ORIGINAL ARTICLE

Effects of high intensity interval training and resistance training on blood pressure and heart rate variability in young subjects

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ABSTRACT

High-intensity training, including resistance training (RT) and high-intensity interval training (HIIT), has demonstrated acute change cardiovascular on blood pressure (BP) and heart rate variability (HRV).This study aimed to analyse the acute effects of RT and HIIT on BP and HRV among young adults. This study used a crossover trial design conducted with 15 participants (19–25 years old). Participants underwent RT and HIIT sessions. BP systolic (SBP), diastolic (DBP), and mean arterial pressure (MAP) and HRV (SDNN, RMSSD, pNN50) were measured at baseline (pre), immediately post-intervention (post), and after 8 minutes of recovery (post 8 min). The results showed that both types of training significantly increased SBP and DBP immediately post-exercise ($p < .001$). DBP demonstrated a significant reduction at post 8 min for RT ($p = .003$). HRV indices showed significant reductions post-intervention in both training modalities (SDNN: RT, -11.6 ms; HIIT, -26.1 ms; $p = .01$). HIIT resulted in greater decreases in HRV parameters compared to RT ($p = .01$). In conclusions, RT and HIIT elicit significant acute changes in BP and HRV, with HIIT demonstrating a more pronounced impact on autonomic modulation. These findings highlight the differential cardiovascular responses to high-intensity training modalities and suggest potential implications for exercise prescription.
Keywords: Sport medicine, High-intensity interval training, Resistance training, Blood pressure, Heart rate variability, Autonomic modulation.

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INTRODUCTION

Cardiovascular health is rooted in an epidemiological context where lifestyle factors, sedentary behaviour, and physical inactivity contribute to a progressive decline in cardiac function (Van Deutekom & Lewandowski). Within this framework, cardiovascular diseases stand out as some of the most prevalent pathologies, with high rates of morbidity and mortality worldwide (Troncoso-Pantoja et al., 2020). In Chile, the factors associated with the development of cardiovascular diseases are particularly concerning. The elevated risk of arterial hypertension (Petermann et al., 2017), combined with high levels of physical inactivity and a significant prevalence of obesity, presents a worrisome scenario that underscores the urgent need for strategies to mitigate these risks and improve cardiovascular outcomes.

Exercise is an effective non-pharmacological intervention to address cardiac pathologies (Lellamo et al., 2021), as well as being a relevant physiological parameter for improving clinical criteria in patients with these conditions (Ross et al., 2016). Epidemiological studies have shown an inverse relationship between the practice of physical activity and the incidence of cardiovascular disease and mortality associated with these causes (Cotignola et al., 2023). Exercise is also a beneficial strategy for promoting cardiovascular health (Son et al 2016) by improving arterial pressure and elasticity arterial (Jeon, Lee & Hwang et al., 2018; Figueroa et al., 2014). This evidence demonstrates the ability of the heart to adapt to constant stimuli and to produce positive changes at a structural and physiological level.

This evidence shows that exercise should be an essential part of cardiovascular health care. Resistance training (RT) is an effective option for improving cardiorespiratory fitness as it increases maximum cardiac output, peak stroke volume, accelerates DBP filling and delays left ventricular remodelling (Moris et al.,2020). Similarly, high-intensity interval training (HIIT) has been shown to have a positive effect on cardiovascular capacity through the alternation of submaximal intensity activation and recovery periods. This alternation promotes cardiovascular efficiency, which is reflected in HRV during the intervals (Abreu et al., 2019).

During exercise, cardiac function undergoes transient autonomic adjustments through sympathetic and parasympathetic modulation, influencing BP and heart rate dynamics (Mariano et al., 2022). These responses are essential for maintaining cardiovascular homeostasis during increased metabolic demands. Research has demonstrated that there is an increase in cardiac output immediately following exercise, resulting in elevated BP (Nayor, Gajjar & Murthy, 2023). However, this effect is transient, as autonomic recovery ensues during the repose phase, leading to a decrease in BP and an increase in HRV (De Brito et al., 2019; Mongin et al.,2020). These processes are of paramount importance because the heart plays a pivotal role in responding to energy demands, which are regulated by the balance of the autonomic system (Mongin et al.,2020). This, in turn, controls heart rate and R-R wave interval fluctuations, which have been shown to be relevant to cardiovascular health. Autonomic dysfunction is associated with cardiovascular disease, sudden death and mortality from all causes (Costa, 2020). However, it has been demonstrated that high intensity exercise exerts a beneficial effect on responses in cardiac autonomic modulation and cardiac biomarkers (Wang et al., 2024).

