Comparison of the Ratio of the Standard Deviation of the R-R Interval and the Root Mean Squared Successive Differences (SD/rMSSD) to the Low Frequency-to-High Frequency (LF/HF) Ratio in a Patient Population and Normal Healthy Controls

John J. Sollers III[1], Tony W. Buchanan[2], Samantha M. Mowrer[1],
LaBarron K. Hill[1] & Julian F. Thayer[1]

[1]The Ohio State University, 1835 Neil Avenue, Columbus, OH 43210
[2]University of Iowa, 200 Hawkins Dr., Iowa City, IA 52242

KEYWORDS

Heart rate variability, autonomic control, r-r interval, patients

ABSTRACT

Heart rate variability (HRV) analysis involves examining the normal rhythmic fluctuations in heart rate using statistical indices (e.g. standard deviation, root mean square of the successive differences) or more complex spectral analytic techniques. Recently, Balocchi et al (2006) found that the ratio of the standard deviation of the r-r interval (SD) over the root mean squared of the successive differences (rMSSD), a simple statistical index, could be used as a surrogate for the low-to-high frequency ratio (LH/HF) typically calculated from the spectral estimates. We sought to extend this work by examining a patient population. Results indicate that the SD/rMSSD ratio is a good surrogate for the LF/HF ratio across multiple contexts in both patients and normal healthy controls.

INTRODUCTION

Heart rate variability (HRV) analysis involves examining the normal rhythmic fluctuations in heart rate using statistical indices (e.g. standard deviation, root mean square of the successive differences) or more complex spectral analytic techniques. The spectral analysis technique allows the heart rate time series to be decomposed into its oscillatory components that, in turn, are associated with the engagement or withdrawal of the parasympathetic and sympathetic branches of the autonomic nervous system (ANS). This represents a more sophisticated mode for analyzing cardiovascular time series but requires more expertise to apply correctly and is more computationally intensive than the classical time domain approach.

Recently, Balocchi et al **[1]** found that the ratio of the standard deviation of the r-r interval (SD) over the root mean squared of the successive differences (rMSSD), a simple statistical index, could be used as a surrogate for the low-to-high frequency ratio (LH/HF) typically calculated from the spectral estimates. The LH/HF ratio is thought to reflect the interplay between the parasympathetic and sympathetic branches of the ANS In this study, Pearson Correlations (*r*) for the ratio of the SD/rMSSD and the LF/HF ratio were computed for a group of brain injury patients (n=22; prefrontal damage n=8) and controls (n=7) to determine if the Baloochi findings extend to patient populations.

METHODS

Participants

Twenty-nine participants (7 healthy controls and 22 brain injury patients) underwent the procedures.

Procedures

Participants were equipped with electrodes to record electrocardiography and skin conductance. A strain gauge belt was placed on each participant for measure of respiration rate. Each participant completed an orthostasis task **[2]** followed by the Trier Social Stress Task (TSST) **[3]**. In the orthostasis task, the participant was asked to relax for five minutes in each of the following positions: supine, sitting, and standing. Measures of ECG, skin conductance, and respiration were collected throughout. After the orthostasis task, participants were given the instructions for the TSST. Each participant was asked to prepare and deliver a speech in the format of a mock job interview. They were told that they should imagine a job that they would like and to try to convince a committee that they are the best candidate for that job. Participants were given 10 minutes to prepare for the speech (during which physiological measures were collected). At the end of the preparation period, the participant was escorted into a conference room where the participant delivered the 5 minute speech while standing in front of 2 white-coated experimenters. At the end of the 5 minute speech, the participant was asked to complete a 5 minute mental arithmetic task consisting of serial subtraction of 13 from 1022. The speech and math components of the TSST were videotaped and physiological measures were collected throughout.

Time and frequency domain measures of heart rate variability were assessed during sitting, standing, speech preparation, and during the active speech using the Kubios HRV package. The Kubios HRV package provides time (SD, rMSSD), frequency (FFT and Autoregressive; high frequency and low frequency power), time-frequency, and complexity indices of cardiovascular variability (see Contact Information after the reference section).

