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Research Article

The Relationship Between Perceived Stress Scale and Heart Rate Variability in Healthy Adults

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Abstract

Aim: The purpose of this research is to investigate how perceived stress levels relate to heart rate variability (HRV) among healthy adults.

Material and Methods: The study was conducted prospectively and cross-sectionally from December 15, 2024 to February 15, 2025. The study included 80 healthy adults aged 18-55 years without chronic diseases. Participants were administered the Perceived Stress Scale (PSS), after which HRV parameters were measured. Along with the Stress Index (SI), the standard deviation of the time intervals between normal heartbeats (SDNN) and the Poincaré chart indices SD1, SD2 and the SD2/SD1 ratio were measured.

Results: PSS was negatively correlated with SD1 and SDNN, and positively correlated with the SD2/SD1 ratio (r = -0.446, r = -0.482, and r = 0.401; p < 0.001, respectively). There was no significant difference between the groups in terms of SD2 parameter. There were significant differences between the low- and high-stress groups for SI, SD1, SD2/SD1 ratio, SDNN, and heart rate parameters (p<0.001, p=0.001, p=0.002, p<0.001, p<0.001, p<0.001, respectively). However, no significant difference was found between the groups in terms of SD2 parameter.

Conclusion: This study revealed that perceived stress level was significantly associated with HRV parameters in healthy individuals and that especially SD1, SDNN, SD2/SD1 ratio and heart rate were sensitive to stress level. The findings suggest that increased stress level may suppress autonomic nervous system regulation, especially parasympathetic activity, and cause sympathetic response to become dominant.

Keywords: Autonomic nervous systems, Heart Rate Monitoring, Psychological Stress Measurement

INTRODUCTION

Stress is defined as a mental trauma or a mental health problem and is a condition that negatively affects both physical and psychological health (1). Stress is a physiological process consisting of the stages of rest, tension, reaction and relaxation, respectively (2). Short-term, mild stress can help an individual adapt to environmental stimuli. However, long-term intense stress can negatively affect health and reduce quality of life (3). Chronic stress is the internal turmoil and constant feeling of pressure that a person experiences due to their inability to achieve long-term emotional stability (4).

When a person encounters environmental stress, the hypothalamic-pituitary-adrenal axis and the sympathetic-adrenal-medullary systems come into play. The brain activates the autonomic nervous system (ANS) and increases the respiratory rate and heart rate by secreting norepinephrine, thus reaching more blood to the muscles (5). Life-threatening situations, traumatic injuries, socio-economic problems, sedentary lifestyles, or being exposed to or witnessing sexual violence can cause stress to become chronic (6). It has been shown that when stress becomes chronic, it causes pathophysiological processes such as myocardial infarction and myocardial ischemia, resulting in cardiovascular and sympathetic nervous system disorders (7). It has been shown that chronic hypothalamic-pituitary-adrenal axis negatively affects heart rate and blood pressure (8). It has been stated that psychological stress can cause hypertension and systemic atherosclerosis by creating a burden on the cardiovascular system (9). The effect of stress on the ANS has been revealed to result in sympathetic hyperactivity and parasympathetic hypoactivity (10).

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Chronic stress affects not only the cardiovascular system but also the immune system. Increased stress activates the immune system, resulting in increased levels of inflammatory molecules. Interleukin-6 (IL-6), C-reactive protein (CRP) and tumor necrosis factor alpha (TNF-α) are some of the inflammatory molecules that increase in this process (11). Zefferino et al. have shown that chronic stress potentiates the inflammatory response by raising interleukin 1-beta (IL-1β) levels in the body (12). Acute stress increases the production of chemotaxis and adhesion molecules. This increase facilitates the migration of immune cells to sites of infection or inflammation. In contrast, chronic stress weakens antibody production, reducing the body's resistance to infection (13). During chronic stress, the immune system increases the level of inflammatory cytokines such as IL-6 in the blood, increasing the risk of cardiovascular diseases, type 2 diabetes, psychiatric diseases and some types of cancer (14).

