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Psychophysiological profile of ischemic patients according to their resting heart rate variability: one step closer to training individualization

Perfil psico-fisiológico de personas con cardiopatía isquémica según la variabilidad de la frecuencia cardiaca basal: un paso más hacia la individualización del entrenamiento

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Abstract. Ischemic heart disease continues to be a major cause of morbidity and mortality around the world. Nowadays, research is focusing on the role of the brain-heart axis in autonomic nervous system balance. Resting heart rate variability (HRV) could help to identify the readiness of ischemic patients to achieve cardiac rehabilitation exercise stimulus in a safer manner. The objectives of the study were i) to analyze the resting HRV in ischemic cardiopathy, determining whether it was below or within its normal range, and ii) to identify the effect of the psychophysiological parameters of age, body mass index (BMI), blood pressure, cardiorespiratory fitness, and quality of life. This was a cross-sectional study of patients affected by ischemic cardiopathy. The patients were divided into the nonNormal-HRV or Normal-HRV group according to their normal resting HRV. The HRV temporal and frequency domains were recorded along with heart rate and blood pressure, BMI, cardiorespiratory fitness and auto-perception. The sample comprised men with an average age of 58.64±9.54 years. In total, 43.92% were below their normal resting-HRV range. They were older (*P*<.001, d=.856), had worse auto-perception (*P*<.001, d=.473), and higher systolic and lower diastolic blood pressure (*P*<.001, d=.446; *P*=.007, d=.29). HRV domains correlated directly (*P*<.05) with diastolic blood pressure and inversely with heart rate and age. The percentage of low resting-HRV scores in ischemic patients was higher than expected and was conditioned by age, blood pressure and heart rate. Moreover, the patients had worse auto-perception. All these factors should be considered to optimize cardiac rehabilitation programs.
Keywords: HRV, cardiovascular rehabilitation, training, auto-perception, autonomous nervous system, biomarker.

Resumen. La cardiopatía isquémica sigue siendo la mayor causa de morbilidad y mortalidad en todo el mundo. Actualmente se está investigango el papel del eje cerebro-corazón en el equilibrio del sistema nervioso autónomo. La variabilidad de la frecuencia cardiaca (VFC) basal puede ayudar a identificar si los pacientes están preparados para afrontar la rehabilitación cardiaca de forma segura. Los objetivos fueron i) analizar la VFC-basal de pacientes con cardiopatía isquémica determinando su normalidad, ii) identificar el efecto de los parámetros psicofisiológicos edad, índice de masa corporal (IMC), tensión arterial, fitness cardiorrespiratorio y calidad de vida. Los pacientes fueron divididos en dos grupos según la normalidad de su VFC-basal (Normal-HRV, nonNormal-HRV). Los dominios temporal y frecuencial del HRV, la frecuencia cardiaca, la tension arterial, el IMC, el fitness cardiorrespiratorio y la auto-percepción fueron registrados. La muestra se compuso por hombres con media de edad de 58,64±9,54años. El 43,92% presentó una VFC-basal por debajo de su normalidad. Estos eran más mayores (*P*<,001, d=,856), presentaban peor auto-percepción (*P*<,001, d=,473) y mayor tension sistólica y diastólica (*P*<,001, d=,446; *P*=,007, d=.29). Se encontraron correlaciones significativas (*P*<,05) directas entre la VFC y la tension diastólica, e inversas con la frecuencia cardiaca y la edad. El porcentaje de cardiópatas con una VFC-basal por debajo de su normalidad es superior a lo esperado. Estos valores están condicionados por la edad, la tension arterial y la frecuencia cardiaca. Además, tienen peor auto-percepción. Todos estos factores deberían ser tenidos en cuenta para optimizar los programas de rehabilitación cardiaca.
Palabras clave: VFC, rehabilitación cardiaca, entrenamiento, auto-percepción, sistema nervioso autónomo, biomarcador.

