Effect of Postural Changes on Complexity Measures of Heart Rhythm in Late Adolescents

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Abstract

As a result of a change from supine to sitting position, a person is exposed to orthostatic stress for a short period of time. This has effects on the cardiovascular system. Since the cardiovascular system has non-linear characteristic, non-linear dynamics were introduced in this study to understand changes in HR

This study was performed to investigate heart rate asymmetry (HRA) and entropy-based heart rate variability (HRV) in stationary conditions in two body positions. Forty male students participated in this study. Volunteers remained relaxed in supine position. 4 kHz ECG was recorded for 15 minutes first in supine and after that in sitting position. 512 beat-to-beat intervals (RRi) were selected from each recording. Entropy-based parameters such as approximate entropy (ApEn) and sample entropy (SampEn) were computed. Heart cycles shorter (acceleration) or longer (deceleration) from the previous ones and sequential monotonic changes of RRi were also discriminated. Postural change from supine to sitting position resulted in a significant HR increase from 69 to 77 bpm. Both ApEn (from 1.23 to 1.08) as well as SampEn (from 1.54 to 1.20) decreased after changing position. Nonlinear mechanisms related to complexity of the heart rate control systems are involved in cardiac responses to changes in body position.

1. Introduction

Each person deals with orthostatic stresses every day. As a result of changing posture from supine to sitting a volume of blood moves from chest into lower parts of the body. Cardiovascular adaptive mechanisms and reflexes are responsible for heart rate (HR) and blood pressure (BP) adjustments. Autonomic nervous system (ANS) plays major role in maintaining cardiovascular homeostasis. ANS divides in two functionally different parts (sympathetic and parasympathetic) that play in concert to control HR and BP. In our work we investigated beat to beat changes of HR as they reflect ANS regulatory control on the heart. Since temporal changes of HR are most distributed in a non-gaussian pattern our study was focused on heart rate asymmetry (HRA) [1] and non-linear parameters of heart rate variability (HRV) [2, 3].

The study was performed to investigate HRA and entropy-based HRV measures and compare the heart rhythm complexity in stationary conditions in two body positions.

2. Materials and Methods

The study was conducted in accordance with the Declaration of Helsinki and the protocol was approved by the Independent Bioethics Commission.

Forty male students were recruited to participated in this study. Volunteers remained possibly quiescent and relaxed in supine position. After few initial minutes for adaptation for experimental conditions electrocardiogram (ECG) recordings were started. 4 kHz ECG (LabChart 8 Pro software, AdInstruments, Sydney, Australia) was recorded for 15 minutes first in supine and after that in sitting position. Ectopic and artifactual peaks were corrected and 512 beat-to-beat intervals (RRi) were selected from each recording. Entropy-based parameters such as approximate entropy (ApEn) and sample entropy (SampEn) were computed with use of Kubios 3.2 HRV Pro software (Kuopio, Finland). Heart cycles shorter (acceleration) or longer (deceleration) from the previous ones and sequential monotonic (acceleration or deceleration runs) changes of RRi were discriminated with use of dedicated software (Microsoft Excel, USA).

Statistical analysis was performed using GraphPad Prism 7 software (La Jolla, CA, USA) and Statistica 13 software (StatSoft, Tulsa, USA). All data sets were tested for normality with Shapiro-Wilk test. Statistical analysis was based on Wilcoxon and paired Student t-tests, depending whether data have normal or non-normal distribution. Correlation were performed with the use of Statistica 13 and shown as Pearson correlation coefficient r. P values <0.05 were considered statistically significant. All data are shown as mean values ± standard deviation of the mean (±SD).

3. Results

Postural change from supine to sitting position resulted in a significant HR increase from 69.2 ± 9.3 to 77.1 ± 10.2 beats per minute (bpm; $p < 0.01$). Following HR changes we observed RRi prolongation from 780 to 881 ms ($p < 0.01$). As shown on Figure 1 both ApEn (A) as well as SampEn (B) decreased after changing position from supine to sitting: from 1.23 to 1.08 and from 1.54 to 1.20 ($p < 0.05$) respectively.

