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ORIGINAL ARTICLE

Journal of Biomedical Sciences

DOI: https://doi.org/10.3126/jbs.v7i1.29848

Influence of acute mental stress on blood pressure, heart rate and heart rate variability in male medical students: An experimental study from tertiary care hospital, Nepal

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Information about the article:

Received: Feb 19, 2020
Accepted: May. 3, 2020
Published online: June 30, 2020

Cite this article:

Pandey KR, Khadka R, Panday DR, Agrawal K, Paudel BH. Influence of acute mental stress on blood pressure, heart rate and heart rate variability in male medical students: An experimental study from tertiary care hospital, Nepal. Journal of Biomedical Sciences. 2020; 7(1):11-17

Publisher

Nepal Health Research Society, Bahundhara -6, Gokarnesowor Municipality, Kathmandu, Nepal
eISSN 2382-5545, ISSN 2676-1343 (Print)

ABSTRACT

Background

Medical students experience immense mental stress while understanding and retaining new terms, drug names and mechanisms and eventually generating a concept. Such stress, in long run, may affect their cardiovascular health. This can be assessed by heart rate variability, a reliable non-penetrating tool to determine the cardiac autonomic tone.

Material and methods

Thirty healthy young male medical students of BPKIHS, Nepal of age 21.03 ± 1.73 years, and BMI 20.83 ± 2.07 kg/m^2 were recruited for the present study. Their resting BP, HR, RR, and short-term heart rate variability (HRV) were recorded in sitting position. Each subject was given a mental stress for 5 min. Their BP, HR, and RR were recorded at 5th min of mental stress. HRV of 5 min was also recorded simultaneously during mental stress.

Results

Mental stress increased SBP (p=0.001), DBP (p= 0.001), PR (p= 0.005) and RR (p= 0.042) in young male medical students. Time domain measures of HRV viz; RMSSD (p= 0.001), NN50 (p= 0.001) and PNN50 (p=0.001), which are markers of parasympathetic activity, were significantly decreased during mental stress.

Conclusion

Acute mental stress increases BP and HR by withdrawing parasympathetic nervous control in young, healthy male medical students.

Keywords

Blood pressure, cardiovascular, heart rate variability, mental stress

Background

Stress is imposed on any subject when he/ she is required to actively cope (do something) or perform a challenging situation [1]. Medical education is one such field where the medical students are continuously exposed to stressful situations such as learning and memorizing the concepts and applying the gained knowledge in human subjects [2]. Hence medical students are continuously exposed to mental stress.

This mental stress triggers the sympathetic-adrenal-medullary axis leading it to discharge catecholamine, which consecutively elevates blood pressure (BP) and heart rate (HR) [3, 4]. It also releases cortisol from the hypothalamo-pituitary-adrenal axis [5, 6], which has a permissive action on the catecholamine for vascular reactivity. Additionally, it has also been proposed that the increase in BP and HR responses are by virtue of diminution in vagal tone [7, 8], or an increment in the stimulation of afferent sympathetic nervous system [9, 10]. Regardless of the underlying mechanisms, researches have deduced that enhanced reactivity or slowed down recovery are the ways through which stress and other psychosocial factors help to develop cardiovascular disease risk [11, 12].

Also, when one is exposed to such stress for an extended period, it is linked with the progression of atherosclerosis, inflammatory reactivity, endothelial dysfunction, and oxidative stress, which are weighed as primary factors to the development of eventual cardiovascular diseases.

