Influence of Mental Stress on Heart Rate and Heart Rate Variability

Chapter *in* IFMBE proceedings · January 2009

DOI: 10.1007/978-3-540-89208-3_324

Influence of Mental Stress on Heart Rate and Heart Rate Variability

J. Taelman[1,2], S. Vandeput[2], A. Spaepen[1] and S. Van Huffel[2]

[1] Katholieke Universiteit Leuven, Department of Biomedical Kinesiology, Leuven, Belgium
[2] Katholieke Universiteit Leuven, Department of Electrical Engineering, Leuven, Belgium

Abstract — **Stress is a huge problem in today's society. Being able to measure stress, therefore, may help to address this problem. Although stress has a psychological origin, it affects several physiological processes in the human body: increased muscle tension in the neck, change in concentration of several hormones and a change in heart rate (HR) and heart rate variability (HRV). The brain innervates the heart by means of stimuli via the Autonomic Nervous System (ANS), which is divided into sympathetic and parasympathetic branches. The sympathetic activity leads to an increase in HR (e.g. during sports exercise), while parasympathetic activity induces a lower HR (e.g. during sleep). The two circuits are constantly interacting and this interaction is reflected in HRV. HRV, therefore, provides a measure to express the activity of the ANS, and may consequently provide a measure for stress. We therefore explored measures of HR and HRV with an imposed stressful situation. We recorded changes in HR and HRV in a group of 28 subjects at rest, and with a mental stressor. The results suggest that HR and HRV change with a mental task. HR and HRV recordings may have the potential, therefore, to measure stress levels and guide preventive measures to reduce stress related illnesses.**

Keywords — **mental stress, heart rate, heart rate variability**

I. Introduction

Mental stress is a huge problem in today's society: about half of work-related illnesses are directly or indirectly related to stress [1,2]. Although stress has a psychological origin, it affects several physiological processes in the human body. When a person is exposed to a stressor, the autonomic nervous (ANS) system is triggered: the parasympathetic nervous system is suppressed and the sympathetic nervous system is activated [3]. This results in the secretion of the hormones epinephrine and norepinephrine into the blood stream which leads to, for example, vasoconstriction of blood vessels, increased blood pressure, increased muscle tension and a change in heart rate (HR) and heart rate variability (HRV). This process is known as the 'fight-or-flight' reaction [4]. When the stressor is no longer present, a negative feedback system stops cortisol production in the body, and a sympathovagal balance is established through homeostasis between the parasympathetic (vagal) and sympathetic system.

Chronic stress, such as experienced in working situations, can lead to a chronic activation, overload and eventually exhaustion of the hormonal, cardiovascular, neural and muscular systems due to insufficient recovery and repair. Long term consequences include, for example, an impairment of immune systems, delay of healing processes and musculoskeletal overload.

During the last few decades, researchers have used HRV to measure mental stress. This important parameter provides a window through which to observe the heart's ability to respond to normal regulatory impulses, which affect its rhythm. HRV measures are calculated from the tachogram, also called RR interval time series. These data are derived from the ECG signal by defining the distance between two consecutive R peaks. The variance in time between two consecutive R-peaks reflects the status of the ANS, since HRV is regulated by the sympathovagal balance.

HRV in response to stress differs between individuals due to genetic composition, age and environment. One of these factors is gender, which has been investigated in many studies [5-7]. The biobehavioral "fight-or-flight" theory has dominated stress research for the past five decades, but has been disproportionally based upon studies of males. Additionally, women's neuroendocrine responses have often presented a seemingly disturbed and uninterpretable image in studies [4]. It has been theorized that women respond to stress with a 'tend and befriend' reaction rather than with a 'fight-or-flight' reaction [8,9]. This 'tend and befriend' pattern is not only linked with gender differences, but also with social and cultural roles [10,11]. This theory could explain why women show greater stress with social exclusion than men do, and why women suffer more from affective disorders (due to social exclusion) [11].

With this study, we aim to investigate the interaction between HR, HRV and mental stress on group level and for individual changes. In this test ECG was measured during rest and during a mental task. We analyzed HRV to provide insight into how the heart reacts to a mental task. Linear HRV measures were included in this paper.

J. Vander Sloten, P. Verdonck, M. Nyssen, J. Haueisen (Eds.): ECIFMBE 2008, IFMBE Proceedings 22, pp. 1366–1369, 2008

II. METHODS

A. Data acquisition

28 participants were monitored, 15 men and 13 women with mean age of 22 (±1.96) and an average body mass index of 22.2 (±0.43). Participants were students and young people working at the Katholieke Universiteit Leuven. Measurements were recorded for two conditions for each subject: with and without a mental task [12]. The mensa test was used as mental stressor [13]. In a laboratory environment, the subjects were first shown relaxing pictures to put them at ease and were then asked to perform a mental task. HR was recorded throughout the test for each subject. HRV was calculated as the variance in time between two consecutive R-peaks. Different measures in time and frequency domain were used to express HRV.

