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RESEARCH ARTICLE

Gender-specific response to acute mental stress assessed by heart rate variability

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ABSTRACT

Background: Long-standing stress is an important risk factor for many diseases. Certain diseases are found to be associated with males than females. This difference may be due to the variation in the reactivity to stress exhibited by both the sexes which we assessed in the present study. The responses during stress are mediated partly by sympathetic and parasympathetic branches of autonomic nervous system (ANS). Heart rate variability (HRV) is a simple and non-invasive tool to study ANS. HRV can be analyzed by time domain and frequencydomain methods. The HRV in males and females during mental stress test may point to their disparity in autonomic response to stress and hence the predisposition to various diseases. **Aim and Objective:** The objective of this study was to assess the autonomic activity in males and females at rest and during mental stress test using HRV. **Materials and Methods:** There were 12 males and 18 females in the study who were selected based on inclusion and exclusion criteria. Mental arithmetic test is used to induce mental stress. HRV was calculated during baseline condition and mental stress test. Square root of the mean squared differences of successive NN intervals (RMSSD) and standard deviation of average NN intervals are the variables used in time domain analysis of HRV. Low-frequency (LF), high-frequency (HF), and LF/HF were used under frequency domain analysis. **Results:** There was a statistically significant difference in RMSSD during mental stress test. None of the other variables did not show any difference between two groups at rest and also during mental stress test. **Conclusion:** Less HRV in males during mental stress test indicates a shift of autonomic balance toward sympathetic activity in them. This shows that they are more predisposed to complications associated with stress.

KEY WORDS: Mental Stress Test; Heart Rate Variability; Gender

INTRODUCTION

The word stress has become a proverbial term in today's fast life. Incapability to cope up with a situation leads to stress. Stressful circumstances extend from home to workplace and from child to geriatric age. Stress is associated with a number of physical and biochemical changes in the body including autonomic imbalance with sympathetic overactivity. This, if persists for long phase may lead to various diseases like depression and cardiovascular disorders.

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Many laboratory methods are useful to induce mental stress in human subjects. Stroop test, reaction time tests, mental arithmetic challenges, Sudoku puzzles, and public speaking tasks are some of them.[1] Among this, arithmetic mental stress test is a simple and noninvasive test. Laboratory studies have shown that performing difficult mental tasks can elicit transitory elevations in blood pressure and heart rate.[2] These changes are the results of autonomic variation happening in mental stress. Excessive cardiovascular responses to stress tests are associated with the progression of intimal thickness in carotid arteries.[3-5] Furthermore, elevated blood pressure responses to induced stress are correlated with carotid atherosclerosis in healthy volunteers.[6] These outcome shows that autonomic changes in response to an acute stressful condition may point to its longstanding effects.

Heart rate variability (HRV) represents the time space between heartbeats assessed by R-R intervals from electrocardiographic (ECG). It is a well-documented tool to assess autonomic functions as well as changes in autonomic nervous system (ANS) associated with many cardiovascular diseases.[7,8] In 1996, the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology defined and established the standards for the measurement, physiological interpretation, and clinical use of HRV.[9] HRV is assessed by both time domain and frequency domain methods. Time domain analysis is based on NN interval between consecutive cardiac cycles and the variance between NN intervals. The diverse variables used under this are as follows: Standard deviation (SD) of NN intervals, SD of the average NN intervals (SDANN), the square root of the mean squared differences of successive NN intervals (RMSSD), NN50 (the number of pairs of successive NNs that differ by more than 50 ms), and proportion of NN50 divided by total number of NNs.

Among these, RMSSD is a more stable parameter. SDANN gives information on variation for prolonged period.[10]

Frequency domain analysis consists of the high-frequency (HF) band, low-frequency (LF) band, very LF band (VLF), and LF/HF ratio. The sympathetic or parasympathetic branches of the ANS are represented by separate spectral component of HRV. The HF is a measure of parasympathetic nervous system activity. The LF component is considered by some as a marker of sympathetic modulation (especially, when expressed it as normalized units)[9] and by others as a parameter that includes both sympathetic and parasympathetic influences.[11]

Both time domain and frequency domain components of HRV can be used to study the autonomic fluctuations associated with mental stress test. A study conducted by Orsila *et al*. assessed mental stress by two methods: HRV and a self-rating questionnaire (to know perceived mental stress) during occupational work. They found a strong correlation between HRV parameters and perceived mental stress.[12] Similar results were shown by Taelman *et al.*[13] and Kim *et al*.[14] These previous studies illustrate that HRV is useful in detecting mental stress.

Reactions to acute mental stress assessed by HRV may be an indicator to its long standing effects. Although there are ample studies showing the changes in HRV in mental stress, there is a lacuna in information about sex-wise predisposition to autonomic imbalance associated with stress. This individual difference in reactivity to stress may be the cause for gender-specific health problems in men and women. Difference in HRV exhibited by both the sexes in response to acute stress may give some insights to this aspect.

