Relación entre la variabilidad de la frecuencia cardiaca, nivel de actividad física y factores sociodemográficos en adultos jóvenes: estudio transversal

Relationship between heart rate variability, physical activity levels, and sociodemographic factors in young adults: cross-sectional study

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Abstract

Introduction: heart rate variability is a key indicator of cardiovascular health and autonomic balance, influenced by various factors such as age and stress.
Objective: to relate heart rate variability to body composition, physical activity levels, sleep quality, and self-perceived stress in young Chilean adults with low cardiometabolic risk.
Methodology: a cross-sectional study was conducted in 2024 with the participation of 32 young adults (18 to 30 years old), selected based on inclusion criteria related to adequate physical activity levels and the absence of chronic diseases. The analysis considered variables such as body composition, sleep quality, stress levels, physical activity levels, and heart rate variability, with the latter measured over a 5-minute resting period.
Results: age showed a significant negative relationship with RMSSD ($\beta = -0.43$, $t = -2.48$, $p = .02$), indicating a decrease in parasympathetic activity as age increases. Self-perceived stress, however, did not show a significant impact on RMSSD ($\beta = .09$, $p = .60$) or the RR/RMSSD ratio ($\beta = -0.37$, $p = .04$).
Discussion: the findings highlight the importance of heart rate variability as an indicator of autonomic health, emphasizing how age and stress impact vagal modulation. These results reinforce the need to integrate autonomic monitoring into preventive strategies to improve cardiovascular health.
Conclusion: heart rate variability is significantly related to age and self-perceived stress. These findings underline the importance of integrating autonomic monitoring into preventive health strategies.

Keywords

Autonomic nervous system; exercise; body composition; subjective stress; sleep quality.

Resumen

Introducción: la variabilidad de la frecuencia cardiaca es un indicador clave de la salud cardiovascular y del equilibrio autonómico, influido por diversos factores, como la edad y el estrés.
Objetivo: relacionar la variabilidad de la frecuencia cardiaca con la composición corporal, el nivel de actividad física, la calidad del sueño y el estrés autopercibido en adultos jóvenes chilenos con bajo riesgo cardiometabólico.
Metodología: estudio transversal realizado durante el 2024, participación de 32 adultos jóvenes (18 a 30 años), seleccionados mediante criterios de inclusión basados en niveles adecuados de actividad física y la ausencia de enfermedades crónicas. El análisis considero las variables composición corporal, calidad del sueño, niveles de estrés, niveles de actividad física y la variabilidad de la frecuencia cardiaca, siendo esta última medida registrada en un periodo de 5 minutos en reposo.
Resultados: la edad mostró una relación negativa significativa con RMSSD ($\beta = -0.43$, $t = -2.48$, $p = .02$), lo que indica una disminución de la actividad parasimpática a medida que aumenta la edad. El estrés autopercibido, sin embargo, no mostró un impacto significativo en RMSSD ($\beta = .09$, $p = .60$) ni en la relación RR/RMSSD ($\beta = -0.37$, $p = .04$).
Discusión: Los hallazgos subrayan la importancia de la variabilidad de la frecuencia cardiaca como indicador de salud autonómica, destacando cómo la edad y el estrés afectan la modulación vagal. Estos resultados refuerzan la necesidad de integrar el monitoreo autonómico en estrategias preventivas para mejorar la salud cardiovascular.
Conclusiones: la variabilidad de la frecuencia cardiaca se relaciona de manera significativa con la edad y el estrés autopercibido. Estos hallazgos subrayan la importancia de integrar el monitoreo autonómico en estrategias preventivas de salud.

