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Application and Limitation of Frequency Domain, LF/HF Component in Heart Rate Variability as an Acute Stress Index

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***Abstract*–** Stress response is initiated from brain to periphery via two pathways, i.e. the hypothalamus-pituitary-adrenal (HPA) axis and autonomic nervous system. Cortisol, the end product of the HPA axis, has been used as a stress biomarker. The heart rate variability (HRV) is preferred as a non-invasive stress biomarker representing autonomic adaptation. Herein we investigate the correlation between cortisol level and power of HRV components, and the effectiveness of HRV components as a stress biomarker. Acute stress biomarker, LF/HF ratio of male 30's was significantly higher than that of male 40's ($p<0.03$). Diurnal salivary cortisol levels were not correlated with LF/HF ratio. However, LF/HF ratio was positively correlated with cortisol level in subjects preferring passive stress coping strategies ($p<0.09$), whereas LF/HF ratio was negatively correlated with cortisol level in subjects preferring active stress coping strategies against stress ($p<0.01$). Therefore this study suggests that the power of HRV may be significantly influenced by personal trait, and that effectiveness of HRV as a stress biomarker may be enhanced by differential application based on stress coping strategy of an individual.

***Keywords*:** Heart rate variability, Stress, Cortisol, Stress coping strategy.

1. Introduction

Cortisol, the end product of the HPA axis, has been used as a stress biomarker (Sjor et al., 2014; Hellhammer et al., 2009). Serum cortisol level is fluctuated by circadian rhythm, and is elevated by activation of the HPA axis caused by stress regardless of circadian rhythm (Dorn et al., 2007). It is the reason behind utilizing cortisol as a stress biomarker. HRV has been investigated to figure out the physiological function of the autonomic nervous system (ANS). HRV is R wave peak to R wave peak (RR) interval variation in time of consecutive heart rate record on a pulse wave or an electrocardiogram (Task Force, 1996). The RR interval variation results from dynamic balance of sympathetic and parasympathetic autonomic activity. The RR interval variation can be transformed to frequency domain. Generally the HRV means the total power (TP, 0.003–0.4 Hz) of frequency domain. The power of low frequency (LF, 0.04–0.15 Hz) is associated with both sympathetic and parasympathetic activities; on the other hand the power of high frequency (HF, 0.15–0.4 Hz) is associated with parasympathetic activity (Task Force, 1996). Chronic stress is associated with lower HRV (Togo et al., 2009). Acute work stress is predicted to be associated with LF/HF ratio because workload increases the power of LF and decreases that of HF (Dixit et al., 2012). However, the relationship between two stress biomarkers has not been clarified. Herein we investigate the correlation between the cortisol level and the power of HRV component, and the effectiveness of HRV component as a stress index.

2. Materials and Methods

2. 1. Subjects

Volunteers of this study were healthy officers and civilian workers in Korean Air Force Academy, between the ages of 27 to 40 (33 years old in average). There were 27 males and 23 females. Experimental data were collected several times from a subject on different days. All volunteers agreed on the collection of their bio-signal data. Collected data were coded and then analysed for privacy protection.

2. 2. Salivary Cortisol Quantification

Saliva from subjects was collected at around 10:00AM right before HRV is measured, to analyse diurnal cortisol levels in experimental tubes. Salivary cortisol level was measured by Enzyme-linked immunoassay (EIA). Cortisol EIA kits were purchased from Salimetrics (USA). EIA followed a protocol provided by Salimetrics.

2. 3. HRV Measurement

The blood volume pulse (BVP) of subjects was measured through the photoplethysmography (PPG) sensor. HRV was measured at a resting state in the morning, except when measuring under alcohol consumption state from 6 to 8 PM. The power of HRV components, such as TP, HF, LF, and LF/HF ratio, was analysed by HRV analysis program (Infiniti, Thought Tech., USA).

Table 1. The powers of HRV in healthy male and female.

HRV Comp.	Male(mean±SD)			Female(mean±SD)	
	Age ≤29	Age 30-39	Age 40-49	Age ≤29	Age 30-39
TP	1303.26 ±2429.47	1047.50 ±2244.63	669.46 ±1675.21	1590.77 ±2996.45	1294.09 ±2620.70
LF	509.17 ±894.36	407.53 ±841.89	252.69 ±582.72	625.72 ±1448.77	484.04 ±1130.11
HF	464.35 ±929.79	359.10 ±742.51	226.39 ±604.16	662.45 ±1113.12	549.56 ±1007.71
LF/HF	2.10 ±1.66	2.31 ±2.16	2.07 ±1.83	1.57 ±1.92	1.38 ±1.47

2. 4. Blood Alcohol Concentration Measurement

Blood alcohol concentrations were measured through exhale breath of volunteers with Lion SD400 alcolmeter (Lion Laboratories Limited, United Kingdom) after alcohol consumption.

