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ORIGINAL RESEARCH

# Effect of different intensities of inspiratory muscle exercise on cardiac autonomic control in the post-exercise recovery in healthy adults: a controlled and randomized study

*Efeito de diferentes intensidades de exercício muscular inspiratório no controle autonômico cardíaco no período de recuperação pós esforço em adultos saudáveis: estudo controlado e randomizado*

*El efecto de diferentes intensidades de entrenamiento muscular inspiratorio en el control autonómico cardíaco en el periodo de recuperación tras el esfuerzo en adultos sanos: estudio controlado y aleatorizado*

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**ABSTRACT |** This study aimed to investigate the effect of different intensities of Inspiratory Muscle Exercise (IME) on cardiac autonomic control during the period of post-exertion recovery in healthy adults. Thus, an experimental, controlled, and randomized study was conducted with 15 men aged from 18 to 40 years, including sedentary and healthy individuals. Participants underwent four IME sessions: a sham session, followed by sessions with 30%, 40%, and 60% of maximal inspiratory pressure. Pulse intervals were recorded using digital infrared photoplethysmography to obtain heart rate (HR) values. Measurements included HR, interbeat interval, standard deviation of all normal RR intervals (SDNN), root mean square of successive differences between adjacent normal RR intervals (RMSSD), percentage of adjacent RR intervals greater than 50ms (pNN50) (time domain), total power, power of low-frequency spectral bands (LF), and power of high-frequency spectral bands (HF) ($ms^2$), LF and HF (n.u.), and LF/HF (frequency domain). These measures were assessed simultaneously for 10 minutes at rest and during recovery period (15, 30, 45, and 60 minutes). Two-way analysis of variance was used, considering a 5% significance level. We observed that RMSSD and pNN50 showed higher values compared to baseline (Time Effect: $P=0.004$; $P<0.01$, respectively). No differences were found in HRV measures in the frequency domain (Time Effect: $P>0.05$). Additionally, there was no difference in the comparison between intensities for all HRV measures (Session Effect: $p>0.05$). We conclude that, regardless of the applied load, there is a similar increase in parasympathetic cardiac autonomic modulation indices in the post-IME recovery period in healthy adults.

Keywords | Breathing Exercise; Autonomic System; Heart Rate Variability.

This study was carried out at the Universidade Federal de Juiz de Fora (UFJF) – Juiz de Fora (MG), Brazil.

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**RESUMO** | O objetivo deste trabalho foi investigar o efeito de diferentes intensidades de exercício muscular inspiratório (EMI) no controle autonômico cardíaco no período de recuperação pós esforço em adultos saudáveis. Foi realizado estudo experimental, controlado e randomizado com 15 homens entre 18-40 anos, sedentários e saudáveis em quatro sessões de EMI: Sham, 30%, 40% e 60% da pressão inspiratória máxima. Intervalos de pulso foram registrados por fotopletismografia digital infravermelha obtendo valores frequência cardíaca (FC). FC, intervalo entre batimentos, desvio-padrão da média de todos os intervalos RR normais (SDNN), raiz quadrada da média do quadrado das diferenças entre intervalos RR normais adjacentes (RMSSD), porcentagem dos intervalos RR adjacentes com diferença de duração maior que 50ms (pNN50) (domínio do tempo), potência total, potência das bandas espectrais de baixa frequência (LF) e potência das bandas espectrais de alta frequência (HF) ($ms^2$), LF e HF (n.u.) e LF/HF (domínio da frequência) foram medidos simultaneamente por dez minutos no basal e período de recuperação (15, 30, 45 e 60 minutos). Foi utilizado ANOVA two-way, considerando nível de significância de 5%. O RMSSD e pNN50 apresentaram no período de recuperação valores maiores em relação ao basal (efeito tempo: P=0,004; P<0,01, respectivamente). Não houve diferença para variáveis de VFC no domínio da frequência (efeito tempo: P>0,05). Não houve diferença na comparação entre as intensidades para todas as variáveis de VFC (efeito sessões: P>0,05). Concluímos que, independentemente da carga empregada, há aumento semelhante dos índices da modulação autonômica cardíaca parassimpática no período de recuperação pós sessão de EMI em adultos saudáveis.
**Descritores** | Exercício Respiratório; Sistema Autonômico; Variabilidade da Frequência Cardíaca.