Existing evidence supports the efficacy of exercise in producing beneficial adaptations in the body. However, there is a need to further investigate how the cardiovascular system responds from a comprehensive perspective that includes both vascular and central components, particularly in relation to different types and intensities of exercise. Despite the established benefits of high-intensity exercise, little is known about the acute cardiovascular responses to RT and HIIT in healthy young adults, particularly in terms of short-term autonomic modulation and hemodynamic recovery. Understanding these acute responses is essential for designing appropriate exercise stimuli to promote cardiovascular health, optimize exercise prescriptions, and minimize cardiovascular risk across diverse populations. Therefore, this study aims to analyse the effects of RT and HIIT on cardiovascular responses in young individuals.

METHODS

Participants

Sample size was calculated using a sample size calculator for reliability studies. Based on data from Wang et al (2024), a minimum acceptable intraclass correlation coefficient (ICC) of 0.8, a power of 90% and two replicates per participant (k = 2) yielded a required sample size of 14. The participants are young people aged between 19 and 25 years (5 females and 9 males). Subjects were selected through a non-probabilistic convenience sampling method. Inclusion criteria required participants to have controlled BP (<130/80 mm Hg at rest). Exclusion criteria included having a chronic non-communicable disease (e.g. hypertension, diabetes, cancer, respiratory disease), a lower or upper limb injury that would prevent participation in resistance or interval training, or a medical contraindication to exercise.

It is important to note that the entire assessment process in this research followed the ethical guidelines established by the Ethics Committee of the University of Santo Tomas (CEC Accredited Res. No. 23136643/2023).

Protocol

This research used a randomized, single-blind, crossover clinical trial design. consisted of two training sessions: RT and HIIT (fig 1). The evaluation and control of the interventions were conducted between March and August 2024 at the Bodybuilding Laboratory of the University of Santo Tomas.

The protocol was the same for both interventions. Upon arrival at the laboratory, participants underwent baseline measurements of BP (pre) and HRV (pre), for 8 minutes lying supine on a stretcher. Following these measurements, completed the assigned intervention. Immediately after the end of the session, blood pressure was measured again (Post). After they had a period recovery of 8 minutes (Post 8 min), during which cardiovascular variables were measured again.

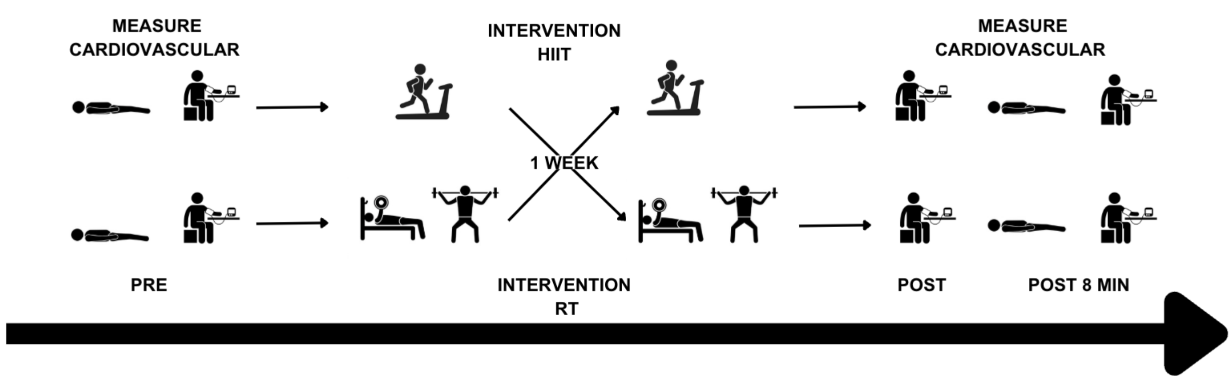


Figure 1. Protocol of intervention (Illustration created by the author).

Participants attended the laboratory on three separate occasions. During the first visit, they were informed about the experimental procedures, and their eligibility was confirmed according to the inclusion criteria.

Participants signed informed consent forms and familiarized themselves with the training sessions. In addition, anthropometric measurements were taken using a calibrated scale (Seca model 720, Hamburg, Germany).