Electrodes (Ag-AgCl, 10 mm diameter, Nikomed, Denmark) were placed on the body to measure the ECG. The data were registered with EMG preamplifiers from Mega Electronics Ltd (Finland). These analog signals were amplified and low pass filtered (450Hz). The Daqbook 2005 (IoTech, Ohio, USA) was used to digitize the signals at a frequency of 1000 Hz with 16-bit resolution.

B. Data Analysis

Average heart beat period in ms (Mean RR) was calculated for each subject for the two conditions derived from the raw RR-interval. The Pan-Tompkins algorithm was used to detect the QRS-complexes in the ECG-signal from which we could determine the RR-intervals [14].

HRV analysis is possible in the time or frequency domain. Time domain analysis is the easiest way, calculated directly from the raw RR-interval. The frequency domain shows us the variability of the RR-signal over time by looking at the proportion of the frequencies relative to the original RR-signal.

Frequently used time domain parameters are mean and standard deviation (SD) of RR, mean and SD of HR, RMS of SD, NN50 (number of consecutive RR intervals that differ more than 50 ms) and pNN50 (proportion of NN50). Frequently used spectral measures are peak frequency and power of very low frequency bands (VLF: 0 to .04 Hz), low frequency bands (LF: .04 to .15 Hz) and high frequency bands (HF: .15 to .4 Hz) and the ratio of LF/HF, which is often interpreted as a measure of sympathovagal balance.

We calculated the following time domain measures of HRV: standard deviation (SD) of HR and proportion of successive NN intervals with a difference greater than 50 ms (pNN50).

We completed a Fourier transformation to establish the frequency parameters. The Fourier transform was converted to the power spectrum (the magnitude of each frequency component squared). The underlying frequency components were estimated by integrating the periodogram. We calculated LF and HF components for each subject in each condition, and the LF/HF ratio was determined for further analysis.

We used paired and unpaired t-tests for normal distributed data. Mann-Whitney U-tests and Wilcoxon signed-rank tests were used for skewed data. We chose a critical p-value lower than 0.05 as significant and a p-value between 0.05-0.10 as indicative.

III. RESULTS

The results are presented in Table 1. Mean RR was significantly lower with the mental task than in the rest condition (p=2.29E-06). Comparing rest and mental task conditions, 24 of the 28 subjects had significantly lower mean RR with the mental stressor.

Table 1: Comparing HR and HRV across different conditions

	Rest	Mental task
Mean RR (ms)	0.816 (±0.13)	0.790 (±0.13)*
Mean SD	0.0496 (±0.0174)	0.0452 (±0.0134)
Mean pNN50 (%)	18,6 (±14.8)	14.2(±12.6)*
Mean LF/HF	2.55(±1.94)	3.14(±2.68)

* indicates a significant difference between the rest and mental task conditions

We calculated the SD and pNN50 for each subject for each condition. The pNN50 was significantly higher in the rest condition than with the mental task (p=2.99E-04). SD did not vary significantly between the two conditions (p=.53).

In the frequency domain (Table 1: LF/HF), the results do not show any significant differences. However there is a tendency for elevated LF/HF with the mental task compared with the rest condition (although insignificant: p=.11).

IV. Discussion

The main aim of this study was to examine the influence of mental stress on HR and HRV. We explored this relation recording data for two conditions: rest and with a mental task.

The differences between the rest and mental task conditions in mean HR and pNN50 were expected. These differences show that the short term variability (pNN50) [15] is less with a mental task than during rest. SD, which is a measure for longer term variability, did not differ significantly between the conditions, however.

Intra-subject analysis demonstrated that mean HR increased significantly from rest values in 24 out of 28 subjects with the additional load of a mental task.

LF/HF is a measure of sympathovagal activity. LF has been shown experimentally to be influenced by both sympathetic and parasympathetic activity [16,17]. LF range is associated mainly with sympathetic activity and HF with parasympathetic activity [18]. LF/HF ratios increased with the mental task in our research, although not significantly ($p = .11$). This tendency towards an increase could indicate a higher sympathetic activity with a mental task, compared to rest.

We have presented preliminary results here, and continue to analyse HRV data. In addition, linear and non-linear techniques will be applied in future research.

V. Conclusion

From the HR and HRV data reported here, we conclude that short term HRV was reduced with a mental task, and that an increased sympathovagal (LF/HF) balance may have been imposed.

Acknowledgment

We thank the European Commission for funding part of this work under contract IST-027291 (ConText). We thank the European partners of Context: Philips Research (The Netherlands), TNO (The Netherlands), Clothing+ (Finland), TITV (Germany), TU Berlin (Germany) and KU Leuven (Belgium).