**RESUMEN** | Este trabajo tuvo el objetivo de investigar el efecto de diferentes intensidades de entrenamiento muscular inspiratorio (EMI) en el control autonómico cardíaco durante el periodo de recuperación tras el esfuerzo en adultos sanos. Se realizó un estudio experimental, controlado y aleatorizado con 15 hombres de 18 a 40 años, sedentarios y sanos en cuatro sesiones de EMI: Sham, el 30%, el 40% y el 60% de la presión inspiratoria máxima. Se registraron los intervalos de pulso mediante fotopletismografía digital infrarroja obteniendo valores de frecuencia cardíaca (FC). FC, intervalo entre latidos, desviación estándar de la media de todos los intervalos RR normales (SDNN), raíz cuadrada de la media del cuadrado de las diferencias entre intervalos RR normales adyacentes (RMSSD), porcentaje de intervalos RR adyacentes con diferencia de duración mayor que 50ms (pNN50) (dominio del tiempo), potencia total, potencia de las bandas espectrales de baja frecuencia (LF) y potencia de las bandas espectrales de alta frecuencia (HF) ($ms^2$), LF y HF (n.u.) y LF/HF (dominio de la frecuencia) se midieron simultáneamente durante diez minutos en el basal y el periodo de recuperación (15, 30, 45 y 60 minutos). Se utilizó ANOVA dos vías, considerando el nivel de significación del 5%. RMSSD y pNN50 presentaron valores más altos en el periodo de recuperación en comparación con el basal (efecto tiempo: P=0,004; P<0,01, respectivamente). No hubo diferencia para variables de VFC en el dominio de la frecuencia (efecto tiempo: P>0,05). No hubo diferencia en la comparación entre las intensidades para todas las variables de VFC (efecto sesiones: P>0,05). Concluimos que, independientemente de la carga utilizada, hay un aumento similar en los índices de la modulación autonómica cardíaca parasimpática durante el periodo de recuperación tras la sesión de EMI en adultos sanos.

**Palabras clave** | Entrenamiento Respiratorio; Sistema Autonómico; Variabilidad de la Frecuencia Cardíaca.

## INTRODUCTION

Inspiratory muscle training (IMT), consisting of inspiratory muscle exercise (IME) sessions, has gained increasing attention in the scientific community and in clinical practice for different populations[1,2]. A range of benefits has been observed, including not only gains in inspiratory muscle strength and endurance, but also improvements in quality of life, increased exercise tolerance, maximum oxygen consumption, and functional capacity in individuals with heart failure history. Additionally, IMT has been linked to better blood pressure control[3-5]. Studies have also demonstrated its influence on the autonomic nervous system (ANS)[6-8].

The ANS regulates physiological homeostatic mechanisms through both sympathetic and vagal pathways[9]. Several studies have shown that IMT has a positive impact on cardiac autonomic control (CAC), particularly regarding heart rate variability (HRV)[6,10,11]. Increased HRV is typically associated with good health, while lower HRV may suggest pathological alterations[12]. Moreover, HRV assessment can help identify patients at a higher risk for cardiovascular events and all-cause mortality[13]. Thus, IMT seems to improve CAC through systemic changes, particularly in cardiovascular patients. However, heterogeneity in IMT prescriptions across studies seems to affect the HRV response[8]. In this sense, the available data indicate that IMT may have long-term effects on the ANS. However, the literature presents conflicting results.

Given the different intensities employed in IME protocols and the potential impact on CAC, one key question is whether IME can influence HRV during post-exercise recovery. Additionally, does the intensity of an IME session affect CAC during recovery in healthy adults? To address these questions, this study investigated the effects of different IME intensities on CAC during post-exercise recovery in healthy adults.

## METHODOLOGY

### Study and sample design

This is an experimental, controlled, and randomized study conducted at the Cardiovascular and Exercise Physiology Research Unit (InCFEx) at UFJF. The sample included male adults aged 18–40 years. Eligibility criteria required participants to be non-smokers, not using cardiovascular medications, and to have no prior diagnosis of cardiovascular or pulmonary disease. Additionally, participants were required to be sedentary (not regularly engaging in physical activity at least once per week for the past six months). Individuals with hypertension[14], high blood pressure[14], obesity (body mass index of 30 kg/m$^2$ or greater), and those with electrocardiogram abnormalities detected during rest were excluded. The study followed the CONSORT guidelines[15].

### Measurements and procedures

A clinical interview was conducted to identify any exclusion factors. Electrocardiographic monitoring was performed continuously at rest using the Dixtal 2023® multiparametric monitor (Amazônia, Brazil).

#### *Assessment of respiratory muscle strength*

Inspiratory muscle strength was assessed via maximum inspiratory pressure (MIP) using a digital manovacuometer (GlobalMed®). While seated, volunteers were instructed to perform a maximal inspiratory effort following complete expiration, maintaining the effort for at least one second. This procedure was repeated trice, with no more than a 10% variation between measurements. The highest absolute value recorded was considered the MIP[16]. Expiratory muscle strength was similarly assessed by requesting a maximal expiratory effort using the same procedure. Predicted values for MIP and maximum expiratory pressure (MEP) were calculated based on age and sex using previously described equations[17].

