



## Effects of concurrent training on heart rate variability in sedentary and trained healthy young adults.

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### ABSTRACT

**Background:** Heart Rate Variability (HRV) has been established as a reliable and useful indicator of autonomic regulation and the specific physiological responses of the body to physical exercise. **Aims** The objective of this pilot study was to describe the specific differences in HRV responses between trained and sedentary healthy young adults before and after a concurrent training session. **Methods** The researchers employed a quasi-experimental design with descriptive analysis involving four participants categorized by their training status. HRV data was recorded at rest through photoplethysmography, while the concurrent training protocol integrated both resistance and endurance exercises with intensity monitored via the rating of perceived exertion scale. **Results** The findings indicated that trained participants possessed higher baseline HRV values and experienced a smaller decrease in HRV following exercise compared to the sedentary group. Furthermore, the trained individuals demonstrated an apparently faster recovery rate after the training session was completed. **Conclusion** The study suggests that prior training status may significantly influence the acute autonomic response to concurrent training. However, due to the small sample size and descriptive nature of the study, these results are considered preliminary and should be interpreted with caution, highlighting the need for future research with larger samples to confirm these patterns.

**To cite this article:** Cobos-Valiente, D. (2025). Effects of concurrent training on heart rate variability in sedentary and trained healthy young adults. *Journal of Sports and Physical Activity*, 2(1), 1-9. <https://doi.org/10.64268/jospa.v2i1.23>

### ARTICLE HISTORY

Received: December 2, 2025

Revised: January 5, 2026

Accepted: February 22, 2026

### KEYWORDS

Heart rate variability;  
Concurrent training;  
Autonomic nervous system;  
Physical exercise;  
Young people.

### INTRODUCTION

Heart rate variability (HRV) has emerged as a key non-invasive indicator of autonomic nervous system (ANS) regulation and of physiological adaptation to physical exercise. Its growing use in both clinical and sports settings reflects the increasing scientific interest in understanding how the body responds to stress stimuli and recovers after exertion (Shaffer & Ginsberg, 2017; Plews et al., 2013; Esco, 2025). By analyzing the temporal variation between consecutive heartbeats—commonly derived from RR intervals—HRV provides valuable insight into the dynamic balance between sympathetic and parasympathetic activity, which plays a central role in cardiovascular regulation and homeostasis (Capdevila et al., 2008; Thayer et al., 2010).

From a physiological perspective, HRV is closely linked to the functioning of the ANS, which automatically regulates essential bodily processes. A predominance of parasympathetic activity at rest is generally associated with greater physiological adaptability and better cardiovascular health, whereas reduced HRV has been linked to sympathetic dominance, diminished stress resilience, and

increased cardiovascular risk (Shaffer & Ginsberg, 2017; Thayer et al., 2010). Regular physical exercise has been associated with positive adaptations in autonomic regulation, including increased resting parasympathetic tone and more efficient post-exercise recovery (Stanley et al., 2013; Ishaque et al., 2021).

Scientific evidence consistently shows that physically active and trained individuals tend to exhibit higher resting HRV than sedentary subjects, reflecting more favorable cardiovascular and autonomic adaptations (Achten & Jeukendrup, 2003; Araújo et al., 2016; Zhang et al., 2024). These differences are particularly relevant in young populations, as early adulthood represents a critical stage for the consolidation of physical activity habits and long-term physiological adaptations. Given the increasing prevalence of sedentary lifestyles among young adults, understanding how different training profiles influence acute autonomic responses to exercise is both scientifically and socially relevant.

Regarding the type of exercise stimulus, much of the literature has traditionally focused on aerobic training and its effects on HRV and cardiovascular adaptations (Karavirta et al., 2009; Araújo et al., 2016). However, concurrent training is defined as combining strength and endurance exercises in the same session, which has attracted considerable attention for its efficiency and applicability across recreational and competitive contexts. Despite its widespread use, concurrent training has generated debate over the potential interference between strength and endurance adaptations (Wilson et al., 2012; Fyfe et al., 2014; Angostinelli et al., 2025). Variables such as exercise order, intensity, prior training status, and residual fatigue appear to influence physiological responses to this type of training stimulus.