Heart rate variability (HRV) has been used as a tool to assess the influence of acute mental stress on cardiac autonomic activity [1]. It is a non-penetrating device that monitors and measures any alterations or changes in HR as well as fluctuations of the R–R (N-N) interval. Among many ways of analyzing HRV, the most popular and easy measures is the standard deviation of the mean R–R interval (SDRR/ SDNN) [13]. Researches have demonstrated that healthy subjects respond to acute mental stress by an increase in HR while there is a decrease in SDNN [14, 15]. The fluctuations in this instantaneous heartbeat in an irregular style have been postulated to result from numerous influences such as autonomic discharge (PNS & SNS), hormones, neurochemical substances, end diastolic volume, and afterload [16]. Additionally, it has also been put forwarded that even under regular states, the HR generating system tends to vary between a set of metastable positions [17, 18]. This functional diversity of sinus node (SA node) not only makes heart capable of shifting from one state to another but also helps to meet all the known and unknown challenges [19]. In this perspective, the regularity of HR rhythm and decreased responsiveness of SA node to varying situations is related to heightened liability of forthcoming cardiovascular diseases [20].

HRV studies have been done utilizing different cognitive challenges such as mental arithmetic, digits repeated backward, delayed auditory feedback task, reaction time test, speech stress, computer quiz and so on [1]. Whereas, standard laboratory stressors have not been explored for the problem-solving ability, which is actually the stressors to CVS and other responses in the body. Thus, in our study, we have used a few selected workout MENSA [21], problem-solving questions as stress, and we are exploring its effect on the cardiovascular autonomic function of young, healthy male medical students. It has been found that increased reactivity to mental stress or delayed recovery from it foresees poor impending cardiovascular disease progression. Thus, this study may also help in identifying this group of students as well.

Material and methods

Study design and the participants

An experimental cross-sectional study was done in 30 young, healthy male medical students of B. P. Koirala Institute of Health Sciences (BPKIHS), Dharan.

Mental stress design and its validity

In this study, the acute mental stress was in the form of nine problem-solving questions from the MENSA workout questionnaire. It was determined after conducting a pilot study on 10 apparently healthy young male medical students. The mental stresses included were 1) reverse counting from 100, 2) subtracting 7 from 1000, and 3) computer-based MENSA workout questionnaire. Among them, the first two stressors did not produce expected cardiovascular effects, and also the tasks were completed before the timeframe of 5 min. Whereas, the nine questions selected on a random basis from MENSA workout questionnaire containing 30 questions effectively produced the desired cardiovascular response, and it took 5 min to complete the task. In this way, the MENSA workout questionnaire was selected as mental stress in our study.

Data collection

The subjects who volunteered for the study were asked to come to the neurocardiology laboratory, Department of Basic and Clinical Physiology, BPKIHS, at 10 am- 12 noon. They were instructed to have a light breakfast 2 hours before the recording. On arrival, they were allowed to rest for 15 min, and then their resting BP, HR, and respiratory rate (RR) were recorded in sitting position. Their resting short term HRV for 5 min was also recorded using polar S810i HRM (Heart rate monitor). For this, a strap with electrodes fitted on either side was used. It was applied around the chest after wetting the electrodes with water. The telemetric signals of ECG were received using a Polar watch placed within 1m distance. Subjects were then exposed to acute mental stress. BP was recorded at 4th minute of mental stress, whereas HR and RR were recorded in the 5th min. Short term HRV was continuously recorded during the stress period. Rest of 5 min was allowed for recovery. Again BPs, HR, RR, and HRV were recorded as explained earlier during recovery. The R-R interval calculated by the polar watch was then transmitted to a

computer installed with Polar Precision Performance software via infra-red. HRV software (Kubios HRV version 2.1 released in July 2012, Kuopio, FINLAND) was used to analyze the data.
In order to maintain confidentiality, a serial number was allotted for each data entered.

Inclusion criteria
Subjects enrolled were healthy young male medical students' of age 21.03 + 1.73 years and BMI of 20.83 kg/m^2 ± 2.07. For this study, the age group included were 18-26 years who had a BMI < 25 kg/m^2.

Exclusion Criteria
Subjects with any history of cardiovascular diseases, diabetes, and psychiatric illness or currently under medication for any diseases were excluded from the study.