SD and rMSSD were assessed using the less complex statistical approach, while autoregressive spectral analytic techniques were used to decompose the signal into characteristic components highlighting the frequency bands described below:

	Band (Hz)
Very Low Frequency	0.020 – 0.060
Low Frequency	0.061 – 0.145
High Frequency	0.146 – 0.400

LF/HF ratio was calculated as the absolute low frequency power divided by the absolute high frequency power.

Statistical Analysis

Pearson Correlations for the ratio of the SD/rMSSD and the LF/HF ratio were computed for the brain injury patients (n=22; prefrontal damage n=8) and controls (n=7).

RESULTS

As can be seen in Tables 1, 2, & 3 the correlations were significant for the SD/rMSSD and LF/HF ratio for all participants combined, all of the patients alone (n=22), and the sub-group of prefrontal damage individuals n=8. Sample scatterplots are presented in Figures 1 & 2.

Table 1: Pearson Correlations for Ratio of Low Frequency to High Frequency Power and Standard Deviation of the Interbeat Interval to Root Mean Squared Successive Differences

	SD_rMSSD SIT	**SD_rMSSD STAND**	**SD_rMSSD PREP1**	**SD_rMSSD PREP2**	**SD_rMSSD TSST1**	**SD_rMSSD TSST2**
LF_HF	***.5718***	.2555	.2368	.2413	.0348	.0398
SIT	***N=29***	N=29	N=29	N=29	N=29	N=28
	p=.001	p=.181	p=.216	p=.207	p=.858	p=.841
LF_HF	.1667	***.6316***	.2752	.3472	.0691	.4111
STAND	N=29	***N=29***	N=29	N=29	N=29	N=28
	p=.387	***p=.000***	p=.149	p=.065	p=.722	p=.030
LF_HF	-.0487	.0063	***.5757***	.4677	.2447	.1209
PREP1	N=29	N=29	***N=29***	N=29	N=29	N=28
	p=.802	p=.974	***p=.001***	p=.011	p=.201	p=.540
LF_HF	.1845	.4091	.5981	***.7886***	.3777	.4543
PREP2	N=29	N=29	N=29	***N=29***	N=29	N=28
	p=.338	p=.028	0	***p=.000***	p=.043	p=.015
LF_HF	-.0494	.2270	.2885	.1711	***.4210***	.2244
TSST1	N=29	N=29	N=29	N=29	***N=29***	N=28
	p=.799	p=.236	p=.129	p=.375	***p=.023***	p=.251
LF_HF	.3445	.5013	.2303	.4788	.4825	***.6474***
TSST2	N=26	N=26	N=26	N=26	N=26	***N=26***
	p=.085	p=.009	p=.258	p=.013	p=.013	***p=.000***

Table 2: Pearson Correlations for Ratio of Low Frequency to High Frequency Power and Standard Deviation of the Interbeat Interval to Root Mean Squared Successive Differences for ALL 22 Patients

	SD_rMSSD SIT	**SD_rMSSD STAND**	**SD_rMSSD PREP1**	**SD_rMSSD PREP2**	**SD_rMSSD TSST1**	**SD_rMSSD TSST2**
LF_HF	***.6294***	.2930	.2649	.2579	.1100	.1016
SIT	***N=22***	N=22	N=22	N=22	N=22	N=21
	p=.002	p=.186	p=.234	p=.246	p=.626	p=.661
LF_HF	.1896	***.6882***	.3099	.3667	.1277	.4783
STAND	N=22	***N=22***	N=22	N=22	N=22	N=21
	p=.398	***p=.000***	p=.160	p=.093	p=.571	p=.028
LF_HF	-.0438	.0080	***.5738***	.4524	.3001	.1562
PREP1	N=22	N=22	***N=22***	N=22	N=22	N=21
	p=.846	p=.972	***p=.005***	p=.035	p=.175	p=.499
LF_HF	.2186	.4143	.6157	***.8078***	.4278	.4983
PREP2	N=22	N=22	N=22	***N=22***	N=22	N=21
	p=.328	p=.055	p=.002	***p=.000***	p=.047	p=.022
LF_HF	-.0153	.1183	.3852	.2067	***.4926***	.2177
TSST1	N=22	N=22	N=22	N=22	***N=22***	N=21
	p=.946	p=.600	p=.077	p=.356	***p=.020***	p=.343
LF_HF	.3928	.5578	.3333	.5553	.5895	***.7081***
TSST2	N=19	N=19	N=19	N=19	N=19	***N=19***
	p=.096	p=.013	p=.163	p=.014	p=.008	***p=.001***