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Introduction

Cardiovascular disease is one of the most important causes of morbidity and mortality worldwide (Vaccarino et al., 2021). Nowadays, research is focusing on understanding the role of the brain-heart axis in the development of these diseases (Seligowski et al., 2022). The connection between the brain and heart is explained by physiological and pathological interactions between the nervous system and the cardiovascular system (Liu et al., 2022). It is the autonomic nervous system (ANS), with its sympathetic and parasympathetic branches, that allows brain structures to participate in cardiac activity and to respond to stressful and/or emotional situations (Manea et al., 2015). However, more recent data (Kukanova & Mravec, 2006; Armour, 2008) have suggested that heart function is also modulated by an intrinsic cardiac nervous system, known as the "little brain". Thus, efferent sympathetic and parasympathetic activity is integrated with the activity occurring in the heart's intrinsic nervous system (Shaffer et al., 2014), all of which contribute to beat-to-beat changes.

In a healthy organism, there is a dynamic relative balance between the sympathetic and the parasympathetic nervous system (Shaffer et al., 2014), with the parasympathetic dominating at rest. This ANS balance is reflected in the heart rate and the blood pressure although it also provokes time variability between each heartbeat (Laborde et al., 2017), referred to as heart rate variability (HRV). According to Shaffer et al. (2014), an optimal level of variability is a predictor of inherent flexibility, adaptability and resilience, which is related to healthy function and well-being. However, as a consequence of ischemic heart disease, the sympathetic system prevails over the parasympathetic (Seligowski et al., 2022). Sympathetic predominance is associated with a decrease in HRV (Rodas et al., 2008), and low HRV has been confirmed as a strong and independent predictor of future health problems and all-cause mortality (Tsuji et al., 1994), especially after myocardial infarction (Hadaya & Ardell, 2020). Polypharmacy is commonly used in this kind of population to improve their clinical diagnosis although non-cardiovascular medications are almost always prescribed (Goyal et al., 2019); these are associated with adverse outcomes including falls, disability, and hospitalization. Cardiac rehabilitation has recently been approved for enhancing several other aspects of chronic disease management, along with addressing medication optimization, as a new model of ischemic patient care.

Exercise training is one of the five core components of cardiac rehabilitation (Mehra et al., 2020) together with nutritional counselling, risk factor modification, psychosocial management, and patient education. According to the scientific evidence, high-intensity interval training (HIIT) reported greater benefits for overall cardiac patient performance than a moderate-intensity program (Ballesta et al., 2019; Collados-Gutiérrez & Gutiérrez-Vilahú, 2023; Li et al., 2023). However, recent studies (Carrasco-Poyatos et al., 2022; McGregor et al., 2023) have recommended low volumes of HIIT training owing to the lack of adaptability found in ischemic patients during their trials. In the sports context, it is well known that Selye's general adaptation syndrome (GAS) tries to explain how a disturbance necessitates the generation of biological adaptations and functional enhancements (Cunanan et al., 2018). However, training responses vary greatly depending on multiple underlying factors (Kiely, 2012), including the basal ANS dynamics. This idea was used by Kiviniemi et al (2007) to propose a training schema based on the resting HRV. In this regard, the training stimulus should be decreased when the resting HRV is low or increased when it is high. Resting HRV becomes a potential basal biomarker allowing one to identify the individual endogenous load before a stressful stimulus such as exercise (Parrado et al., 2010); this favors safer intervention and helps to avoid the occurrence of other cardiac events.

Resting HRV corresponds to the basal HRV value measured prior to a stressful stimulus (Laborde et al., 2018). According to Laborde et al. (2017), HRV analysis can be performed in the time-domain, in the frequency-domain, and with non-linear indices. Following these authors, in the time-domain, the most representative indicators are SDNN, rMSSD, or pNN50. The former is linked to the cyclic components responsible for HRV; the rMSSD reflects vagal tone and is highly correlated with high-frequency (HF) but it is not mediated by respiratory influences. The pNN50 is also correlated with rMSSD and HF so reflects vagal tone (Shaffer et al., 2014). In the frequency-domain, the low frequency (LF) band reflects a mix between sympathetic and vagal influences (Malik, 1996), and HF is influenced by breathing when breathing rates are between nine cycles per minute (0.15 Hz) and up to 24 cycles per minute (0.40 Hz) (Malik, 1996), thus reflecting vagal tone. The non-linear indices SD1 and SD2 can be seen as indicators of vagal activity and reduced cardiac vagal control which are associated not only with physiological but also withpsychological strain and stress (Melillo et al., 2011). Nonetheless, there are multiple factors that have an influence - circadian rhythms, core body temperature, hypoxia, metabolism, or hormones (Shaffer et al, 2014; Rochel-Vera et al., 2024) are such examples. Moreover, age is considered a determining factor, with resting HRV decreasing as the years go by (Hernández-Vicente et al., 2020). High blood pressure (Ishaque et al., 2021), a high body mass index (BMI) (Koenig et al., 2014), low levels of physical fitness (Graham et al., 2019), or impaired mental health and quality of life (Dormal et al., 2021) also have a negative influence on resting HRV values. Cardiovascular diseases such as myocardial infarction or hypertension reflect reduced regulatory capacity (Berntson et al., 2008, Schroeder et al., 2003) as well as other pathologies including anxiety, depression, and asthma (Agelink et al., 2002; Lehrer et al., 2004; Cohen and Benjamin, 2006).

