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Heart Rate and Arterial Pressure Variability in Humans During Different Orthostatic Load

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Summary

The influence of posture on the rhythms in blood pressure, heart rate and respiration was tested by means of spectral analysis in 14 healthy subjects. During squatting, standing and sitting, the finger blood pressure was recorded by the non-invasive Peňáz technique together with cardiac intervals and respiratory movements. The power spectra obtained from five-minute samples showed that the respiratory components of cardiac interval and pulse pressure were reduced significantly in standing. Compared to squatting, a significant increase of total power in the medium frequency band (0.05–0.15 Hz) for cardiac interval, diastolic and mean pressure could be detected.

Key words
Posture – Heart rate – Blood pressure – Spectrum analysis

Introduction

The circulatory response to changes of posture has been well investigated and interpreted, to a great extent, in an uniform way (Gauer and Thron 1965). However, there are few quantitative studies of the circulatory dynamics during and after changes in posture. An additional problem is the lack of exact parameters for assessment of orthostatic tolerance. Above all, it is difficult to determine the values which would characterize normal cardiovascular regulation, because different orthostatic procedures – such as active or passive maneuvres, different tilt angles and velocities or lower body negative pressure – are applied. With reference to the orthostatic late response essentially the classifications proposed by Schellong and Lüderitz (1954), by Delius (1964) and by Thulesius (1970) must be cited. However, only limited information can be obtained by traditional statistical measures based on changes in heart rate and blood pressure relative to control values in the supine position only. Therefore, in recent years, the heart rate and blood pressure dynamics associated with beat-to-beat fluctuations during orthostatic load have been investigated. It was especially spectral analysis which was utilized as a useful technique, above all for the analysis of heart rate variability with the aim of evaluating the influence of the autonomic nervous system during active orthostatic load or tilting.

Besides the change of posture from lying to standing, a special and very effective form of active orthostatic maneuvre is the squatting test as applied by Barbey *et al.* (1966a, 1966b). In a previous study, we described the dynamics of the transient cardiovascular response on the active change from squatting to standing using non-invasive methods (Rossberg and Peňáz 1988). The present study was undertaken to determine, by means of spectral analysis, the rhythms of fluctuations of circulatory parameters during the squatting, standing and sitting position.

Methods

The measurements were performed on fourteen young subjects, 8 females and 6 males, with a median age of 21.4 years. All subjects were screened with a careful case history, no one had clinical evidence of cardiac or other disease, no one suffered from signs of impaired orthostatic late regulation. Subjects were non-smokers and did not take any medication, except anticonceptives. Simultaneous recordings of ECG (bipolar lead: second intercostal space just to the right of the sternum, and heart apex), cardiotachogram, respirogram (changes in thoracic circumference) and finger blood pressure (the hand fixed at the level of the diaphragm) were made on a Mingograph 82 and a tape recorder. The time intervals between the R-waves and the instantaneous heart rate were measured by R-wave detector output from a cardiotachometer, the finger blood pressure was recorded with the non-invasive Peňáz technique (Peňáz 1973).

Test procedure. The experiments were performed in a quiet room in the late morning (10.00–11.30 h), the temperature being 20–21 °C. In each experiment the registration lasted for 6 min in the squatting as well as in the standing and sitting position.

Data collection and statistical analysis. The power spectra were computed for systolic, diastolic, mean and pulse pressure as well as for cardiac intervals and the respirogram using the two-step procedure of Blackman and Tuckey (1958). Five-minute periods were chosen from the recordings for the spectral analysis; care was taken that initial transients were not included in these sections. Analog tape recordings of blood pressure and the respirogram were digitized at a sampling rate of 94/s. The beat-to-beat values of systolic, diastolic and mean pressure were computed and the cardiac interval and the corresponding instantaneous value of the respirogram estimated. Equidistant values at 1 s intervals were obtained by linear interpolation. The linear trend was estimated and subtracted from the data. The resulting values were normalized by dividing them by the standard deviation. The normalized autocorrelation function was then computed for a maximum time lag of 60 s with a lag interval of 1 s. Fourier analysis of the autocorrelogram gave the power spectrum for frequencies 0–0.5 Hz (0–30 cycles . min^{-1}; cpm) with a resolution of 0.017 Hz (1 cpm). For statistical comparisons the sum of the relative power in the frequency range of 0.05–0.15 Hz as well as of 0.17–0.42 Hz for each volunteer and each position was calculated. Moreover, the arithmetical means and standard errors of the five-minute periods were determined for blood pressure and cardiac interval in each experiment. For differences between measurements in the squatting, standing and sitting position, the Wilcoxon matched pairs signed rank test was applied in each case.

Results and Discussion

Fig. 1 shows the mean values (± S.D.) for blood pressure (systolic, diastolic, mean, pulse pressure) and cardiac interval during different postures. It should be noted that in the squatting position, the systolic, diastolic, mean and pulse pressure, in the sitting position, the systolic and pulse pressure were significantly higher in relation to standing ($p \leq 0.05$). At all three body positions the cardiac intervals differed significantly ($p \leq 0.05$). In contrast with the above-mentioned results, the power spectra provided more information about the dynamics of the blood pressure and heart rate during different orthostatic load.