Table 3: Pearson Correlations for Ratio of Low Frequency to High Frequency Power and Standard Deviation of the Interbeat Interval to Root Mean Squared Successive Differences for 8 Prefrontal Cortex Patients

	SD_rMSSD SIT	**SD_rMSSD STAND**	**SD_rMSSD PREP1**	**SD_rMSSD PREP2**	**SD_rMSSD TSST1**	**SD_rMSSD TSST2**
LF_HF	***.7611***	.1056	.4381	.5839	.5166	.2276
SIT	***N=8***	N=8	N=8	N=8	N=8	N=7
	p=.028	p=.803	p=.278	p=.129	p=.190	p=.624
LF_HF	.0427	***.7833***	.6935	.6070	.2195	.5789
STAND	N=8	***N=8***	N=8	N=8	N=8	N=7
	p=.920	***p=.021***	p=.056	p=.110	p=.601	p=.173
LF_HF	.6068	.6721	***.9070***	.9001	.6517	.7233
PREP1	N=8	N=8	***N=8***	N=8	N=8	N=7
	p=.111	p=.068	***p=.002***	p=.002	p=.080	p=.066
LF_HF	.5705	.8118	.9441	***.9371***	.7233	.9155
PREP2	N=8	N=8	N=8	***N=8***	N=8	N=7
	p=.140	p=.014	p=.000	***p=.001***	p=.043	p=.004
LF_HF	.6480	.5512	.6015	.7500	***.9452***	.6790
TSST1	N=8	N=8	N=8	N=8	***N=8***	N=7
	p=.082	p=.157	p=.115	p=.032	***p=.000***	p=.093
LF_HF	.7384	.6922	.8555	.9259	.8756	***.9358***
TSST2	N=6	N=6	N=6	N=6	N=6	***N=6***
	p=.094	p=.127	p=.030	p=.008	p=.022	***p=.006***