MATERIALS AND METHODS

The present study was a cross-sectional study conducted in 30 young adults consisting of 12 males and 18 females. The institutional Ethics Committee approval was obtained from Manipal Academy of Higher Education. Young adults in the age group of 17–20 years who have normal body mass index (BMI) (18.5–24.9 kg/m^2) were included in the study and those with a history of any recent illness during the past 2 weeks were excluded from the study. The procedure was explained to the subjects in detail. A written informed consent was obtained on the day of the experiment.

A detailed relevant clinical history was obtained from the subjects. This was followed by a brief general physical examination, examination of vital signs, and a complete systemic examination.

The height (in m) and weight (in kg) were noted, and BMI was calculated. After the basic examination, the subjects were asked to lie down calmly and relax in supine position. ECG was recorded for 5 min, in the baseline condition. This was followed by recording during mental stress test.

Mental Stress Test

The mental stress test was carried out by asking the subject to subtract serial sevens from 200 as fast as they could in 3 min. Subjects answered verbally and were encouraged by the investigator to subtract as quickly as possible.

Assessment of HRV

ECG was recorded from limb lead II using BPL ECG machine and analog output from the machine was digitalized by A/D converter from National Instruments, Bengaluru. HRV analysis of the subjects was done as per the Task Force guidelines.[9] The HRV was analyzed using Digital Data Acquisition System HRV Soft 1.1 Version, AIIMS, New Delhi. Both time domain and frequency domain analyses were done. In time domain analysis, SD of average NN interval (SDANN) and RMSSD (root of mean of squared successive R-R interval difference) were done. In frequency domain, LF in normalized units, HF in normalized units, and LF/HF were assessed.

Statistical Analysis of Data

The collected data were entered into MS Excel, and analysis was performed using Statistical Package for the Social Sciences version 11.5.

The outcome variables included the mean scores HRV at baseline condition and during mental stress test in males and females. Statistical tests used are Whitney U-test. *P*-value was taken as statistically significant at 5% confidence level ($P < 0.05$).

RESULTS

There were 12 males and 18 females included in the study. Results are expressed as mean ± SD. There was a Non-significant (NS) difference when study group was compared with control group. $P < 0.05$ is taken as statistically significant.

HRV of Males and Females at Rest

Time domain analysis: Table 1 summarizes time domain analysis of males and females at basal condition. NS difference was obtained between males and females by time domain analysis.

Frequency domain analysis: Table 2 comprises frequency domain analysis of males and females at rest. NS difference was obtained between males and females by frequency domain analysis.

HRV of Males and Females during Mental Stress Test

Time domain analysis: Table 3 summarizes time domain analysis of males and females during mental stress test. RMSSD of males and females is 21.018 ± 10.87 and 33.731 ± 15.33*, respectively. This showed a highly significant difference between males and females ($P = 0.01$). 33.462 ± 18.56 and 40.044 ± 34.57 are the SDANN values of males and females which did not show any significant difference.

Frequency domain analysis: Table 4 comprises frequency domain analysis of males and females during mental stress test. We did not get any significant difference between males and females in any of the variables of frequency domain analysis.

Males and females did not show any significant difference in HRV at rest.

Table 1: Time domain analysis of males and females at rest

Group	SDANN	RMSSD
Male	29.542±22.24	41.13±18.76
Female	35.543±43.89NS	54.45±49.75NS

SDANN: Standard deviation of averaged NN intervals, RMSSD: Square root of the mean squared differences of successive NN intervals, NS: Not significant

Table 2: Frequency domain analysis of males and females at rest

Parameter	Group	Mean±SD
LF	Male	61.36±21.16
	Female	62.88±23.13NS
HF	Male	38.64±21.16
	Female	37.12±23.22NS
LF/HF	Male	3.06±2.06
	Female	3.31±5.16NS

LF: Low frequency, HF: High frequency, NS: Not significant

Table 3: Time domain analysis of males and females during mental stress test

Group	RMSSD	SDANN
Male	21.018±10.87	33.462±18.56
Female	33.731±15.33*	40.044±34.57

SDANN: Standard deviation of averaged NN intervals, RMSSD: Square root of the mean squared differences of successive NN intervals, *significant

Table 4: Frequency domain analysis of males and females of study group during mental stress test

Parameter	Group	Mean±SD
LF	Male	70.55±15.53
	Female	70.35±8.03
HF	Male	29.46±15.53
	Female	29.65±8.04NS
LF/HF	Male	3.06±2.06
	Female	2.61±0.99NS

LF: Low frequency, HF: High frequency, NS: Not significant, SD: Standard deviation

DISCUSSION

We assessed the HRV of males and females at rest and during mental stress test using time domain method and frequency domain method. Our study revealed a low parasympathetic activity in males during mental stress test although such a disparity was absent at rest.

