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A CORRELATION BETWEEN GDV AND HEART RATE VARIABILITY MEASURES: A NEW MEASURE OF WELL BEING

Cioca GH, Giacomoni P, Rein G

New Venture Technologies, Estee Lauder Companies, Melville, NY. grein@Estee.com

Abstract

GDV and heart rate variability (HRV) measures were taken in healthy volunteers before and after three different physiological conditions: the orthostatic test consisting of deep breathing followed by rapid standing; ten minutes of strenuous exercise and consumption of chocolate. Statistical significance was observed between certain GDV parameters and spectral analysis of HRV for all three conditions. Such an analysis of HRV supplies information on the balance between the sympathetic and parasympathetic nervous system as they regulate heart rate. Previous investigations have shown that the parasympathetic system dominates during exercise, whereas the sympathetic system predominates during the orthotest. In either situation the sympathetic component of HRV was correlated with the GDV. Similar correlations were observed when there was balance between the sympathetic and parasympathetic systems. These correlations indicate that GDV measures can be used as a measure of well-being in different physiological conditions.

INTRODUCTION

Well being is a relatively new terminology for the biomedical community. From a psychological perspective, well being has been defined in terms of our mental and emotional attitudes, since these are known to influence health. Thus negative thoughts and emotions like anger and fear are known to have detrimental effects on a variety of physiological parameters (He, 1993). On the other hand, positive thoughts and emotion have a beneficial effect on health (Rein, 1995). Therefore, well being is associated with maintaining positive mental and emotional states, particularly in the presence of psychological stressors. A standard questionnaire for well being is available offering a scientific tool to quantify the subjective emotional component of feeling healthy.

From a physiological perspective, the balance between the sympathetic and parasympathetic nervous system has been proposed as a measure of general health (Langdeau, 2000). Each of these branches is in turn regulated by a variety of biochemical processes including neuronal, hormonal and immunological regulators which function at the molecular level. In addition to balance between the two branches of the nervous system, well being can be considered in terms of a healthy, robust response to harmful physical stimuli. Thus health and well being can be assessed in terms of balance and resilience to harmful or stressful environmental stimuli.

Electrophysiological measures are typically used by the biomedical community to measure and monitor the progression of disease states. However, they also offer non-invasive tools to measure well being. Electrocardiographic measures of the variability of the heart rate and the beat to beat (RR) interval have been used to measure the health status of the cardiovascular system. Furthermore, power spectrum analysis of typical time-domain ECG measures results in lower frequency components which have been correlated to the activity of the sympathetic nervous system as well as higher frequencies which reflect parasympathetic activity. Therefore heart rate variability (HRV) measures can be used to measure the relative activities of these two branches of the nervous system as they regulate normal cardiovascular activity. This ratio is known to shift toward sympathetic dominance under stress and other disease states (Morillo, 1997) and shift toward parasympathetic dominance in healthy physical (Curtis, 2002) and emotional (McCraty, 1995) states.

The correlation between GDV and HRV has not been previously investigated in a well-characterized non-diseased population. It is therefore of interest to study the correlation between HRV and GDV and determine whether such a correlation offers as a new measure of well being.

METHODS

This study is an extension of the studies previously presented (Bundzen, 2002; Korotkov, 2002; Buyantseva, 2003). The control subjects (n=24) from that study were volunteers from the State Medical Academy in Russia and were used for the Orthostatic test. Fourty-three athletes (age 19-24) from the State Research Institute of Sport in Russia volunteered for the exercise tests. Twelve volunteers from the same institute participated in the chocolate test.

Gaseous Discharge Visualization (GDV). Registration of both dynamic and static GDV images were implemented using GDV Compact device developed by Kirlioniks Technologies International Ltd (Russia). GDV Processor software (provided by the manufacturer) was used for image analysis. GDV parameters obtained from the software have been described elsewhere (Korotkov, 2001, 2002).