Palabras clave

Sistema nervioso autónomo; ejercicio; composición corporal; estrés subjetivo; calidad de sueño

Introduction

Heart rate variability (HRV) refers to the variation in time, measured in milliseconds, between consecutive heartbeats (RR intervals), traditionally recorded using an electrocardiogram (Billman et al., 2015). HRV reflects the activity of the autonomic nervous system and plays a crucial role in cardiovascular regulation. It is considered a key indicator of physiological stability and the body's ability to adapt to various internal and external stimuli. These adaptations significantly influence overall health and cardiometabolic risk (D'Angelo et al., 2023).

HRV typically predominates vagal (parasympathetic) tone in healthy individuals under basal conditions, indicating greater capacity for adaptation and recovery. Conversely, in individuals with conditions such as overweight and obesity, sympathetic activity predominates, which is associated with an increased risk of cardiovascular and metabolic complications (Yadav et al., 2017; Turcu et al., 2023). Factors such as body composition, physical activity levels, sleep quality, and perceived stress can disrupt homeostasis and autonomic balance. Thus, monitoring autonomic function is essential for restoring equilibrium based on individual needs (Espinoza-Salinas et al., 2022; Koenig & Thayer, 2016; Gathright et al., 2024; Fuentes-Barría et al., 2024a; Fuentes-Barría et al., 2024b).

Metabolic stress associated with overweight, obesity, and hypertension modulates the vagus nerve, potentially altering heart rate dynamics in both sedentary and physically active individuals. Changes mediated by altered leptin levels affect vagal tone and immune responses (He et al., 2015; Facioli et al., 2021; Li et al., 2022). In this context, HRV analysis using time-domain, spectral, and non-linear metrics allows observation of homeostatic processes and adaptive responses, both at rest and during physical activity. Metrics such as RMSSD (root mean square of successive differences between RR intervals) and RR intervals are particularly valuable in assessing vagal tone and parasympathetic activity, facilitating the monitoring of autonomic function and the prediction of clinical conditions (Wiewelhove et al., 2018; Porras-Álvarez & Bernal-Calderón, 2019; Ravé et al., 2020; Boullosa et al., 2021; Grässler et al., 2021; Medina Corrales et al., 2021; El-Malahi et al., 2024).

Despite its importance as an assessment tool, the literature highlights limitations in integrating HRV analyses into specific contexts, such as studies involving healthy young adults. Moreover, autonomic balance is not exclusively dependent on evident pathologies but also on underlying factors such as sleep quality and chronic stress. These factors can significantly alter HRV even in apparently healthy individuals. Understanding the interaction of these variables and their impact on cardiovagal dynamics is critical for developing preventive and personalized strategies that enhance cardiovascular health (Gutiérrez-Maldonado et al., 2018).

This study aims to analyze the relationship between HRV and health determinants such as body composition, physical activity levels, sleep quality, and perceived stress in young Chilean adults with low cardiometabolic risk. We hypothesize that cardiovagal dynamics are significantly influenced by multiple factors, contributing to a comprehensive understanding of autonomic health in this population.

Method

Design

This study followed a cross-sectional design, adhering to the 'Strengthening the Reporting of Observational Studies in Epidemiology' (STROBE) guidelines (Cuschieri, 2019). The research protocol and informed consent were approved by the Ethics Committee of the Central University of Chile (Act No. 59-2024), in accordance with the Declaration of Helsinki (World Medical Association, 2013). This design was selected to provide a snapshot of the characteristics and relationships between variables at a specific point in time. Cross-sectional studies are particularly useful for identifying prevalences, describing current phenomena, and exploring associations between variables without requiring long-term follow-up. Additionally, this design serves as a preliminary analysis, with findings that could inform future, more complex studies.

Context

The study was conducted at the municipal stadium in Puente Alto, Santiago, Chile, between March and June 2024. Recruitment was facilitated through direct coordination between a professor and students, considering mutual availability to ensure participant engagement. While this recruitment method was not random, it was chosen for its practicality and feasibility in a specific population familiar with the intervention. After recruitment, participants attended the facility individually or in groups. The intervention was supervised by a sports science specialist, certified as a World Athletics Level I coach, who ensured appropriate participant selection based on physical readiness. This professional also provided a written description of the study's purpose and participant selection criteria, as well as informed consent forms. Participants who agreed to participate signed the consent form before undergoing evaluations of physical activity levels, sleep quality, perceived stress, and HRV. The intervention lasted 90 minutes.