Changes in the time interval between heartbeats are called heart rate variability (HRV), and these changes provide an important indicator of the status of the sympathetic and parasympathetic branches of the ANS (15). In predicting ANS disorders in chronic diseases, meaningful data on sympathetic-parasympathetic balance can be obtained by using time and frequency dependent HRV parameters (16). A high HRV is characterized by being healthy, while a low one indicates ANS dysfunction and disease risk (17). High stress levels may be associated with low HRV (18). Emotional disorders cause irregular ANS activity, suggesting that HRV may be an effective biomarker for assessing stress levels (19).

The aim of this study was to investigate how perceived stress is related to HRV in healthy adults and to assess differences in HRV measurements between groups with low and high perceived stress.

MATERIAL AND METHODS

Study Design

This study was designed as a prospective cross-sectional investigation and was carried out over the period from December 15, 2024, to February 15, 2025. Within the prospective approach, data were collected prospectively within a predefined protocol over a defined period of time. The cross-sectional design involves a single assessment of the participants' current health status and physiological responses during the time period in which the study is conducted. This type of research model was chosen to describe the current situation in a specific population and to examine possible relationships between variables. The study was conducted under controlled laboratory conditions, and data reliability was increased thanks to the standardized measurement environment. Participant selection was based on voluntariness; healthy individuals who were found suitable according to the inclusion and exclusion criteria were included in the sample. The Igdir University Non-Interventional Clinical Research Ethics Committee approved the study (Date: 31.11.2024 and Decision Number: 12/1). Individuals participating in the study were asked to read, approve and sign the written informant consent. The Declaration of Helsinki was followed in the conduct of this investigation.

Participants

The universe of this study consists of healthy individuals who do not have any chronic or acute diseases and who fit into the age range determined during the research period (18–55 years). The universe covers an accessible population of healthy adult individuals in the society based on voluntary participation. Participants were selected using the convenience sampling technique, a non-probability sampling strategy. This approach was deemed necessary due to the limited timeframe and the specific laboratory setting in which the study was conducted, along with constrained resources, which required the researcher to select participants from individuals who were readily accessible. Convenience sampling is an effective method that allows the researcher to quickly collect data from readily available and suitable participants. Especially considering the practical limitations such as time, cost, access limitation and measurement in the laboratory environment, it was possible to reach a sufficient number of healthy individuals in a short time with this sampling method (20). In our study, a homogeneous sample group was effectively reached by convenience sampling method to examine physiological responses in a specific group.

Study Procedure

After the participants were invited to the Physical Therapy laboratory, their general health status was initially checked through the E-Pulse (National Health System) system with the permission of the participants to determine whether they met the study inclusion criteria. Basic demographic characteristics of participants who met the study criteria were recorded. Then, the Perceived Stress Scale-14 questionnaire was administered to the participants. Finally, 5-minute HRV measurements were completed.

Data collection

Demographic Characteristics

Physical characteristics of the participants such as age (years), gender, height (centimeters) and weight (kilograms) were recorded. Height and weight measurements were made using a Medikaltec (BYH01, Ankara, Türkiye) device. Participants' body mass index was determined using the standard formula (BMI; kg/m2).

Perceived Stress Scale (PSS)

The perceived stress level was assessed using the Perceived Stress Scale (PSS). This scale consists of 14 items (21). Cohen et al. created the PSS first, and Eskin et al. later carried out a validity and reliability assessment in Turkey (21, 22). The PSS consists of a five-point Likert scale (score 0–4). Reverse-scored items are 4, 5, 6, 7, 9, 10, and 13. The lowest and highest scores that participants can obtain are between 0-56.

Heart Rate Variability (HRV)

HRV was recorded with a Polar H7 (Polar Electro Oy, Kempele, Finland) device. The Polar H7 device was aligned to the heart level with a belt across the chest, and HRV was measured for 5 minutes while the participants were in a long sitting position. In our study, a short-term HRV recording of 5 minutes was chosen. The literature indicates that this duration is widely used as a valid and reliable method for assessing autonomic nervous system activity in healthy individuals (23). The HRV measurement standardization protocol of Catai et al. was followed. The room temperature was kept between 20-22°C thanks to the air conditioning system in the Physical Therapy Laboratory where the study was conducted (17). The study was completed during the daytime between 08.00-15.00. Before the data was recorded, the laboratory where the measurement would be made was introduced to the participants. Before the HRV measurement, the heart rate was measured and in individuals whose pulse was higher than normal (due to physical effort), 30 minutes were waited for the pulse to drop to the normal range. During the measurement, the participants were ensured to be in a long sitting position on the stretcher. Participants were instructed not to look at their cell phones during the measurement to avoid distraction. The measurements were instantly transferred to Iphone SE (third generation) with Polar Flow application. Recorded data were analyzed with Kubios HRV software.

