Changes in Heart Rate Variability Parameters During Exercise do not Reliably Predict Changes in Cardiac Autonomic Tone

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Abstract

PURPOSE: The use of heart rate variability (HRV) analysis to reflect cardiac autonomic tone in humans at rest is well established. However, the use of HRV to derive cardiac autonomic tone during exercise is controversial, due to the conflicting results. HRV has been used as an indicator of cardiac tone during exercise, while other investigators have determined that HRV analysis during exercise is more indicative of the changes in ventilation and peripheral hemodynamics. In the present study we sought to determine if changes in HRV parameters during exercise in two body positions reliably predicted changes in cardiac autonomic tone during exercise. METHODS: Following IRB approval, two groups of subjects completed supine (S; n=10) or upright (U; n=13) cycling exercise. For each subject, HRV was recorded continuously at 1,000 Hz for 20 minutes of rest prior to exercise, 15 minutes during exercise at 40-65% of age predicted maximum heart rate and 10 minutes of recovery post-exercise using a Lead II electrocardiogram. Unpaired t-tests were used to compare the delta values derived from the difference between spectral HRV parameters at rest and exercise in each group. RESULTS: The change in heart rate was not different between the groups (S: 29 + 2.3 vs. U: 21+ 3.3 bpm) nor was the change in SDNN (S: -41 + 9.8 vs. U: -23+5.0 ms). Changes in frequency domain indices were significantly (p<0.05) different comparing S and U cycling. The %LF Power increased in S (4.3+3.3) and decreased in U (-8.5+4.5) while %HF predictably decreased in S (-12.5+5.0) there was little change in U (0.63+1.8) and an increase in LF/HF ratio in S (1.1+0.4) and decreased in U (-1.3+0.9). Total power decreased similarly in both groups (S: -3961+881 vs. U: -3412+1019 ms2). CONCLUSION: Because HRV parameters did not predictably change as established in terms of changes in cardiac autonomic tone during exercise, it is hypothesized that HRV analysis during exercise likely reflects changes in ventilation and peripheral hemodynamics. The greatest limitation in this study was that different groups of subjects were used for supine versus upright exercise. Future studies are intended to verify these findings by having the same group of subjects undergo exercise in both body positions and attempt to clarify the mechanisms behind the primary findings.

Introduction

- Heart rate variability (HRV) analysis is a well-established non-invasive method for measuring cardiac autonomic tone at rest (1).
- The use of HRV analysis during exercise is more controversial.
- Some studies have used heart rate variability analysis as an indicator of cardiac autonomic tone during exercise (2).
- If HRV analysis during exercise is a valid technique, parameters should shift in response to exercise in a predictable manner regardless of the posture of the subject.
- Alternatively, some studies have determined that heart rate variability analysis is not a valid means to measure cardiac autonomic tone during exercise (3).
- It has been hypothesized that changes in heart rate variability during exercise are not reflective of changes in autonomic tone, but rather due to changes in ventilation or peripheral hemodynamics (3).
- If peripheral hemodynamics influences the change in HRV during exercise, then preforming exercise in different body postures should effect the change in HRV.
- Likewise, if changes in HRV during exercise are not a reflection of changes in cardiac autonomic tone during exercise, HRV parameters will not change in a predictable manner when exercise is performed in an upright versus supine body posture.
- Therefore we sought to measure the change in HRV during exercise preformed in two different body postures.

Hypothesis

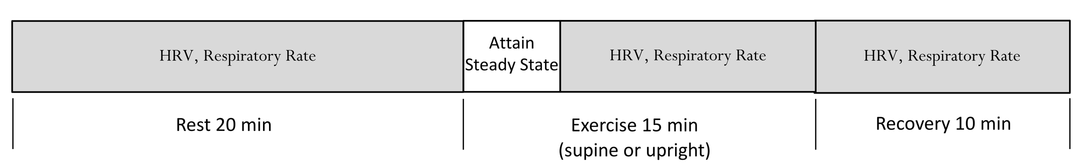
The change in HRV parameters in response to exercise will be different in response to exercise in supine versus upright cycling exercise.