Participants

The sample consisted of 32 adults (21 males and 11 females), selected through non-probabilistic sampling. The inclusion criteria were: a) adults aged 18 to 30 years to ensure a homogeneous group in terms of physical and metabolic development, minimizing variations related to aging or puberty; and b) adults classified as having moderate or high levels of physical activity in the past seven days, according to the International Physical Activity Questionnaire-Short Form (IPAQ-SF) (Serón et al., 2010; Balboa-Castillo et al., 2023), ensuring sufficient experience with physical activity for accurate assessments of cardiovagal dynamics and perceived stress. The exclusion criteria included: c) adults diagnosed with non-communicable diseases, such as hypertension, type 1 or type 2 diabetes, heart failure, chronic pulmonary diseases (e.g., COPD), chronic kidney diseases, or severe cardiovascular and respiratory conditions (e.g., myocardial infarction, arrhythmias, severe asthma, or sleep apnea); d) adults with severe musculoskeletal diseases (e.g., severe arthritis or acute injuries) or recent infectious or autoimmune diseases; e) individuals who had engaged in moderate or intense physical activity within the past 48 hours or consumed substances (e.g., caffeine, alcohol, diuretics, corticosteroids, or other medications) within the past 24 hours, as these conditions could interfere with measurements of HRV, sleep quality, stress response, and physical activity levels; and f) individuals who failed to attend the intervention or did not sign the informed consent form.

Procedure

Variables related to physical activity levels, sleep quality, perceived stress, and HRV were assessed using validated and standardized instruments. Below is a detailed description of the procedures and justifications for each instrument used:

Instrument

- Body composition was assessed using a Seca digital scale with a precision of 100 g and a portable Seca stadiometer (220 cm) to measure weight and height. Body mass index (BMI) was calculated using the formula:

$$BMI = weight\ (kg)\ /\ height\ (m)^2$$

  BMI provided insights into the relationship between body composition and the studied variables, particularly cardiovagal dynamics, and perceived stress. This measure is widely used for general physical status classification without requiring complex body composition analysis.
- International Physical Activity Questionnaire Short Form (IPAQ-SF): The short form of the IPAQ was used to assess the frequency and intensity of physical activity over the past seven days, categorizing activity levels as low (<599 METs), moderate (600-1499 METs), or high (≥1500 METs) (Serón et al., 2010; Balboa-Castillo et al., 2023). The IPAQ-SF is globally recognized for its reliability and validity, offering a practical method for estimating physical activity levels and correlating them with HRV and perceived stress.
- Pittsburgh Sleep Quality Index (PSQI): This 19-item questionnaire evaluated sleep quality over the previous month, scoring results on a scale of 0-21 points: 0-5 (good sleep quality), 6-10 (mild disturbances), 11-15 (moderate disturbances), and 16-21 (severe disturbances) (Nevels et al.,

2023). The PSQI is a sensitive and specific tool for detecting sleep disorders, making it essential for obtaining reliable data on sleep quality.

- Perceived Stress Scale (PSS-10): This 10-item scale measured subjective stress levels over the previous month, with responses scored on a Likert scale from 0 (never) to 4 (very often). Total scores ranged from 0 to 40 points, classified as low (0-13), moderate (14-26), or high (27-40) stress (Baik et al., 2019). The PSS-10 is a reliable instrument for evaluating perceived stress and correlating it with HRV and physical activity levels.
- HRV: HRV was measured in a supine position for 15 minutes, with participants instructed to avoid speaking or moving. The final 5 minutes of data were analyzed, recorded using a Polar® Vantage watch and Polar® H10 heart rate monitor (Nuuttila et al., 2021; Schaffarczyk et al., 2022). Data were exported to the ELITE HRV app and analyzed using Kubios HRV software (Rogers et al., 2022; Vondrasek et al., 2023), focusing on metrics such as RMSSD and the RR/RMSSD ratio. This analysis provided detailed insights into the vagal tone and autonomic balance