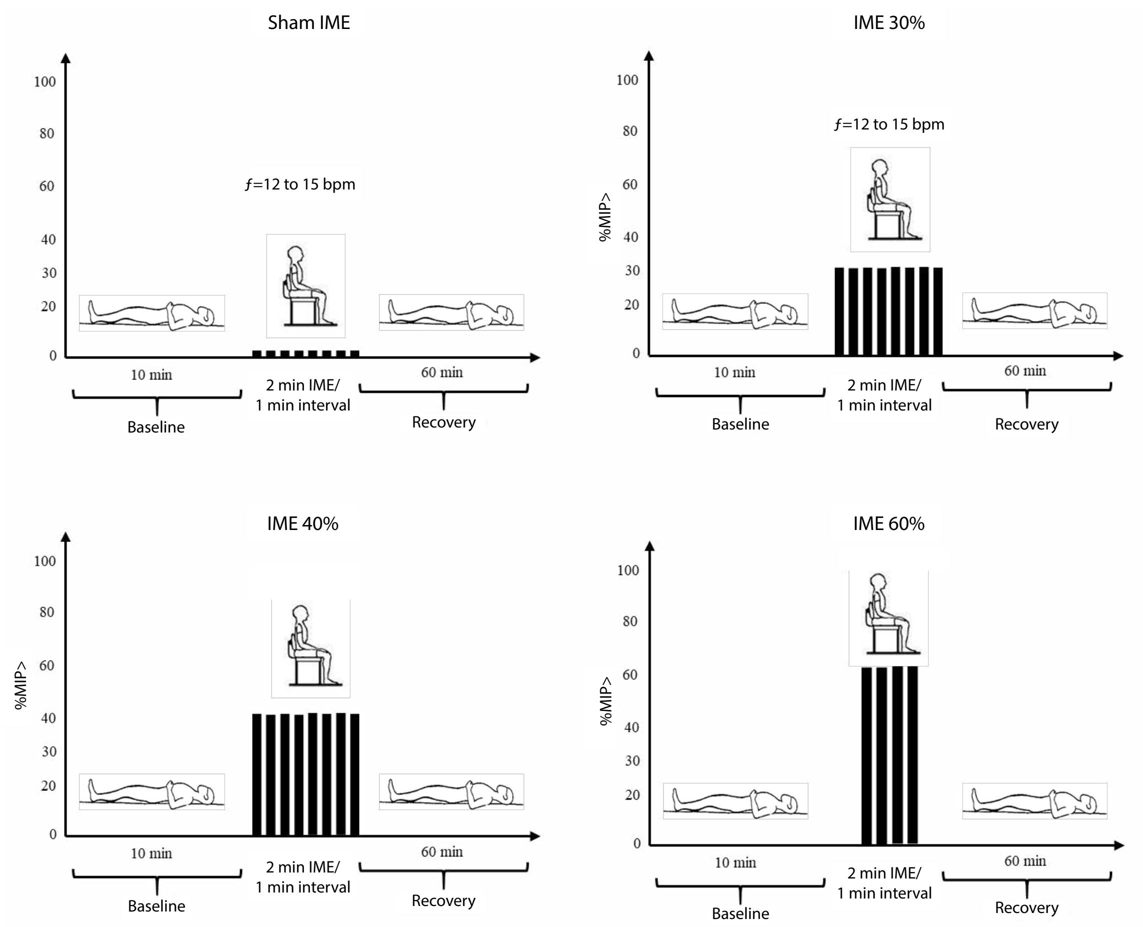
#### *Inspiratory muscle exercises*

In total, four sessions were conducted on separate days with at least 72 hours between each, using the Powerbreathe® device. The intensities used were 30%, 40% (eight sets of two minutes with a one-minute interval)[18], and 60% of MIP (four sets of two minutes with a one-minute interval), along with a sham session (no inspiratory load) involving eight sets of two minutes with a one-minute interval. The order of sessions was randomized using a website, and volunteers were not informed of the session they would undergo beforehand. Additionally, participants were instructed to perform diaphragmatic breathing, maintaining a respiratory rate (RR) of 12 to 15 breaths per minute, which was monitored via feedback from the evaluator (Figure 1).

#### *Familiarization and instructions*

A familiarization session was conducted using the device with no load, while volunteers wore a nasal clip and controlled their respiratory rate (RR). Volunteers were instructed in the diaphragmatic breathing technique and were advised to avoid consuming alcoholic and caffeinated beverages, refrain from intense physical exercise for 24 hours before the sessions and have a light meal at least one hour before the assessment.

Figure 1. Experimental protocols




IME: Inspiratory Muscle Exercise; MIP: Maximum Inspiratory Pressure; RR: Respiratory Rate

*Assessment of HRV*

Heart rate variability (HRV) was assessed by recording the interbeat intervals (IBIs) using infrared digital photoplethysmography (FinometerPro)[19]. Measurements were taken for 10 minutes at rest and for 60 minutes during post-exercise recovery to analyze the effect of the different sessions on cardiac autonomic modulation (CAM). The last five minutes of each period were analyzed, with the baseline considered from minute 5 to 10 and recovery periods from 10 to 15 minutes, 25–30 minutes, 40–45 minutes, and 55–60 minutes.