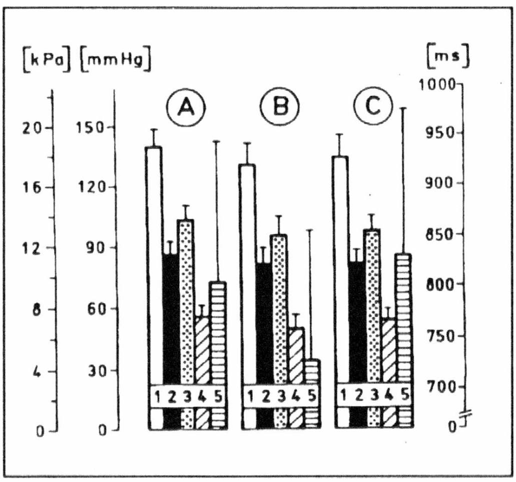

Fig. 1
Mean values (± S.D.) of systolic (1), diastolic (2), mean (3), pulse pressure (4) and cardiac interval (5) in squatting (A), standing (B) and sitting position (C).

In Fig. 2 illustrative responses are given in the form of mean values of all the power spectra. Compared with squatting, the standing position clearly demonstrates a depression of high frequency fluctuations (HF=0.17–0.42 Hz=10–25 cpm) of cardiac intervals and an increase of the relative power in the medium frequency band (MF=0.05–0.15 Hz =3–9

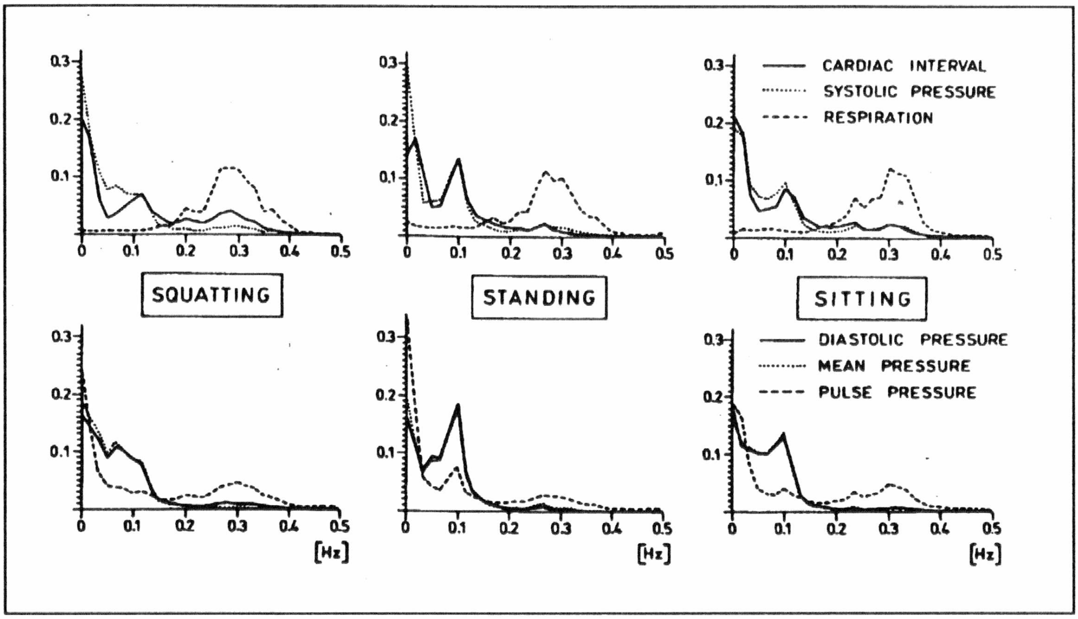

Fig. 2
Power spectra of circulatory parameters in response to postural change. Values are means of 14 subjects, power is given in arbitrary units.

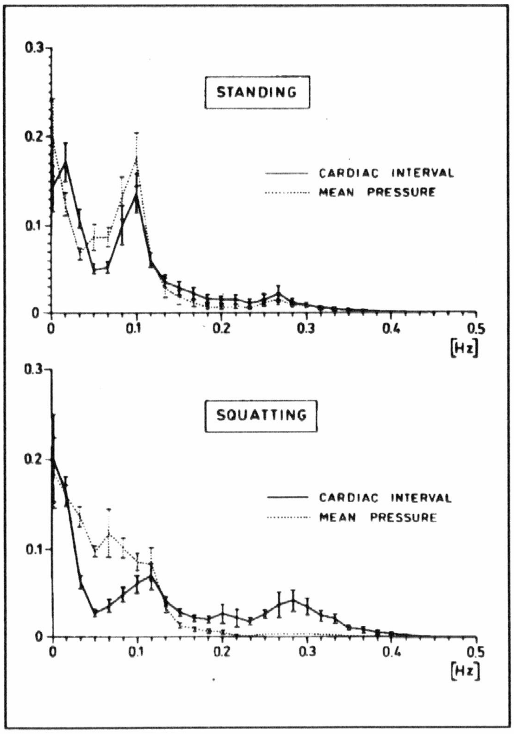

Fig. 3
Mean values (± S.D.) of power spectra in different posture (n = 14).

cpm) for systolic, diastolic and mean pressure as well as for the cardiac interval.