Methods

Subjects

- All procedures were approved by the Institutional Review Boards of both institutions.
- Informed written consent was obtained prior to enrolling in the study.
- Subjects were screened for participation on the following criteria:
  - Be cleared to participate in exercise as determined by the PAR-Q
  - Be at least 18 years of age
  - Be able to cycle on a stationary bike for 15 minutes
- Exclusionary criteria included:
  - Cardiovascular problems
  - Diabetes
  - Asthma
  - Smoking
  - Currently pregnant
  - Long distance runners & well-conditioned athletes

Protocol



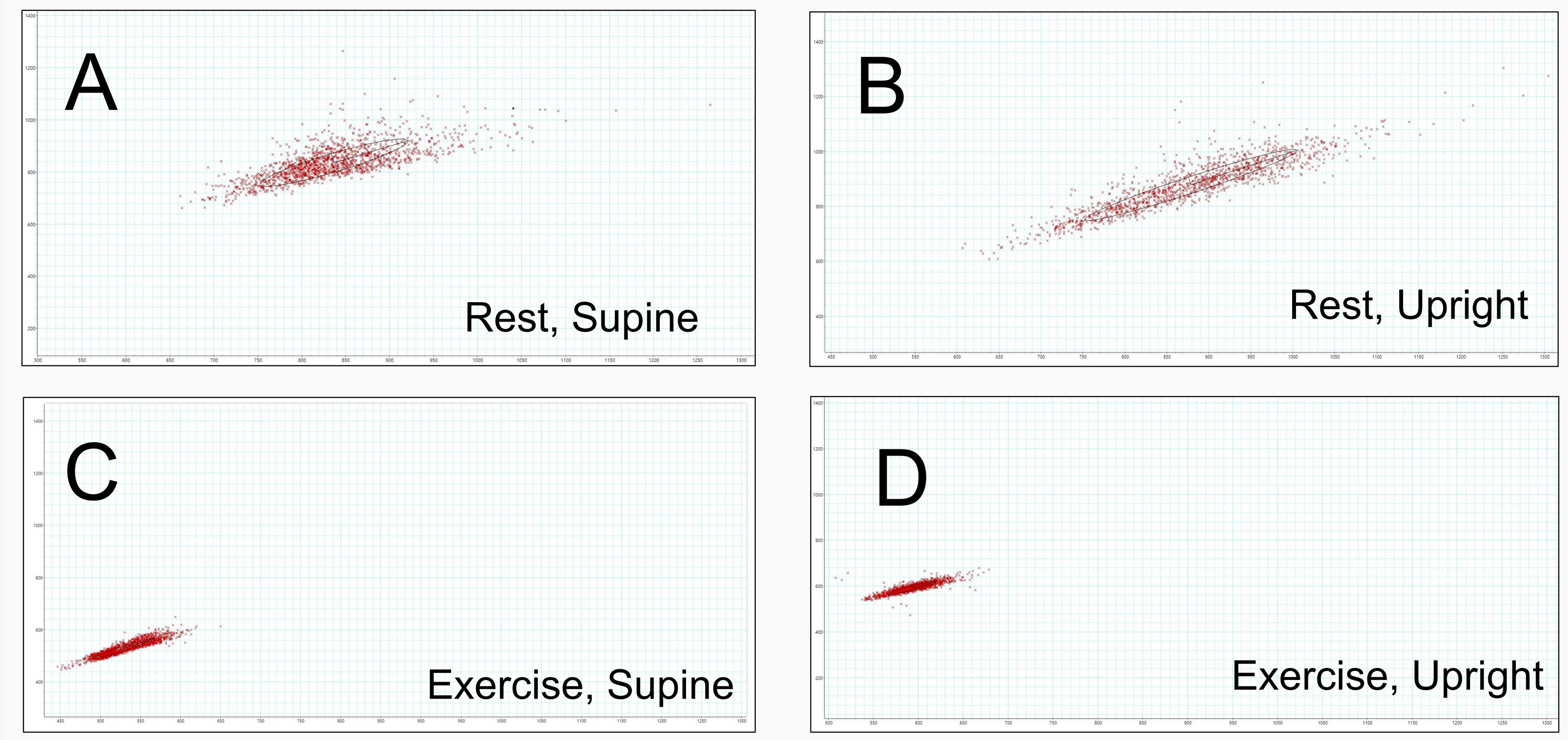
Chronological depiction of the experimental protocol followed in both the upright and supine groups.

