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Postural variations in Cardio Stress Index scores

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Abstract

Numerous factors influence heart rate variability, including age, exercise and posture. The Cardio Stress Index (CSI) is a transformed measure of heart rate variability that is determined via a miniature digital multi-channel electrocardiogram system. Although the CSI and heart rate variability are reportedly analogous, little is known about how the two concepts compare in peer-reviewed research. The aim of this study was to examine the differences between CSI and heart rate as measured on a mini- electrocardiogram device when subjects were sitting upright and when they were lying down (in supine position). This is a case-series study with no intervention or follow-up. Sitting and supine CSI and heart rate readings were compared in a random sample of 55 women volunteers recruited through advertising in Pretoria, South Africa. The mean age of the sample was 25.01 years (SD = 7.56). After completing a biographical questionnaire, subjects' CSI and heart rates were evaluated using a digital medical device, the Viport™. The combined CSI for the group was elevated above the normative value of 20% (31.00%; SD = 14.03). The seated, supine and combined CSI all differed significantly from one another ($p<0.05$) and the CSI was significantly correlated with heart rate ($p=0.41$). In conclusion, the CSI readings, like heart rate variability measurements taken in different postures, cannot be used interchangeably in clinical practice or in research. The CSI appears to mirror existing research evidence on heart rate variability and posture.

Keywords: Heart rate, heart rate variability, cardio stress index, autonomic activity, posture.

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Introduction

Heart rate variability (HRV) is an important and widely-used measure of autonomic functioning, especially in the assessment of autonomic cardiac activity. HRV is the variation in beat-to-beat intervals of the human heart that allows the organ to react to stimuli (Pumprla, Howorka, Groves, Chester & Nolan, 2002; Koskinen, Kähönen, Jula, Laitinen, Keltikangas-Järvinen, Viikari, Välimäki & Raitakari, 2009). HRV is of particular significance in cardiac assessment because variations in the heart rate (HR) affect cardiac output.

HRV is usually represented as sympathetic or sympathetic and parasympathetic (low frequency) output versus vagal (high frequency) output. A depressed heart rate variability level usually indicates the presence of pathological conditions such as coronary artery disease; heart failure; diabetes and hypertension (Umetani, Singer, McCraty & Atkinson, 1998; Burger, Charlamb & Sherman, 1999; Pumprla *et al.*, 2002). HRV is also a predictor of left ventricular dysfunction following myocardial infarction and is a risk factor for morbidity and mortality (Wennerblom, Lurje, Karlsson, Tygesen, Vahisalo & Hjalmarson, 2001; Thayer, Yamamoto & Brosschot, 2010).

The CSI is a transformed measure of HRV. CSI is measured via a mini-electrocardiogram (ECG) that collects data from the heart's excitation through a digital multi-channel system. The device translates HRV parameters into a CSI percentage. A CSI value of 20% or more corresponds with a reduced variability (low HRV). Normal HRV is, therefore, any value below 20% (Viport, 2006). An unpublished study from the Institute of Sport Medicine in Muenster, Germany indicates that CSI and HRV are analogous (Rudack, 2005). However, while HRV is an accepted clinical measure of autonomic functioning, the CSI still requires more peer reviewed investigation and scrutiny.

The aim of this study was to examine the differences between CSI and HR as measured on a mini-ECG when subjects were sitting upright and when lying down. Comparing these CSI and HR trends with existing literature will add to an understanding of the CSI concept and its potential role in cardiovascular research.

Factors that influence short-term measurement of heart rate variability (HRV)

Normal HRV is predominantly affected by age and exercise. People under the age of 30 years tend to have a higher HRV than their older counterparts because of their active autonomic modulations. Conversely, an increase in sedentary lifestyle in people over the age of 50 leads to a lower HRV, with regular exercise proposed as the solution (Umetani *et al*., 1998; Zhang, 2007).

