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Circadian stability of some cardiac parameters

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Along with cardiac parameters as dependent variable, their resting values are usually used as reference points to be compared with changes caused by the independent variables. However, the resting level parameters were frequently shown unreliable, due to environmental effects. The aim of this study was to examine the reliability and validity of resting level cardiac parameters, against their level during the delta phase of EEG (deep sleep). This study included 16 subjects, aged 19 to 22, whose cardiac R-R intervals were registered hourly during 24 hours. Further, cardiac R-R intervals were recorded for each subject during the periods of EEG delta phase (deep sleep).

The comparison of the mean R-R intervals and their variability in the EEG delta phase of sleeping with the same parameters at the wake resting level showed marked differences, suggesting that cardiac parameters in the EEG sleep phase should be used as more reliable cardiac reference value than the resting level parameters, since the reliability of the latter changes in the course of the day.

Various cardiac output parameters are often used as physiological correlates of mental load, but in a number of studies, with similar methodological approach and tasks, the results are not in agreement. Mulder & Mulder-Hajonides van der Meulen (1973) found that increase in task difficulty in choice reaction time tasks caused an increase in heart rate and a fall in heart rate variability. To the contrary, Mulder & Mulder (1981) and Aasman et al. (1987) did not find changes in cardiac parameters as mental load changed in choice reaction time tasks. Tattersall & Foord (1996) obtained only changes in heart rate, while Kalsbeek & Etteme (1963) reported on changes in heart rate variability as a mental load changed in choice reaction time task.

Backs et al. (1994) argued that, most probably, the basic reason for disagreement of results of various studies are in the fact that the effects of changes in mental load to various cardiac parameters are too small, in comparison with the effects of various metabolic processes.

Cohen et al. (1999) found that the problem of different outcomes in similar studies concerning the heart rate and its variability are differences in the parameters used. For example, Opmeer (1973) put forward more than 30 parameters of heart rate variability, which gave different values of changes on the same R-R interval continuum.

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Some researchers used relative values of R-R intervals, i.e. the differences between the R-R interval levels in experimental situation and resting. Mulder (1998) pointed to stability as the major problems of this measure, is its stability and reliability in resting situation. Furthermore, in some studies, HRV parameters were used in connection with the control of the effects of the time of day where circadian effects were found (Van Dongen et al. 2001).

Apart from this, Mulder (1988), and Backs et al. (1994) pointed to the importance of the effects of various extraneous variables on changes in the parameters, which are not directly controllable in a resting situation. On the contrary, delta phase of EEG, which signifies deep sleep, is thought to have lower degree of the reticular system activity, which, in turn, lowers the sensitivity of the organism to various external factors, and therefore lowers their effects on cardiac activity.

It would be reasonable to assume that the magnitude and variability of R-R intervals in delta phase of EEG could be more suitable and more stable reference situation for the assessment of the effects of various independent variables. This is primarily due to the fact that the changes would be assessed in relation to the same basal state (deep sleep) for all the subjects.

The aim of this study was to examine reliability and consistency of cardiac activity in a usual experimental resting situation, compared with the same cardiac parameters during delta phase of the EEG.

METHOD

In a series of circadian experiments, which included 16 subjects, aged 19 to 22 years, R-R intervals were, *inter alia,* measured and recorded hourly during resting periods through 24 hours. During this period of 24 hours subjects did not sleep and took only food three times at usual meal times. After the 24-hour period the subjects went to sleep, with the EEG and ECG electrodes connected to computerised polygraph. The aim of this sleeping period was to bring the subjects in deep sleep where delta waves of the EEG were dominant. When this delta phase was identified, the R-R intervals were measured and registered for at least 10 minutes.

RESULTS AND DISCUSSION

The parameters used for this comparison were mean of R-R intervals and the DM index as the parameter of HRV which represents the mean of absolute differences between successive R-R intervals. First of all, it was necessary to examine whether the two parameters changed throughout the 24-hour period.

The analysis of variance showed significant circadian variations of R-R intervals parameters (Figure 1 and 2). These results should be taken into account when resting levels of such parameters are taken as the values for estimation of the effects of different independent variables on cardiac activity.

One of the ways how to deal with these effects is to take measurements on the same subjects at the same time during consecutive days when the experiment takes more then one day. The interindividual differences, however, cannot be dealt with in the same way. Since it is reasonable to expect that different individuals function at different physiological levels, meaning that basal metabolism is different from person to person, the only way of dealing with interindividual differences seems to be measuring of the parameters in the same state of the individuals. Since many intrinsic and extrinsic variables affect various individuals in different ways, it cannot be expected that they are in the same state while resting awake. It seems that the only situation where different individuals are in the most similar state is deep sleep, which is characterised by the dominance of delta waves of EEG. When R-R intervals of delta EEG phase are compared with the R-R intervals in resting, significant differences can be observed.