Despite the importance of HRV in the context of cardiac rehabilitation as an indicator of ANS balance and the patients' readiness to achieve a higher or lower-intensity stimulus, there is a lack of information in the literature regarding the resting HRV of ischemic patients or the factors that influence it. Moreover, to the best of our knowledge, only two studies (Carrasco-Poyatos et al., 2022; Manresa-Rocamora et al., 2022) have used it as a basal biomarker to design exercise training for cardiac patients. Therefore, the objectives of this study were i) to analyze resting HRV in patients with ischemic cardiopathy, determining whether it was below or within its normal range, and ii) to identify the effect of the psychophysiological parameters of age, body mass index, blood pressure, cardiorespiratory fitness, and quality of life. The hypotheses were that, in most cases, the resting HRV would be below its normal range in patients with ischemic cardiopathy and that this would be significantly conditioned by the psychophysiological parameters mentioned above.

Materials and Methods

Study design, settings, and participants

This descriptive study followed a cross-sectional design (Sánchez-Martín, Ponce-Gea et al., 2024). Patients from University Hospital Torrecárdenas (Almería, Spain) affected by ischemic cardiopathy were studied after having been attended by the cardiologist, having their physical condition level determined, and medication prescribed. Following this first phase, they were encouraged to participate in the hospital's cardiovascular rehabilitation program, which was conducted by a multidisciplinary group comprising a rehab doctor, a physiotherapist, a nurse, and a sports sciences graduate. The protocol followed during the cardiovascular rehabilitation program has already been published (Carrasco-Poyatos et al., 2022). It was also retrospectively approved by the University of Almería's Bioethics Committee (UALBIO2019/026) and registered with ClinicalTrials.gov. as NCT04150952. The eligibility criteria, the sources, the participant selection methods, and the consent form used are all detailed in the published protocol. The present study was conducted in accordance with the World Medical Association's Declaration of Helsinki and reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement (Vandenbroucke et al., 2007; Sánchez-Martín et al., 2024).

Variables and measurement

The study's primary outcome was the resting LnrMSSD. The secondary outcomes were: i) the other HRV domains, ii) the resting heart rate and blood pressure; iii) the body mass index (BMI); iv) cardiorespiratory fitness; and v) quality of life. Participants were instructed not to consume sympathetic system stimulant substances, such as coffee, tea or chocolate, in the 24 hours prior to assessment.

The resting HRV was measured just before starting the exercise session to record the ischemic patients' basal autonomous nervous system modulation. It was recorded for 1' while the patients were comfortably seated and breathing normally. There were made two measures. To carry out the recording, the HRV4Training smartphone application, validated by Plews et al., (2017), was used. The app records the time domain SDNN, rMSSD and pNN50, and the frequency domains LF and HF. The LF/HF quotient was calculated to determine the sympathetic-parasympathetic balance (Eckberg, 1997). The HRV normality was determined using rMSSD as the vagal index, based on its greater suitability and reliability than other indexes (Plews et al, 2012; Javaloyes et al, 2019). To assume a normal distribution, the Napierian logarithm of the variable rMSSD (LnrMSSD) was calculated. Following Javaloyes et al (2018) procedure, it was considered a normal LnrMSSD if the mean of the measurers did not fall outside the upper or the lower statistical extreme values. The resting heart rate and the systolic and diastolic blood pressure were also recorded before the training session (and always before the HRV recording); an Omron M3 sphygmomanometer was used for this purpose. The cardiorespiratory fitness data were recorded by the cardiologist during the screening and selection phase. The Bruce protocol treadmill test was employed as this is recommended for heart disease patients (Herward, 2008). The VO2max was calculated using the formula described by McConnell and Clark [VO2max=2.282(time)+8.545] (McConnell & Clark, 1988). The BMI and quality of life were recorded on the first day of the first phase. Weight and height were recorded using a SECA 756 measuring rod with a flat scale. BMI was calculated as BMI=kg/m2. Quality of life was measured using the self-administered validated Spanish version of the MacNew QLMI (Brotons-Cuizart et al., 2000). This consisted of 27 items on a scale from 1 to 7, where 1 is the worst score and 7 the best. The physical, emotional, and social dimensions were calculated for the corresponding items using the lineal mean. The global score can also be calculated using the lineal mean of all the items.