- A Lead II configuration of the surface ECG was used throughout the study
- Strain-gage used to measure ventilation and assure that the respiratory rate did not exceed the HF band cutoff of 0.45Hz
- During rest:
  - Supine subjects rested flat on back for 20+ min
  - Upright subjects sat on a cycle ergometer for 20 min
- During exercise:
  - Subjects pedaled at 60 revolutions per minute
  - Resistance adjusted to attain a target HR range of 40-65% of age-predicted maximal HR
  - Only data collected after subject reached state was used, therefore providing about 10 minutes of usable exercise data
  - Supine subjects laid flat on back while pedaling for 15 minutes
  - Upright subjects cycled sitting upright on a cycle ergometer for 15 minutes
- Subjects recovered in the same posture for 10 minutes

Data Analysis

- •Digitized ECG, artifact free, 1000 samples/second
- •PowerLab HRV Software Analysis System (ADInstruments)
- •Calculated time- (RMSSD) and frequency- (LF, HF) domain measures.
- •The LF and HF frequency-domain measures were calculated as a percentage of the total power to account for a reduction in total power in response to exercise.
- •Indices of cardiac autonomic tone were assumed to be a reflection of:
  - •RMSSD: overall variability/cardiac autonomic tone
  - •%LF: Sympathetic and parasympathetic tone
  - •%HF: Parasympathetic tone
  - •LF/HF ratio: Sympathetic tone
- •Guidelines from the Task Force on HRV interpretation were used (Bigger Jr. 1996)
- •LF: 0.04-0.15Hz
- •HF: 0.15-0.45Hz
- •Independent t-tests were used to statistically compare groups

Sample Raw Data



Sample raw data tracings showing Poincaré plots which illustrate heart rate variability and in the resting supine (A) and upright (B) postures. This shows a dramatic reduction in heart rate variability during exercise in both postures (C,D).

Results

Table I: Descriptive Data

Group	n	Age
Supine	10	29+2.7
Upright	13	42+3.4*

The number of subjects that met final exclusionary criteria and average age. *p<0.05

Table II: Absolute Heart Rate Variability Parameters at Rest and Exercise in the Supine Group

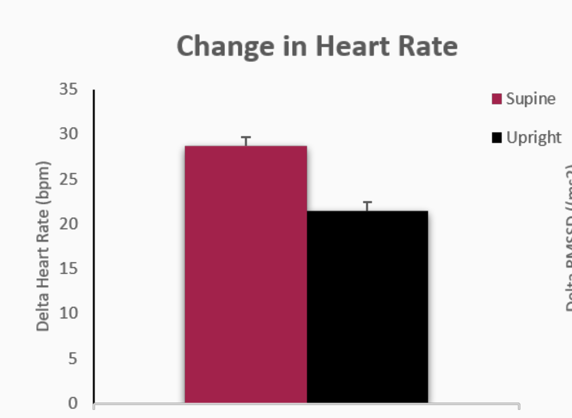
State	Heart Rate (BPM)	Total Beats	Total Power (ms)^2
Rest	63+3.3	1264+66.7	4582+896.2
Exercise	92+2.3 *	1332+34.1	621+130.3 *

Absolute heart rate and heart rate variability analysis parameters in the supine group (n=10) at rest and exercise. *p<0.05

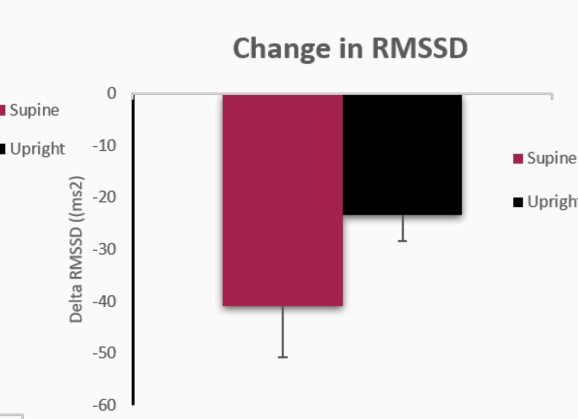
Table III: Absolute Heart Rate Variability Parameters at Rest and Exercise in the Upright Group

State	Heart Rate (BPM)	Total Beats	Total Power (ms)^2
Rest	78+2.8	1579+43	3937+953.5
Exercise	99+2.1 *	1447+49.7	525+99.1*