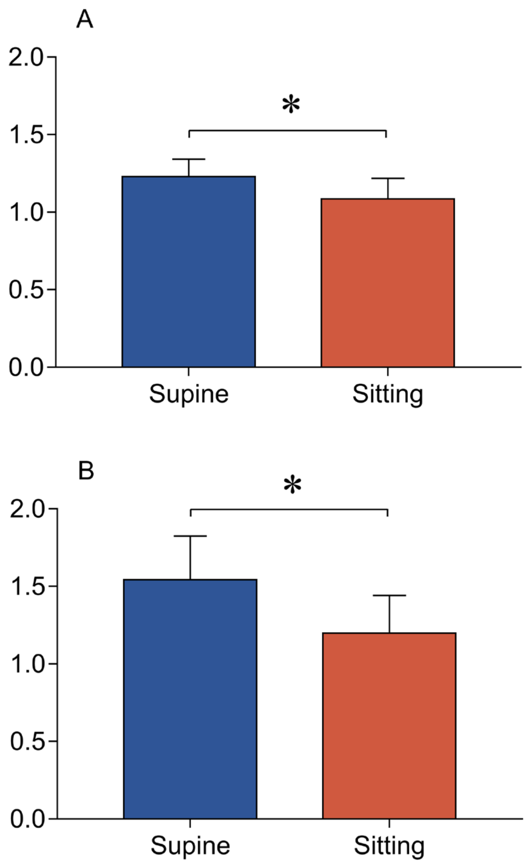

Figure 1. Non-linear HRV parameters: approximate entropy (A) and sample entropy (B) after changing position from supine to sitting. * - $p < 0.05$.

Decelerations to accelerations ratio of HR cycles was higher in supine compared to sitting position, (0.93 ± 0.20 to 0.90 ± 0.18;-$p < 0.05$; Figure 2). The total number of monotonic sequential RRi changes was significantly lower in sitting than in supine position (Figure 3). The observed decrease reached 18.5 % and was mainly covered by a decrease runs of lengths of 2 heart beats (-52 %). The number of longer monotonic runs (lengths of 4 to 9 heart beats) was significantly higher (up to + 263 %).

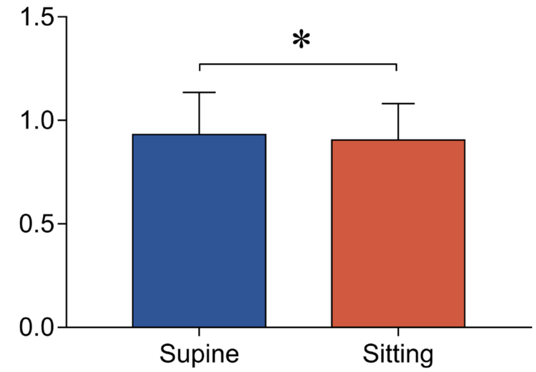

Figure 2. Deceleration to acceleration ratio of HR cycles, * - $p < 0.05$.