The reliability of short-term measures of HRV has come under some scrutiny (Burger *et al.*, 1999). Sandercock, Bromley and Brodie (2005) conclude that the results of short term measures may vary, especially in studies with intervention and pharmacological stimulation. On the other hand, measurements carried out at rest and on healthy subjects were found to be reliable.

Results of HRV measures also differ according to sex. Some researches indicate that males are more sympathetically dominant than females. Younger females exhibit lower HRV than age-matched males, but these gender differences appear to fade by the age of 50 years (Burger *et al.*, 2009). By contrast, Liao, Barnes, Chambless, Simpson, Sorlie and Heiss (1995) and Zhang (2007) showed that, in fact, women had slightly higher HRV than men.

Furthermore, there is a circadian variation of HRV in humans (Singh, Cornélissen, Weydahl, Schwartzkopff, Katinas, Otsuka, Watanabe, Yano, Mori, Ichimaru, Mitsutake, Pella, Fanghong, Zhao, Rao, Gvozdjakova & Halberg, 2003; Burger *et al.*, 2009), with a decline in vagal modulation ascribed to a decrease in nocturnal parasympathetic activity (Zhang, 2007).

Postural measures have been used to increase the level of vagal modulation in previous research (Acharya, Kannathal, Hua & Yi, 2005). The right lateral decubitus position increases vagal modulation in healthy subjects and improves the HRV indices that are correlated with high mortality in coronary artery disease (CAD), myocardial infarction and chronic heart failure in patients. This suggests that body position is a vagal enhancer (Valentini & Parati, 2009). Acharya *et al*. (2005) found that HRV is higher in the sitting than in the lying position, while others report inconsistent findings (Vuksanovic, Gal, Kalanj & Simeunovic, 2005). The increase in HR from supine to sitting may be as much as 35% (Valentini & Parati, 2009).

Just as in HRV, CSI measurements fluctuate and may also depend on the circumstances of the subject, such as exercise status and illness (Rudack, 2005). This study examined the influence of posture on HRV.

Methods and Material

Subjects (n=55) were recruited in Pretoria, South Africa through an advertisement. The study was limited to women over the age of 18 years And excluded pregnant or lactating women. Ethical approval was granted by the Faculty of Health Sciences Research Ethics Committee, University of Pretoria (S30/2009). Informed consent was obtained from all subjects.

The research is a case-series study with no intervention or follow-up. After completing a biographical information questionnaire, subjects' HR and CSI were evaluated using the Viport™. The Viport™ was placed on the left side of the chest, just below the collar bone with conducting gel. Two measurements were taken while the subjects were sitting down and another two measurements were obtained in the supine position. Each measurement was taken over two minutes. Two consecutive readings, a minute apart, were taken at each position. Tests were carried out between 10am and 3pm at the subjects' work or at the Department of Physiology, University of Pretoria.

The Viport

The Viport™ is a digital medical device for measuring the signal of the heart's excitation in the same manner as an ECG. It measures various parameters for HRV which are transformed via algorithms into the CSI. Heart rate (HR), heart rhythm and the QRS complex (ventricular excitation) can also be measured (Viport, 2006).

Statistical analysis

Statistical analyses were performed using SPSS 17.0 for Windows (SPSS, Inc., Chicago, IL, USA). The means and standard deviations were calculated for descriptive statistics (age, income and lifestyle habits). Mean CSI and HR readings were calculated for the sitting and supine positions. An overall mean reading was calculated using the two sitting and two supine readings for CSI and HR. The three CSI and HR means were compared using the paired samples t-test. The level of significance was set at $p \leq 0.05$.

