

Short-Term Effect of Stress on Heart Rate Variability

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Abstract

The aim of this study was to evaluate the effect of short-term mental stress on cardiac autonomic function. Sixty healthy adults (35 males and 25 females), aged 20 - 32 years, were participated in this study. Resting electrocardiogram for heart rate variability (HRV) analysis at spontaneous respiration was recorded at rest and under stress. Time and frequency domain and nonlinear HRV metrics were used to assess the effect of mental stress. HRV measurements showed consistent differences between stress and non-stress phases; and are associated with parasympathetic withdrawal and sympathetic activation. Heart rate increased under stress phase reflecting lowered functionality of the cardiac pacemaker. This study indicates that stress has an impact on the cardiac autonomic function as measure by HRV.

Keywords: Mental Stress; Heart Rate Variability; Blood Pressure; Rest

Introduction

Cardiovascular diseases are traditionally related to well known risk factors like diabetes, smoking, obesity, high blood pressure and high blood cholesterol levels. More recently, stress, anxiety and depression have been proposed as risk factors for heart diseases including heart failure, ischemic disease, hypertension and arrhythmias [1]. Stress is body's way of responding to any kind of demand or threat. The adverse consequences of stress result from the inability of the person to cope up with the stressful stimuli that may restore the homeostasis in short-term but may impose damage at different body systems in the long-term. Although stress has a psychological origin, it affects several physiological processes in the human body. It is a common belief that daily stressful situations predispose individuals to adverse cardiovascular events. Stress induces a state of excess sympathoadrenal activation influencing blood pressure, heart rate and the secretion of catecholamines and release of blood lipids and glucose into the bloodstream [2].

Heart rate variability (HRV) that refers beat to beat variations in heart rate is an established, non-invasive and quantitative method of assessing cardiac autonomic nervous activity. A reduced variability in heart rate is a sign of impaired autonomic control of cardiovascular regulation. Autonomic imbalance is characterized by elevated sympathetic tone, decreased parasympathetic tone, or both. Heart rate variability has been used in different clinical settings, including diabetes, hypertension and epilepsy or during exercise or different physiological conditions [3-6]. During the last few decades, researchers have shown an association between HRV and stress, and use HRV as a psychophysiological index of mental stress. With this background, this paper is focused on the hypothesis that mental stress causes an increase in the cardiovascular reactivity, i.e. increased blood pressure and decreased HRV.

Materials and Methods

Subjects

Sixty healthy adults (35 males and 25 females) between the age group of 20 and 32 years were recruited from the student population of Nepalgunj Medical College, Banke. All participants were healthy and free of mental and cardiovascular disease. In case of smokers and alcohol users, the subjects with the low nicotine and alcohol dependent, were included [7,8]. The Mensa IQ Test (made by Mensa Norway) was used as mental stressor [9]. In a laboratory environment, the subjects were instructed to keep silent for five minutes keeping their mind clean of any stressful thought and were then asked to perform a mental task. HRV was recorded throughout the test for each subject. At the end of each test, two recordings were obtained: baseline from the period of no stress activation during the silence and mental stress task. All participants in the study were instructed to avoid alcohol or caffeine-containing drinks and cigarette smoking during the 12h preceding the study. The ethical clearance was obtained from the Ethics Committee of the College. Informed consent was obtained from all the participants before commencement.

Clinical examination

All the subjects were subjected to clinical examination. Each participant underwent the measurement of his/her weight and height recorded while wearing light indoor clothes but no shoes. Using a measuring tape, waist circumference (midway between the lower rib margin and the iliac crest) and hip circumference (the maximal circumference over the buttocks) were measured. Baseline blood pressure was measured using an automatic blood pressure device (Omron HEM-7130-L Blood Pressure Monitor with Large Cuff) with an arm cuff placed on the left arm in supine position after 10 minutes of rest. Beat-to-beat systolic and diastolic blood pressure were continuously measured during sessions.

At the time of testing, all the subjects were stable in terms of cardiopulmonary function and showed no withdrawal symptoms. Possible diurnal variation was minimized by performing all tests in the same sequence between 09:00 am and 11:00 am and maintaining laboratory temperature at $26 \pm 2^\circ\text{C}$.