In comparison with standing to sitting, the spectral power at approximately 0.1 Hz – the so-called 10-second rhythm – was lower in the cardiac interval, systolic, diastolic and mean pressure.

Fig. 3 demonstrates the same results in more detail. The mean relative power of the MF component with a prominent spectral peak centred at approximately 0.1 Hz was evidently enhanced in the standing position both in the cardiac interval and in mean pressure.

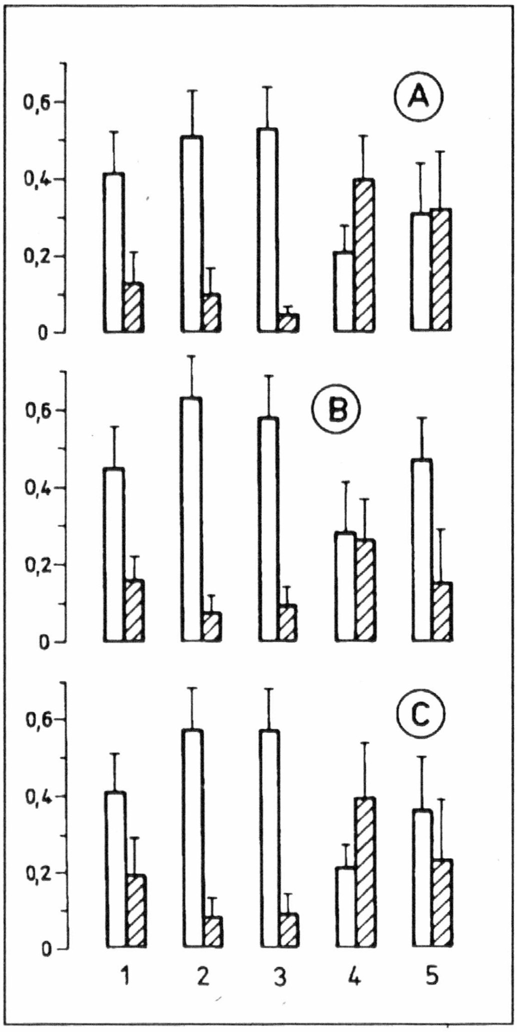

Fig. 4
Total power of medium frequency band (open bars) and high frequency component (hatched bars) during squatting (A), standing (B) and sitting (C). 1: systolic pressure, 2: diastolic pressure, 3: mean pressure, 4: pulse pressure, 5: cardiac interval. Values are the average sums (± S.D.) of relative power for 14 volunteers.

As is shown in Fig. 4, the mean values calculated from the amplitudes of all frequencies of the MF band were elevated during standing (B in Fig. 4). In this position the total relative power in the MF band increased significantly for the cardiac interval, diastolic and mean pressure versus squatting (A in Fig. 4; $p \leq 0.05$). In addition, standing upright caused a significant reduction of total power in the HF band for pulse pressure and heart rate fluctuations ($p = 0.01$). Comparison of standing with the sitting position (C in Fig. 4) resulted in a significant decrease in fluctuations of heart rate ($p = 0.01$) in the MF band, whereas the HF band shows a significant increase in pulse pressure and heart rate fluctuations during sitting ($p = 0.01$). On sitting, the total power of systolic and mean pressure in the HF range increased significantly ($p \leq 0.05$), whereas the heart rate fluctuations were distinctly reduced compared with squatting ($p = 0.05$); in the MF range solely the fluctuations of diastolic pressure were significantly reduced during squatting ($p = 0.05$). In conclusion, the experiments have demonstrated a marked increase of the spectral energy in the MF band during standing. With reference to the heart rate fluctuations, our findings are in good agreement with the results found after active or passive change of posture (Zwiener 1979, Pomeranz *et al.* 1985, Pagani *et al.* 1986, Weise *et al.* 1987, Lipsitz *et al.* 1990).

The blood pressure variability during orthostatic stress was examined by Pagani *et al.* (1986) using direct arterial pressure measurement. These experiments showed a predominant MF component in systolic and diastolic pressure after upright tilting compared with recumbency. Our results confirm this finding. Moreover, the new result of our study is the detection of the spontaneous fluctuations of systolic, diastolic, mean and pulse pressure together with the heart rate variability in the squatting, sitting and standing position using non-invasive methods. These results represent the heart rate and blood pressure fluctuations in healthy young subjects and could be used as a base for the study of impaired cardiovascular responsiveness.

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Reprint Requests

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