Sample size and statistical power

The study included a sample of 32 participants, selected through non-probabilistic sampling based on practical criteria ensuring adequate levels of physical activity and the absence of chronic diseases. A retrospective power analysis was conducted to evaluate the study's capacity to detect significant correlations. Using a significance level of .05 and a moderate effect size (r = 0.4), the statistical power was estimated at approximately 35%.

Although the sample size was small, it was sufficient for basic statistical analyses in a cross-sectional study. According to the Central Limit Theorem, a sample size of 30 or more allows the distribution of the sample mean to approximate normality, enabling the application of parametric statistical methods such as Pearson's correlation, provided other assumptions, such as independence of observations and homogeneity of variance, are met (Sidebotham & Barlow, 2024).

Biases

Potential biases in this study include selection bias, as the sample was non-probabilistically selected, which limits the ability to generalize the results to a broader population. Additionally, information bias is present because the evaluator was not blinded during the administration of the measurement instruments, which could have influenced the interpretation or handling of the data, introducing potential biases in the participants' responses. This type of bias is particularly relevant in subjective measurements, such as perceived physical activity, sleep quality, and perceived stress, where the evaluator's influence can alter responses due to direct interaction with participants. To mitigate these biases, future research could implement a probabilistic selection design and a blinding procedure for both evaluators and participants during data collection.

Data analysis

The data were analyzed using IBM SPSS Statistics version 27.0 for Windows. Normality was assessed using the Shapiro-Wilk test, and homogeneity of variance was tested with Levene's test, confirming the data followed a normal distribution. Descriptive statistics, including measures of central tendency and dispersion (mean, standard deviation, and 95% confidence interval), were provided. For inferential analysis, a multiple linear regression model was employed to examine the relationship between the predictor variables (IPAQ, PSS-10, PSQI, and age) and the outcome variables (RMSSD and RR/RMSSD). A significant level of .05 was set for all analyses. The strength of correlations was categorized as weak (≥ 0.2), moderate (≥ 0.4), strong (≥ 0.6), and very strong (≥ 0.8), based on previous recommendations (Schober et al., 2018).

Results

Table 1 shows the baseline anthropometric characteristics of the study population, with an average age of 20 years, a body composition classified as eutrophic, and a high physical activity level. This is reflected in mild sleep difficulties and moderate self-perceived stress.

Table 1. Sociodemographic characteristics of the study sample (n = 32)

	Mean ± SD	CI 95% (Lower limit - Upper limit)
Age (years)	20.91 ± 2.91	19.86 – 21.96
Weight (kg)	70.56 ± 12.14	65.42 – 75.70
Height (cm)	169.31 ± 9.76	165.79 – 172.83
BMI (kg/m²)	24.56 ± 3.42	25.79 – 24.40
IPAQ (METs)	1947.16 ±496.03	1768.32 - 2125.99
PSQI	10.34 ± 6.27	8.08 -12.60
PSS-10	21.59 ±12.19	17.20 – 25.99

SD: Standard deviation. CI: Confidence interval

Table 2 reports normal resting heart rate, reflecting good cardiovascular health, as indicated by RR intervals. Regarding HRV, there is a predominance of vagal tone expressed through the RMSSD parameter, while the relationship of this parameter with RR intervals indicates an autonomic balance.