HRV measurement

The ECG signals for HRV were recorded using ECG machine (Maestros Magic R Series, India) after a supine rest of 10 min at chart speed 100 mm/s. From ECG, R-R intervals were measured manually with a ruler. Then these R-R intervals were saved as ASCII file and analyzed by 'HRV analysis software 2.1' (Kuopio, Finland) for the time domain results, frequency domain results, and nonlinear results.

The time domain analysis of HRV consisted of the standard deviation of all RR intervals (SDNN); the square root of the mean of the sum of the squares of differences between adjacent RR intervals (RMSSD); and pNN50, which is the proportion of the total RR intervals that have differences of RR intervals greater than 50 milliseconds [10].

The frequency-domain analysis of HRV consisted of power of high frequency (HF), (0.15 - 0.40 Hz) and low frequency (LF), (0.04 - 0.15 Hz) [10].

It has been speculated that analysis of HRV based on the methods of nonlinear dynamics might elicit valuable information for the physiological interpretation of HRV. One nonlinear method is Poincare plot. The Poincare plot is a scatterplot of the current R-R interval plotted against the preceding R-R interval. Using the method described by Brennan [11], these plots were used to extract indexes, such as length (SD2) and width (SD1) of the long and short axes of Poincare plot images.

Statistical analysis

Anthropometric and cardiorespiratory variables were expressed as mean and standard deviation. Arterial blood pressure was compared between the two conditions using paired t-test and the data are presented as mean \pm SD. In order to evaluate whether there is

statistical difference between stress free control condition and mental task in HRV measures, non-parametric Wilcoxon signed-rank test was applied, and the data are presented as median (interquartile range). A p value of < 0.05 was considered statistically significant. Data were analyzed with statistical software IBM SPSS Statistics 23.

Results

The mean age of the sample, body mass index and waist hip ratio were 25.73 ± 3.8 years, 21.23 ± 3.8 kg/m² and 0.84 ± 0.64 respectively. The systolic blood pressure (mmHg) 104.33 ± 2.93 vs 114.58 ± 3.24 and diastolic blood pressure (mmHg) 68.68 ± 5.49 vs 81.22 ± 6.24 were significantly increased during mental stress task. Wilcoxon test confirmed the significant differences in HRV measures. In the time domain variables, RMSSD and pNN50 were significantly decreased during the mental task than in a stress-free control condition while SDNN was comparable between the two conditions. HF (ms²) and HF (nu) were significantly decreased while LF (ms²), LF (nu) and LF/HF ratio were significantly increased during mental task. In Poincare plot measures, SD1 was significantly higher in the stress-free control condition than during the mental task.

Variables	During stress free (n = 60)	During mental task (n = 60)	p value
SDNN (ms)	29 (26.25 - 31.75)	28.5 (24 - 31)	NS
RMSSD (ms)	32 (27 - 37)	26 (22 - 30.75)	0.001
pNN50 (%)	15 (8 - 22)	7 (3 - 11)	0.001
LF (ms ²)	113 (102.25 - 129)	177 (135.25 - 221.5)	0.001
LF (nu)	51 (44.25 - 59)	57.50 (50.25 - 67)	0.001
HF (ms ²)	173 (138.25 - 207.75)	130 (91.25 - 154.75)	0.001
HF (nu)	56 (49 - 63)	39 (33.5 - 45.75)	0.001
LF/HF (%)	0.63 (0.42 - 1.35)	0.97 (0.65 - 2.29)	0.001
SD1 (ms)	24 (22 - 27)	19 (17 - 21)	0.001
SD2 (ms)	42 (28 - 46)	42 (39 - 45)	NS
SD1/SD2	0.58 (0.51 - 0.63)	0.46 (0.41 - 0.51)	0.001

Table 1: HRV measures of participants during stress free and mental task conditions.

Discussion

This study was designed to determine influence of short-term mental stress on cardiovascular autonomic function. The finding of the current study indicates predictable change in arterial blood pressure and cardiac autonomic activity as measured by HRV.

