) patterns with no variation (0V: all symbols are equal, that is, 2,2,2 or 4,4,4); (b) patterns with one variation (1V: 2 consecutive symbols are the same, and one symbol is different, that is, 4.2.2 or 4.4.3); (c) patterns with two similar variations (2LV: 3 symbols that form an ascending or descending ramp, that is, 5.4.2 or 1.3.4); (d) 2 different variations (2ULV: 3 symbols that form a peak or a tail, that is, 4,1,2 or 3,5,3). The rate of occurrence of each pattern is defined as 0V%, 1V%, 2LV%, and 2ULV%, and 0V% and 2ULV% can be considered markers of sympathetic and vagal modulation, respectively.

Conditional entropy (CE) was also assessed using the complexity index (CI). Besides, this index was normalized by the RRi Shannon entropy to obtain a normalized CI (NCI), thus expressing the complexity in terms of dimensional units, ranging from 0 (null information) to 1 (maximum information). The higher the CI and the NCI, the greater the complexity and the less regular the series (Guzzetti et al., 2005).

2.5 Statistical analysis

Data were processed and analyzed using SPSS (SPSS Inc., Chicago, IL, USA, Release 16.0.2, 2008). Initially, Shapiro-Wilk's test and Bartlett's criteria were used for descriptive statistics. Continuous variables were presented as mean and standard deviation (SD), while categorical variables were expressed as absolute and relative frequency. Paired sample *t*-test was performed to compare linear and nonlinear HRV measures between the moments' baseline and after interventions. All statistical methods were two-tailed, P values were calculated, and the significance level was set as $P \leq 0.05$.

3. Results and Discussion

All patients who underwent ergometric tests did not experience any clinical complications during or after the test that prevented them from participating in the research. Thus, all were released by the cardiologist to perform the experimental protocols. Table 1 shows the clinical baseline characteristics (pre-session) of the patients. The analyzes and results presented are from the 11 patients (06 men; 54.5%) who completed the experimental protocols.

Table 1. Anthropometric characteristics of the population (baseline).

Variables	Mean ± standard deviation (n = 11)
Age (years)	48 ± 9
Total body mass (kg)	85.1 ± 21.2
Height (m)	1.67 ± 0.10
Body mass index (kg.m^{-2})	30.4 ± 5.8

Source: Authors.

The nutritional status was stratified as first-grade obesity according to the mean body mass index and did not have other comorbidities or used medications to control blood glucose (Barroso et al., 2020). All enrolled patients used antihypertensive medications, diuretics, or angiotensin-converting-enzyme inhibitors such as levamlodipine besylate, enalapril, captopril, hydrochlorothiazide, and losartan.

According to the CPET results (Table 2), the patients reached 91% of the age-predicted maximal heart rate and had low to reasonable functional physical capacity, according to the VO$_{2max}$ achieved. No patient, during or after the test, experienced any clinical complications.

Table 2. Results of the cardiopulmonary exercise test (n = 11).