In this context, HRV represents a particularly valuable tool for analyzing acute autonomic responses to concurrent training sessions, as it enables non-invasive assessment of exercise-induced stress and recovery capacity (Plews et al., 2013). However, most previous investigations have focused on homogeneous adult or athletic populations and have predominantly examined chronic adaptations rather than immediate autonomic responses. There remains limited evidence directly comparing the acute HRV response to concurrent training in young individuals with clearly differentiated training status under a standardized intervention protocol.

Furthermore, research on concurrent training has predominantly examined chronic adaptations or performance-related outcomes, with less attention given to immediate autonomic responses and potential differences between trained and sedentary individuals during early adulthood. In this context, it becomes relevant to descriptively explore how prior training status may modulate the acute HRV response to a structured session combining resistance and endurance exercise. Therefore, the present pilot study aims to descriptively compare HRV responses before and after a concurrent training session in trained and sedentary young adults of both sexes. It was hypothesized that trained participants would exhibit higher baseline HRV values and a smaller post-exercise decrease in HRV than sedentary participants, reflecting more efficient autonomic regulation.

## METHOD

This pilot study followed a quasi-experimental intervention design with repeated measurements of heart rate variability (HRV) before and after a concurrent training session. The primary objective was to describe acute autonomic responses to exercise in young adults with varying training backgrounds. This design is appropriate for analyzing short-term physiological responses to physical exercise and enables comparisons between groups while maintaining control over experimental conditions (Hopkins et al., 2009; Buchheit, 2014). The study is part of an exploratory pilot investigation aimed at identifying preliminary patterns of autonomic modulation by training status. This approach is consistent with previous research using HRV as a sensitive marker for assessing the impact of training on the autonomic nervous system in both sports and health contexts (Plews et al., 2013; Stanley et al., 2013).

All procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki for research involving human subjects (World Medical Association, 2013). Participants received detailed information regarding the study objectives, procedures, and potential risks before participation and provided written informed consent. Confidentiality and anonymity were guaranteed in compliance with Organic Law 3/2018 on the Protection of Personal Data and the

General Data Protection Regulation (EU) 2016/679. All collected data were used exclusively for scientific purposes.

The sample consisted of healthy young adults of both sexes, divided into two groups based on training status: trained and sedentary. Participants were considered trained if they engaged in structured strength and/or endurance training at least three times per week for more than one year. Sedentary participants were those who did not engage in regular structured training and whose physical activity was occasional or absent during the previous 6 months (World Health Organization, 2019). Inclusion criteria included the absence of diagnosed cardiovascular disease, no use of medications affecting autonomic function, and no intense physical activity within 24 hours of testing, to minimize potential interference with HRV values (Buchheit, 2014).

HRV was assessed by recording RR intervals using the HRV4Training application via photoplethysmography through a smartphone camera (Lassing et al., 2025). This methodology has demonstrated acceptable validity and reliability for short-term resting HRV analysis, showing strong correlations with electrocardiogram-derived measurements in applied research settings (Plews et al., 2013; Perrotta et al., 2017). Measurements were conducted over three minutes in the supine position following a standardized rest phase, as recommended by established methodological guidelines for HRV assessment (Task Force of the European Society of Cardiology & North American Society of Pacing and Electrophysiology, 1996; Shaffer & Ginsberg, 2017). The HRV variables analyzed included the mean RR interval, the standard deviation of NN intervals (SDNN), the root mean square of successive differences (rMSSD), the percentage of successive intervals differing by more than 50 ms (pNN50), and the low-frequency (LF) and high-frequency (HF) components in the frequency domain. Mean heart rate (HR) was also recorded as a complementary physiological indicator. These variables are commonly used to evaluate autonomic modulation both at rest and following exercise.

The experimental protocol consisted of a concurrent training session combining resistance and endurance exercises. After the baseline HRV measurement, participants performed a strength-training block composed of six multi-joint exercises organized into trisets, targeting the upper and lower limbs. Each exercise was completed in three sets of eight repetitions at an intensity corresponding to an RPE of approximately 7, with 60 seconds of rest between trisets and 90 seconds between blocks. This was followed by a 15-minute continuous aerobic exercise performed at a similar perceived intensity (RPE  $\approx$  7). The sequence of strength followed by endurance was selected based on existing literature addressing concurrent training order and its influence on physiological and autonomic responses (Fyfe et al., 2014; Wilson et al., 2012). The protocol was designed to provide sufficient stimulus to elicit measurable autonomic changes while ensuring participant safety. The overall experimental timeline is illustrated in Figure 1.