The stress level was measured with the Stress Index (SI) parameter calculated using HRV. SI, one of the HRV sub-parameters, is a parameter produced from the Baevsky SI formula and reflects the stress on the cardiovascular system (24). SI provides data that allows individuals to monitor their stress levels simultaneously (25). The nonlinear parameters SD1, SD2 and SD2/SD1 ratio included in the Poincaré chart analysis were recorded. The standard deviation of the time intervals between regular heartbeats (SDNN) was also measured. SD2 and SDNN reflect the mutual influence of the sympathetic and parasympathetic nervous systems, while SD1 is an indicator of parasympathetic activity. In addition, the SD2/SD1 ratio is an important parameter used in the evaluation of sympathetic and parasympathetic balance (26).

Heart rate

Heart rate data were collected from the participants' upper arm as they maintained a long sitting posture. Omron M2 (Basic, Hem-721j-e) device was used for heart rate measurement. Measurement was performed on the right arm of each participant.

Statistical Analysis

To analyze the data, IBM SPSS version 26.0 was used. While categorical variables are expressed with numbers and percentages, continuous variables are presented with mean, standard deviation, median and minimum-maximum ranges. Whether the data were suitable for normal distribution was determined using the Kolmogorov-Smirnov test. Participants were divided into high (PSS>24) and low stress (PSS<24) groups according to the median (median=24) value of PSS value. When comparing HRV parameters between groups based on PSS stress levels, the Mann Whitney u test was used for data that did not indicate a normal distribution and the Independent Samples t test was used for data that did. Pearson correlation test (normally distributed) and Spearman correlation test (not showing normal distribution) were used for correlation between HRV variables and PSS. Correlation coefficient (r) ≥ 0.4 was considered satisfactory. According to the correlation coefficient (r) values; 0.00-0.20 was interpreted as poor, 0.21-0.40 as moderate, 0.41-0.60 as good, 0.61-0.80 as very good and 0.81-1.0 as excellent relationship (27). The significance limit was determined as 0.05. Values below this value were considered statistically significant.

RESULTS

Eighty healthy individuals (37 male, 43 female) participated in the study as indicated in the flow chart (Figure 1). The participants had an average age of 25.05±11.17 years and an average BMI of 21.34±2.43 kg/m². The individuals' basic clinical and demographic information is shown in Table 1.

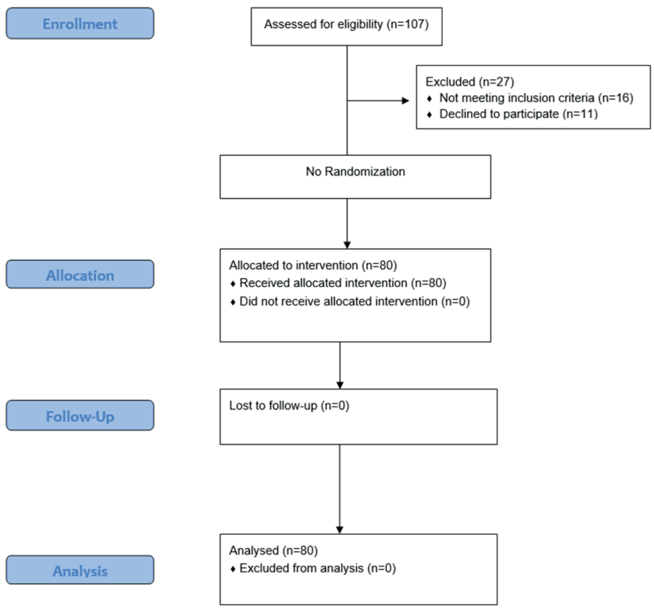

Figure 1. Flow diagram of the study

PSS and SI showed a very good positive correlation (r=0.638; p<0.001). There was a good negative correlation between PSS and both SD1 and SDNN, while a good positive correlation was noted with the SD2/SD1 ratio (r = -0.446, r = -0.482, r = 0.401; p<0.001, respectively). A moderate positive correlation existed between PSS and heart rate (r=0.304; p=0.006), but no correlation was found with SD2 (p>0.05) (Table 2).