Stress affects our body through hypothalamic pituitary adrenal (HPA) axis and ANS. The ANS and HPA axes are highly harmonized and interconnected. HPA axis stimulation leads to a cascade of responses resulting in the release of adrenaline and noradrenaline from adrenal gland.[15,16] This along with the sympathetic and parasympathetic branches of ANS brings about the physiological responses in stress. Induced mental stress by various laboratory means also shows autonomic activation. In our study, we examined the discrepancy in ANS responses in both the sexes at rest and during mental stress.

HRV in Males and Females at Rest

Previous studies showing the effect of gender on HRV at baseline condition areee inconclusive. Studies by Umetani *et al*. have shown that, in population <30 years of age, HRV is lower in women compared to men, whereas this difference decreases >30 years of age and gender difference disappears above 50 years of age.[17] Comparable observations were made by Jensen-Urstad *et al*.[18] and Sinnreich *et al*.[19] Similarly, Snieder *et al*.[20] investigated whether women show larger HRV than men after controlling for a large number of health-related covariates, using two indices of HRV, and found out that it is affected by gender.

On the other hand, the study conducted by Li *et al.* showed that ethnicity and sex could not affect HRV in young adults.[21] We got a result analogous to this in which there was no statistically significant difference observed in HRV between males and females both in time domain and frequency domain analyses.

HRV in Mental Stress Test in Males and Females - Time Domain

In the present study, we assessed gender-specific reactivity to mental stress by time domain method using two variables RMSSD and SDANN. RMSSD is a measure of vagal activity. It represents short-term HRV. On the other hand, SDANN is an index of long-term variability. Both these values were less in males and females compared to resting state representing a low HRV during stress test. However, when we compared these values between males and females during stress test, a statistically significant difference in RMSSD value was obtained ($P < 0.05$), with males having less values compared to females. SDANN did not differ between the sexes.

Low RMSSD values indicate high stress.[12] Hence, our result indicates a lower parasympathetic activity in males during stress. This shows that males perceive a high stress compared to females to the same stressor. The insignificant result in SDANN values may be due to the short term recording of HRV done in our study.

HRV in Mental Stress in Males and Females - Frequency Domain

In frequency domain analysis, HF component is a guide to parasympathetic activity and LF represents both sympathetic and parasympathetic modulations of the heart. LF/HF ratio stands for sympathovagal balance. Pooled frequency domain analysis showed a parasympathetic predominance during mental stress.[22] High LF indicates high stress and high HF indicates low stress.[12] LF/HF increases with mental stress.[13] Satish *et al.* demonstrated a statistically significant difference in LF/HF between the genders during Stroop Colour test and Word test.[23] Carter and Ray demonstrated enhanced blood pressure response in males compared to females on mental stress.[24]

Although the foregoing results are intriguing, our study has failed to find significant differences in frequency domain analysis of HRV between males and females. We got a high LF and low HF in males representing a shift of ANS toward the sympathetic predominance in them even though the association was statistically insignificant. The reason for this absence of correlation is unclear. This may be because of the reason that the procedure of the test had demanded an active and enduring participation from the subjects which we might have failed to elicit. Hence, a more prolonged test and HRV recording might have given a conclusive result as long-term recording of frequency domain variables often shows strong correlations.[25]

Limitation of the Study

The sample size of the present study was small, and the recording was done for a short period. More extensive study with a larger sample size would have elicited a more promising result.

CONCLUSION

Our study exposed a lower parasympathetic activity present in males compared to females during mental stress. These results indicate that there is an exaggerated autonomic response in males than females on exposure to stressful conditions. Hence, they are more predisposed to the development diseases associated with stress.

REFERENCES

1. Boutcher SH, Stocker D. Cardiovascular response of young and older males to mental challenge. J Gerontol B Psychol Sci Soc Sci 1996;51:P261-7.
2. Falkner B, Onesti G, Angelakos ET, Fernandes M, Langman C. Cardiovascular response to mental stress in normal adolescents with hypertensive parents. Hemodynamics and mental stress in adolescents. Hypertension 1979;1:23-30.
3. Everson SA, Lynch JW, Chesney MA, Kaplan GA, Goldberg DE, Shade SB, *et al*. Interaction of workplace demands and cardiovascular reactivity in progression of carotid atherosclerosis: Population based study. BMJ 1997;314:553-8.
4. Lynch JW, Everson SA, Kaplan GA, Salonen R, Salonen JT. Does low socioeconomic status potentiate the effects of heightened cardiovascular responses to stress on the progression of carotid atherosclerosis? Am J Public Health 1998;88:389-94.
5. Kamarck TW, Everson SA, Kaplan GA, Manuck SB, Jennings JR, Salonen R, *et al.* Exaggerated blood pressure responses during mental stress are associated with enhanced carotid atherosclerosis in middle-aged finnish men: Findings from the Kuopio ischemic heart disease study. Circulation 1997;96:3842-8.
6. Barnett PA, Spence JD, Manuck SB, Jennings JR. Psychological stress and the progression of carotid artery disease. J Hypertens 1997;15:49-55.
7. Quintana M, Storck N, Lindblad LE, Lindvall K, Ericson M. Heart rate variability as a means of assessing prognosis after