Results

The mean age and body mass index (BMI) of the sample were 25.02 years (SD = 7.56) and 23.06 $kg.m^2$ (SD 3.85), respectively. English was the most frequently-spoken language (45.5%), followed by Afrikaans (41.8%). All subjects had completed either high school (43.6%) or tertiary studies (54.5%). The majority of the subjects were not employed (50.9%) or employed only part-time (12.7%), with the remaining 36.3% employed full-time. The sample was generally healthy: only 5.4% had a history of chronic physical illness; 15.4% were on chronic medication (including oral contraception); 9.1% had been using acute treatments over the previous two weeks (including antibiotics and analgesics). Only one subject reported a personal history of coronary disease, while all denied any use of narcotics. None of the subjects suffered from diabetes, hypertension or hypotension. A few of the subjects smoked (7.2%) and only 29.1% did not drink any alcohol.

Cardio stress index

Table 1 summarises the scores on the mean CSI in sitting and supine positions. The mean for the first reading (while subjects were seated) reflects an abnormal CSI (35.11±21.41%). This drops slightly, but remains above the normative value cut-off of 20%, to 30.24±20.34% at the second reading. Although slightly lower (for the first reading: 27.78± 16.86% and the second: 23.21±13.51%) the supine readings are both still in the twenties. The two seated and two supine values were used to calculate a mean value for each of the two positions. The means were 35.06±20.76% (seated) and 26.96± 16.49% (supine). The four CSI readings were then used to calculate a combined (seated and supine) mean CSI, which was 31.00±14.03%. This group's combined CSI is above the normative value and indicates low heart rate variability.

Table 1: Mean and standard deviation for Cardio Stress Index readings

Variable	Mean (%)	Std Deviation (%)
CSI seated reading 1	35.11	21.41
CSI seated reading 2	30.24	20.34
CSI supine reading 1	27.78	16.86
CSI supine reading 2	23.21	13.51
Mean CSI seated	35.06	20.76
Mean CSI supine	26.94	16.49
Combined mean CSI	31.00	14.03

The paired samples t-test was conducted to determine if the combined mean CSI was significantly different from the means of the values obtained from the seated and supine measurements and if the seated and supine results differed significantly from one another. The results of the t-tests appear in Table 2. The differences were all significant ($p<0.05$).

Table 2: T-test comparison of mean, seated and supine CSI values

Variable 1	Variable 2	P-value
Combined mean CSI	Mean CSI seated	0.019
Combined mean CSI	Mean CSI supine	0.019
Mean CSI supine	Mean CSI seated	0.019

Heart rate

The means and standard deviations of HR are shown in Table 3. The readings were within normal values. The two seated and two supine values were used to calculate a mean value for each of the two positions. These means were 80.17 ±11.76 bpm (seated) and 77.08 ± 11.51 bpm (supine). A combined (seated and supine) mean HR was calculated using the four HR readings (77.67 ± 11.32 bpm).

Paired t-tests were conducted to determine if the difference seen on the mean HR was significantly different from those obtained based on means of the seated and supine measurements, or if the seated and supine results differed significantly from one another. The results of the t-tests appear in Table 4. Significant differences were found between the combined mean HR and the mean HR in the seated position and also between the mean HR in seated and supine positions ($p<0.05$). These results indicate an increase in HRV.

Table 3: Mean and standard deviations of heart rate readings

Variable	Mean (beats/minute)	Std Deviation (beats/minute)
HR seated reading 1	79.75	11.85
HR seated reading 2	80.41	9.89
HR supine reading 1	75.40	11.47
HR supine reading 2	73.17	9.09
Mean HR seated	80.17	11.76
Mean HR supine	77.08	11.51
Combined mean HR	77.67	11.32

Table 4: Comparison of the mean, supine and seated heart rates

Variable	Variable 2	P-value
Combined mean HR	Mean HR supine	0.108
Combined mean HR	Mean HR seated	0.000
Mean HR seated	Mean HR supine	0.000

Pearson correlation analysis revealed a number of significant relationships between HR and CSI (Table 5). The combined mean CSI was significantly correlated with the combined mean HR and the seated and supine HR means. The mean CSI value in the seated position was also significantly correlated with all three HR means. These correlations were all weakly positive ($0.395 \leq r \leq 0.430$) despite being significant at levels of $0.001 \leq p \leq 0.003$. The mean supine CSI was not significantly correlated with any HR means.