Sample size and power

Assuming a standard deviation of 7.15 ms for the rMSSD (Mendes et al., 2010) and an estimated error (d) of .75, a total of three hundred and forty-nine subjects would comprise a valid sample size, providing a 95% confidence interval (CI) (n=CI2 x d2/SD2). Thus, the final study sample size (n=362 registries) provided a power of 100%, and the nonNormal-HRV group (n=159) and the Normal-HRV group (n=203) provided a power of 99.4% and 99.9%, respectively, if between and within a variance of 0.5. The calculations for establishing the sample size were performed using RStudio 3.15.0 software. The significance level was set at $P \leq 0.05$.

Bias

Patient distribution was randomly implemented through a central telephone registration system. Both the participants and the research staff were blinded. An excel sheet was used to implement the patient randomization process and to record the data. This process was carried out by the principal researcher.

Statistical methods

The Kolmogorov-Smirnov test was used to determine the normal distribution of the variables. Levene's test was also performed to determine the homogeneity of variance. The logarithm in base 10 was calculated for the HRV domains to reduce heteroscedasticity. The descriptive analysis included the mean, standard deviation, and range (Ibáñez-López et al., 2024). An unpaired sample t-test was used to determine differences between groups. The treatment magnitude was calculated using the standardized mean differences (Cohen's effect size) together with the 95% confidence intervals. An effect size value of 0.20 indicates a small effect, 0.50 a moderate effect, and 0.8 a large effect (Hopkins et al., 2009). A bivariate Pearson correlation (r) was utilized to assess the relationships between the variables together with the r2 regression. The correlation thresholds were 0.1, small; 0.3, moderate; 0.5, large; 0.7, very large; and 0.9, nearly perfect (Hopkins et al., 2009). Statistical analyses were performed using Jamovi 2.3 (2022) computer software. The level of significance was set at $P \leq 0.05$ and all P values were 2-tailed.

Results

From October 2021 to July 2022, 400 HRV recordings were made, of which 362 were used for the analysis. The reasons for non-participation are detailed in Figure 1.

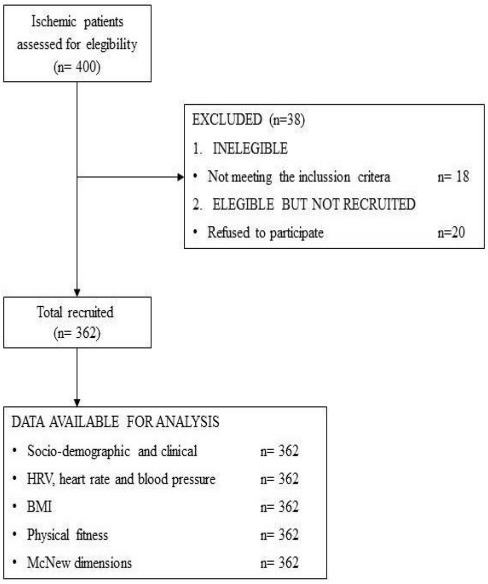

Figure 1. Participant Flow Diagram.
Note. BMI=body mass index. Flow diagram from Hay et al. (2003)

The sample was composed of men with an average age of 58.64±9.54 years. Most of them (54.3%) were diagnosed with angina, while 27.7% presented with an ST-elevation myocardial infarction. The comorbidities were: hypertension (40.9%), family history (45.45%), diabetes (9.1%), current smoking (4.54%) and mental health diseases (4.54%). The patients were taking the following medications: beta-blockers (54.26%), anti-hypertensives (45.45%), antiplatelets (80.96%), statins (86.1%), anti-anginals (31.82%), and diuretics (23.01%). Their mean BMI was 27.3±3.2 kg/m2, and their mean VO2max was 29.62±6.55 ml/kg/min. Regarding their auto-perception, the mean McNew global score was 4.77±1.32, with the emotional, social and physical scores as follows: 4.43±1.08, 4.79±1.43, and 5.12±1.54.