Randomization

Randomization was performed during the second visit to the laboratory using an opaque envelope containing the assigned training type (RT or HIIT). On the same day, participants completed the session indicated on the envelope. After a one-week washout period, participants returned to complete the alternate training session. A second investigator, blinded to the training session, performed all assessments. Despite the use of an automated device to measure BP and HRV, precautions were taken to avoid any influence from the assessors.

Cardiovascular variables

HRV was measured during the pre-exercise (PRE) and recovery phases (POST 8 MIN). During both periods, participants lay supine on a stretcher for 8 min and data were collected using a Polar V800 heart rate monitor paired with an H10 sensor (Trevesini et al., 2018). R-R intervals were analysed using *Kubios* software version 3.3.1. Key metrics included the standard deviation of the intervals (SDNN), the natural logarithm of the root mean square of the consecutive differences between adjacent R-R intervals (In RMSSD), and the percentage of R-R interval pairs that differed by more than 50 milliseconds (PNN50%).

BP was measured during the pre-exercise (PRE), immediately post-exercise (POST) and recovery period (POST 8 MIN). Participants were seated comfortably, and measurements were taken using a sphygmomanometer (Omron HEM-907, Healthcare, Tokyo, Japan) placed on the left arm near the elbow. SBP, DBP and MAP were recorded. MAP was calculated using the formula: ([2 × DBP] + SBP) ÷ 3.

RT intervention

The session began with a warm-up focusing on free weight exercises, including squats and bench presses, performed at light loads for 10-15 repetitions. Participants then performed up to three sets of two repetitions for each exercise at maximum velocity to determine the load corresponding to approximately 80% of their one-repetition maximum (squat >0.7 m/s, bench press >0.58 m/s) (Hernandez-Belmonte et al., 2023). This measurement was made using a linear transducer (ADR®, Castilla, Spain). If the target velocity was not reached within three sets, the session was postponed to the following day.

Once the appropriate load was determined, the participants performed the RT session, which consisted of four sets of six repetitions performed within the established speed parameters of exercise squats and bench presses.

HIIT intervention

The session began with a 5-minute warm-up on a treadmill at an intensity below 70% of the participant's maximum heart rate (HRmax). Following the warm-up, running speed was calibrated based on heart rate, during which the participant ran at a speed higher than that of the warm-up, reaching at least 80% of their HRmax. Once the appropriate speed was determined, the participant completed six continuous high-intensity sprints, each lasting 20 seconds, with 40 seconds of rest between sprints.

It is important to note that HRmax was estimated using the formula: 220 minus the participant's age (Robergs and landwehr, 2002). Additionally, throughout the intervention, heart rate was monitored in real time using the Elite HRV app. This allowed for immediate adjustments to the running speed to ensure the intensity aligned with the desired target.

Statistical analysis

The SPSS statistical programmer version 21 (IBM, USA) was used for data analysis. In the case of HRV, the multiple imputation method was used to estimate missing values (less than 15% of the total) based on fully observed variables. After this procedure, the Shapiro-Wilk test was performed to check the normality of the sample.

A two-factor repeated measures ANOVA was used to analyse the cardiovascular variables, comparing the interactions between time (pre vs. post, pre vs. post 8 min, post vs. post 8 min) and type of training (RT vs. HIIT). The Greenhouse-Geisser correction was used to adjust for sphericity, as the Mauchly test was significant for the variables analysed. The level of statistical significance was set at 5%.

RESULTS

The Table 1 shows the descriptive data of the subjects. Observed values demographic anthropometric (weight, height and body mass Index), indicators auto perception of activity physical (type of activity and number of days) and parameters baseline cardiovascular (heart rate and BP).