Table 5: Pearson correlation and p-values between heart rate and cardio stress index readings

Variable	MeanHR	MeanHRsitting	MeanHRsupine
MeanCSI	0.41 (p=0.002)	0.41 (p=0.002)	0.40 (p=0.003)
MeanCSIsitting	0.43 (p=0.001)	0.42 (p=0.001)	0.41 (p=0.002)
MeanCSIsupine	0.16 (p=0.234)	0.16 (p=0.238)	0.16 (p=0.259)

Discussion

The CSI readings for the whole study group were higher than anticipated given the self-reported health of the subjects and the age group. A CSI above 20% purportedly reflects a reduced HRV. This is an indication of a number of potential cardiovascular disease states such as hypertension (Umetani *et al.*, 1998; Burger et *al.*, 1999; Pumprla *et al*., 2002). Although the youthfulness and health status of the group may call into question the CSI readings, these poor CSI results could be a re-iteration of the warning of an increased risk of cardiac morbidity amongst the South Africans (Tibazarwa, Ntyintyane, Sliwa, Gerntholtz, Carrington, Wilkinson & Stewart, 2009). The CSI readings may, therefore, be an accurate reflection of HRV.

The results indicate that the seated, supine and combined CSI results differ significantly from one another; CSI being highest in the seated position. Chan, Lin, Chao and Lin (2007) examined HRV in physical activity related posture changes. The HRV of subjects was measured while they were supine, sitting, standing and walking. The researchers found that HRV was higher when subjects sat than when they were recumbent, although these differences were not statistically significant. Acharya *et al*. (2005) also found significant increases in HRV from lying to sitting positions. The results of the current research are consistent with those of previous studies which showed that the position of the body affects heart rate control (Acharya *et al.,* 2005; Chan *et al.,* 2007).

As a higher CSI reading indicates reduced HRV, the current results indicate that HRV is in fact higher in the supine than the sitting position. This contradicts findings that HRV increases with the change from lying to sitting (Acharya *et al.,* 2005; Chan *et al.,* 2007). However, in their study of HR and spectral HRV in children Vuksanovic *et al*. (2005) found that while HR increased from supine to standing positions, this increase was at times related to increased HRV and at other times to a decrease in HRV. The latter is exhibited in this study.

HR readings also differed significantly with the change in posture: the mean seated HR was significantly higher than mean supine HR. These results are consistent with findings from other research (Acharya, *et al*., 2005; Vuksanovic, *et al*., 2005).

HR is reportedly inversely associated with HRV (Koskinen et al, 2009). Correlation analysis in the current study revealed that the CSI was significantly positively correlated with HR. This appears to strengthen the case for an analogous relationship between CSI and HRV, given the inverse relationship between HRV and CSI described in the literature (Rudack, 2005).

Study limitations

The results obtained from the relatively small sample of the study should be supplemented with further research, which include larger samples. Additional factors, such as respiratory rate and psychological distress and their influence on CSI readings, should also be investigated. Furthermore, the time of measurement should be increased to the five minutes recommended by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, or to three minutes as suggested by Van Schelven, Oey, Klein, Barnas, Blankestijn and Wieneke (2000) for the measurement of HRV. With regard to confounding variables, 70.9% of subjects stated that they do drink alcohol. Although moderate drinking does not cause changes in sympathetic nerve firing, drinking in the intoxicating range does (Valentini & Parati, 2009). The quantity of alcohol consumed was not assessed in this study and therefore remains a confounding variable.

Conclusion

The results of this study indicate a significant difference in CSI readings in response to postural changes. CSI is higher in the seated than the supine position. The most important implication of this result is that CSI readings, like HRV measurements taken in different postures, should not be used interchangeably in clinical practice or research. The results also reflect that HR is higher in the seated than supine position. Although a clear connection between body position and CSI was not found, it mirrors the uncertainty in the literature on HRV and posture.

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