When the resting HRV recording was made, 159 registries were below the normal LnrMSSD range, and the patients were thus assigned to the nonNormal-HRV group. Conversely, 203 registries were within the normal LnrMSSD range and thus they were assigned to the Normal-HRV group (Figure 2).

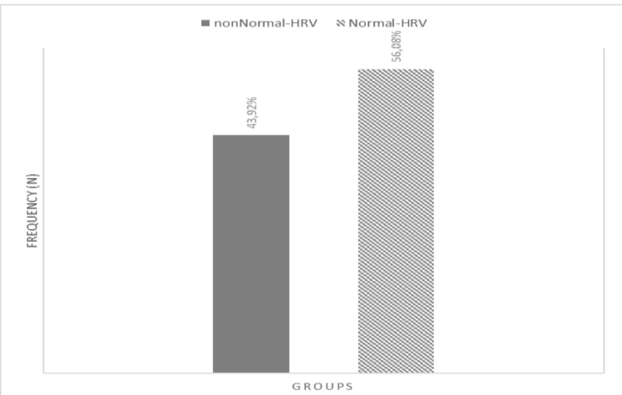

Figure 2. Patients' distribution according to their resting LnrMSSD

The patients in the nonNormal-HRV group were statistically older, had worse auto-perception (either in the McNew global score or in its' three dimensions), had higher systolic and lower diastolic blood pressure, and presented lower scores in the rest of the HRV domains (Table 1).

Table 1.
Inter-group differences after resting HRV recording

Variables	n	Mean	SD	*P*	95% CI for Mean Difference		ES η²
					Lower	Upper	
Age (years)							
nonNormal-HRV	159	62.83	8.69	<0.001	.624	1.086	.856
Normal-HRV	203	55.3	8.87				
BMI (kg/m2)							
nonNormal-HRV	159	27.6	2.9	.102	-.036	.387	.176
Normal-HRV	203	27.04	3.41				
VO2max (ml/kg/min)							
nonNormal-HRV	159	29.71	4.66	.82	-.186	.235	.024
Normal-HRV	203	29.55	7.74				
McNew Global score							
nonNormal-HRV	159	4.42	1.59	<0.001	-.689	-.255	-.473
Normal-HRV	203	5.04	.99				
McNew Emotional score							
nonNormal-HRV	159	4.2	1.3	<0.001	-.617	-.187	-.428
Normal-HRV	203	4.62	.81				
McNew Social score							
nonNormal-HRV	159	4.48	1.74	<0.001	-.61	-.18	-.396
Normal-HRV	203	5.04	1.07				
McNew Physical score							
nonNormal-HRV	159	4.61	1.77	<0.001	-.835	-.393	-.615
Normal-HRV	203	5.52	1.18				
Systolic Blood pressure (mmHg)							
nonNormal-HRV	159	116.11	11.02	<0.001	.23	.662	.446
Normal-HRV	203	111.24	10.81				
Diastolic Blood pressure (mmHg)							
nonNormal-HRV	159	65.76	8.24	.007	-.502	-.077	-.29
Normal-HRV	203	67.81	5.92				
Heart Rate (bpm)							
nonNormal-HRV	159	60.56	.75	.651	-1.638	2.618	.047
Normal-HRV	203	60.29	.54				
LnSDNN (ms)							
nonNormal-HRV	159	1.72	.02	.02	-.109	-.009	.251
Normal-HRV	203	1.75	.01				
LnrMSSD (ms)							
nonNormal-HRV	159	1.82	.02	.061	-.11	.002	.202
Normal-HRV	203	1.85	.01				
LnpNN50 (ms)							
nonNormal-HRV	159	1.48	.03	.003	-.161	-.033	.319
Normal-HRV	203	1.54	.02				
LnLF (Hz)							
nonNormal-HRV	159	-1.39	.03	.002	-.176	-.039	.331
Normal-HRV	203	-1.33	.02				
LnHF (Hz)							
nonNormal-HRV	159	-1.14	.02	.019	-.121	-.011	.252
Normal-HRV	203	-1.12	.01				
LnLF/HF (Hz)							
nonNormal-HRV	159	-.25	.02	.135	-.097	.013	.161
Normal-HRV	203	-.23	.01				

Note. BMI=body mass index. Ln represents the logarithm in a base 10 of each HRV domain. HF=high frequencies; LF=low frequencies; pNN50=the percentage of successive normal sinus RR intervals >50ms; rMSSD=the root mean square of successive differences; SDNN=the standard deviation of al R-R intervals.