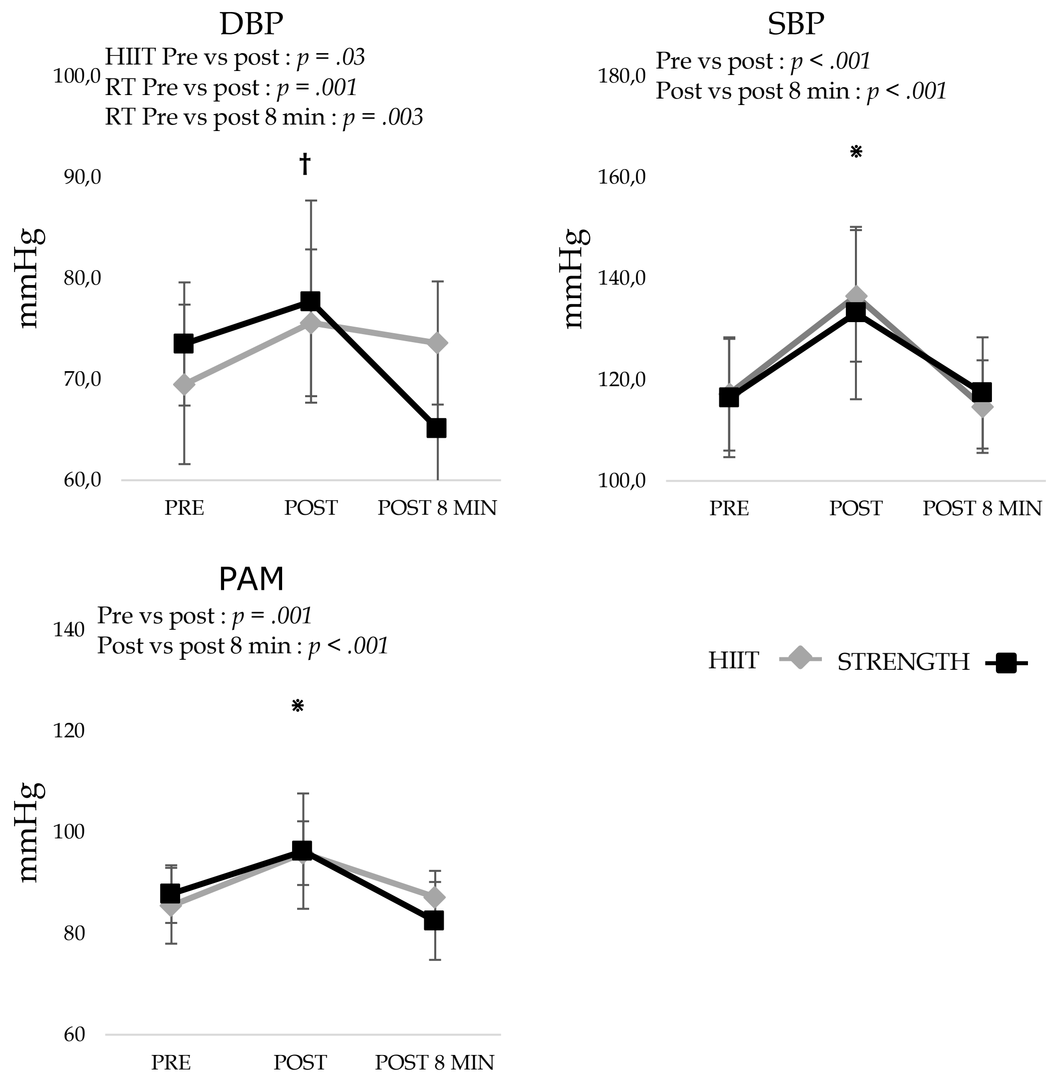
Table 1. Descriptive statistics.

Variable	**Data**
Age (years)	21.3 ± 2.8
Male/female	5/9
Weight (kg)	66.6 ± 8.1
Height (cm)	168.8 ± 7.0
Body Mass Index (kg/m2)	23.4 ± 3.0
physical activity (day in week)	3.1 ± 1.2
Type activity sport	64.3%
Type activity health	35.7%
Baseline heart rat	68.9 ± 10.8

The Figure 2 shows the behaviour of BP during the two types of high-intensity training. For SBP, no significant differences were observed in the interaction between time and training. However, the main effect of time ($F_{1,13}$ = 0.24, *p* = .78) showed significant changes, with an increase in SBP from pre- to post-measurement (p < 0.001) and a subsequent decrease from post- to 8-minute measurement (*p* < .001).

For DBP, significant interaction were observed between time and training ($F_{1,13}$ = 5.9, *p* = .01). Specifically, HIIT training showed an increase from pre- to post-measurement (*p* = .03), while RT showed a significant increase immediately post-training (*p* = .001), followed by a decrease after 8 minutes compared to the previous value (*p* = .03).

MAP showed a similar pattern to SBP, with a significant increase immediately after the intervention (p = .001) and a significant decrease at 8 minutes post-exercise compared to the immediate post-measurement (p < .001).



Note. ⁎ Significant time differences; † significant time/training differences.

Figure 2. Behaviour of blood pressure during the two protocols of high-intensity training.

