Effect of Mental Activity on Heart Rate, Heart Rate Variability and Respiratory Rate in Healthy Volunteers

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Introduction: The link between mental stress and cardiac autonomic regulation plays a significant role in the patho physiological process of cardio neural feedback loop. This study assessed the effect of mental arithmetic and silent reading on heart rate variability, heart rate and respiratory rate in young healthy volunteers.
Materials and Methods: R-R intervals were recorded for five minutes in ten healthy volunteers aged 22-24 years of either sex while resting, doing mental arithmetic, and silent reading in a sitting position. Time and frequency domain approaches were used to measure heart rate variability (HRV). In them, heart rate and respiratory rate were also calculated. Using the paired 't' test, mean differences in values were evaluated between resting and mental arithmetic; resting and quiet reading conditions.
Results: Heart rate and respiratory rate were significantly higher during mental arithmetic ($p = 0.012$, $p<0.0001$ respectively) and silent reading compared to resting state ($p=0.005$, $p=0.0002$ respectively). There was no significant change in HRV during mental arithmetic and silent reading compared to resting state.
Conclusion: Mental arithmetic and silent reading primarily evoke a rise in respiratory rate and heart rate.

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1. INTRODUCTION

The autonomic nervous system controls a number of physiological activities that take place involuntarily in our body systems. Normal functioning of ANS is crucial in preserving homeostasis, effective working of the various visceral organs and their physiological functions like spontaneous heart rhythm, breathing and gastro-intestinal movements [1]. Indicators of heart rate variability (HRV) are commonly used to assess cardiac sympathetic and parasympathetic activity [2]. Population studies have demonstrated that in healthy adults, decreased HRV predicts mortality [3,4]. Additionally, reduced HRV is considered to be one of the predictors of mortality in post myocardial infarcted patients [5]. The evaluation of diabetic cardiac autonomic neuropathy is another major clinical application of HRV [6,7]. Clinical utility of measurement of HRV is also explored in neurology, psychiatry and cancer [8]. Ongoing research on association between stress and autonomic control has reported increased sympathetic activity during acute respiratory stress and mental stress [9,10]. However, findings are inconclusive. This study assessed the influence of mental arithmetic and silent reading on heart rate, HRV and respiratory rate.

2. MATERIALS AND METHODS

2.1 Subjects

The study comprised ten healthy young adults aged 22-24 years of either sex (5 males and 5 females) who volunteered to participate and informed consent was received from the study participants. The study parameters included were, heart rate, HRV and respiratory rate.

2.2 Methods

The study was carried out between 10 and 11 a.m. Subjects were briefed on the study protocol before beginning the test procedures. ECG was then taken in sitting position for continuously for five minutes during the following conditions: Normal (spontaneous) breathing, Mental arithmetic AND Silent reading.

For mental arithmetic, the subjects were asked to continuously carry out certain mental calculations as communicated through verbal signals for 5 minutes. For silent reading the text was held in front of the subject that was unfamiliar to him/her and the subjects were asked to read silently for 5 minutes.

2.3 Data Acquisition

The ECG was continuously taken at a rate of 25mm/second through limb lead II of ECG leads. ECG signals were simultaneously acquired and transmitted to a computer using a digital acquisition device. HRV parameters were then calculated using time and frequency domain HRV analysis methods using ADC box-6008 USB device [9].

2.4 Time Domain

The time domain HRV measures quantified by computer enabled method were ratio of maximum R-R interval to minimum R-R interval (Max/Min RR), the root mean square of the difference of successive R-R intervals (r-MSSD) and standard deviation of the R-R intervals (SDNN). Values were given in milliseconds.

2.5 Frequency Domain

The tachogram was analyzed using power spectral density. The power spectral density was done by using the fast Fourier transform method. High Frequency (HF), band between 0.015-0.400 Hz, Low Frequency (LF), band between 0.040-0.015 Hz, and Total Power (TP) were the power spectrum obtained. Absolute power was used to express values (ms2). Normalized units were also used to denote HF and LF (HF norm and LF norm respectively). Fraction low frequency (LF percent) and fraction high frequency (HF percent) were used to express power spectral components. Further Low Frequency–to–High Frequency Ratio (LF/HF Ratio) was also obtained.

2.6 Heart Rate

The averaged RR interval from 5 minutes during resting, mental arithmetic and reading was considered as heart rate for each activity and expressed as heart rate/minute.

