Analysis of Heart Rate Variability Indices with Slowly Changing Heart Rate

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Abstract

Cardiac autonomic function is often assessed by a variety of cardiac ECG indices. The ECG is usually assessed from recordings during stable ECG conditions with subjects in comfortable lying or sitting positions. However, it is accepted that heart rate may change during the recording, usually by becoming slower as the subject relaxes. Such changes are usually small, and therefore normally neglected. We were interested in assessing the effect of very small changes.

ECGs were recorded in sequential one-minute samples, during sitting as this induces smaller changes than would be the case if subjects were asked to lie down. Recordings were made with electrodes positioned to give a stable positive QRS complex, and the RR was measured between consecutive complexes. All RR intervals were converted to instantaneous beat-to-beat heart rate. Indices were calculated from these data, and averaged over 1 min periods.

Heart rate over one min periods changed from 75.9 ± 1.1 to 68.8 ± 1.7 (mean ± SD) beats/min (p<0.001), with an 1 min average change over the 30 min period of -0.25 ±1.11 beats/min. The figures respectively for successive beat differences were -0.024 ± 0.383 to -0.025 ± 0.519 (p=NS) and 0.000 ± 0.037 beats/min, and for successive RMS beat differences were 0.27 ± 0.27 to 0.37 ± 0.37 (p=NS) and 0.0034 ± 0.088 beats/min. In spite of very significant changes in rate, the indices calculated from successive differences were less prone to the rate changes.

1. Introduction

Heart rate variability analysis has been used in many clinical studies, including for diabetes [1], heart transplant [2,3], Alzheimer's disease and vascular dementia [4], and sleep [5], as well as for studies of multifractal characteristics [6], variation over 24 hours [7], during sleep [8,9] and Zen meditation [10].

However heart rate is known to fall when subjects relax, and this can also occur over any recording period used to study heart rate variability.

It was the aim of this research to examine the effect of falling heart rate on two common heart rate variability indices.

2. Methods

ECGs were recorded over a 30 min period, and analysed for changes in heart rate and heart rate variability.

2.1. ECG recording

Single lead ECGs were obtained with three electrodes applied directly to the chest. The ECG amplifier gain was set at 1000. The output of the amplifier was connected to an analogue-to-digital converter at a sample rate of 200 Hz, and stored to a computer for off-line analysis.

The subject was asked to remain seated and still, without talking for the 30 minute recording period.

2.2. QRS detection

ECG were filtered using time domain Savitzky-Golay filtering [11,12] and each ECG beat was detected by identifying the fast response associated with each QRS as well as by coarse grained local maxima procedures, followed by cardiologist's confirmation.

2.3. Heart rate variability analysis

The ECGs were split into a series of non-overlapping one minute segments, and each segment was analysed for instantaneous heart rate in each 1 min period and for changes in instantaneous heart rate over the 30 min period.

For the analysis of heart rate variability, the successive beat differences were calculated, retaining the sign of the change. Then absolute change in successive beat differences were calculated to obtain the root mean square (RMS) of successive beat differences.

Computing in Cardiology 2016; VOL 43 ISSN: 2325-887X DOI:10.22489/CinC.2016.289-243

Figure 1. An ECG example from the first and last minute of the 30 min recording. Ten seconds from each is shown. It can be seen that the heart rate has become slower during the recording period.