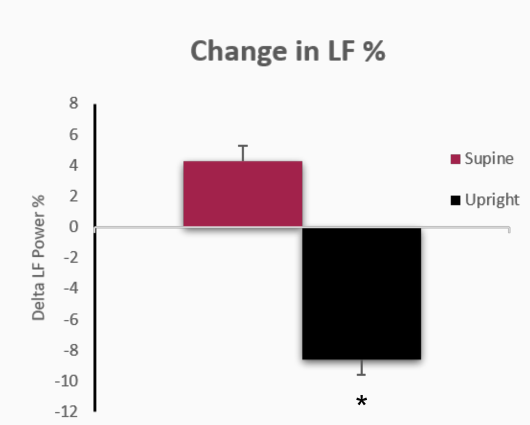
Absolute heart rate and heart rate variability parameters of the upright group (n=13) at rest and exercise. *p<0.05



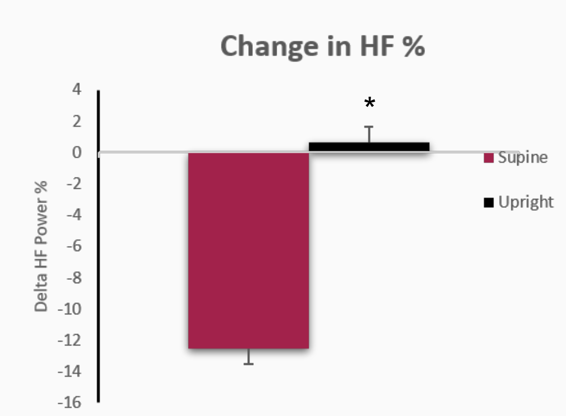
The change in heart rate (HR) in response to exercise between the supine and upright groups. Both groups attained a similar HR response to exercise.



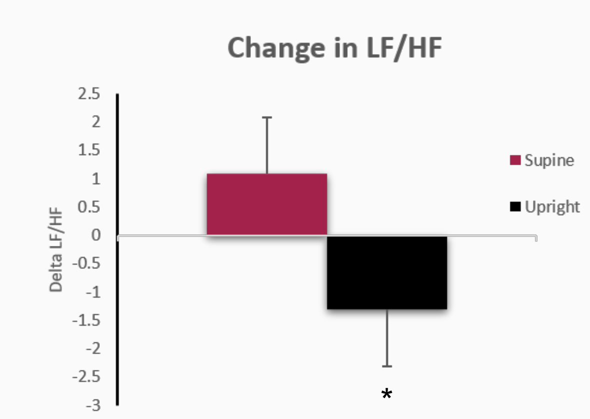
The change in RMSSD in response to exercise between the supine and upright groups. Although there was no significant difference between groups, there was a trend toward less of a reduction in RMSSD in the upright posture.



The change in LF% in response to exercise between the supine and upright groups. There was an increase in the LF% of the supine group, and a decrease in LF% in the upright group. *p<0.05



The change in HF% in response to exercise between the supine and upright groups. There was a substantial decrease in HF% in the supine group, and a slight increase in HF% in the upright group. *p<0.05



The change in LF/HF ratio in response to exercise in the supine and upright groups. There was an increase in LF/HF in the supine group, and a decrease in LF/HF in the upright group. *p<0.05

Conclusions

- Changes in frequency domain measures during exercise in different postures were significantly different.
- These data suggest that heart rate variability analysis techniques do not accurately predict changes in cardiac autonomic tone during exercise.

Discussion

- The results of this study imply that that the changes in heart rate variability parameters during exercise are not a reflection of cardiac autonomic tone.
- Therefore, it is postulated that these changes in HRV during exercise may instead reflect changes in peripheral hemodynamics.
- This is supported by the observation that the change in HF% and LF/HF ratio were diametrically opposed during exercise in the upright vs. supine posture.
- These findings agree with previous data by Perini et al, 1992 (3).

Future Directions

- Investigate the mechanisms responsible for these effects, focusing on peripheral hemodynamics.
- Use of the same subjects for all groups with repeated measures.
- Better control for age of the subjects.

References

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2. Bernardi L, Salvucci F, Suardi R, Solda PL, Calciati A, Perlini S, Falcone C and Ricciardi L. Evidence for an intrinsic mechanism regulating heart rate variability in the transplanted and the intact heart during submaximal dynamic exercise? *Cardiovascular Res.* 1990; 24: 969-981
3. Perini R, Orizio C, Milesi S, Biancardi L, Baselli G, Veicsteinas A. Body position affects the power spectrum of heart rate variability during dynamic exercise. *European Journal of Applied Physiology*. 1992;66:207-213