Sample size calculation
For this purpose, we considered a mean and standard deviation of the heart rate from a closely related article "Decrease in heart rate variability response to the task is related to anxiety and depressiveness in normal subjects" by Shinba T, Kariya N, Matsui Y, Ozawa N, Matsuda Y and Yamamoto K, published in 2008. In their study, the HR at rest (mean ±SD): 71.1 ± 10.5 b.p.m and HR during the mental task (mean ±SD): 78.4 ± 12.4 b.p.m. These variables were considered for the sample size estimation. The G* Power 3.1.9.7 software was used for it using "means" of two normally distributed variables of effect size 0.631. A two-sided test with test hypothesis at significance level 0.05 and power 0.91, the sample size calculated is 30.

Data management and statistical analysis
The data collected were entered in Microsoft excel and were statistically analyzed using SPSS version 17 (SPSS INC., Chicago, ILL, USA). Repeated measures of ANOVA followed by Bonferroni test were used to analyze cardiorespiratory measures. Whereas, HRV was analyzed using the Friedman test followed by multiple comparisons. All data were considered statistically significant at p<0.05.

Outcome variable
i. Cardiovascular variables: resting BP (SBP & DBP) and HR and BP (SBP & DBP) and HR in the 4t^h min of mental stress and recovery
ii. Respiratory rate: during rest, mental stress, and recovery
iii. HRV variables:
During rest, mental stress, and recovery
a. Time-domain: SDNN, RMSSD, NN50, PNN50
b. Frequency domain: VLF power, HF power, LF power, HF (nu), LF (nu), Total power, LF/HF.

Explanatory variables
The socio-demographic variables and anthropometric variables.

Ethical committee approval
The study was carried out after obtaining Ethical approval from the Institutes Review Board, BPKIHS. The Memo number of Ethical Committee Letter issued is Acd.655/069/070. Informed written consent was obtained from all of the enrolled subjects.

Results

Mental stress significantly increased the cardiorespiratory variables in young male medical students (Table 1, refer P value p1). The cardiorespiratory variables measured during recovery was comparable to their resting states (Table 1, refer P value p2).

Table 1: Comparison of cardiorespiratory measures of young male medical students obtained during rest, mental stress and recovery from mental stress

Variables	Rest Mean ± SD	Mental stress Mean ± SD	Recovery from mental stress Mean ± SD	*P* value p1	p2	p3
SBP (mmHg)	112.73±6.74	121.8± 9.43	111.47±5.96	0.001	0.520	0.001
DBP (mmHg)	76.33± 7.60	86.87± 8.11	75.93±7.06	0.001	1.00	0.001
MAP (mmHg)	100.6±5.6	110.15± 8.10	90.56±29.56	0.001	0.568	0.001
PR (bpm)	67.20 ± 9.17	75.30±11.92	67.80±9.62	0.002	1.00	0.006
RR (cycles/min)	16.43 ± 2.90	18.13 ± 3.24	15.60 ± 3.28	0.042	0.190	0.001

SBP=systolic blood pressure (mm Hg), DBP=diastolic blood pressure (mm Hg), MAP= mean arterial pressure, PR=pulse rate (bpm), RR=respiratory rate (per min) , p1= between rest and mental stress (task), p2=between rest and recovery from mental stress, p3= between mental stress (task) and recovery from mental stress.

In time domain measures of HRV, there were significant decrease in RMSSD, NN50 and PNN50 during mental stress (Table 2, refer P value p1). Whereas, these variables during recovery were comparable to resting states (Table 2, refer P value p2). In frequency domain, there were significant decrease in LF power and HF power during mental stress (Table 2, refer P value p1). The variables obtained during recovery was comparable to resting states (Table 2, refer P value p2).