## Protocols

During the first visit, participants underwent a clinical interview, anthropometric measurements, electrocardiogram, respiratory muscle strength assessment, and familiarization with the procedures. From the second to the fifth visit, the interbeat intervals (IBIs) were recorded at rest, followed by IME sessions according to volunteers' randomization.

## Pulse interval signal processing

The time series data were transferred to Kubios HRV Analysis software (version 3.1.0) for estimation of heart rate (HR) and heart rate variability (HRV) measurements in the time domain (TD): IBIs, standard deviation of NN intervals (SDNN), root mean square of successive NN interval differences (RMSSD), and the percentage of NN interval pairs that differ by more than 50 ms, divided by the total number of NN intervals (pNN50).

In the frequency domain (FD), power spectral density was estimated using the Fast Fourier Transform[20]. The trend component of the NN interval time series was removed using a pre-smoothing technique[21]. The following metrics were estimated in the FD: total power, power in the low-frequency spectral band (LF; 0.04–0.15 Hz) in absolute units ($ms^2$) and normalized units (n.u.), power in the high-frequency spectral band (HF; 0.15–0.4 Hz) in $ms^2$ and n.u., and the LF/HF ratio[22].

## Statistical analysis

The assumption of normality was assessed using the Shapiro-Wilk test.

A two-factor repeated measures analysis of variance (ANOVA) was employed to evaluate the effect of the intervention on HRV, comparing exercise sessions and pre- and post-exercise periods. When significant differences were identified, ANOVA was followed by Bonferroni post-hoc tests. Mauchly's test of sphericity was conducted, and Huynh-Feldt corrections were applied when necessary. The significance level was set at 5%. Effect sizes were analyzed using partial eta squared ($\eta p^2$), with small effect sizes defined as values between 0.01 and 0.06, medium effects between 0.07 and 0.14, and large effects for values greater than 0.14. Additionally, the observed power of the statistical analyses was calculated. All tests were performed using SPSS version 20.0.0.

## RESULTS

Figure 2 shows participant entry and exclusion criteria. Table 1 describes the physical, demographic, and respiratory muscle strength characteristics of the sample.

Figure 2. Flow chart

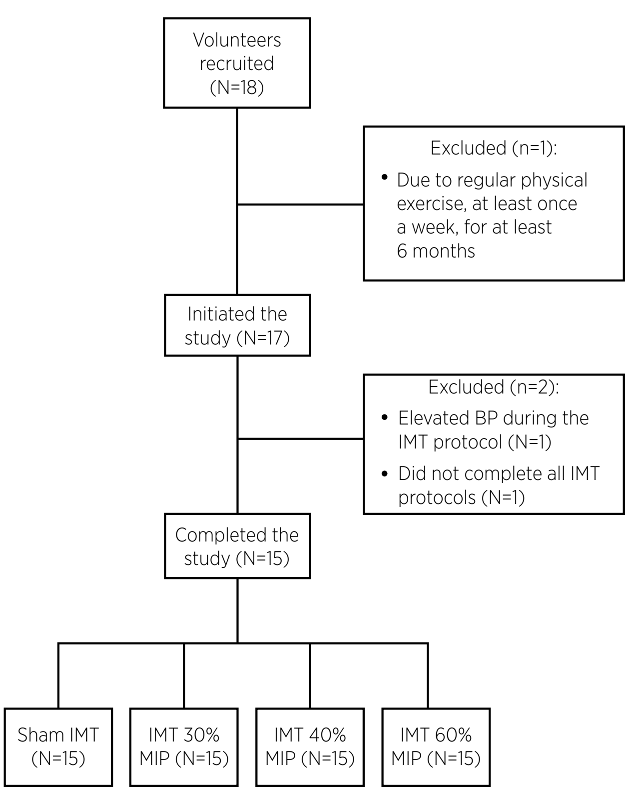



Table 1. Sample characterization

| Parameter | Group (N=15) |
|---|---|
| Age (years) | 25 ± 4.7 |
| BMI (Kg/m$^2$) | 23.5 ± 3.3 |
| MIP (cm$H_2O$) | −112.9 ± 31.9 |
| Predicted MIP (%) | 135.2 ± 3.8 |
| 30% MIP (cm$H_2O$) | 33.9 ± 9.6 |
| 40% MIP (cm$H_2O$) | 45.1 ± 12.8 |
| 60% MIP (cm$H_2O$) | 67.7 ± 19.1 |
| MEP (cm$H_2O$) | 132.4 ± 28.8 |
| Predicted MEP (%) | 145.0 ± 3.8 |