When comparing the low stress and high stress groups based on perceived stress levels, significant differences were identified in SI, SD1, SD2/SD1 ratio, SDNN, and heart rate parameters (p<0.001, p=0.001, p=0.002, p<0.001, p<0.001, respectively). However, no significant difference was observed between the groups concerning the SD2 parameter (p>0.05) (Table 3).

Table 1. Basic demographic and clinical characteristics of participants

	Mean±SD (n=80)
Age, year	25.05±11.17
BMI, kg/m2	21.34±2.43
Gender (F/M), n	43/37
PSS	24.74±7.10
SI, ms–2	25.77±8.42
SD1, ms	5.02±2.17
SD2, ms	18.64±7.36
SD2/SD1	5.24±4.81
SDNN, ms	29.78±16.91
Heart rate, bpm	80.65±11.98

BMI: Body Mass Index; F: Female, M: Male; PSS: Perceived Stress Scale; SI: Stress Index; SD1, Standard deviation of minor axis of Poincare' Plot; SD2, Standard deviation of major axis of Poincare'x Plot; SDNN: Standard deviation of all ECG complex intervals, SD: Standart deviation.

Table 2. Correlation between PSS and HRV parameters

		PSS	SI	SD1	SD2	SD2/SD1	SDNN	Heart rate
PSS	r	1.000	0.638	-0.446	0.149	0.401	-0.482	0.304
	p	.	<0.001b	<0.001a	0.186a	<0.001b	<0.001b	0.006b

[a]Pearson correlation test, bSpearman correlation test, BMI: Body Mass Index; F: Female, M: Male; PSS: Perceived Stress Scale; SI: Stress Index; SD1, Standard deviation of minor axis of Poincare' Plot; SD2, Standard deviation of major axis of Poincare'x Plot; SDNN: Standard deviation of all ECG complex intervals, SD: Standart deviation.

Table 3. Comparison of HRV parameters according to PSS score

	Low Stress (n=44)	High Stress (n=36)	P
SI, ms–2	23.40 (2.4-31.5)	31.90 (20.4-46.5)	<0.001b
SD1, ms	5.73±2.02	4.15±2.05	0.001a
SD2, ms	17.60±8.11	19.91±6.22	0.164a
SD2/SD1	3.17 (0.17-29.14)	4.71 (1.54-19.85)	0.002b
SDNN, ms	35.20 (11.3-63.6)	14.85 (6.4-67.2)	<0.001b
Heart rate, bpm	76.18±7.06	86.11±14.38	<0.001a

Mean±SD, Median (min-max), aIndependent samples t test; bMann Whitney U test. SI: Stress Index; SD1, Standard deviation of minor axis of Poincare' Plot; SD2, Standard deviation of major axis of Poincare'x Plot; SDNN: Standard deviation of all ECG complex intervals, SD: Standart deviation.

DISCUSSION

This study investigated the relationship between perceived stress level and HRV in healthy adults. The results showed that stress level was significantly associated with SD2 and HRV parameters except heart rate. In addition, it was concluded that HRV parameters except SD2 and Heart rate were significantly different in individuals with different stress levels.

HRV is an important biomarker indicating ANS health. Low HRV is associated with psychological stress, anxiety, depression, and cardiovascular risk, while high HRV is considered an indicator of physiological flexibility and adaptability (28). This study showed that perceived stress level is positively correlated with SI and negatively correlated with parasympathetic activity indicators such as SD1 and SDNN, and that with increasing stress level, deteriorations occur in HRV parameters such as SI, SD1, SD2/SD1 ratio and SDNN. This suggests that stress negatively affects ANS balance. Consistent with previous studies (10, 15, 19), our findings show that ANS balance is disrupted in the face of stress, parasympathetic activity decreases and sympathetic activity increases.