On the other hand, statistically significant and direct correlations were found between each of the HRV domains and diastolic blood pressure (LnSDNN, r2=.08; LnrMSSD, r2=.06; LnpNN50, r2=.06; LnLF, r2=.06; LnHF, r2=.08), and there were statistically significant and indirect correlations with heart rate (LnSDNN, r2=.13; LnrMSSD, r2=.08; LnpNN50, r2=.05; LnLF, r2=.05; LnHF, r2=.03). Moreover, every HRV domain correlated statistically with each other, and age was inversely correlated with LnSDNN (r2=.01), LnpNN50 (r2=.015) and LnLF (r2=.03) (Table 2).

Table 2.
Basal correlations between variables

Variables	Mean	SD	1	2	3	4	5	6	7
1. Age (years)	58,64	9,54							
2. Diastolic Blood pressure (mmHg)	66,9	7,11	,251 <,001						
3. Heart Rate (bpm)	60,29	10,1	,019 .723	,101 ,059					
4. LnSDNN (ms)	1,75	0,24	-,115 ,031	,292 <,001	-,356 <,001				
5. LnrMSSD (ms)	1,75	0,24	-,097 ,07	,251 <.001	-,279 <,001	,837 <,001			
5. pNN50 (ms)	1,54	0,31	-,124 ,02	,243 <,001	-,22 <,001	,661 <,001	,756 <,001		
7. LnLF (Hz)	-1,33	0,33	,17 ,001	,246 <,001	-,229 <,001	,585 <,001	,567 <,001	,467 <,001	
8. LnHF (Hz)	-1,11	0,26	-,05 ,345	,286 <,001	-,182 <,001	,619 <,001	,665 <,001	,583 <,001	,634 <.001

Discussion

The present study showed that, after ischemic cardiopathy, nearly half of all the patient registries presented an HRV below their normal range (43.92%). The baseline data showed that those in this group were older patients with lower scores in emotional, social, and physical auto-perception, as well as higher systolic and lower diastolic blood pressure. Moreover, the rest of the HRV domains showed the same tendency as the LnrMSSD. In addition, lower HRV scores were associated with lower diastolic blood pressure, higher heart rates and age.

Although it was hypothesized that most of the participating patients would have an HRV below their normal range, the results showed that 43.92% of them were below it. This is an interesting finding that suggests that the brain-heart connection is somewhat normalized in most patients after ischemic cardiopathy, and that this may be due mainly to the pharmacological treatment they receive. However, we must not lose sight of the fact that approximately half of the patient registries did not show a normalized cardiovascular response even though they received pharmacological treatment, in contrast to the data obtained by García-Flores et al (2023) in a sample of healthy adults. This is important to note since an HRV below the normal range indicates autonomic imbalance (Rodas et al., 2008) and this is related to impaired ventricular function, structural remodeling with increased myocyte apoptosis, ventricular dilation, and an increased risk of electrical instability and arrhythmias (Klein et al., 2010). In this regard, it should be pointed out that the nonNormal-HRV group also presented statistically higher systolic blood pressure, which is a fundamental variable in the cardiovascular response system, the regulation of which conditions HRV adaptability (Lehrer et al., 2007). Furthermore, these patients had a lower diastolic blood pressure, which is an early indicator of increased cardiac output/stroke volume and/or arterial stiffness in young adults and a late indicator of ventricular-arterial stiffness in the elderly (Franklin, 2007). Both data sets indicate that almost half of the patients assessed in this study presented a pathological picture, coinciding with what the scientific literature suggests (Rodas et al., 2008; Seligowski et al., 2022); this must be taken into account when carrying out cardiac rehabilitation programs so as not to overstimulate the cardiovascular system and generate adverse events. For subjects who are susceptible to a poor training response in standard training programs, individualized training programs are recommended. Following Kiviniemi et al. (2007), the basic idea was to decrease the training stimulus when the HRV decreased and to keep the training stimulus high when the HRV remained the same or increased.