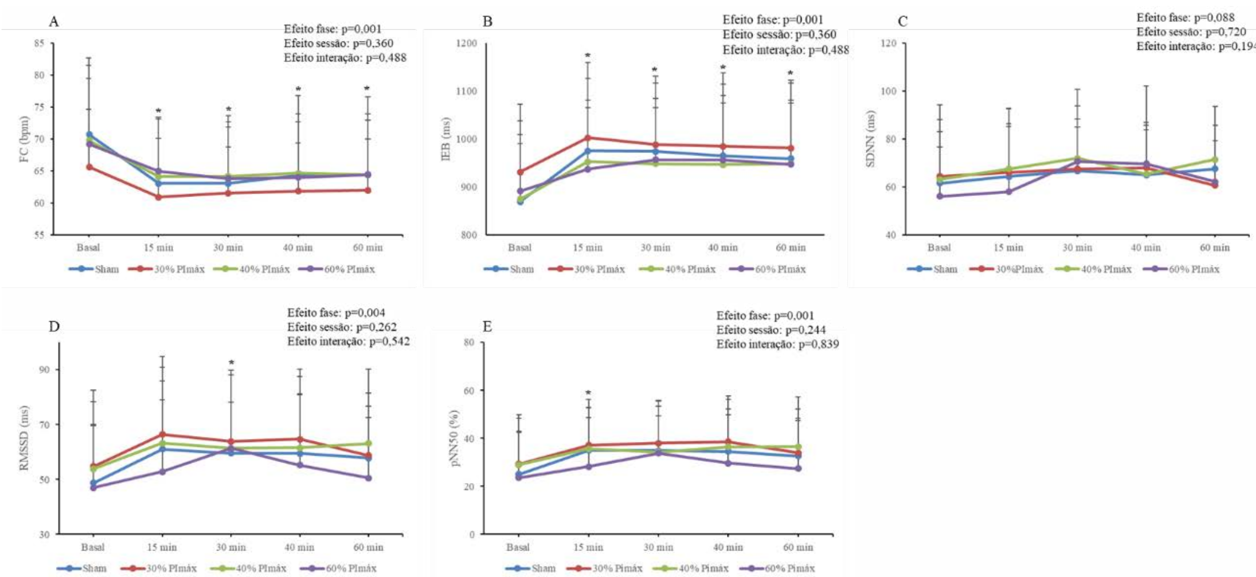
Values are presented as mean ± standard deviation. BMI: body mass index; MIP: maximal inspiratory pressure; Predicted MIP: maximal inspiratory pressure predicted by age; MEP: maximal expiratory pressure; Predicted MEP: maximal expiratory pressure predicted by age.

## HRV response between different IME intensities

Heart rate values decreased significantly throughout the entire recovery period compared to baseline for all intensities (time: $P$<0.01; $\eta_p^2$=0.569; observed power: 1.000; group: $P$=0.360; $\eta_p^2$=0.073; observed power: 0.275) (Figure 3A). Meanwhile, the RR intervals increased throughout the recovery period (time: $P$<0.01; $\eta_p^2$=0.633; observed power: 1.000; group: $P$=0.388; $\eta_p^2$=0.069; observed power: 0.260) (Figure 3B). The RMSSD showed significantly higher values compared to baseline at 30, 45, and 60 minutes for all intensities (time: $P$=0.004; $\eta_p^2$=0.280; observed power: 0.898; group: $P$=0.262; $\eta_p^2$=0.090; observed power: 0.340) (Figure 3D). Additionally, pNN50 exhibited increased values compared to baseline at 15, 30, and 45 minutes for all intensities (time: $P$<0.01; $\eta_p^2$=0.345; observed power: 0.994; group: $P$=0.244; $\eta_p^2$=0.093; observed power: 0.354) (Figure 3E). Notably, no difference was found regarding the different intensities evaluated for all the above variables.