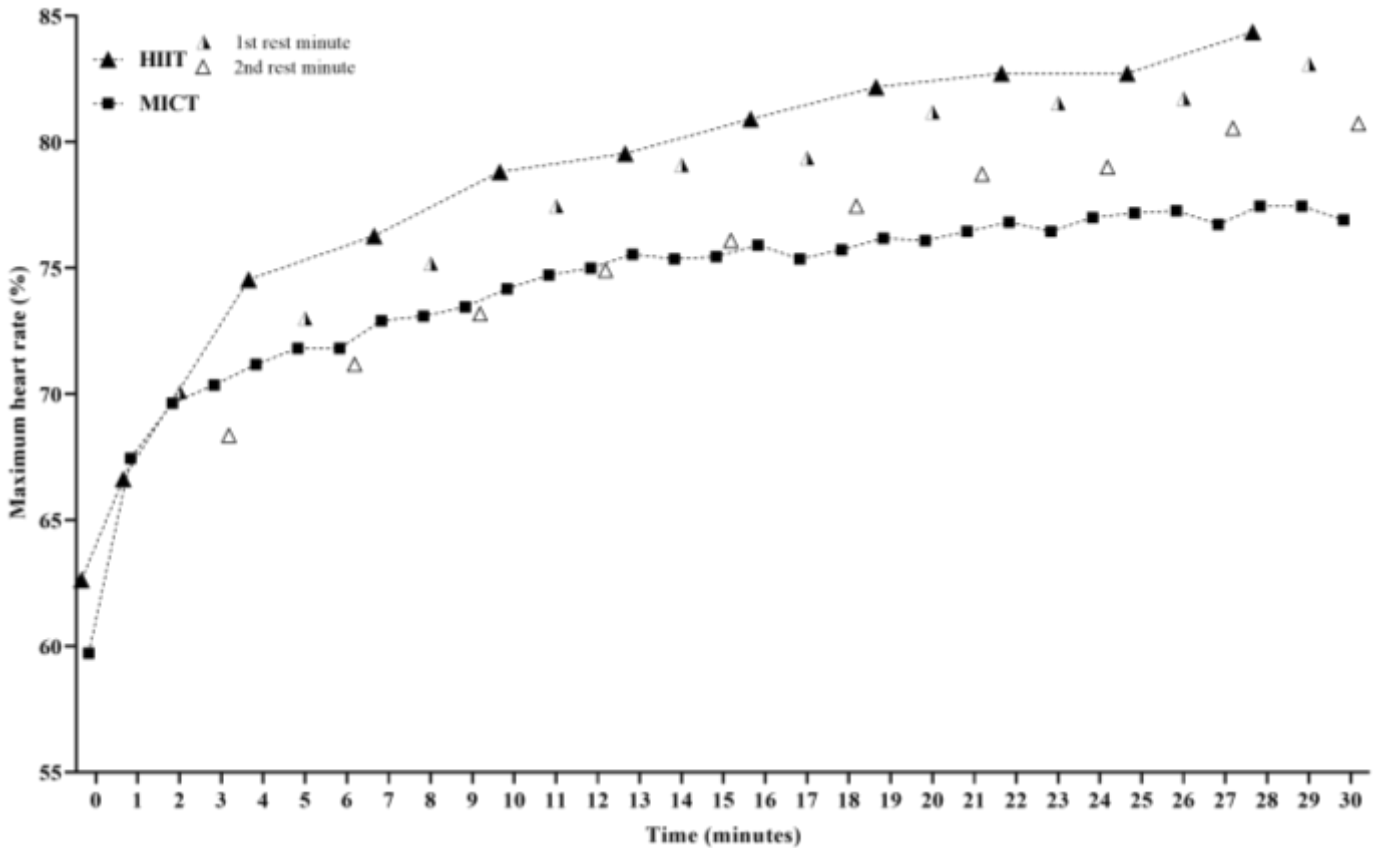| Variables	Mean ± Standard Deviation
Maximum power (Watts)	129.5 ± 30.9
Maximum oxygen consumption (ml.kg^{-1}.min^{-1})	25.1 ± 4.9
Resting heart rate (beats per minute)	80.8 ± 9.7
Maximum heart rate (beats per minute)	149.0 ± 13.6
Subjective effort perception (number)	15.9 ± 3.3

Source: Authors.

In addition to VO_{2max}, CPET provided the maximum power reached that was used to prescribe the intensity of continuous and interval pieces of training. However, some studies use the range of 85 to 95% of maximum HR to appoint the intensity during the MICT and HIIT (Hannan et al., 2018; Wewege et al., 2018). In the present study, we selected P_{max} as a parameter to prescribe physical exercise in both protocols to have greater control over the intensity of effort (Mezzani et al., 2013).

As an inclusion criterion, only patients who did not practice any activity in the last 3 months could participate in the study. Thus, the patients had low to regular aerobic physical capacity, which could classify them as sedentary. The mean VO_{2max} for men (n = 06) was 26.95 ± 4.39 ml.kg^{-1}.min^{-1} and for women (n = 05) was 21.60 ± 4.41 ml.kg^{-1}.min^{-1}. The classification of the level of physical fitness was weak for both, according to the VO_{2max} by the age and gender, according to the criteria of the Brazilian cardiorespiratory fitness classification based on maximum oxygen consumption (Herdy & Caixeta, 2016).

Figure 1 shows that the heart rate in the HIIT group was higher than the MICT group from the third minute of effort and was also higher at active rest interval by 50% of P_{max} from the 15th minute with maintenance throughout the effort time. Using a similar approach for analyzing the HR responses to exercise intensities, Michael et al. (2016) identified higher results for HR in the group performing high-intensity training (90 to 95%: 174 ± 7 bpm) in comparison to moderate (75 to 80%: 155 ± 6 bpm) and low (40 to 45%: 112 ± 8 bpm) intensity pieces of training.

Figure 1. Heart rate responses to 30 minutes of moderate-intensity continuous training (MICT) or 30 minutes of high-intensity interval training (HIIT) protocols (n = 11).

Source: Authors.