Discussion

Effect of mental stress in BP and HR

This study assessed the effects of stress on cardiovascular functions using Mensa work-out questionnaire, which had 9 problem solving questions, as mental stress. The stress was given for 5 min. It resulted in a significant increase in SBP, DBP, HR, and RR in young male medical students as compared to both rest and recovery states.
Mental activity is known to increase HR [22, 23]. In a study done by Emilie Pérusse-Lachance et al., [24] mental stress

in the form of 45-min reading-writing session, elevated 10% HR.

Table 2: Comparison of HRV measures of young male medical students obtained during rest, mental stress and recovery from mental stress

Variables	Male (n=30) median (interquartile range)			*P* value		
	Rest	Mental stress (task)	Recovery from mental Stress	p1	p2	p3
Time domain of HRV						
SDNN (ms)	70.9 (58.33 - 85.85)	72.7 (60.1 - 103.6)	72.85 (58.83 - 85.53)	0.267	0.355	0.558
RMSSD (ms)	59.8 (52.63 - 79.88)	45.7 (38.13 - 63.88)	59.5 (48.55 - 78.48)	0.001	0.565	0.001
NN50	130 (99.5 - 182.25)	95.5 (57 - 155.5)	118.5 (91.5 - 169)	0.001	0.229	0.008
pNN50 (%)	36.6 (26.35 - 59.1)	24.65 (14.5 - 47.38)	36.25 (26.88 - 56.23)	0.001	0.313	0.001
Frequency domain measures of HRV						
VLF power (ms^2)	1508 (832.75 - 2617.25)	1971 (1012.25 - 585.5)	1758.5 (1006.25 - 2865.5)	0.125	0.382	0.586
LF power (ms^2)	1582 (588.25 - 2289)	990 (564 - 1602.5)	1306.5 (815.25 - 1967.5)	0.017	0.644	0.045
LF (nu)	51.9 (38.83 - 59.78)	51.6 (38.83 - 62.63)	54.3 (43.18 - 65.95)	0.636	0.159	0.170
HF power (ms^2)	1460 (1033.25 - 2091)	820 (561.75 - 1834.75)	1190 (741 - 2043.25)	0.025	0.057	0.120
HF (nu)	48.05 (40.2 - 61.08)	48.3 (37.3 - 60.85)	45.7 (33.95 - 56.55)	0.629	0.147	0.178
TP(ms^2)	4805 (3167.5 - 6756.75)	4554.5 (2907 - 7304.25)	5111.5 (2761.25 - 6675)	0.658	0.766	0.926
LF/HF	1.08 (0.65 - 1.49)	1.07 (0.64 - 1.68)	1.19 (0.77 - 1.95)	0.530	0.139	0.106

SDNN = standard deviation of RR interval, RMSSD= root mean square of differences of successive RR intervals, NN50 = number of RR intervals that differ by ≥50 ms, pNN50 = percentage of NN50, VLF = very low frequency, LF = low frequency, HF = high frequency, power expressed in ms2 (millisecond), nu = normalized units, TP= total power. p1=between rest and mental stress (task) p2= between rest and recovery, p3= between mental stress and recovery.

This finding was in line with Martin et al., [23] who reported an increase in HR by 20% (+6.7 bpm), and Durocher et al., [25] also noted a similar increase of HR ~20 during a single arithmetic task of 5-min duration. Likewise, our study also showed an increase in HR by 13.01% during mental stress. The reason for this increase was deduced to be due to a reduction in cardiac parasympathetic modulation during mental work [26].

Mental work increases BP. The underlying mechanisms that stimulate the cardiovascular response due to mental work is still not clearly understood; however, a contraction in cardiac parasympathetic tone may be accountable for the hemodynamic changes [24]. Another possibility is an increase [27] or decrease [28] muscle sympathetic nerve stimulation, which exemplifies the actions of the sympathetic nervous system [29] as a result of mental activity.

Since both HR and BP increased during mental activity compared to resting states, a reestablishment of the driving point of baroreflex to a higher BP must have been induced by mental work [30]. Possibly, this could be another mechanism that attempts to clarify the cardiovascular changes.