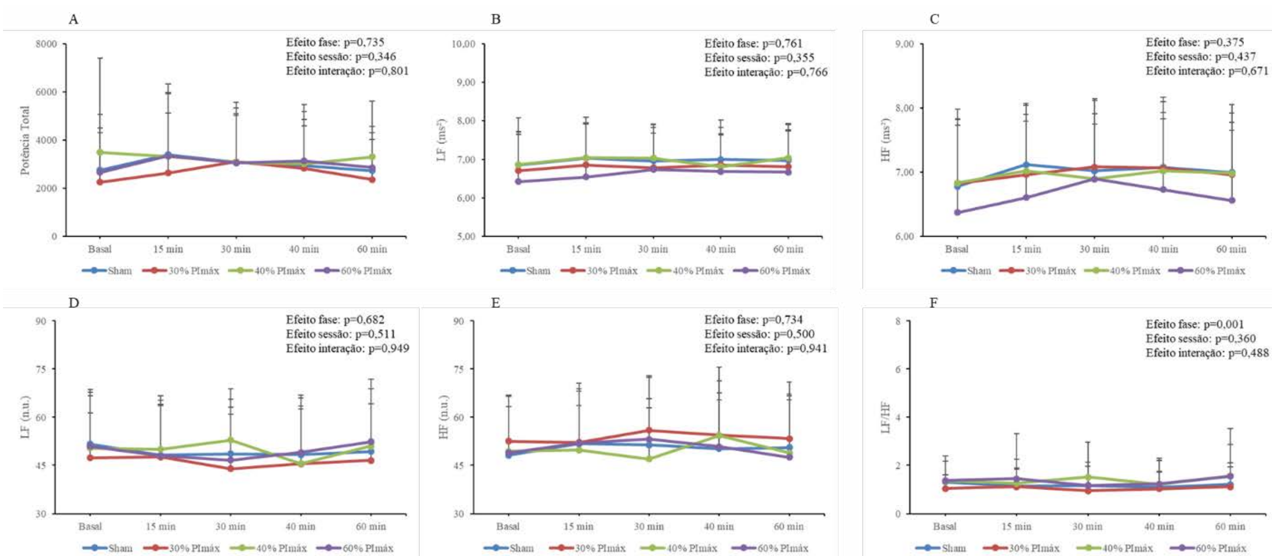
Regarding the frequency domain HRV indices, no significant changes were found for low-frequency (LF) (ms$^2$) (time: P=0.761; $\eta p^2$=0.025; observed power: 0.110; group: P=0.355; $\eta p^2$=0.073; observed power: 0.255) (Figure 4B) and high-frequency (HF) (ms$^2$) (time: P=0.375; $\eta p^2$=0.071; observed power: 0.269; group: P=0.437; $\eta p^2$=0.062; observed power: 0.236) (Figure 4C). Similarly, there were no significant changes for LF (normalized units, n.u.) (time: P=0.682; $\eta p^2$=0.037; observed power: 0.156; group: P=0.511; $\eta p^2$=0.053; observed power: 0.203) (Figure 4D) and HF (n.u.) (time: P=0.734; $\eta p^2$=0.032; observed power: 0.142; group: P=0.500; $\eta p^2$=0.054; observed power: 0.208) (Figure 4E). Additionally, the LF/HF ratio showed no significant differences at any point, indicating no variation between intensities (time: P=0.539; $\eta p^2$=0.044; observed power: 0.151; group: P=0.232; $\eta p^2$=0.096; observed power: 0.364) (Figure 4F).

Figure 3. Comparison of time domain variables




Data are presented as mean ± standard deviation of the mean. (A) HR: heart rate; (B) IBI: interbeat intervals; (C) SDNN: standard deviation of R-R intervals of sinus origin; (D) RMSSD: root mean square of successive R-R interval differences of sinus origin; (E) pNN50: percentage of adjacent RR intervals differing by more than 50ms; * = p≤0.05 vs. baseline.

Figure 4. Comparison of frequency domain variables




Data are presented as mean ± standard deviation of the mean. (A) Total Power (B) lnLF (ms²): natural logarithm of the low-frequency spectral band in absolute units; (C) lnHF (ms²): natural logarithm of the high-frequency spectral band in absolute units; (D) LF (n.u.): low-frequency spectral band in normalized units; (E) HF (n.u.): high-frequency spectral band in normalized units; (F) LF/HF: sympathovagal balance.

## DISCUSSION

Our main findings indicate that, regardless of the workload applied, there was an increase in HRV measures reflecting cardiac vagal modulation during the post-IMT recovery period. Specifically, increases in the RMSSD and pNN50 were observed at 15, 30, and 45 minutes of recovery, demonstrating parasympathetic dominance in the post-exercise period. Additionally, a decrease in HR compared to baseline was noted throughout the 60 minutes of recovery, along with an increase in RR intervals. This reduction in HR supports the findings of increased parasympathetic indices.

Previous studies suggest that the effect of IMT on cardiac autonomic control may be influenced by the workload applied[10,11]. Acutely, IMT at 60% of MIP compared to 30% of MIP showed greater MAC in healthy individuals, with an increase in LF (n.u.) and a significant decrease in HF (n.u.) for the 60% MIP workload during the recovery period . However, since the protocol used was identical for both intensities (comprising cycles of 30 breaths with 30-second intervals over a total duration of 15 minutes) the total work performed at the 60% MIP intensity was greater. Thus, their results should be interpreted with caution. In contrast, comparing different workloads of 30%, 60%, and 80% of MIP for four minutes of effort, separated by five minutes of rest, showed that lower workloads are capable of promoting greater autonomic gains through parasympathetic modulation in older adults[10].