Table 2. Characteristics of the heart rate variability in the study sample (n = 32)

	Mean ± SD	CI 95% (Lower limit - Upper limit)
HR (ppm)	63.44 ± 7.49	60.74 – 66.14
RR (ms)	928.29 ± 110.15	918.58 – 998
RMSSD (ms)	67.79 ± 7.77	64.84 – 70.74
RR:RMSSD	14.10 ± .03	14.07 – 14.13

SD: Standard deviation. CI: Confidence interval

Table 3 presents the results of a regression analysis to predict RMSSD. The overall model shows a moderate correlation (R = .47) and an R^2 of .22, indicating that the predictor variables explain 22% of the variability in RMSSD. The Standard Error of the model is 7.22. The model's t-value is 7.34, and the p-value is .14, indicating that the overall model is not statistically significant. Regarding individual variables, IPAQ (METs) shows a positive but non-significant effect on RMSSD (β = .16, p = .39), PSS-10 also shows a non-significant relationship (β = .09, p = .60), and PSQI has no significant effect (β = -.04, p = .82). However, age shows a significant negative relationship with RMSSD (β = -.43, t = -2.48, p = .02), suggesting that age significantly influences heart rate variability, while physical activity, perceived stress, and sleep quality do not have a strong impact on the model.

Table 3. predictive model for RMSSD (n = 32)

	R	R²	Standard error	B	t	p
Total, Model (RMSSD)	.47	.22	7.22		7.34	.14
IPAQ (METs)				.16	.88	.39
PSS-10				.09	.53	.60
PSQI				-.04	-.23	.82
Age (years)				-.43	-2.48	.02

R: correlation coefficient, R^2: model fit coefficient, B: Beta standardized, t: t-statistic, p: p-value.

Table 4 presents the results of a regression analysis to predict the RR/RMSSD ratio. The overall model shows a moderate correlation (R = .42) and an R^2 of .18, indicating that the predictor variables explain 18% of the variability in the RR/RMSSD ratio. The Standard Error of the model is 0.03. Regarding individual variables, IPAQ (METs) does not have a significant effect on the model (β = -.02, p = .92), while PSS-10 shows a negative relationship approaching significance (β = -.35, t = -1.94, p = .06), suggesting that higher perceived stress may decrease the RR/RMSSD ratio. Additionally, PSQI and age do not have a significant effect on the model (β = .13, p = .49 and β = -.14, p = .45, respectively). These findings suggest that perceived stress (PSS-10) may influence the RR/RMSSD ratio, while physical activity, sleep quality, and age are not strong predictors in this model.

Table 4. predictive model for RR/RMSSD (n = 32)

	R	R²	Standard error	B	t	p
Total, Model (RR/RMSSD)	.42	.18	.03			.24
IPAQ (METs)				-.02	-.10	.92
PSS-10				-.35	-1.94	.06
PSQI				.13	.70	.49
Age (years)				-.14	-.77	.45

R: correlation coefficient, R^2: model fit coefficient, B: Beta standardized, t: t-statistic, p: p-value.

Discussion

This study focused on analyzing the relationship between HRV and health determinants such as body composition, physical activity levels, sleep quality, and perceived stress in young Chilean adults with low cardiometabolic risk. A significant negative correlation was observed between age and HRV parameters, such as RR intervals and RMSSD. This suggests that with aging, parasympathetic activity, mainly mediated by the vagus nerve, tends to decline, which is associated with an increased cardiovascular risk. This finding aligns with previous studies linking reduced vagal tone and diminished heart rate variability to higher risks of cardiovascular diseases, such as hypertension and heart failure (Shaffer & Ginsberg, 2017).