**Figure 1.** Experimental Design and Timeline of Measurements

*Note.* Outline of the experimental protocol applied in the study. After an initial 5-minute rest period, baseline Heart Rate Variability (HRV) was measured for 3 minutes in the supine position. Participants then completed a concurrent training session consisting of a strength block followed by a continuous aerobic block. HRV was recorded again after the session and during the recovery period.

Given the pilot nature of the study and the small sample size ( $n = 4$ ), statistical analysis was limited to descriptive procedures. Means and standard deviations were calculated for all variables at baseline and post-exercise, and percentage changes were computed to describe the magnitude of variation within each group. No inferential statistical tests were performed.

## RESULTS AND DISCUSSION

### Result

#### *Autonomic Response at Rest According to Training Level*

The descriptive results from the baseline Heart Rate Variability (HRV) measurement showed higher values in the trained young people group than in the sedentary young people group. These differences are evident in the mean values reported in Table 1 and should be interpreted in light of the study's small sample size.

From an interpretative perspective, these patterns could be consistent with previous scientific evidence indicating that regular physical exercise is associated with a greater predominance of parasympathetic tone at rest and better regulation of the autonomic nervous system (ANS). However, given the exploratory nature of the study, this correlation should be considered preliminary.

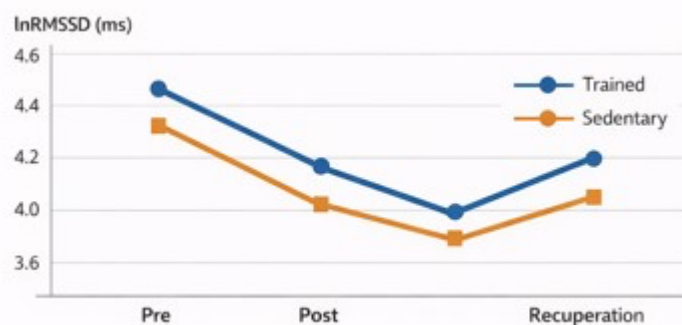
**Table 1.** Participant Characteristics According to Training Status

Variable	Group trained (n=2)	Sedentary group (n=2)	Total (n=4)
Age (years)	23.5 ± 3.54	22.5 ± 0.71	23.0 ± 1.87
Body mass (kg)	78.0 ± 5.66	62.5 ± 9.19	70.25 ± 9.44
Height (cm)	174.0 ± 12.73	166.0 ± 9.90	170 ± 9
BMI (kg·m <sup>-2</sup> )	25.7 ± 2.11	22.6 ± 2.69	24.1 ± 2.86

*Note.* Values expressed as mean ± standard deviation. BMI = body mass index.

From a physiological perspective, higher HRV at rest reflects greater vagal modulation capacity of the heart and better cardiovascular adaptability to external stimuli (Thayer et al., 2010; Zhang et al., 2025). In young people, these differences are particularly relevant, as they indicate early ANS adaptations associated with habitual physical activity levels. Previous studies have shown that, even at an early age, physically active subjects exhibit more favorable autonomic profiles than their sedentary peers, with long-term implications for cardiovascular health (Araújo et al., 2016; Buchheit, 2014).

The lower HRV values observed in sedentary young people may be related to less developed autonomic regulation and to less exposure to physiological stimuli capable of inducing positive adaptations in the cardiovascular system. This pattern has been described in studies comparing active and inactive subjects, in which sedentary individuals exhibit lower cardiac variability and greater sympathetic activation at rest are observed in sedentary individuals (Shaffer & Ginsberg, 2017).



**Figure 2.** Changes in HRV Before and After the Concurrent Training Session

*Note.* Evolution of Heart Rate Variability (HRV) in trained young people (GEE) and sedentary young people (GES) before the concurrent training session (Pre), immediately after (Post), and immediately after the session. A greater post-exercise decrease and slower recovery are observed in the sedentary group compared to the trained group.