Differences between groups were also found in age. The nonNormal-HRV group were statistically older than the normal-HRV group. Moreover, age was inversely associated with LnSDNN, LnpNN50 or LnLF. Although there were no statistical correlations between age and the other HRV domains, the study by Raphaely Beer (2018) reported that all the domains correlated between each other, presenting very high regressions. In this regard, we can predict that every HRV domain will work along the same lines (with a probability between 32% and 70%), allowing us to inversely correlate age to HRV in ischemic patients. This was reported in a previous study by Carrasco-Poyatos et al. (2023). In addition, Hernández-Vicente et al. (2020) recently demonstrated a clear decrease in the main parasympathetic HRV variables with age. However, it is important to point out that in their study they compared a group of young people (18-26 years) with octogenarians (80-90 years) and centenarians (>100 years) who had no heart disease pathologies or took any cardiac medication. In the present study, the age difference between the groups was only 7.53±.18 years, with mean ages of 62.83 years in the nonNormal-HRV group and 55.3 years in the Normal-HRV group. As pointed out by Grässler et al., (2021) normal ageing processes cause impaired autonomic cardiac control and this manifests in reduced parasympathetic modulation of the cardiovascular system. However, our data suggest that the reduction in the brain-heart regulatory capacity in patients with ischemic pathology is exacerbated by age, even in people of similar ages. Accordingly, it is recommended that every HRV domain is analyzed in cardiac patients to carefully determine the influence of the variables. Age should also be considered in this population when designing a cardiac rehabilitation program.

Likewise, emotional, social, and physical auto-perception was statistically different between groups, being lower in the group whose HRV was below the normal range. Moreover, there was a statistically significant association between HRV and global auto-perception, meaning that patients with higher auto-perception had higher HRV scores. Our work accords with studies looking at psychophysiological variables, such as the one by Thayer et al. (2009), which found an association between higher levels of resting HRV and better executive function, emotion, health, and better body self-regulation overall. This supports the theory posited by Beauchaine, 2001, arguing that HRV is an indicator of psychological resilience and behavioral flexibility, reflecting the individual's capacity to adapt effectively to changing social or environmental demands. It has been demonstrated that ischemic patients use unsuitable coping mechanisms, such as denial-avoidance or blame, to overcome a stressful experience such as heart disease (Zavala-Yoe et al., 2015). This, together with their lifestyles and biology, is closely related to serious relapses or death (Stein et al., 2005). Moreover, a meta-analysis carried out by Moritz et al. (2000) provided clear evidence of a significant relationship between self-efficacy and performance in sport, pointing out that self-efficacy is both a cause and effect of performance. Thus, this relationship between HRV and auto-perception provides further evidence that HRV is not only an indicator at the physiological level but also at the psychological level, indicating the ischemic patients' self-regulatory capacity and adaptability. Additionally, this finding highlights the need to include psychological therapies within the multidisciplinary intervention in cardiac rehabilitation to improve the quality and effectiveness of ischemic patient therapy.

In light of these results, the use of resting HRV as a basal biomarker is recommended to design safer cardiac rehabilitation programs. This means that HRV is an interesting specific indicator for ischemic patients′ internal load, likewise for healthy adults or athletes (Barreto et al., 2023; Capdevila et al., 2024; García-Flores et al., 2023; Nieto-Jiménez et al., 2020). According to the normality of the resting HRV, higher or lower intensity interventions could be carried out by ischemic patients more safely, controlling the training impact in this population physical condition and its impact in public health. However, the patients' age, blood pressure, and heart rate should also be considered together with the resting HRV scores to individualize the program as much as possible. Furthermore, it is important to provide a multidisciplinary treatment that encompasses and addresses a variety of aspects such as physical exercise, emotional and social states, food, and sleep, amongst others.

Conclusion

Almost half of the middle-aged patients with ischemic cardiomyopathy have resting HRV scores below their normal range. They are older, have worse auto-perception, and suffer from blood pressure imbalance. Lower resting HRV scores are also conditioned by age, blood pressure, and heart rate - hence, they should be considered when designing safer cardiac rehabilitation programs. In this regard, multidisciplinary interventions including self-regulation techniques are recommended.

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