acute myocardial infarction. A 3-year follow-up study. Eur Heart J 1997;18:789-97.
8. La Rovere MT, Pinna GD, Maestri R, Mortara A, Capomolla S, Febo O, *et al.* Short-term heart rate variability strongly predicts sudden cardiac death in chronic heart failure patients. Circulation 2003;107:565-70.
9. Heart rate variability: Standards of measurement, physiological interpretation and clinical use. Task force of the european society of cardiology and the north american society of pacing and electrophysiology. Circulation 1996;93:1043-65.
10. Sztajzel J. Heart rate variability: A noninvasive electrocardiographic method to measure the autonomic nervous system. Swiss Med Wkly 2004;134:514-22.
11. Laborde S, Mosley E, Thayer JF. Heart rate variability and cardiac vagal tone in psychophysiological research-recommendations for experiment planning, data analysis, and data reporting. Front Psychol 2017;8:213.
12. Orsila R, Virtanem T, Tiina L, Mika T, Pasi K, Jari V, *et al*. Perceived mental stress and reactions in heart rate variability-a pilot study amongemployees of electronics company. Int J Occup Saf Ergon 2008;14:275-83.
13. Taelman J, Vandeput S, Spaepen A, Van Huffel S. Influence of Mental Stress on Heart Rate and Heart Rate Variability. In: Sloten JV, Verdonck P, Nyssen M, Haueisen J, editors. 4th ed., Vol. 22. European Conference of the International Federation for Medical and Biological engineering. Leuven, Belgium: IFMBE Proceedings; 2008. p. 1366-9.
14. Kim HG, Cheon EJ, Bai DS, Lee YH, Koo BH. Stress and heart rate variability: A meta-analysis and review of the literature. Psychiatry Investig 2018;15:235-45.
15. Rotenberg S, McGrath JJ. Inter-relation between autonomic and HPA axis activity in children and adolescents. Biol Psychol 2016;117:16-25.
16. Egliston KA, McMahon C, Austin MP. Stress in pregnancy and infant HPA axis function: Conceptual and methodological issues relating to the use of salivary cortisol as an outcome measure. Psychoneuroendocrinology 2007;32:1-3.
17. Umetani K, Singer DH, McCraty R, Atkinson M. Twenty-four hour time domain heart rate variability and heart rate: Relations to age and gender over nine decades. J Am Coll Cardiol 1998;31:593-601.
18. Jensen-Urstad K, Storck N, Bouvier F, Ericson M, Lindblad LE, Jensen-Urstad M, *et al.* Heart rate variability in healthy subjects is related to age and gender. Acta Physiol Scand 1997;160:235-41.
19. Sinnreich R, Kark JD, Friedlander Y, Sapoznikov D, Luria MH. Five minute recordings of heart rate variability for population studies: Repeatability and age-sex characteristics. Heart 1998;80:156-62.
20. Snieder H, van Doornen LJ, Boomsma DI, Thayer JF. Sex differences and heritability of two indices of heart rate dynamics: A twin study. Twin Res Hum Genet 2007;10:364-72.
21. Li Z, Snieder H, Su S, Ding X, Thayer JF, Treiber FA, *et al.* A longitudinal study in youth of heart rate variability at rest and in response to stress. Int J Psychophysiol 2009;73:212-7.
22. Castaldo R, Melillo P, Bracale U, Casertaa M, Triassi M, Pecchiaa L. Acute mental stress assessment via short term HRV analysis in healthy adults: A systematic review with meta-analysis. Biomed Signal Process Control 2015;18:370-7.
23. Satish P, Muralikrishnan K, Balasubramanian K, Shanmugapriya. Heart rate variability changes during stroop color and word test among genders. Indian J Physiol Pharmacol 2015;59:9-15.
24. Carter JR, Ray CA. Sympathetic neural responses to mental stress: Responders, nonresponders and sex differences. Am J Physiol Heart Circ Physiol 2009;296:H847-53.
25. Veena HC, Itagi V, Takalikar RH, Patil RS. Effect of deep breathing on heart rate variability in normotensive male offspring's of hypertensive parents. Indian J Appl Basic Med Sci 2013;15:80-8.

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