HRV is a validated and easily obtainable measurement of the influence of autonomic function on the heart and by itself associated with cardiovascular risk factors and mortality [12]. In the present study, RMSSD and pNN50, which reflects the vagal tone were statistically decreased during a mental task. The RMSSD and pNN50 also correlate highly with HF power [13] and have been considered good variables for stress assessment [14]. However, SDNN which reflects total variability and carries the strongest prognostic information in heart disease was comparable. It may be because the study was conducted on healthy individual in stress free control condition and mental stress condition. Thus, it indicates that short term mental stress in healthy individual decrease short term variability indicator of parasympathetic activity, however, overall variation in heart rate is maintained.

By using more specific information obtained from frequency domain measures concentrated around respiratory frequency, HF (ms²) and HF (nu) were significantly decreased as evidence of withdrawal of vagal activity during mental task while LF (ms²), LF (nu) and LF/HF ratio were statistically increased during short-term stress. Some authors have suggested that the LF component is a quantitative marker of sympathetic modulation [15,16] and others that it is a marker of both sympathetic and vagal modulation [17]. The LF/HF ratio increases showing the most influence of sympathetic system during the stress condition. Thus, frequency domain analysis of HRV indicates that decreased in vagal activity and increased in sympathetic activity during mental task compared with the stress-free control condition.

The Poincare plot pattern is a semi-quantitative tool which can be applied to the analysis of R-R interval data [18]. This nonlinear pattern was used for stress assessment and showed that it could be effective in stress detection. SD1 that reflects short-term variability showed significantly lower values in stress condition than in resting condition, reflecting a significant inhibition of the parasympathetic activity. SD2 shows a decrease with stress but did not show significant result between the stress and non-stress phases. SD2 reflects the continuous long-term variability of the RR intervals. Increasing stress led to a significant decrease in SD1/SD2 value. SD1/SD2 ratio is interpreted as a measure of the balance between short and long-term HRV. SD1 is equivalent to the RMSSD while SD2 is equivalent to SDNN [18,19]. SDNN (Poincare length) correlates with both LF power and HF power; and RMSSD (Poincare width) correlates with HF power and, to a lesser extent LF power [20]. Thus, Poincare plot supports time domain and frequency domain measures being significant.

Several studies have shown an association between HRV and stress; and used HRV as a psychophysiological index of mental stress. The findings of this study are consistent with several other studies using either long or short-term exposure to psychosocial stressors [21-23]. The studies by de Geus [24] and Sloan [25] suggested a withdrawal of vagal modulation of the heart during short-term stress. A study by Delaney and Brodie [26] indicated short-term exposure to psychosocial stressors caused parasympathetic withdrawal along with an increased sympathetic activity that was responsible for increased LF/HF ratio. Other studies report a lack of association between HRV and mental stress. This may, however, be due to the character of the experimental stressors applied. In this regard Garde, *et al.* [27] suggested that the effects of the mental demands in a computerized version of the color word conflict task were too small to elicit significant changes in HRV variables.

Decreased heart rate variability has been associated with mental stress in laboratory experiments. It has been suggested that decreased HRV may be a sign of lack of ability to respond by physiological variability and complexity, thus making the individual physiologically rigid and, therefore, more vulnerable [28]. If the autonomic disturbance is long lasting, it may impact numerous physiological processes, and thereby pose a risk of cardiovascular disorders.

Conclusion

In conclusion, this study indicates that the short-term mental stress led to decrease in parasympathetic activity, increase in sympathetic activity but no changes in overall HRV and a sustained increase in both systolic and diastolic blood pressure. More studies are necessary to understand the response of HRV measurements in the short and long-stress situations. In the present study HRV was recorded in stress free control condition and during the mental task. The next step will be to design a test that consist recording of HRV after stress also to understand the pattern of HRV after stress and more tasks and find the threshold of stressor that has effect on HRV measurements. The relation and time response between a stimulus and the physiological effect of a stressor could be studied with HRV.

Conflicts of Interest

The authors state no conflicts of interest.

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