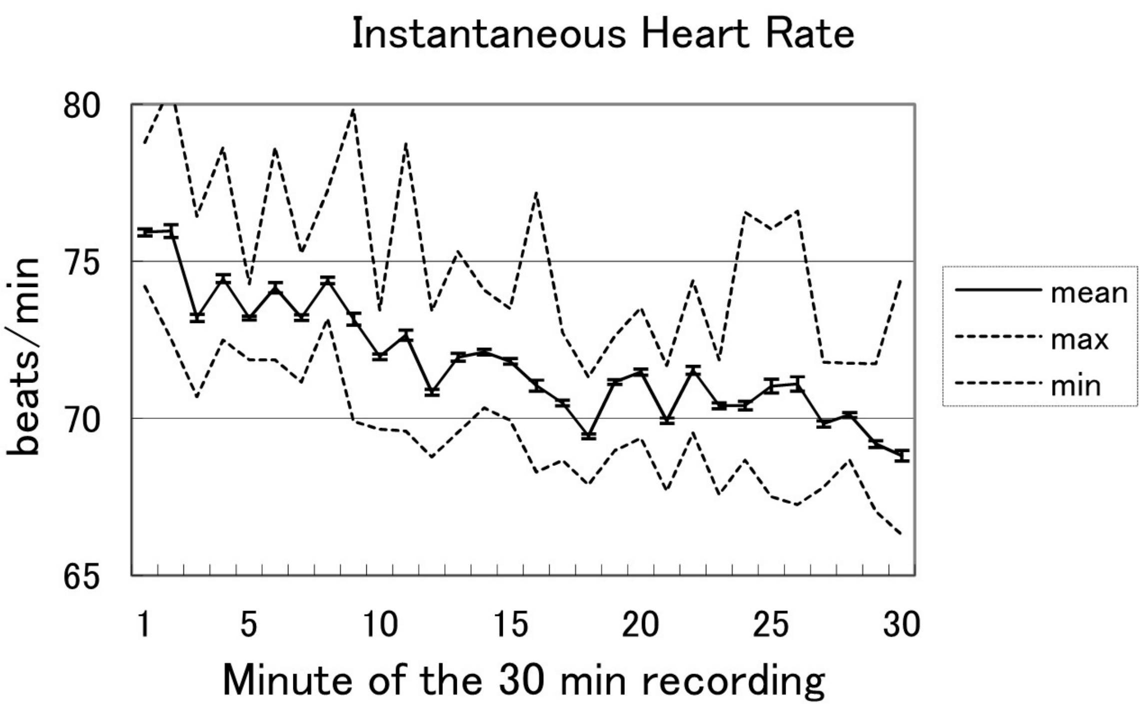

Figure 2. Mean, maximum and minimum instantaneous heart rate (calculated from all beats in each minute) from the first to the final minute at 30 min. The horizontal axis gives the minute recording, and the vertical shows the changes in the mean instantaneous heart rate for each minute segment over the 30 min period.

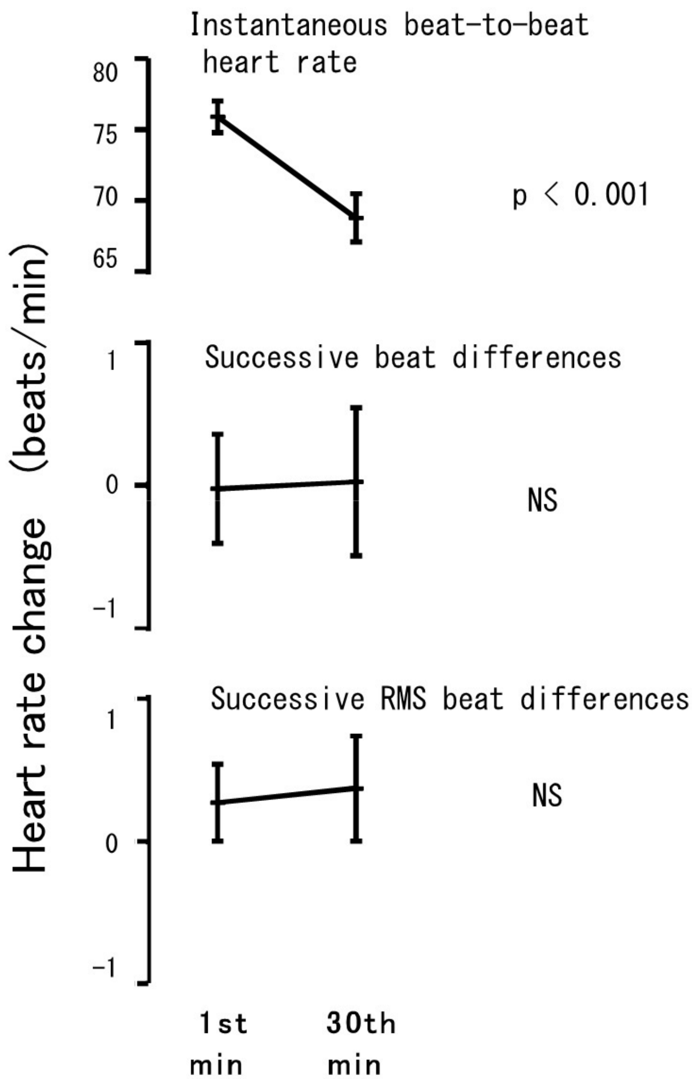

Figure 3. Change in heart rate, including instantaneous beat-to-beat heart rate, and successive beat differences and successive RMS beat differences.

3. Results

3.1. Heart rate changes

Example of short 10 s sections from the beginning and end of a 30 s period is shown in Figure 1, illustrating the small but noticeable change in heart rate, with the heart rate slowing as expected.

Heart rate over one min periods changed from 75.9 ± 1.1 to 68.8 ± 1.7 (mean ± SD) beats/min ($p<0.001$), with a 1 min average change over the 30 min period of -0.25±1.11 beats/min.

Figure 2 shows the changes in the mean instantaneous heart rate for each 1 min segment over the 30 min period.

3.2. Successive beat differences in instantaneous heart rate

The successive beat differences in instantaneous heart rate for the first and last one minute segments over the 30 min period were -0.024 ± 0.383 to -0.025 ± 0.519 (p=NS), with an average change over the 30 min period of 0.000 ± 0.037 beats/min.

3.3. Successive RMS beat differences in instantaneous heart rate

The successive beat differences in instantaneous heart rate for the first and last one minute segments over the 30 min period were 0.27 ± 0.27 to 0.37 ± 0.37 (p=NS), with an average change over the 30 min period of 0.0034 ± 0.088 beats/min.

4. Discussion and conclusion

In spite of very significant changes in rate, the indices calculated from successive differences were less prone to the rate changes.

Acknowledgement

We acknowledge the support of the Great Britain Sasakawa Foundation.

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