On the other hand, a high but non-significant relationship was observed between perceived stress and a lower RR/RMSSD ratio, indicating that both acute and chronic stress can negatively impact the autonomic nervous system. This may induce sympathetic dominance, characterized by reduced parasympathetic activity and increased heart rate, potentially contributing to cardiovascular disorders. These results are consistent with previous research showing how perceived stress affects HRV and vagal modulation, where sympathetic nervous system activation may inhibit the parasympathetic system's ability to regulate heart rate, thereby increasing the risk of chronic diseases (Burlacu et al., 2021; Goodyke et al., 2022; Immanuel et al., 2023). However, the impact of stress on HRV may also be mediated by a complex interaction of factors. While perceived stress is associated with reduced HRV, other factors such as nutritional status, exercise habits, sleep quality, and substance consumption, including caffeine and alcohol, also play a crucial role in autonomic regulation. Indeed, the literature has shown that certain foods, such as those rich in omega-3 fatty acids and some fruits, are associated with improved vagal function, modulating the autonomic stress response (Young & Benton, 2018; Reginato et al., 2020). Furthermore, stress-reactive sleep has been identified as a potential biomarker for greater vulnerability to stress-related sleep disturbances, increasing the risk of elevated depressive symptoms in response to chronic stress. These factors highlight the importance of considering physical activity and sleep quality in stress management and preventing cardiovascular and psychological disorders (da Estrela et al., 2021).

Regarding body composition, although this study did not find significant correlations between HRV and variables such as body composition, the literature has documented that obesity and factors related to abdominal fat distribution negatively affect autonomic health (Espinoza-Salinas et al., 2015; Espinoza-Salinas et al., 2022). These discrepancies may be explained by the cross-sectional design of the study and the small sample size, which limit the ability to detect more complex relationships due to reduced statistical power, potentially making some correlations weaker or undetectable.

Additionally, the high level of physical activity among participants in this study helps explain the modulation of cardiovascular health and autonomic balance. It is well-established that regular exercise, especially of moderate or high intensity, both aerobic and anaerobic, promotes parasympathetic dominance, leading to higher HRV. Physical activity acts as a buffering agent against the negative effects of stress by promoting balance between the sympathetic and parasympathetic systems, thereby reducing the incidence of cardiovascular diseases (Gronwald & Hoos, 2020; Facioli et al., 2021; Marasingha-Arachchige et al., 2022). Furthermore, physical activity improves sleep quality and reduces symptoms of anxiety and depression, factors closely related to autonomic dysfunction and cardiovascular risk (Goel et al., 2021). Thus, physical activity is not only essential for maintaining overall health but also for protecting the cardiovascular system from the harmful effects of chronic stress.

It is essential to consider this study's limitations. First, the small sample size limits the generalizability of the findings to a broader population. Additionally, the cross-sectional design does not allow for causal relationships, only associations between the studied variables. Resting HRV measurements, while valuable, did not account for variations during exercise or acute stress situations, which could have provided a more comprehensive view of autonomic modulation. Where, the lack of control over external factors such as diet, lifestyle habits, and substance consumption may have influenced participant measurements, limiting the accuracy of some correlations. Despite these limitations, this study highlights the importance of integrating cardiovagal dynamics monitoring into preventive strategies, especially in young adults, to detect autonomic imbalances early and promote personalized interventions that enhance cardiovascular health and overall well-being.

Finally, this study emphasizes the need to incorporate HRV monitoring into stress prevention and management strategies, especially in young adults. This suggests that interventions promoting regular physical activity and improving sleep quality could have a positive impact on autonomic modulation and cardiovascular disease prevention. In the future, conducting longitudinal studies with larger samples would be valuable to assess the causality between stress, physical activity, and HRV. Additionally, other lifestyle-related variables, such as diet and substance consumption, could be explored to better understand how they influence cardiovagal dynamics and long-term cardiovascular risk.

Conclusions

The study established significant relationships between HRV and factors such as age and self-perceived stress in young Chilean adults with low cardiometabolic risk. The negative correlation between age and heart rate variability suggests a decrease in parasympathetic activity with aging. Additionally, higher levels of self-perceived stress were associated with reduced vagal modulation, indicating sympathetic predominance.

Although no significant relationships were found with body composition, physical activity levels, or sleep quality, these findings highlight the importance of analyzing cardiovagal dynamics as a tool to assess autonomic balance and its link to psychosocial factors in this population.

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