2.7 Respiratory Rate

Respiratory rate was calculated separately during resting, mental arithmetic and silent reading by inspection and expressed as respiratory rate/minute.

2.8 Statistical Analysis

As data on HRV parameters were highly skewed it was log transformed. Paired t test was used for comparison of mean differences of all the study parameters between resting and mental arithmetic / silent reading. Statistical significance was taken to be at $P<0.05$.

3. RESULTS

The data on each state is given as mean with standard deviation and the comparison between two conditions is given as mean difference with standard deviation. Comparison of study parameters between resting state and mental arithmetic is presented in table 1 and comparison of study parameters between resting state and silent reading is presented in table 2. Comparison of heart rate and respiratory rate between silent reading and mental arithmetic is presented subsequently in the appropriate section of the result presentation.

3.1 Comparison of Study Parameters between Resting State and Mental Arithmetic

3.1.1 Comparison of HRV parameters

There was no significant difference in Max/Min RR r-MSSD, SDNN between resting state and mental arithmetic (Table 1). There was no significant change in total power, HF (absolute), LF (absolute), HF (nu), LF (nu), LF%, HF% and LF/HF during mental arithmetic compared to resting state (Table 1).

3.1.2 Comparison of heart rate and respiratory rate between before and during mental arithmetic

Heart rate was significantly higher in mental arithmetic condition compared to resting state (p= 0.012, Table 1). The respiratory rate was significantly higher in mental arithmetic condition compared to resting state (p<0.0001, Table 1).

3.1.3 Comparison of study parameters between resting state and silent reading

Comparison of HRV parameters: There was no significant difference in Max/Min RR, r-MSSD, SDNN between resting state and silent reading (table 2). There was no significant difference in Total Power, HF (absolute), LF (absolute), HF (nu), LF (nu), LF%, HF% and LF/HF during silent reading compared to resting state (Table 2).

3.1.4 Comparison of heart rate and respiratory rate between resting and silent reading

Heart rate was significantly higher in silent reading condition compared to resting state (p= 0.004, Table 2). The respiratory rate was significantly higher in silent reading condition compared to resting state (p=0.0002, Table 2).

3.1.5 Comparison of heart rate and respiratory rate between silent reading and mental arithmetic

There was no significant change in heart rate between mental arithmetic and silent reading conditions (Mean difference = -2.22±3.304, t=-0.67, p=NS). There was no significant difference in respiratory rate between mental arithmetic and silent reading conditions (mean difference = 0.3 ±0.63, t= 0.20, p= NS).

4. DISCUSSION

In the present study, we investigated autonomic modulation in response to five minutes mental activities such as mental arithmetic and silent reading. HRV parameters, heart rate and respiratory rate were considered. Among these study parameters, only heart rate and respiratory rate were higher in response to mental activity compared to resting state. In the present study, HRV parameters obtained both from time and frequency method did not change significantly during mental arithmetic and silent reading compared to resting state (table 1 and table 2 respectively). In the study of Luciano Bernardi et al and Aupma Deepak et al mental load in the form of mental arithmetic showed significant increase in HRV parameters suggestive of sympathetic activity [10,11,12]. In contrast, in another study pNN50 an index of parasympathetic activity decreased significantly [13]. In the present study no significant change in HRV parameters suggestive of parasympathetic as well sympathetic function was observed. Mental activity is speculated to be high when the optimal resources for an acceptable task completion exceed operator capacity [14]. Thus, it appears that in our study subjects, offered mental tasks/mental load was not exceeding the operator capacity and therefore no significant changes were observed in HRV. Additionally, the difference in study findings between the present study and Luciano Bernardi et al, could be due to the difference in study design between the two studies. In their study electrocardiogram was