Research supported by:

- Research Council KUL: GOA-AMBioRICS, CoE EF/05/006 Optimization in Engineering (OPTEC), IDO 05/010 EEG-fMRI, IOF-KP06/11 FunCopt, several PhD/postdoc & fellow grants;
- Flemish Government:
  - FWO: PhD/postdoc grants, projects, G.0407.02 (support vector machines), G.0360.05 (EEG, Epileptic), G.0519.06 (Noninvasive brain oxygenation), FWO-G.0321.06 (Tensors/Spectral Analysis), G.0302.07 (SVM), G.0341.07 (Data fusion), research communities (ICCoS, ANMMM);
  - IWT: TBM070713-Accelero, TBM-IOTA3, PhD Grants;
- Belgian Federal Science Policy Office IUAP P6/04 (DYSCO, 'Dynamical systems, control and optimization', 2007-2011);
- EU: BIOPATTERN (FP6-2002-IST 508803), ETUMOUR (FP6-2002-LIFESCIHEALTH 503094), Healthagents (IST–2004–27214), FAST (FP6-MC-RTN-035801), Neuromath (COST-BM0601)
- ESA: Cardiovascular Control (Prodex-8 C90242)

References

1. Commission asks workers and employees what action should be taken to combat musculoskeletal disorder at European commission press release IP/04/1358, Brussels, 12 November 2004
2. Issue 201 – Work-Related Neck and Upper Limb Musculoskeletal disorders. European Agency for Safety and Health at Work, 15/11/1999, at http://agency.osha.eu.int/publications/reports/201/en/index.htm
3. Akselrod S, Gordon D, Ubel FA, Shannon DC, Berger AC, Cohen RJ (1981). Power spectrum analysis of heart rate fluctuation: A quantitative probe of beat-to-beat cardiovascular control. Science 213: 220–222
4. Van Houdenhove B (2005), In wankel evenwicht. Over stress, levensstijl en welvaartsziekten. Lannoo, Tielt; Belgium. ISBN- 978-90-209-6020
5. Ryan SM, Goldberger AL, Pincus SM, Mietus J, Lipsitz LA. (1994) Gender- and age-related differences in heart rate dynamics: are women more complex men? J Am Coll Cardiol 24:1700-1707
6. Molgaard J, Hermansen K, Bjerregaard P. (1994) Spectral components of short-term RR interval variability in healthy subjects and effects of risk factors. Eur Heart J 15:1174-1183
7. Liao D et al. (1995) Age, race and sex differences in autonomic cardiac function measures by spectral analysis of heart rate variability – the ARIC study. Am J Cardiol 76:906-912
8. Taylor SE. (2000) Biobehavioral responses to stress in females: tend-and-befriend, not fight-or-flight. Annu Rev Psychol 107:411-429
9. Klein CL & Corwin EJ (2002) Seeing the unexpected: how sex differences in stress responses may provide a new perspective on the manifestation of psychiatric disorders. Current Psychiatry Reports 4:441-448
10. Cyranowski JM, Frank E, Young E, Shear MK (2000) Adolescent onset of the gender difference in lifetime rates of major depression: a theoretical model. Arch Gen Psychiatry 57:21-27
11. Stroud LR, Salovey P, Epel ES (2002) Sex differences in stress responses: social rejection versus achievement stress. Biol Psychol 52: 318-327
12. Westgaard RH and Bjørklund R (1987) Generation of muscle tension additional to postural muscle load. Ergonomics 30(6):911-923
13. Mensa home test at http://www.mensa.be/en/toelatingstest.html

14. Pan J & Tompkins WJ (1985) A real time QRS detection algorithm. IEEE Trans Biomed Eng 32:230-236
15. Malik M, Bigger JT, Camm AJ, Kleiger RE, Malliani A, Moss AJ, Schwartz PJ (1996) Heart rate variability: standards of measurement, physiological interpretation and clinical use. Eur Heart J 17:354-381
16. Hjortskov N, Rissèn D, Blangsted AK, Fallentin N, Lundberg U, Sǿgaard K (2004). The effect of mental stress on heart rate variability and blood pressure during computer work. Eur J Appl Physiol 92:84-89
17. Lombardi F (2004) Physiological Understanding of HRV components. In M.Malik & A J Camms (EDS), Dynamic electrocardiography. New York: Blackwell Futura
18. Piccirillo G, Busca S, Tarantini S, Santagada E, Viola E, et al. (1998) Sympathetic activity and anxiety in hypertensive and normotensive subjects. Archives of gerontology and geriatrics 26:399-406

Author: Joachim Taelman
Institute: Katholieke Universiteit Leuven
Street: Tervuursevest 101
City: 3000 Leuven
Country: Belgium
Email: Joachim.taelman@faber.kuleuven.be