To equalize the work and verify the effect of IMT intensity on CAC, specifically on HRV, we performed a sub-analysis comparing 30% and 60% MIP intensities with equalized work. We found no differences in autonomic response (AR) across any of the variables compared between groups (data not shown). This result suggests that, at least from an autonomic perspective, IMT appears to influence cardiac AR without the workload having a significant effect.

Notably, the sham session (no load) showed an increase in time domain variables, which can be partially explained by the controlled respiratory rate during the session. It is well-established that breathing directly affects HRV values[23,24]. This phenomenon, described as respiratory sinus arrhythmia, occurs when HRV is synchronized with breathing, leading to RR intervals shortening during inhalation and lengthening during exhalation[25]. Thus, controlling the respiratory rate during the sham IMT session may have contributed to the observed reduction in HR and the increase in vagal indices during the recovery period.

It is important to note that this study maintained RR within a respiratory pattern considered normal. This leads us to interpret that IMT applied to this population at different intensities may have contributed to a change in MAC, primarily justified by RR control. After exercise, there is a phenomenon described in the literature as bradycardia, in which HR values may fall below baseline levels[26,27], as observed in this study. This observation further supports the notion that IMT may effectively promote beneficial outcomes within the cardiac autonomic system of these individuals.

Understanding the effects generated by different IMT intensities on CAC, particularly during the post-exercise recovery period, is crucial, as this is when cardiac physiological adjustments occur in response to the physical exercise session. Such insights can contribute to clinical practice by enabling safer IMT prescriptions tailored to the treated population. Our findings suggest that, regardless of the workload applied, there is an activation of the autonomic nervous system, indicating that this exercise modality may be safe, as it demonstrated increased parasympathetic indices during recovery without posing risks to the cardiovascular system. Therefore, knowing that higher loads yield greater results in other variables and do not impair cardiac autonomic response (CAR), the application of this modality becomes feasible. However, the literature on this subject remains limited, and the protocols used vary significantly, leading to discrepant results that complicate drawing firm conclusions.

### Study limitations

One potential limitation of our study is its small sample size, which means our outcomes should be cautiously interpreted and not generalized to other populations or age groups. Furthermore, we did not measure the volume during the IMT sessions, nor did we control the durations of inspiration and expiration. To mitigate these biases, we maintained the respiratory rate between 12 and 15 breaths per minute (bpm). Therefore, we believe these limitations did not significantly impact the results.

## CONCLUSION

Regardless of the intensity applied during the IMT sessions, we observed similar cardiac autonomic responses in the post-exercise recovery period in healthy adults. This was reflected in a comparable increase in parasympathetic cardiac autonomic modulation, with no changes in sympathetic cardiac autonomic modulation during this period.

## REFERENCES

1. Caruso FCR, Simões RP, Reis MS, Guizilini S, Alves VLS, et al. High-intensity inspiratory protocol increases heart rate variability in myocardial revascularization patients. Br J Cardiovas Surg. 2016;31:38-44. doi: 10.5935/1678-9741.20160007
2. Sasaki M, Kurosawa H, Kohzuki M. Effects of inspiratory and expiratory muscle training in normal subjects. J Jpn Phys Ther Assoc. 2005;8(1):29-37. doi: 10.1298/jjpta.8.29
3. Di Mambro TR, Figueiredo PH, Wanderley TR, Kritski AL, Guimarães F. Treinamento muscular inspiratório na doença pulmonar obstrutiva crônica: impacto na qualidade de vida, intolerância ao esforço e dispnéia. Fisioter Pesqui. 2007 [cited 2024 10 06];14(2):65-71. Available from: https://pesquisa.bvsalud.org/portal/resource/pt/lil-469892
4. Plentz RDM, Sbruzzi G, Ribeiro RA, Ferreira JB, Dal Lago P. Treinamento muscular inspiratório em pacientes com insuficiência

cardíaca: metanálise de estudos randomizados. ASOBRAFIR. 2012;99:762-71. doi: 10.1590/S0066-782X2012001100011

5. Vranish JR, Bailey EFJS. Inspiratory muscle training improves sleep and mitigates cardiovascular dysfunction in obstructive sleep apnea. Sleep. 2016;39(6):1179-85. doi: 10.5665/sleep.5826

6. Ferreira JB, Plenz RDM, Stein C, Casali KR, Arena R, et al. Inspiratory muscle training reduces blood pressure and sympathetic activity in hypertensive patients: a randomized controlled trial. Int J Cardiol. 2013;166(1):61-7. doi: 10.1016/j.ijcard.2011.09.069

7. Kaminski DM, Schaan BD, Silva AMV, Soares PP, Dal Lago P. Inspiratory muscle training in patients with diabetic autonomic neuropathy: a randomized clinical trial. Clin Autonomic Research. 2015;25(4):263-6. doi: 10.1007/s10286-015-0291-0