2. 5. Stress Coping Strategy Questionnaire

Preference in stress coping strategy of an individual was investigated by self-reported questionnaire. It was achieved by the coping strategy indicator (CSI), which was developed by Amirkhan (1990), and Shin and Kim (2002) modified it to a Korean version. The CSI is comprised of 33 questions in total. Questions are divided equally into three categories, i.e. coping strategy, passive coping strategy, and social support strategy.

3. Results

3. 1. HRV Variation in Healthy Individuals

The powers of HRV components generally represented the same tendency with other studies and were within the normal range of general population (Kim et al., 2011). TP was decreased with age in both male and female. TP of female was relatively higher than that of male. LF/HF ratio of male was significantly higher than that of female ($p<0.001$). LF/HF ratio of male 30's was significantly higher than that of male 40's ($p<0.03$).

3. 2. Application of LF/HF Ratio of HRV to Alcohol Consumption

HRV is not stable. HRV can be fluctuated by posture, stress, time of measurement, and life style. Alcohol consumption increased the LF/HF ratio up to approx. 0.15% of blood alcohol concentration, but was rapid decreased in higher concentration (Fig. 1). This suggests that the power of LH/HF ratio is a sufficient acute stress index.

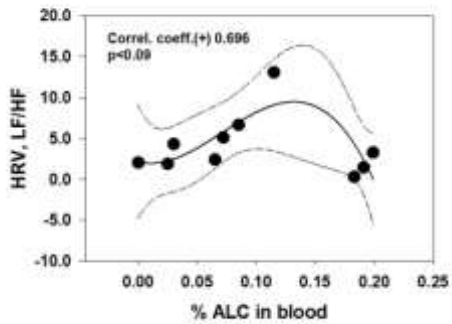

Fig. 1. Correlation between LF/HF ratio and blood alcohol concentration.

3. 3. Correlation between Salivary Cortisol Levels and LF/HF Ratios

Salivary cortisol levels were not correlated with the power of LH/HF ratio (Fig. 2). Simple comparison of two stress biomarkers may not be proper, but higher levels of cortisol were also not associated with higher power of LF/HF ratio. This can be interpreted as the power of LF/HF ratio not being effective as both chronic and acute stress biomarker. However, acute work stress increased the power of LF and decreased that of HF, eventually increasing the LF/HF ratio (Dixit et al., 2012; Dussault et al., 2009). Acute workload also increased the cortisol level (Kim et al., 2004). Therefore this study suggests that the power of HRV could be significantly influenced by personal trait.

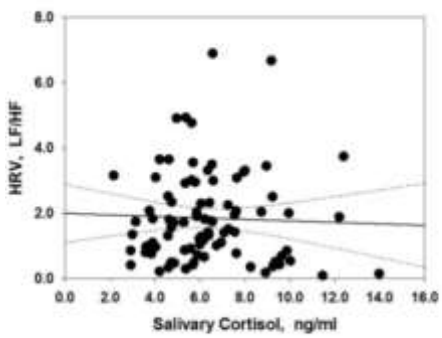

Fig. 2. Correlation between salivary cortisol levels and power of LF/HF ratio.

3. 4. Differential Effectiveness of HRV Component as a Stress Index Depending on Stress Coping Strategies

Subjects were divided into two groups according to their CSI scores. Correlation between salivary cortisol and the LF/HF ratio within each group was analysed (Fig. 3). The LF/HF ratio was positively correlated with the cortisol level in subjects preferring passive stress coping strategies ($p<0.09$), whereas it was negatively correlated with cortisol level in subjects preferring active stress coping strategies against stress ($p<0.01$). Also salivary cortisol levels of subjects preferring passive stress coping strategies were relatively higher than those of subjects preferring active stress coping strategies. This study suggests that the relationship between the LF/HF ratio and the cortisol level may be dependent on stress coping strategy preferences of an individual.

4. Conclusion

Two biomarkers of stress did definitely not complement each other; however, they were complementary when subjects were newly categorized by their stress coping strategy preferences. Conclusively this study suggests that the power of HRV may be significantly influenced by personal trait, and that effectiveness of HRV as a stress biomarker may be enhanced through considerations on personal trait.

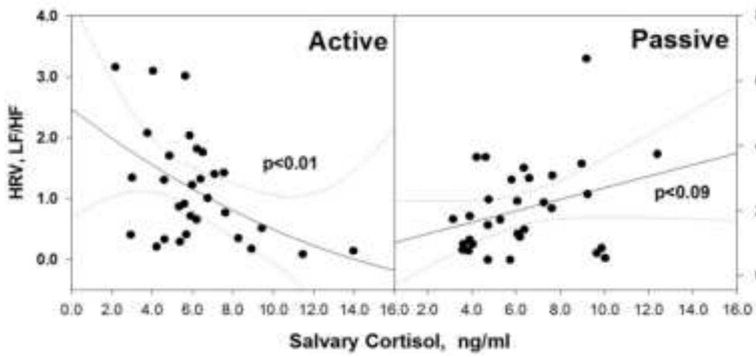

Fig. 3. Correlation between salivary cortisol levels and power of LF/HF ratio within group preferred passive stress coping strategy (above, n=31) and group preferred active stress coping strategy (below, n=30).

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