The Table 3 presents the HRV data in the time domain, categorized by the effects of the training interventions. All variables showed significant differences in the time*training interaction: SDNN ($F_{1,13}$ = 9.2; *p* = .001), RMSSD ($F_{1,13}$ = 24.8; *p* < .001), and PNN50 ($F_{1,13}$ = 8.9; *p* = .01).

For SDNN, a significant decrease was observed in RT (11.6 ms; *p* = .01; d = 0.8) and in HIIT (26.1 ms; *p* < .001; d = 1.8). Regarding RMSSD, HIIT resulted in a decrease of 31.6 ms (*p* < .001; d = 2.4), while RT showed a reduction of 13.3 ms (*p* = .004; d = 1.0). Similarly, PNN50 exhibited a significant decrease over time for both RT (9.6%; *p* = .01; d = 0.9) and HIIT (1.6%; *p* = .001; d = 1.6).

It is important to note that pre-training values for all variables showed no significant differences, indicating consistency in the subjects' baseline HRV regardless of the time of evaluation. However, in the post-training measurements, HIIT resulted in lower HRV values compared to RT.

Table 3. Comparation of heart rate variability.

	HIIT	RT	Delta (HIIT – RT)	*p*-value
SDNN (ms)				
Pre	52.7 ± 15.1	51.3 ± 15.8	1.3 ± 6.8	.46
Post	26.6 ± 12.7⁎	39.7 ± 15⁎	-13.1± 2.3	.01
Ln RMSSD (ms2)				
Pre	3.6 ± 0.1	3.4 ± 0.1	0.1 ± 0.3	.10
Post	2.1 ± 0.1⁎	3.1 ± 0.1⁎	-1 ± 0.1	<.001
pNN50 (%)				
Pre	19.6 ± 14.6	16.7 ± 14.4	2.9 ± 8.1	.2
Post	1.6 ± 3.8⁎	7.1 ± 6.8⁎	-5.5 ± 3	.01

Note. ⁎ Differences significative between pre vs post with p < .05.

DISCUSSION

The aim of this study was to analyse the behaviour of the cardiovascular system during RT and HIIT. The main outcomes indicate an immediate increase in BP after the intervention, followed by a decrease after 8 minutes in the case of RT. In addition, HRV decreased 8 minutes post-exercise in both types of exercise, with a smaller reduction observed in the resistance exercise.

These results are supported by the literature, as the post-exercise increase in BP is attributed to an increase in blood flow to the activated muscles (Nayor et al., 2023). This hypertensive response aligns with findings from Corte et al (2020), which indicate that RT leads to an immediate rise in BP, with SBP increasing by approximately 20 mmHg and DBP by 10 mmHg. Similarly, HIIT has been shown to significantly elevate MAP compared to baseline value and control group (Liu et al., 2024). These results suggest that BP changes are primarily driven by the physiological demands of exercise rather than the specific training modality.

After 8 minutes, DBP decreased following RT compared to baseline, a response attributed to post-exercise vasodilation, a well-established mechanism that facilitates cardiovascular recovery and adaptation (Mariano et al., 2022). While our study observed this effect primarily in DBP, Lemos et al. (2018) reported reductions in both SBP and DBP with similar exercise protocols. These findings suggest that blood pressure changes depend on exercise load and individual vascular responses.

The variation in pressure during cardiac filling is a response that is observed to occur in the context of cardiovascular health training and is considered to be a normal consequence of the training stimulus. In study of Ashton et al. (2020) show that that high-intensity RT significantly improves health in adults at risk cardiovascular, primarily through the hypotensive effect. Thus, the reduction in BP following RT contributes to an optimal health state. When practiced regularly, it could lead to myocardial relaxation, enhanced autonomic modulation, and improved endothelial function (Guillem et al 2020). Additionally, vascular benefits such as increased nocturnal vasodilation and reduced nocturnal BP have been observed (Cardozo, 2022).

Building on the above findings, the data revealed significant differences between the values recorded immediately after training and those measured 8 minutes post-session, irrespective of the type of stimulus. This projects a hypotensive effect and highlights the potential long-term influence of training on BP regulation. However, our hypothesis was that DBP and MAP would also exhibit this behaviour, with HIIT exerting a greater influence on pressure reduction. This assumption is supported by literature indicating that HIIT induces hypotensive effects across all pressure variables (Boeno et al.,2019; Edwards et al., 2021). It is important to note that studies reporting hypotensive effects on SBP (Lemos et al., 2018; Boeno et al., 2019, Edwards et al., 2021) typically employed rest periods exceeding 10 minutes. Therefore, the shorter recovery time used in the present study may have been insufficient to detect post-exercise hypotension across all variables.