Figure 3 and 4 show scatter plots of R-R intervals against the same R-R intervals with lag 1 for the delta phase and resting period. It is obvious that in delta phase there is no systematic relationship between the data and their lagged version, which means that the scatter looks almost random. On the contrary, resting state intervals are characterised with systematic changes, which suggests almost linear relationship between R-R intervals and their lagged version.

Spectral analysis of R-R intervals in delta phase of the EEG and the resting situation showed also significant differences (Figure 5 and 6). In the first spectrogram, effects of the respiratory activity can be identified at the frequency of 0.30 Hz, while in the second spectrogram, apart from the breathing effects, there are marked differences in the frequency range from 0.07 to 0.14 Hz, which some authors have associated with level of arousal or mental work (Mulder, 1988). This could be interpreted that while resting, the subject is either aroused or thinks about something, which seems a logical assumption. On the contrary, in deep sleep any known mental activity is non-existent, therefore, there were no changes in this part of the spectrum.

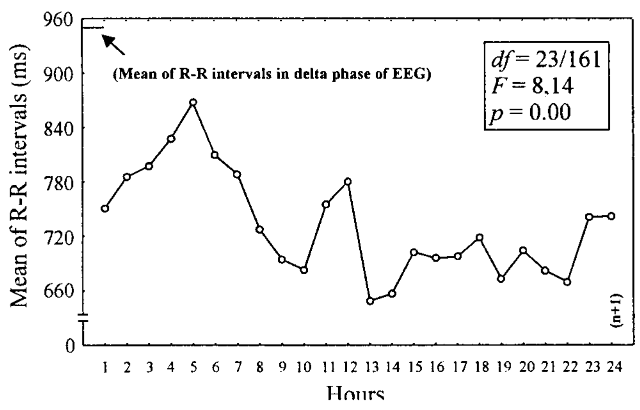

Figure 1. Circadian changes in R-R intervals during resting

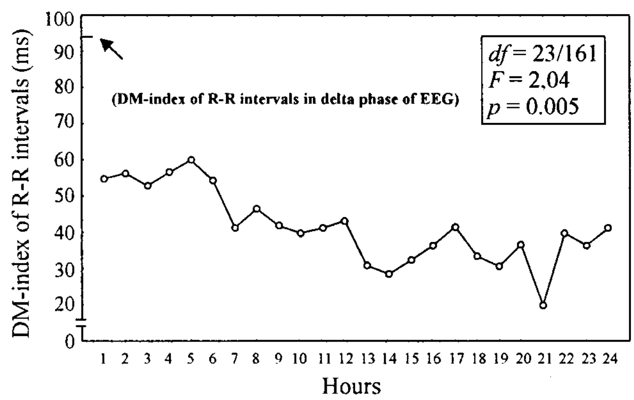

Figure 2. Circadian changes in the R-R intervals variability (DM index) during resting