#### *HRV Response After the Concurrent Training Session*

After the concurrent training session, a generalized decrease in HRV values was observed in both groups, as reflected in the percentage variations shown in Table 2. The magnitude of the decrease was greater in the sedentary group, though this difference should be interpreted with caution, given the descriptive nature of the analysis. From a physiological perspective, this decrease in HRV after exercise could be associated with activation of the sympathetic nervous system and a

temporary withdrawal of parasympathetic tone, a phenomenon widely described in the scientific literature (Plews et al., 2013; Stanley et al., 2013). However, given the exploratory nature of this study, this interpretation should be considered preliminary.

**Table 2.** Heart Rate Variability Values Before and After Concurrent Training

Variable	Group	Pre (Mean ± SD)	Post (Mean ± SD)	% Change
RR (ms)	Sedentary	889.74 ± 88.53	746.95 ± 19.59	-16.05%
	Trained	1018.98 ± 8.73	910.74 ± 7.04	-10.62%
SDNN (ms)	Sedentary	88.73 ± 13.98	45.38 ± 10.64	-48.86%
	Trained	113.24 ± 9.35	61.30 ± 1.71	-45.86%
rMSSD (ms)	Sedentary	39.00 ± 4.18	26.08 ± 10.08	-33.13%
	Trained	53.75 ± 4.97	46.35 ± 6.80	-13.76%
pNN50 (%)	Sedentary	30.28 ± 4.31	11.98 ± 0.60	-60.44%
	Trained	46.61 ± 1.95	34.93 ± 10.25	-25.05%
HF (Hz)	Sedentary	0.124 ± 0.014	0.076 ± 0.016	-38.71%
	Trained	0.205 ± 0.037	0.153 ± 0.010	-25.37%
LF (Hz)	Sedentary	0.043 ± 0.007	0.011 ± 0.0007	-74.42%
	Trained	0.134 ± 0.011	0.044 ± 0.013	-67.16%
HR (bpm)	Sedentary	53.69 ± 7.87	78.79 ± 4.31	+46.74%
	Trained	65.83 ± 10.34	78.83 ± 8.73	+19.75%

*Note.* RR = mean beat-to-beat interval; SDNN = standard deviation of NN intervals; rMSSD = root mean square of successive differences; pNN50 = percentage of consecutive intervals differing by more than 50 ms; LF = low frequency; HF = high frequency; HR = heart rate.

However, the magnitude of this decrease was greater in the sedentary youth group, suggesting greater disruption of autonomic balance after exercise. This finding is consistent with previous research indicating that less trained subjects exhibit a more pronounced autonomic response to similar load stimuli, which may reflect lower physiological efficiency and lower exercise stress tolerance (Buchheit, 2014; Ishaque et al., 2021). The individual percentage variations observed in each participant after the concurrent training session are detailed in Table 3.

**Table 3.** Individual HRV Responses to Concurrent Training

Subject	Group	RR Change (%)	SDNN Change (%)	rMSSD Change (%)	HR Change (%)
Female	Sedentary	-23.02%	-51.97%	-47.41%	+38.10%
Male	Sedentary	-8.01%	-46.34%	-20.85%	+57.36%
Female	Trained	-10.56%	-43.64%	-17.03%	+16.21%
Male	Trained	-10.67%	-47.84%	-10.68%	+24.16%

In the context of concurrent training, this response is particularly interesting, as combining strength and endurance exercises in the same session is a complex stimulus that can place a significant load on the cardiovascular system. Some authors have pointed out that this type of training can lead to greater autonomic demand, especially when applied to subjects with low physical fitness or little experience in structured training (Fyfe et al., 2014; Wilson et al., 2012). The results of the present study reinforce this idea, showing that sedentary young people exhibit greater alterations in HRV after a concurrent training session than trained subjects.