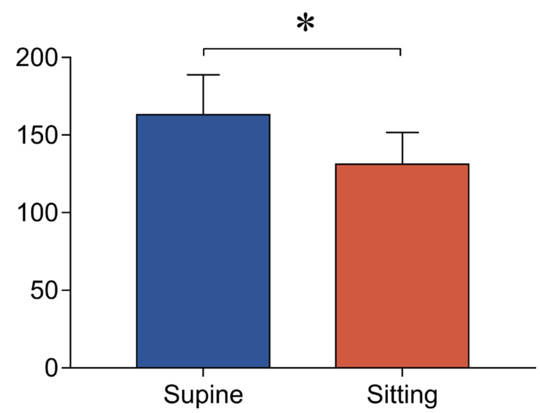

Figure 3. Total number of monotonic sequential RRi changes. * $p < 0.05$

Regardless the body position, the total number of HR sequential runs significantly correlated with ApEn: r = 0.7093 (supine; Figure 4 A) and r = 0.7076 (sitting; Figure 4 B). Similar correlation was observed with SampEn: r = 0.6597 (supine; Figure 4 C) and r = 0.7076 (sitting; Figure 4 D). The ratio of decelerations to accelerations did not correlate with either ApEn: r = 0.4800 (supine; Figure 4 E) and r = 0.3638 (sitting; Figure 4 F) or SampEn: r = 0.4136 (supine; Figure 4 G) and r = 0.3589 (sitting; Figure 4 H). Changes in deceleration to acceleration ratio evoked by the postural changes were closely related to both entropy HRV parameters: ApEn (r = 0.6298) and SampEn (r = 0.5809; Figure 5 A and B).