Effect of mental stress in HRV

Our study also observed changes in cardiac autonomic function using HRV during mental stress. There was a significant decrease in markers of parasympathetic activity i.e., RMSSD, NN50, and pNN50. The mental stress of mild intensity induces parasympathetic withdrawal [31-33]. Other studies have also shown a decrease in SDNN [1], whereas, in our study, the SDNN was reduced during stress but was not statistically significant.

Another measure of HRV analysis is Power Spectral Density. It yields knowledge about how power is distributed in the form of frequency. It also helps to distinguish between the activity of the sympathetic and parasympathetic nervous systems. Our study found a significant reduction in LF and HF powers. LF power reflects activity of both arms of autonomic nervous system (parasympathetic and sympathetic), while HF power measures only parasympathetic activity [1]. We found no changes in LF nu and LF/HF ratio, both of which are the markers of sympathetic stimulation. These results additionally indicate that only withdrawal of parasympathetic activity occurred during acute mental stress.

Thus, the findings obtained from HRV in this study undoubtedly points out that a decrease in cardiac parasympathetic tone is responsible for the rise in HR during mental activity. Likewise, another factor could be attenuated baroreflex sensitivity in response to mental work. Nonetheless, further researches are still required to discern the impact of mental work on cardiac autonomic modulation.

Response of the cardiovascular system to recovery from mental stress

During recovery, the cardiorespiratory variables returned to resting values within five minutes. Additionally, HRV during recovery was also comparable to resting, whereas other studies have found that BP increased with mental activity and remained significantly elevated even during recovery [26]. The degree of the acute changes in BP brought about by acute mental stress may not be a matter to worry about in young, healthy individuals, but such increase in BP produced by mental activity, for a long duration, could cause progression to future cardiovascular disease risk [26, 34, 35]. On the other hand, an adjustment in cardiovascular variables might occur when such stress are exposed in a chronic basis. Hence, further researches are required to figure out the influence of mental activity during the recovery phase.

Conclusion

The acute mental stress of 5 min in the form of MENSA workout questionnaire (9 sample questions) increased the blood pressure and heart rate in young, healthy male medical students. These cardiovascular changes seem to be brought by parasympathetic withdrawal during mental stress. These males recovered from the mental stress within 5 min.

Limitation and future scope of the study

The stress level was not accessed using cortisol, which could have provided a better outlook to the study.

Abbreviations

Blood pressure (BP), B.P. Koirala Institute of Health Sciences (BPKIHS), Diastolic BP (DBP), Electrocardiogram (ECG), Heart rate (HR), HRM (Heart rate monitor), heart rate variability (HRV), high frequency (HF), low frequency (LF), number of RR intervals that differ by ≥50ms (NN50), normalized units (nu) parasympathetic nervous system (PNS), percentage of NN50 (pNN50), Pulse Rate (PR), Respiratory rate (RR), root mean square of differences of successive RR intervals (RMSSD) sinus node (SA node), sympathetic nervous system (SNS), Systolic BP (SBP), standard deviation of the mean R–R interval (SDRR/ SDNN), total power (TP), very low frequency (VLF)

Acknowledgments

We thank all the participants for volunteering during the study. Also, sincere appreciation to all the faculty members and staffs of Department of Basic and Clinical Physiology, BPKIHS for their support during the study period.

Authors' contribution

a. Study planning: KRP, RK, BHP
b. Data collection: KRP, DRP
c. Data analysis/ interpretation: RK, KRP, DRP
d. Manuscript writing: KRP
e. Manuscript revision: KRP, RK, DRP, KA, BHP
f. Final approval: KRP, RK, DRP, KA, BHP
g. agreement to be accountable for all aspects of the work: KRP, RK, DRP, KA, BHP

Funding

No funding was available for this research study.

Availability of data and materials

All data underlying the results are available as part of the article, and no additional source data are required separately as additional material for this research.

Competing interests

None declared.

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