Table 1. Study parameters between resting state and mental arithmetic

Variables	Resting (mean± SD)	Mental calculation (mean± SD)	Mean difference (mean± SD)	*t* value	*P* value
Max/Min RR	0.33±0.20	0.29± 0.12	0.04±0.22	0.57	0.579
r-MSSD (ms)	1.67±0.33	1.58± 0.20	0.08±0.41	0.61	0.55
SDNN (ms)	1.79 ±0.21	1.72±0.11	0.06 ± 0.23	0.82	9.43
HF Power (ms2)	2.96 ±0.56	2.95± 0.51	-0.0004± 0.77	0.0001	0.999
LF Power(ms2)	3.28 ± 0.35	3.32±0.36	-0.03± 0.62	0.15	0.88
Total Power (ms2)	3.72 ±0.32	3.75± 0.33	-0.03± 0.54	0.17	0.86
HF Power (n.u)	1.46±0.22	1.44± 0.20	0.01±0.25	0.12	0.90
LF Power (n.u)	1.80± 0.09	1.81 ±0.09	-0.01 ±0.14	0.22	0.82
LF/HF Ratio	0.33 ±0.30	0.37±0.29	-0.03±0.40	0.22	0.82
LF% Power	1.56±0.14	1.57±0.06	-0.003±0.17	0.05	0.96
HF % Power	1.23±0.26	1.20±0.29	-0.03 ±0.35	0.05	0.95
Heart rate (per min)	79.82±3.54	83.96±3.712	-4.14±4.23	3.09	0.012
Respiratory rate (per min)	15.4±0.72	17.8±0.43	-2.24 ±0.69	10.26	<0.0001

Change in autonomic and cardio- respiratory parameters during mental arithmetic compared to resting state in young healthy subjects

Table 2. Study parameters between resting state and silent reading

Variables	Resting (mean ±SD)	Silent reading (mean ±SD)	Mean difference (mean ±SD)	*t* value	*P* value
Max/Min RR	0.33±0.20	0.26±0.13	0.06 ± 0.19	0.99	0.34
r-MSSD (ms)	1.67±0.33	1.55 ±0.22	0.11±0.30	1.15	0.27
SDNN (ms)	1.79 ±0.21	1.71 ±0.13	0.08 ± 0.18	1.40	0.19
HF (ms2)	2.96 ±0.56	2.81 ±0.43	0.13± 0.30	1.37	0.20
LF (ms2)	3.28 ± 0.35	3.14 ± 0.38	0.14 ± 0.30	1.47	0.17
Total Power (ms2)	3.72 ±0.32	3.58± 0.33	0.13± 0.21	1.95	0.08
HF Power (n.u)	1.46±0.22	1.48±0.16	-0.01± 0.24	0.13	0.89
LF Power (n.u)	1.80± 0.09	1.80 ±0.092	-0.006 ± 0.10	0.18	0.85
LF/HF Ratio	0.33 ±0.30	0.32±0.25	0.008 ±0.34	0.07	0.94
LF % Power	1.56±0.14	1.46±0.17	0.009 ±0.20	0.14	0.89
HF % Power	1.23±0.26	1.23±0.20	0.0006 ± 0.19	0.09	0.92
Heart rate (per min)	79.82±3.54	83.18± 3.42	-3.36 ± 2.83	3.75	0.004
Respiratory rate (per min)	15.4±0.72	17.5±0.45	-2.1 ±1.19	5.87	0.0002

Change in autonomic and cardio- respiratory parameters during silent reading compared to resting state in young healthy subjects

done for three minutes in supine position unlike five minutes in sitting position in the present study [10]. In their study, for mental arithmetic tasks subjects were asked not only to perform mentally but also made to write the answer against time pressure [10]. In contrast, in the present study subjects performed only mental calculation as communicated through verbal signals. In the study of Anupama Deepak et al, SDNN was significantly higher during mental arithmetic compared to resting state [12]. In their study SDNN was obtained from five minutes ECG during mental arithmetic similar to our study design. But ECG tracing was in supine position. Thus, it appears that position of the subject could also be another confounding factor in assessment of influence of mental activity on HRV parameters.

In the present study heart rate increased significantly during mental arithmetic and silent reading (Table 1 and Table 2 respectively). This finding is in accordance with the findings of some previous studies [10,12,15,]. In the mental arithmetic state heart rate ranged from 85 beats/minute to 94 beats/minute. Whereas during silent reading, heart rate range was from 76 beats/minute to 86 beats/minute. Even though lower and upper limits of heart rate observed in mental arithmetic state were relatively higher compared to silent reading, the mean difference between these two conditions did not differ significantly. Thus, it could be stated that mental activity irrespective of the type of mental task undertaken evokes autonomic modulation at the SA node. Respiration is the body's most powerful oscillator, regulating functions in response to environmental demands and preserving homeostasis [16]. When people concentrate or perform a difficult activity, their breathing patterns differ according to the intensity and time of activity. Accordingly, in the present study respiratory rate was significantly higher during mental arithmetic and silent reading [Table1 and Table 2]. This finding is in agreement with the findings of Bernardi et al, who had also observed higher respiratory rate during mental arithmetic and silent reading [10]. Thus, respiratory rate could be an important physiological parameter in assessing autonomic modulation in relation to mental health [11]. In the experimental set up, mental stress is assessed mainly by a mental arithmetic test. It has been proven that mental activity in the form of mental calculation increases sympathetic activity as assessed by HRV [10,12]. However, in the present study, there was no significant change in HRV under mental arithmetic and silent reading conditions. On the other hand, there was a significant rise in heart rate and respiratory rate under mental arithmetic and silent reading compared to resting state.