SI, one of the HRV parameters, is an indicator reflecting the situations in which sympathetic tone increases (29). Our study showed that PSS and SI have a significant correlation in the same direction, and people who are under a lot of stress have higher SI. This demonstrates that people who experience high amounts of stress are subjected to higher cardiovascular system stresses. The findings also support the sympathetic dominance model put forward by Sahoo and colleagues and Yoo and Chung (24, 25).

SD1 and SDNN are the most basic HRV parameters reflecting parasympathetic tone (30). In the present study, it was found that SD1 and SDNN decreased as the perceived stress level increased, and SD1 and SDNN were significantly lower in individuals with higher stress levels than in individuals with lower stress levels. This suggests that parasympathetic activity is suppressed in stressed individuals and that these individuals have reduced ANS flexibility. The results of our research are consistent with the data in the existing literature. Thayer and Lane emphasized that low HRV reflects poor emotional regulation capacity and increased risk of psychopathology (31). Similarly, Immanuel et al. and Gullett et al. reported that low SD1 and SDNN values were associated with chronic stress (18, 19). Additionally, low levels of these indicators have been reported to be associated with a higher risk of mortality and cardiovascular disease (28).

It was concluded that there was no significant relationship between SD2, another HRV-related parameter in our study, and perceived stress level, and that SD2 values did not differ among individuals with different levels of stress. We believe that this result may be related to the fact that SD2 reflects the combined effect of both sympathetic and parasympathetic activity (26), and therefore, changes in this parameter may be less pronounced compared to other variables.

SD2/SD1 ratio is an indicator of sympathomimetic and vagal balance in the ANS (32). In the present study, it was observed that as the perceived stress level increased, the SD2/SD1 ratio also increased and that this ratio was higher in individuals with high stress levels. This suggests that sympathetic activity becomes more dominant than parasympathetic activity in individuals under stress. Consistent with the findings in the literature, this suggests that parasympathetic activity is suppressed (33, 34). Higher emotional well-being is positively correlated with the SD2/SD1 ratio, according to Ghori et al. This implies that individuals with greater emotional stability respond to stress in a more adaptive autonomic manner, as seen by a balanced regulation of sympathetic and parasympathetic nervous system activity (35). Similarly, Faitatzidou et al. found that under mental stress, the SD2/SD1 ratio was noticeably lower (36).

Our results showed a significant correlation between perceived stress levels and heart rate. Individuals with higher perceived stress levels had higher heart rates than those with lower stress levels. The physiological mechanisms that stress increases the heart rate by affecting the sympathetic nervous system (5) may explain this situation. Indeed, increased heart rate is directly related to the stimulation of sympathetic activity, and in the current study, significantly higher heart rates were detected in individuals with high stress levels.

This study has some strengths and limitations. A key strength lies in the use of HRV, a scientifically validated approach, to objectively evaluate the physiological effects of stress. In addition, the standardized measurement protocol and minimizing external factors such as temperature and time control increased the internal validity of the study. The fact that the participant group consisted of healthy individuals allowed the results to reflect basic physiological stress responses. However, the study also has some limitations. First of all, the fact that the sample group consisted of volunteer students from the physiotherapy and rehabilitation department of only one university limits the generalizability of the results. In addition, the fact that short-term variables such as participants' moods, sleep patterns or caffeine use were not controlled can be considered as another limitation.

CONCLUSION

In this study, it was concluded that stress level in healthy individuals has a significant relationship with HRV and heart rate and that HRV parameters deteriorate as stress level increases. Furthermore, HRV measurements are considered to have potential clinical utility for assessing and monitoring individual stress levels, as well as evaluating stress management strategies. The use of such physiological indicators in clinical practice may help to address psychological stress more comprehensively. In future studies, the effects of individual differences such as gender, sleep patterns and lifestyle variables on the relationship between HRV and stress can be evaluated. Additionally, longer-term studies that include broader age groups may better demonstrate the long-term effects of stress on the ANS.

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Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical approval: Ethical approval for this study was obtained from the Igdir University Non-Interventional Clinical Research Ethics Committee (Date: 31.11.2024 and Decision Number: 12/1). All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Informed consent: Written informed consent was obtained from all participants prior to their inclusion in the study.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Previous Presentations: This study has not been previously presented at any scientific meeting or conference.

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