## Discussion

### *HRV Recovery and Ability to Adapt to Exercises*

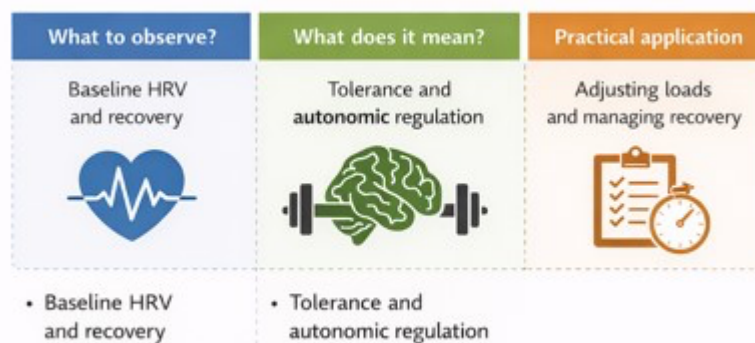
During the post-training phase, HRV values showed a progressive trend toward recovery, which was faster and more pronounced in the trained youth group. This pattern is consistent with the literature, which indicates that faster HRV recovery after exercise is associated with greater physiological adaptability and better cardiorespiratory fitness (Stanley et al., 2013; Plews et al., 2013).

Post-exercise autonomic recovery is a key indicator of the ANS's functional state and the body's ability to restore homeostasis after a stressful stimulus. In this regard, trained subjects tend to exhibit faster parasympathetic reactivation, resulting in a more efficient recovery of baseline HRV values (Buchheit, 2014). Conversely, slower recovery, as observed in sedentary young people, may indicate greater physiological load and lower exercise tolerance, especially in combined training contexts. These results reinforce the use of HRV as a useful tool for monitoring not only the acute response to exercise but also recovery processes, which is of great interest for training planning and the prevention of excessive fatigue or overload, even in apparently healthy young populations (Shaffer & Ginsberg, 2017).

### *Implications of Concurrent Training in Young People with Different Levels of Training*

In relation to concurrent training, the results of the present study show no negative effects on the cardiovascular response in healthy young people, regardless of their training level. However, differences are observed in the magnitude of the autonomic response and in the speed of recovery, highlighting the importance of prior training level as a modulator of the physiological response to exercise.

The literature indicates that concurrent training can be an effective strategy for improving overall physical condition, provided that factors such as intensity, volume, and the order of load application are considered (Wilson et al., 2012; Fyfe et al., 2014). The results obtained in this study suggest that, in trained subjects, this type of training is well tolerated from an autonomic perspective. In contrast, in sedentary subjects, it can be a more demanding stimulus, requiring careful planning and adequate progression. From an applied perspective, these findings support the use of HRV as a complementary indicator for adjusting training load based on the athlete's or practitioner's profile, especially in programs aimed at young people with varying levels of experience and physical condition. HRV monitoring could allow the identification of inadequate responses to concurrent training and the adaptation of programming to promote better tolerance and recovery from exertion (Buchheit, 2014; Plews et al., 2013).



**Figure 3.** Practical Interpretation of HRV in Concurrent Training

*Note.* Schematic representation of the practical interpretation of HRV response to concurrent training. The greater baseline stability and more efficient recovery observed in trained subjects suggest better autonomic regulation compared to sedentary subjects, which can guide the individualization of load and recovery management.

From an international perspective, the findings of this pilot study contribute to ongoing discussions on individualized training monitoring and the prevention of maladaptive responses to exercise in heterogeneous populations. In recent years, HRV has been increasingly incorporated into athlete monitoring systems and health-oriented training programs worldwide, particularly as a practical and non-invasive tool for guiding load management and recovery strategies (Plews et al., 2013; Buchheit, 2014). The growing global concern about sedentary behavior among young adults further highlights the relevance of understanding how different baseline training statuses influence acute autonomic responses to exercise. Early identification of exaggerated autonomic stress responses may help inform safer training prescription strategies and progressive conditioning programs in populations transitioning from sedentary to physically active lifestyles.

Although the present results are preliminary, they align with broader international efforts to integrate physiological monitoring tools into evidence-based exercise programming. In this regard, the descriptive patterns observed may serve as a foundation for larger-scale investigations aimed at refining concurrent training prescriptions in young populations with diverse physical conditioning levels (Esco, 2025). However, the results should be interpreted with caution due to the small sample size typical of pilot studies. Although the patterns observed allow us to identify interesting trends in the autonomic response to concurrent training, future research will need to expand the sample to confirm the consistency of these findings. Overall, the results allow us to identify trends in the acute autonomic response to concurrent training, depending on the level of prior training. However, these findings should not be interpreted as conclusive evidence, but rather as preliminary indications that require confirmation in studies with larger sample sizes and inferential statistical designs.