8. Almeida LB, Seixas MB, Trevizan PF, Laterza MC, Silva LP, et al. Efeitos do treinamento muscular inspiratório no controle autonômico: revisão sistemática. Fisioter Pesqui. 2018;25:345-51. doi: 10.1590/1809-2950/17015425032018

9. Wehrwein EA, Orer HS, Barman SMJCP. Overview of the anatomy, physiology, and pharmacology of the autonomic nervous system. Comprehensive Physiology. 2011;6(3):1239-78. doi: 10.1002/cphy.c150037

10. Archiza B, Simões RP, Mendes RG, Fregonezi GAF, Catai AM, et al. Acute effects of different inspiratory resistive loading on heart rate variability in healthy elderly patients. Br J Phys Ther. 2013;17:401-8. doi: 10.1590/S1413-35552013005000100

11. Plentz RDM, Silva VG, Dipp TJL, Macagnan FE, Lemos LC, et al. Treinamento (Entrenamiento) muscular inspiratório para o controle. Salud(i) Cienc. 2014 [cited 2024 10 06];21:28-34. Available from: https://www.siicsalud.com/dato/sic/211/140299.pdf

12. Fang S-C, Wu Y-L, Tsai P-SJ. Heart rate variability and risk of all-cause death and cardiovascular events in patients with cardiovascular disease: a meta-analysis of cohort studies. 2020;22(1):45-56. doi: 10.1177/1099800419877442

13. Ernst G. Heart-rate variability-more than heart beats? Front Public Health. 2017;5:240. doi: 10.3389/fpubh.2017.00240

14. Malachias MVB, Souza WKSB, Plavnik FL, Rodrigues CIS, Brandão AA, et al. 7ª Diretriz Brasileira de hipertensão arterial: Cap 1-Conceituação, Epidemiologia e Prevenção Primária. Arq Br Cardiol. 2016;107:1-6. doi: 10.5935/abc.20160151

15. Schulz KF, Altman DG, Moher D, et al. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. BMC Med. 2010;1(2):100-7. doi: 10.1186/1741-7015-8-18

16. Med ATSJAJRCC. ATS/ERS Statement on respiratory muscle testing. Am J Respir Crit Care Med. 2002 [cited 2024 10 06];166:518-624. Available from: https://cir.nii.ac.jp/crid/1573105975842035840

17. Neder JA,Andreoni S, Lerario MC, Nery LE. Reference values for lung function tests: II. Maximal respiratory pressures and voluntary ventilation. Br J Med Biol Res. 1999;32:719-27. doi: 10.1590/S0100-879X1999000600007

18. Souza H, Rocha T, Pessoa M, Rattes C, Brandão D, et al. Effects of inspiratory muscle training in elderly women on respiratory muscle strength, diaphragm thickness and mobility. J Gerontol Ser A: Biomed Sci Med Sci. 2014;69(12):1545-53. doi: 10.1093/gerona/glu182

19. Michel-Chávez A, Estañol B, Gien-López JÁ, Robles-Cabrera A, Huitrado-Duarte ME, et al. Variabilidade da frequência cardíaca e da pressão arterial sistólica em diabéticos com diagnóstico recente. Arq Bras Cardiol. 2015;105:276-84. doi: 10.5935/abc.20150073

20. Malik M, Camm AJJBhj. Heart rate variability and clinical cardiology. Br Heart J. 1994;71(1):3. doi: 10.1136/hrt.71.1.3

21. Tarvainen MP, Ranta-Aho PO, Karjalainen PAJ. An advanced detrending method with application to HRV analysis. IEEE Trans Biomed Eng. 2002;49(2):172-5. doi: 10.1109/10.979357

22. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Circulation. 1996;93(5):1043-65.

23. Bernardi L, Porta C, Gabutti A, Spicuzza L, Sleight P. Modulatory effects of respiration. Auton Neurosci. 2001;90(1-2):47-56. doi: 10.1016/S1566-0702(01)00267-3

24. Shamsuzzaman AS, Somers VKJA. Cardiorespiratory interactions in neural circulatory control in humans. Ann New York Acad Scies. 2001;940(1):488-99. doi: 10.1111/j.1749-6632.2001.tb03700.x

25. Yasuma F, Hayano J-iJC. Respiratory sinus arrhythmia: why does the heartbeat synchronize with respiratory rhythm? Chest. 2004;125(2):683-90. doi: 10.1378/chest.125.2.683

26. Seals DR, Chase PBJJ. Influence of physical training on heart rate variability and baroreflex circulatory control. J Appl Physiol. 1989;66(4):1886-95. doi: 10.1152/jappl.1989.66.4.1886

27. Shi X, Stevens GH, Foresman BH, Stern SA, Raven PB. Autonomic nervous system control of the heart: endurance exercise training. Med Sci Sports Exerc. 1995;27(10):1406-13.