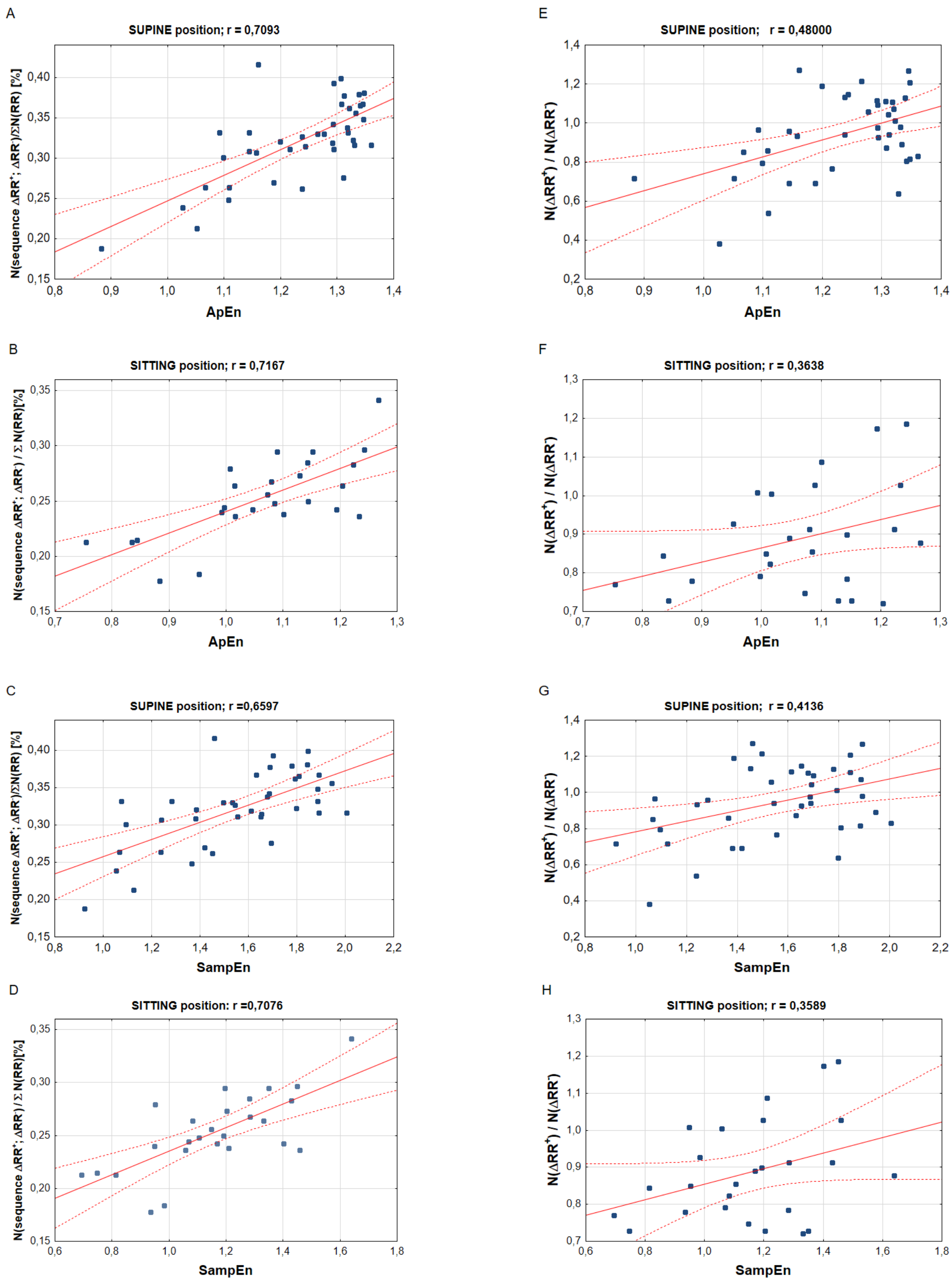

Figure 4. Correlation between entropy measures (ApEn and SampEn) and heart rate asymmetry (HRA) parameters. Total number of sequential runs vs ApEn supine (A) and sitting (B) vs. SampEn supine (C) and sitting (D); the ratio of decelerations to accelerations vs ApEn supine (E) and sitting (F) vs SampEn supine (G) and sitting (H).

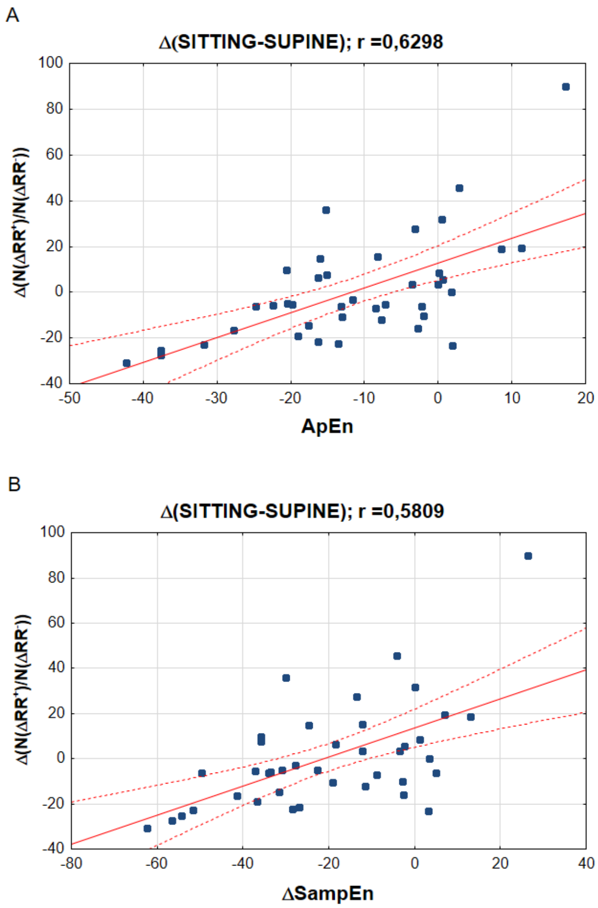

Figure 5. Changes in deceleration to acceleration ratio evoked by the postural changes. A – ApEn, B – SampEn.

4. Discussion

As a result of a postural changes from lying to sitting position, a person is exposed to orthostatic stress for a short period of time. As confirmed by the significant increase in HR the functional effects of such a relatively small postural challenge are not negligible. Our data confirmed the value of the beat-to-beat analysis based on nonlinear dynamics as suggested much earlier by Richman and Moorman [4].

The main response to changing position form supine to sitting was increase in HR with decrease in both ApEn and SampEn. This suggests that ordinary change of position affects complexity and regularity of autonomic regulation upon the heart. Lower value of ApEn in sitting position indicates higher degree of regularity in HR after changing position. Similarly, lower value of SampEn reflects more self-similarity of RRi in sitting position. That might suggest that during orthostatic stress our ANS simplifies its activity in order to maintain cardiovascular homeostasis. Additionally sympathetic branch of ANS predominates which can be seen as increase in HR.

5. Summary

HRA corresponds to the entropy based HRV measures. Nonlinear mechanisms related to complexity of the heart rate control systems are involved in cardiac responses to changes in body position.

Acknowledgments

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