HRV analysis is a simple, non-invasive, and sensitive technique for assessing the modulation of the autonomic nervous system (ANS) over the heart and has been used to assess different populations (Catai et al., 2020), such as those studied in the present study. The scientific literature has documented that progressively intense levels of effort promote an increase in the LF spectral component and a decrease in the HF spectral component (Brechbuhl et al., 2020; Naranjo-Orellana, Ruso-Álvarez & Rojo-Álvarez, 2021; Vanderlei et al., 2009).

Table 3 shows the frequency-domain outcomes of HRV before and 10 minutes after one training session of HIIT and MICT. Both exercise protocols presented a significant reduction ($P < 0.01$) for the RRi between baseline (pre-session) and post-session. All other analyzed variables presented statistically similar results ($P > 0.05$) between the two evaluated moments. In this research, an increase in HRV was observed in the RRi of the MICT group which indicates good cardiac autonomic modulation (Boutcher et al., 1997; Oliveira, Medeiros & Melo, 2020). Studies have shown that changes in HRV patterns are a sensitive and early indicator of health impairments. High HRV is a sign of good adaptation that characterizes a healthy individual with efficient autonomic mechanisms. In contrast, low HRV is often an indicator of abnormal and insufficient adaptation of the ANS, which may indicate the physiological malfunction presence in the individual (Bester et al., 2021). However, some studies correlate the decrease in HRV with a reduction in physical conditioning with aging and, thus, can be reversed with the improvement of aerobic physical condition (Marocolo et al., 2019; Tiwari et al., 2020). In this study, the lower values of RRi after the two different intensities are probably related to the reduced cardiac vagal modulation because of autonomic cardiac control responses by the exercise, and not for the intensity.

Table 3. Linear measures of heart rate variability before and after one training session in high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) groups.

Variables	HIIT (n = 11)		P	MICT (n = 11)		P
	Baseline	Post-exercise		Baseline	Post-exercise	
Time domain						
RRi (ms)	859.27 ± 53.28	729.55 ± 83.63	<0.001	852.91 ± 101.68	788.18 ± 84.53	0.008
Variance (ms^2)	579.22 ± 443.86	402.40 ± 433.10	0.135	730.86 ± 622.43	462.15 ± 367.62	0.193
Spectral analysis						
LF (ms^2)	215.76 ± 227.07	117.07 ± 168.09	0.262	157.99 ± 98.50	179.47 ± 175.88	0.671
HF (ms^2)	193.11 ± 231.83	75.96 ± 109.34	0.100	290.07 ± 518.80	77.05 ± 79.16	0.159
LF/HF ratio	1.66 ± 2.05	2.14 ± 1.55	0.598	2.30 ± 2.24	3.57 ± 2.34	0.140

Data are presented as mean ± standard deviation. RRi: mean of the intervals between the peak of the R waves of the electrocardiogram; HF: high frequency; LF: low frequency.
Source: Authors.

Table 4 presents the non-linear measures of HRV before (baseline) and after one training session of HIIT or MICT. Significant differences (P < 0.05) in the symbolic analysis were identified only in the HIIT group for the 0V, 2LV, and 2ULV variables. The 0V index increased 2.3-times from baseline to post-exercise (P < 0.01), while 2LV and 2ULV indexes reduced to near 50% and 35%, respectively.

Table 4. Non-linear measures of heart rate variability before and after one training session in high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) groups.

Variables	HIIT (n = 11)		P	MICT (n = 11)		P
	Baseline	Post-exercise		Baseline	Post-exercise	
Symbolic analysis						
0V	15.67 ± 7.08	35.32 ± 13.84	0.003	23.08 ± 10.16	29.64 ± 12.94	0.06
1V	49.02 ± 8.29	47.32 ± 8.37	0.65	49.70 ± 6.77	47.90 ± 4.46	0.47
2LV	13.87 ± 8.19	6.44 ± 4.29	0.009	10.63 ± 8.40	9.13 ± 5.72	0.46
2UV	21.43 ± 9.36	13.72 ± 5.60	0.04	16.60 ± 8.34	13.34 ± 5.05	0.17
Entropy						
SE	3.76 ± 0.22	3.23 ± 0.42	0.005	3.45 ± 0.33	3.37 ± 0.44	0.61
NCI	0.77 ± 0.04	0.68 ± 0.08	0.001	0.73 ± 0.07	0.70 ± 0.08	0.40
CI	1.17 ± 0.08	0.96 ± 0.17	0.002	1.04 ± 0.13	1.02 ± 0.18	0.82

Data are presented as mean ± standard deviation. 0V: pattern with no variation; 1V: pattern with one variation; 2LV: pattern with two similar variations; 2ULV: pattern with two different variations; SE: Shannon's entropy; NCI: normalized complexity index; CI: complexity index.
Source: Authors.