Heart Rate Variability (HRV). HRV measures were recorded using a traditional electrocardiogram with four leads attached to the left + right hands and the left + right ankles. HRV was calculated using the NeuroSoft Company (Russia) and Polar Electro (Finland) Software. Heart Rate (HR) was calculated using following formula: $HR = 60 \times 10^3$ msec/R-R, where R-R is the average length in seconds of the R-R intervals (RRNN) for each group. Two parameters were calculated from the time domain measures of R-R interval variability. The standard deviation of R-R intervals (SDNN) can be used as a measure of sympathetic nervous activity, whereas the root-mean square of successive differences in R-R intervals (RMSSD) reflects parasympathetic activity.

Spectral analysis of time domain curves reveals peaks in the very low frequency range (VLF: 0.004-0.04 Hz), the low-frequency range (LF: 0.04-0.15 Hz) and the high frequency range (HF: 0.15-0.5 Hz). LF/HF is the ratio of the low / high frequency power components. The VLF parameter is believed to measure the hormonal regulation (with some sympathetic nervous system activity), the LF parameter is a measure of the sympathetic nervous system and the HF parameter is a measure of the activity of the parasympathetic system. All measures were determined as absolute values and normalized units (n.u.).

RESULTS

Background HRV and GDV measures were taken after 5 minutes of resting in a quiet room. In addition HRV and GDV measures were also taken following the three experimental conditions. For the Orthostatic test, subjects were asked to deep breathe in a supine position for 5 minutes (controlled breathing involved 6 breaths per minute with 5 second inhalations and 5 second exhalations). Then subjects stood up and resumed regular tidal breathing. After 5 minutes GDV and HRV measures were obtained.

The exercise test involved 10 minutes of strenuous physical exercise before GDV and HRV measures were obtained. The third experimental condition was the consumption of dark chocolate, three hours after which GDV and HRV measures were taken. Correlation coefficients were calculated for GDV and HRV results obtained during the background and during the three experimental conditions. In addition to analysis of individual sessions, the difference between the orthostatic and background tests was calculated. Only correlations with statistical significance ($p<0.05$) are presented. Significant correlations were seen using GDV parameters from individual fingers (eg 5R), for differences between two fingers (eg. 5L-5R) or by using all 10 fingers (eg. deviations in absolute values, or mathematical combinations of all ten (stress index).

Summary of the results of different experiments are presented in Table 1.

DISCUSSION

The autonomic nervous system is well known to regulate the function of the cardiovascular system including fluctuations in HRV. Power spectral analysis of time domain fluctuations in HRV offers an experimental tool to measure the relative contributions of the sympathetic and parasympathetic branches of the nervous system. Thus, breaking down the heart rate fluctuations into its component frequencies has revealed that the low frequency component (0.04-0.15 Hz) correlates with sympathetic activity, whereas the high frequency component (0.15-0.5Hz) reflects parasympathetic activity. The low/high frequency ratio is believed to reflect the balance between the two branches of the nervous system.

HRV measurements can be obtained from a living fetus where it is known to be a measure of the activity state of the fetus, particularly fetal breathing movements. It has long been known that short-term variability in the fetal heart rate is associated with fetal well being (Detwiller, 1980). More recently, sensitivity to hypoxia has allowed a correlation between spectral analysis and fetal activity and fetal well being (Oppenheim, 1994).

A correlation between HRV and well being has also been established in the adult human population, albeit with diseased patients. One recent study with fibromyalgia patients showed a high correlation between well being (as measured with quality of life questionnaires) and the ratio of low frequency to high frequency components of HRV (Cohen, 2000). A second study showed a similar correlation in cardiovascular patients within the first 3 days following an acute myocardial infarction (Kummell, 1993).