5. CONCLUSION

Thus, it could be concluded that mental arithmetic and silent reading primarily evokes a rise in respiratory rate and heart rate.

CONSENT

As per international standard or university standard, patients' written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

As per international standard or university standard ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. McCorry LK. Physiology of the Autonomic Nervous System. American Journal of Pharmaceutical Education. 2007;71:1-11.
2. Szatajzel J. Heart rate variability: a non invasive electrocardiographic method to measure the autonomic nervous system. Swiss Med Wkly. 2004;134(35-36):514-22.
3. Liao D, Cai J, Rosamond WD, Barnes RW, Hutchinson RG, whistle EA, Rautaharju P, Heiss G. Cardiac autonomic function and incident of coronary heart disease: a population based case-cohort study. Am J Epidemiol. 1997;145:696-706.
4. TusjiH, Venditti FJ, Manders ES, Evans JC. Reduced heart rate variability and mortality risk in an elderly cohort. The Framingham Heart Study. Circulation. 1994;90:878-83.
5. Malik M. Heart Rate Variability: Standards of Measurement, Physiological Interpretation, and Clinical Use: Task Force of The European Society of Cardiology and the North American Society for Pacing and Electrophysiology. Annals of Noninvasive Electrocardiology. 1996;1: 151–181.

6. Federico Bellavere, ItaloBalzani, Giovanni De Masi, Maurizio Carrara, Pasquale Carenza, Claudio Cobelli and Karl Thomaseth. Power spectral analysis of heart rate variations improves assessment of diabetic cardiac autonomic neuropathy. Diabetes. 1992;41:5633-640.

7. Sampson MJ, Wilson S, Karagiannis P, Edmonds M, Watkins PJ. Progression of Diabetic Autonomic Neuropathy over a Decade in Insulin-Dependent Diabetes. Quarterly Journal of Medicine. 1990;75(278):635-646.

8. Anil Gehi, Dennis Mangano and Mary A. Whooley. Depression and heart rate variability in patients with stable coronary heart disease. Arch Gen Psychiatry. 2005;62(6):661–666.

9. Subbalakshmi NK, Basha Ahamed, Ramesh Bat. Impact of acute respiratory stress on cardiac autonomic control in young healthy subjects explored by time and frequency domain methods. Chinese Journal of Physiology. 2009;52(5):299-305.

10. Bernardi L, Wdowczyk-Szulc J, ValentiC, CastoldiS, PassinoC, Spadacini G, Sleight P. Effects of Controlled Breathing, Mental Activity and Mental Stress With or Without Verbalization on Heart Rate Variability. Journal of the American College of Cardiology. 2000;35(6).

11. Gąsior JS, Sacha J, Jeleń PJ, Zieliński J, Przybylski J. Heart Rate and Respiratory Rate Influence on Heart Rate Variability Repeatability: Effects of the Correction for the Prevailing Heart Rate. Front Physiol: 2016;7:356.

12. Deepak A, Deepak AN, Nallulwar S, Khode V. Time domain measures of heart rate variability during acute mental stress in Type 2 diabetics: A case control study. Natl J Physiol Pharm Pharmacol. 2014;4:34-38.

13. Perusse- Lachance E, Tremblay A, Chaput JP, Poirier P, Teasdale N, Drapeau V, et al. Mental work stimulates cardiovascular responses through a reduction in cardiac parasympathetic modulation in men and women. Bioenergetics. 2012;S1:001.

14. Callister R, Suwarno NO, Seals DR. Sympathetic activity is influenced by task difficulty and stress perception during mental challenge in humans. J Physiol. 1992;454:373-87.

15. Rajaram DP, Karthikeyan R, Saikumar P. The cardiovascular response to the acute physical and mental stress in type 2 diabetes mellitus. J Clin Diagn Res. 2012;6(7):1237-1240.

16. Grassmann M, VlemincxE, Leupoldt A, Mittelstädt JM, Van den Bergh OV. Respiratory Changes in Response to Cognitive Load: A Systematic Review. Neural Plasticity. 2016(16).
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