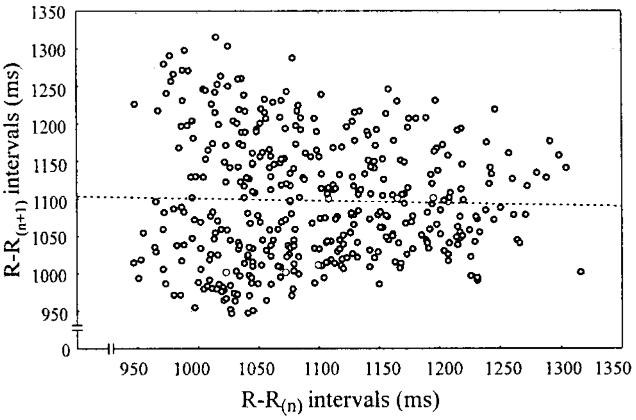

Figure 3. Scatterplot of R-R intervals (lag_0 and lag_1) of delta phase of EEG

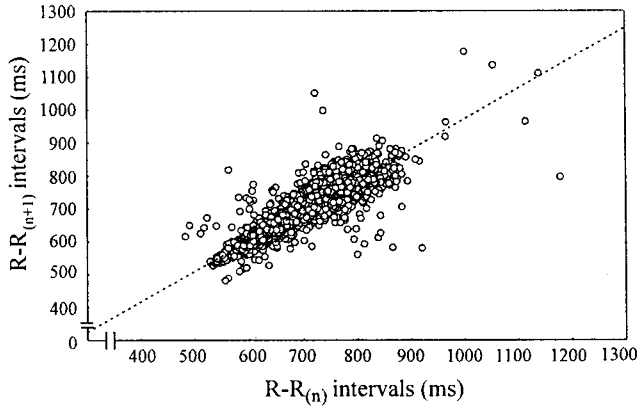

Figure 4. Scatterplot of R-R intervals (lag_0 and lag_1) during resting

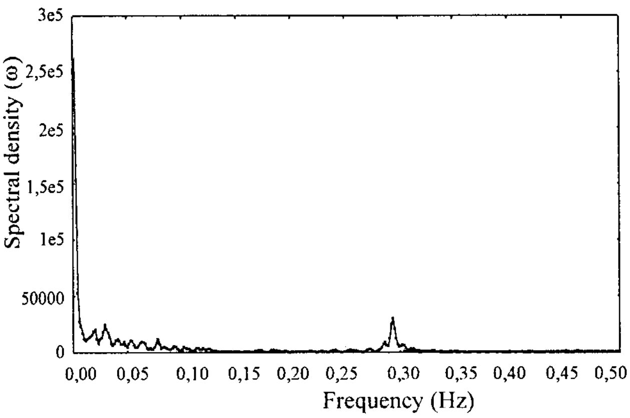

Figure 5. Spectral analysis of R-R intervals in delta phase of EEG

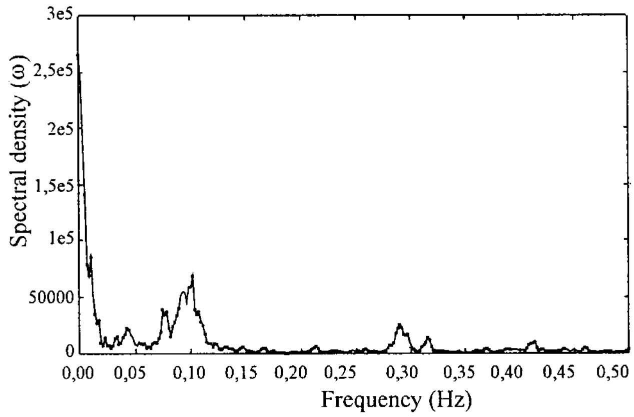

Figure 6. Spectral analysis of R-R intervals during resting

These results suggest that the magnitude of cardiac activity parameters in delta phase of EEG could be taken as „basal level" for the assessment of the effects of various independent variables on such parameters. This seems to be more plausible than using of the resting parameters for such a purpose, especially since the deep sleep parameters put all the subjects to the same level.

When the cardiac parameters obtained in deep sleep were subtracted from those in resting period, the basic parameters of the circadian effects stayed the same, while interindividual variability of the two parameters changed. Interindividual variability of R-R intervals in resting during 24-hours was congruent with general changes in R-R intervals. Their index of variability is rather stable throughout the 24 hours (Figure 7). When the resting level of variability is subtracted from the one in delta phase of EEG, the residual interindividual variability is larger, but more stable.

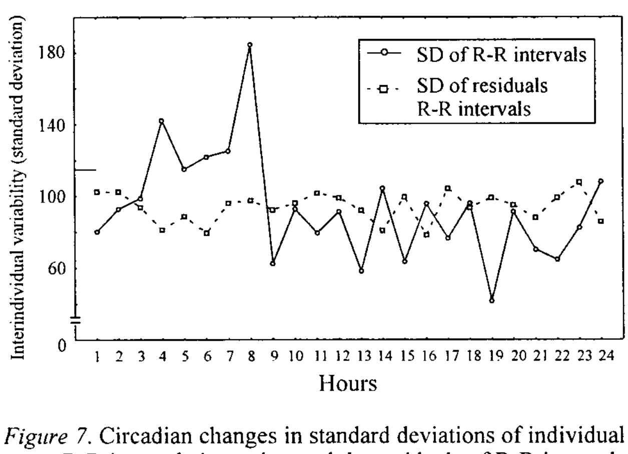

Figure 7. Circadian changes in standard deviations of individual mean R-R intervals in resting and the residuals of R-R intervals between their magnitude in the delta phase of EEG and resting

As could be seen from Figure 8, significant correlation was found between the magnitude of R-R intervals in deep sleep and the same parameters in resting situations during 24-hour period. The most prominent correlation coefficients were found in early morning hours, which coincided

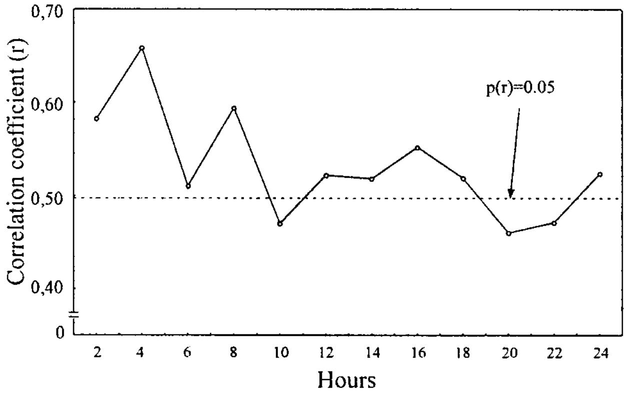

Figure 8. Circadian correlation function between the mean R-R intervals in delta phase of EEG and the mean R-R intervals during resting

with the biggest interindividual cardiac variability in resting situations. It seems, therefore, that interindividual differences in resting, are mainly caused by the interindividual differences in the „basal state“, i.e. delta phase of the EEG.

Finally, it could be said that relating of R-R intervals in resting state to the level in basal state has some advantages. That is, the effects of various independent variables (time of the day, environmental variables, etc.) could be referred to the same basal state of different persons, where interindividual differences are taken into account.

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