### *Implications*

The findings indicate that prior training status plays an important role in shaping autonomic responses to concurrent training in young adults. Trained individuals appeared to demonstrate greater baseline autonomic stability and a more efficient recovery pattern following exercise, whereas sedentary participants showed larger acute reductions in HRV and slower recovery trends. These patterns highlight the importance of individualizing training loads when prescribing combined resistance and endurance exercise, particularly for individuals with limited training backgrounds. In applied settings, HRV monitoring may serve as a practical, non-invasive tool to guide load progression, recovery management, and tolerance to training stimuli. The results also reinforce the relevance of physiological monitoring in health-oriented exercise programs for young adults, especially in populations transitioning from sedentary to active lifestyles.

### *Research Contribution*

This study provides preliminary descriptive evidence on acute autonomic responses to concurrent training in young adults with different training statuses. While previous literature has largely focused on chronic adaptations or athletic populations, the present work contributes by exploring immediate HRV responses under a standardized concurrent training protocol. The comparison between trained and sedentary participants offers insight into how baseline physical conditioning may modulate exercise-induced autonomic stress and recovery dynamics. By incorporating multiple HRV indicators across time and frequency domains, the study adds to the growing body of research supporting HRV as a useful marker for monitoring training responses and recovery processes. Although exploratory in nature, the patterns observed may help inform future research aimed at optimizing individualized training strategies based on physiological monitoring.

### *Limitations*

The primary limitation of this study lies in its pilot design and very small sample size, which restricts the generalizability of the findings and prevents inferential statistical analysis. As a result, the outcomes should be interpreted as descriptive trends rather than conclusive evidence. Additional factors that could influence HRV responses, such as sleep quality, stress levels, and daily activity patterns, were not fully controlled and may have affected the measurements. The use of short-term photoplethysmography via a smartphone application, while practical and supported by prior validation studies, may not provide the same level of precision as electrocardiogram-based assessments. Furthermore, the study examined only acute responses to a single training session, limiting the ability to draw conclusions about long-term adaptations or training effects over time.

### *Suggestions*

Future investigations would benefit from including larger and more diverse samples to strengthen statistical power and improve the generalizability of results. Longitudinal designs examining repeated concurrent training sessions could provide deeper insight into chronic autonomic adaptations and recovery dynamics. Incorporating additional physiological and performance indicators, such as aerobic capacity, strength measures, and biochemical markers, may help clarify the relationship between training status and autonomic regulation. It would also be valuable to explore individualized training prescriptions guided by HRV monitoring to determine

whether such approaches can enhance recovery, adaptation, and adherence in young adult populations. Expanding research in this area may contribute to the development of more personalized and evidence-based training strategies for both health and performance contexts.

### CONCLUSION

The results of this pilot study suggest that heart rate variability may be a useful tool for describing the acute autonomic response to concurrent training in young people. Trends indicated higher baseline values and apparently more efficient recovery in trained subjects compared to sedentary subjects. However, due to the small sample size and the descriptive nature of the analysis, these findings should be interpreted with caution and considered preliminary. Future research with larger samples and more powerful analytical designs will allow the patterns observed in this study to be confirmed and expanded upon. The author sincerely thanks the study participants for their commitment and willingness to participate in this research, as well as the San Isidoro University Center for facilitating the use of its facilities.

### AUTHOR CONTRIBUTION STATEMENT

DCV was responsible for the conceptualization and design of the study, data collection, data analysis, interpretation of the results, and drafting of the manuscript. The author critically revised the content and approved the final version of the manuscript.

### AI DISCLOSURE STATEMENT

The author used digital language assistance tools during the preparation of this manuscript to improve clarity and readability. All content was carefully reviewed and edited by the author, who takes full responsibility for the accuracy and integrity of the work.

### CONFLICTS OF INTEREST

The author confirms the absence of any potential conflicts of interest—financial, institutional, or personal—that could influence the conduct of this study, the analysis of data, the preparation of the manuscript, or its publication.

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