HRV significantly decreased between baseline and 8 minutes post-exercise, reflecting the expected transient shift towards sympathetic dominance during recovery (Polli et al., 2019). This response is consistent with previous (Wang et al., 2024) findings suggesting that the decrease in HRV after exercise is a natural consequence of autonomic rebalancing, rather than exercise-induced fatigue alone. According to Chen et al. (Chen et al., 2011) this temporary autonomic shift reflects the cardiovascular system's effort to meet metabolic demands and gradually restore homeostasis following high-intensity exertion.

The temporal variables and the types of training, the results of the present study showed significant differences in the values after 8 minutes, with RT causing a smaller decrease in the values of RMSSD, SDNN and PNN50%. Our findings align with those of Marasingha-Arachchige et al. (2022), which reported a significant decrease in RMSSD up to 30 minutes post-RT, with training volume identified as the most influential variable. Specifically, decreases in LNRMSSD (≈ 1 ms) were observed 15 minutes after RT involving 75% of a one-repetition maximum in exercises such as the squat, bench press, and deadlift (Kingsley et al., 2018). Similarly, a study by Flatt et al. (2019) demonstrated a decrease in Ln RMSSD following this type of training, however values returning to normal after 24 hours of recovery. For its part, HIIT produces a significant immediate decrease in Ln RMSSD that persists for more than 30 minutes (Wang et al., 2024). These findings are consistent with the results of the present study, where HIIT induced a greater reduction in HRV values after exercise. This suggests that the time required to return to basal autonomic balance may be longer after HIIT compared to RT, therefore the magnitude of change imposed by HIIT suggests greater autonomic demands.

For the PNN50% and SDNN parameters, significant reductions were observed 8 minutes post-exercise in both training sessions. in study by Kassiano et al. (2021) reported similar reductions, lasting up to 30 minutes after performing strength exercises to muscular failure, particularly during the squat exercise. Likewise, HIIT also induces reductions in these parameters, but values typically return to baseline levels within one hour (Burma et al., 2020). According to study by Seo et al, the SDNN returned to normal 60 minutes after performing HIIT for 40 seg and 200 seconds of recovery, but the PNN50% returned to normal after 30 minutes. This difference in the time to return to normal is due to the low influence of the sympathetic system on the PNN50%, so that the values are recovered earlier, as the parasympathetic system tends to position itself during the recovery phase. According to the study by Seo et al., SDNN returned to baseline 60 minutes after completing a HIIT session consisting of 40-second efforts with 200-second recovery periods. In contrast, PNN50% normalized after 30 minutes. This difference in recovery time is likely due to the lower sympathetic influence on PNN50%, allowing for a faster return to parasympathetic predominance during the recovery phase (Seo et al., 2024).

The greater HRV reduction after HIIT compared to RT suggests a stronger autonomic response, likely due to prolonged sympathetic activation during high-intensity intervals. While this is a normal physiological adaptation, it highlights the need for careful monitoring in individuals with pre-existing cardiovascular conditions. In contrast, RT may provide a more controlled autonomic stimulus, making it a potentially safer option for populations at risk of hypertension or autonomic dysregulation. Tailoring exercise prescriptions based on individual cardiovascular profiles could help optimize training adaptations while minimizing potential risks.

CONCLUSION

High intensity training, whether RT or HIIT, induces changes in hemodynamic variables. Blood pressure parameters increased immediately after both training sessions. Specifically, RT induced a hypotensive effect on DBP during the recovery period, while HRV significantly decreased after both training modalities, with HIIT causing a more pronounced reduction than RT. This decrease reflects the expected autonomic shift towards sympathetic dominance during exercise, followed by a gradual parasympathetic reactivation during recovery.

These findings highlight the importance of considering individual cardiovascular profiles when prescribing exercise, particularly for populations at risk of hypertension or autonomic dysregulation.

AUTHOR CONTRIBUTIONS

Luis Benavides, Maritza Miranda, Sebastian Hernández and Alfonso Vega contributed to the conception and design. María Benavides, Luis Campos, Luis Benavides and Maritza Miranda contributed to data acquisition and data interpretation of the work. Sebastian Hernández, Alfonso Vega and Gloria Benavides drafted the manuscript. María Benavides and Gloria Benavides critically revised the manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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