The purpose of this study was to determine whether any parameters of GDV might correlate with HRV and therefore well being in a non-disease population. This was investigated in three different experimental conditions. Spectrum analysis of HRV during orthostatic testing has been used in the diagnosis and prognosis of arterial fibrillation (Galuszka, 2002). Furthermore Buyantseva (2003) showed that orthostatic testing is associated with increased sympathetic activation as measured by an increase in the standard deviation of the normal beat to beat interval (SDNN) and an increase in the low frequency component of spectral HRV. Using the same population of healthy volunteers and the same orthostatic test, the present study demonstrates a statistical correlation between entropy and brightness parameters of the GDV and the VLF component of HRV. The frequency region defined in this study as VLF ranges from 0.003 to 0.04 Hz. The upper region of this frequency band, from 0.01 to 0.04 is considered by most investigators as a reflection of sympathetic activity, whereas the lower frequencies within this band (<0.01 Hz) are believed to measure hormonal regulation of the cardiovascular system. In hindsight, it would have been better to divide the VLF region into its sympathetic and hormonal components. Nonetheless, the results are consistent with the conclusion that GDV brightness and entropy are correlated with HRV in a sympathetic dominant experimental condition.

Physical exercise, the second experimental condition, was chosen since it is associated with parasympathetic dominance. During physical inactivity an interesting correlation has recently been observed between sympathetic dominance and a reduction in well being (Koering, 2003). Although large inter-subject variations are known to occur in individual responses to exercise training programs (Bouchard, 2001), it is generally observed that heart rate and oxygen consumption are increased. Furthermore, it has been reported that exercise increases parasympathetic regulation of HRV (Curtis, 2002). A similar conclusion was reached when studying patients with chronic heart insufficiencies, where an exercise program shifted their cardio-regulatory activity from sympathetic to parasympathetic dominance (Doering, 2003).

In the present study, despite the parasympathetic dominance associated with exercise, the sympathetic component of HRV (LF) was correlated with the stress index parameter of GDV. Thus the sympathetic nervous activity appears to best correlate with GDV parameters in two different experimental conditions controlled by either sympathetic or parasympathetic activity.

A third experimental condition was also used in this study to demonstrate a correlation between HRV and GDV parameters. Although eating sweet chocolate is not know to activate the sympathetic nervous system, like exercise, the consumption of chocolate is beneficial to the cardiovascular system (Visioli, 2000). Furthermore, eating chocolate can be considered a positive emotional experience which in turn is known to activate the parasympathetic nervous system (McCraty, 1995). The results of this study demonstrate that under this condition, two GDV parameters (stress index and area) correlate with a balanced sympathetic and parasympathetic regulation of HRV. The same balanced regulatory state has been previously reported for other positive emotional stimuli (McCraty, 1995).

In conclusion HRV and GDV were correlated in a non-diseased population under different physiological conditions. In situations where either the sympathetic or the parasympathetic nervous systems were activated, the HRV parameter corresponding to sympathetic regulation of heart rate was correlated with GDV. In a situation inducing a positive emotional state, the HRV parameter which correlates with GDV is the balance between the sympathetic and parasympathetic nervous systems. In all cases, GDV entropy correlated with the different HRV parameters. Since these HRV parameters reflect involuntary reactions of the heart to psycho-physical loading, the observed correlation between HRV and GDV allows the conclusion that well being can be measured as a resilience to psycho-physical stimuli.

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Table 1. Statistically significant (p << .05) correlations between GDV and HRV parameters.

Test	GDV parameter	HRV parameter	Fingers	Correlation
Background	Normalized Area	RRNN	5R	0.68
	Area	VLF	5L, 5R	0.64
	Area	LF/HF	5L-5R	0.61
	Entropy	LF	5L-5R	0.64
	Brightness	RMSSD	5L-5R	0.61
Orthostatic	Brightness	VLF	5L-5R	0.71
	Entropy	VLF	5L deviation	0.65
Ortho-Bckgrnd	Brightness	VLF	5L-5R	0.71
	Entropy	VLF	5L deviation	0.66
Exercise	Stress Index	LF	10 fingers	0.85
	Entropy	VLF/HF	10 fingers	0.41
Chocolate	Stress Index	LF/HF	10 fingers	0.81
	Entropy	HF	10 fingers	0.56
	Normalized Area	LF/HF	10 fingers	0.51