Figure 1: Scatterplot: LF/HFRatio vs. SD/rMSSD
Sitting
Correlation: r = .57

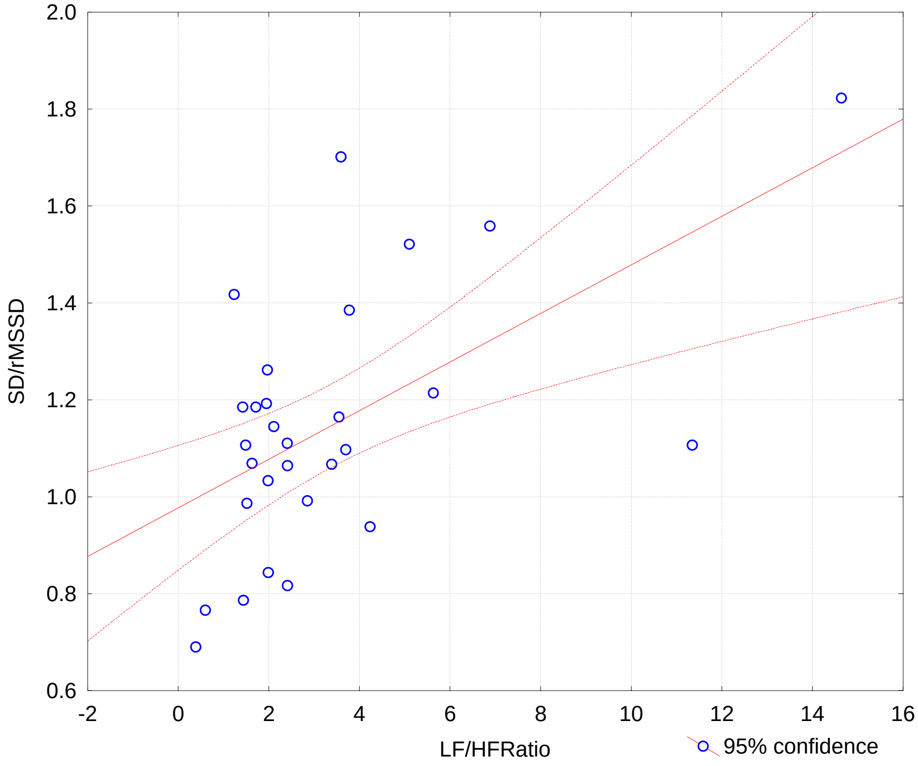
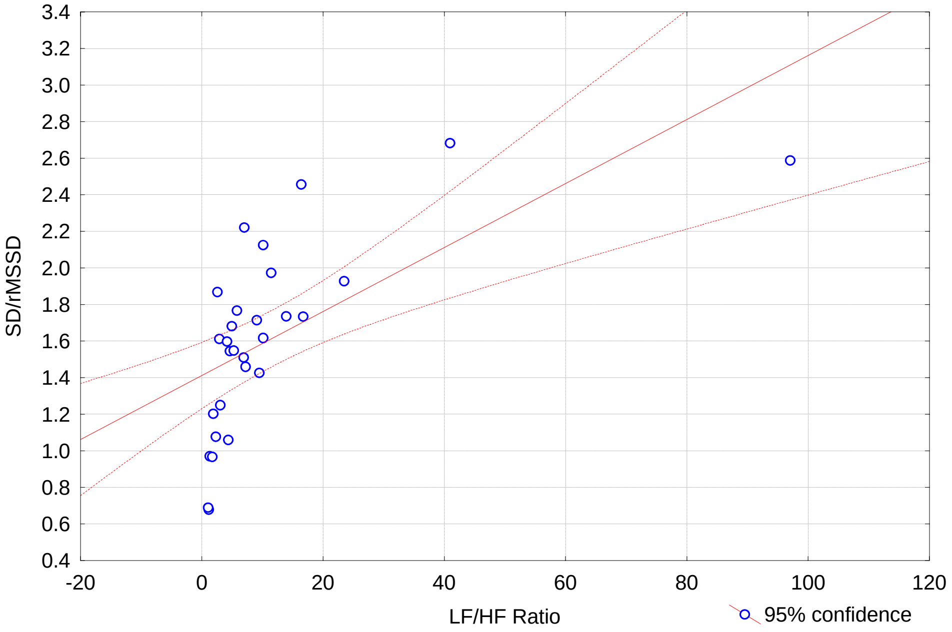


Figure 2: Scatterplot: LF/HF Ratio vs. SD/rMSSD
Standing
Correlation: r = .63



CONCLUSIONS

It appears that the computationally less difficult SD/rMSSD is a good and reliable surrogate for the LF_HF ratio computed from the estimates derived via spectral analysis. This is true across multiple contexts – sitting, standing, and mental challenge. Importantly, the relationship holds for patients as well as normal health controls, with it being most robust in the prefrontal lobe damage patients. There are several distinct advantages in using the time domain derived estimates: (1) less concern about the stationarity of the time series [1] and (2) ease of computation. These data support and extend the work of Baloochi et al and provide a simple, but effective means of indexing autonomic balance. .

ACKNOWLEDGMENTS

We would like to thank all of the staff and volunteers from the Neurology clinic at the University of Iowa.

REFERENCES

[1] Balocchi R, Cantini F, Varanini M, Raimondi G, Legramante JM, Macerata A. 2006) Revisiting the potential of time-domain indexes in short-term HRV analysis. Biomed Tech (Berl).;51(4):190-3.

[2] Weipert, D., Shapiro, D., & Suter, T. (1987). Family history of hypertension and cardiovascular responses to orthostatic stress. Psychophysiology, 24, 251-257.

[3] Kirschbaum, C., Pirke, K.-M., & Hellhammer, D. H. (1992). The 'Trier Social Stress Test'- A tool for investigating psychobiological stress responses in a laboratory setting. Neuropsychobiology, 28, 76-81.

Kubios HRV Analysis Version 3.0 beta
Mika P. Tarvainen, Ph.D. & Juha-Pekka Niskanen
(Mika.Tarvainen@uku.fi)
Biosignal Analysis and Medical Imaging Group
(http://it.uku.fi/biosignal)
Department of Applied Physics
University of Kuopio
Kuopio, FINLAND