The 0V index is a good indicator of the sympathetic pathway and the indexes 2LV and 2ULV are closely related to the parasympathetic autonomic cardiac modulation (Catai et al., 2020; Michael et al., 2016; Neves et al., 2012). In this sense, results from the HIIT group demonstrated an increase in sympathetic modulation and a parasympathetic decrease generating a significant increase in 0V and a decrease in 2V patterns. These conditions indicate that in our study there was an increase in the

sympathetic pathway and a reduction withdrawal in the cardiac vagal modulation in response to the intensity of the exercise (Gambassi et al., 2016; Michael et al., 2016). Therefore, one session of HIIT was capable to promote more stimulus on the autonomic nervous system than MICT as indicated by the entropy indexes (SE, NCI, and CI).

HIIT provides important metabolic changes to the practitioner (Souza et al., 2020). This type of training induces an improvement in VO_{2max}, ventricular function, and systemic BP (Belmonte et al., 2018; Souza et al., 2020). In addition, some studies suggest that HIIT increases insulin sensitivity (Santos & Ribeiro, 2021; Souza et al., 2020). In this context, the main characteristic of HIIT is its intensity can contribute to the production of reactive oxygen species (ROS). The ROS production in skeletal muscle is essential for redox signaling to occur, implying fundamental processes in the muscle cell, such as force production muscle contraction, glucose uptake, and increased concentration of antioxidant proteins (Souza et al., 2020).

When assessing autonomic cardiac control responses to the exercise it is important to analyze how the intensity is handled and how much the autonomic cardiac control is committed (Gambassi et al., 2019). Michael et al. (2016) demonstrated a rapid reactivation of vagal HRV values with recovery to baseline within 5 to 10 minutes after exercise practice in the intensity of the first ventilation threshold (low intensity), like performed by the MICT group. According to these authors, the exercise above this intensity (moderate to high) may result in delayed vagal HRV recovery. The acute exercise practice exerts stress on the organism requiring a balanced prescription between workout and recovery. In this sense, 20 minutes after the end of the exercise test for the HIIT group may be considered a rest period fully adequate for exercise-related beneficial effects on autonomic cardiac control (Francica et al., 2015). Further investigations on the recovery time for high-intensity training are recommended to favor clinical interpretation and exercise prescription.

It was demonstrated that the 0V and 2ULV indices are indicators of sympathetic and parasympathetic autonomic cardiac modulations, where an increase in sympathetic modulation and a parasympathetic decrease generated a significant increase in 0V patterns and a decrease in 2V patterns, thus indicating that in our study there was an increase in sympathetic modulation (Gambassi et al., 2016). This increase and the consequent decrease in HRV, as observed through the predominance of the 0V pattern, are also associated with a worse cardiovascular prognosis (Zwack et al., 2021).

In addition, one HIIT session increases the sympathetic and parasympathetic modulation. Takashi et al. (2011) and Neves et al. (2012) showed that higher sympathetic modulation reduced the complexity indexes. Furthermore, the literature shows that the aging process is related to reduced HRV, which in turn is related to changes in parasympathetic regulation and increased sympathetic modulation, also influencing the appearance of SAH, among other cardiovascular pathologies (Ferreira et al., 2017; Schroeder & Voss, 2017). On the other hand, this is the first study that evaluated the effect acute of one session of HIIT and MICT in hypertension patients by complexity analysis of HRV.

The ease of data acquisition makes HRV an interesting option for interpretations of the ANS functioning and a promising clinical tool for and identifying health problems (Vanderlei et al., 2009). However, different from the HIIT group there were no statistically significant results for the non-linear indexes of HRV obtained through symbolic analysis (0V, 1V, 2LV, and 2ULV) and entropy (SE, NCI, CI) in the MICT group.

Some limitations should be pointed out, such as the non-probabilistic sample by convenience and the preliminary cross-sectional study design, which made it impossible to follow the individuals for a longer time. One disadvantage of non-probability sampling is that it is impossible to know how well the participants representing the population. In addition, the main problem with small studies is an interpretation of results, in particular the p-values.

4. Final Considerations

An increase in sympathetic modulation with a significant decrease in vagal modulation by nonlinear HRV measures was identified in patients with hypertension submitted to one high-intensity interval training session. However, according to

the limitations, more investigations on the effect of HIIT on HRV are recommended to favor clinical interpretation and exercise prescription, or even making it possible to discover cardiovascular diagnoses during exercise.

Acknowledgments

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