Shiftwork tolerance and circadian rhythms in oral temperature and heart rate

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The study aimed at establishing differences in the circadian rhythm parameters of oral temperature and heart rate between three groups of workers matched by age: tolerant shiftworkers with good sleep quality and few psychosomatic and digestive complaints, intolerant shiftworkers with poor sleep quality and more psychosomatic and digestive complaints, and workers who had never worked in shifts. The study was performed at an oil refinery recreation centre where the subjects were isolated for three days. During that period they lived under constant conditions, i.e. their activities, timing and content of meals, ambient temperature and light were controlled. Hourly measurements of oral temperature and heart rate were performed over a 24-h period. The parameters of the physiological rhythms were estimated by means of the COSINA method. Generally, the differences between the groups were low and not statistically significant. The authors could find no difference in the amplitude and phase position between the tolerant shiftworkers unlike other authors. The difference between these results and those of others is likely to be due to the fact that earlier studies were performed in field conditions where many factors that could have masked the results were not controlled for.

1. Introduction

In this study circadian variations in oral temperature and heart rate were measured in three groups of workers: two groups of shiftworkers who differed in tolerance to shiftwork and a group of workers who never worked in shifts. The aim of the study was to find out whether there were differences in circadian rhythm parameters (mesor, amplitude, acrophase) of oral temperature and heart rate between the three groups.


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If the authors could find that there were great and reliable differences between tolerant and intolerant shiftworkers in parameters of these physiological variables and if the measurements of the parameters were sensitive enough to detect small differences between subjects these measures could be used as an objective test of inter-individual differences in tolerance to shiftwork.

The measurements of inter-individual differences must be performed in strictly controlled conditions so that all other factors that could affect the measurements are controlled. For these measurements such conditions were made possible at a recreation centre near the company where the workers worked.

2. Methods

2.1. Subjects

The subjects who took part in this study were male workers employed in a large oil refinery. Before the study they were asked to provide informed consent. Three groups of 29 subjects each were examined: tolerant shiftworkers, intolerant shiftworkers and workers who never worked in shifts. The shiftworkers were selected from an overall sample of 604 shiftworkers. They worked in a 2:2:3 continuous three-shift system with work hours on morning shift from 06:00 to 14:00 h, afternoon shift from 14:00 to 22:00 h and night-shift from 22:00 to 06:00 h. The shifts rotated in the order of mornings-afternoons-nights. Non-shiftworkers worked on morning shift only, from 07:00 to 15:00 h.

Two measures served as criteria for the selection of workers who differed in tolerance to shiftwork: the Sleep Quality Scale and the Psychosomatic-Digestive Complaints Scale (Vidaček et al. 1989) of the Health Information part of the General Health and Adjustment Questionnaire (Tasto et al. 1978). The dimensions that these scales measure were found to be the most important aspects of tolerance to shiftwork (Åkerstedt 1985, Costa et al. 1981, Foret and Benoit 1977, Foret et al. 1981, Segawa et al. 1987).

The Sleep Quality Scale consists of seven items referring to sleep characteristics such as: falling asleep quickly and easily, waking up during the night, taking sleeping pills, quality of sleep during the day in comparison to night sleep, etc. The questions are of the multiple-choice type and the theoretical range of scores is from 7 to 23. The high scorer on this scale claims to have good sleep quality.

The Psychosomatic-Digestive Complaints Scale consists of 15 multiple-choice questions about digestive and psychosomatic complaints and symptoms. The theoretical range of total scores is from 15 to 60. The high scorer on this scale claims to have more psychosomatic and digestive complaints. The internal consistency coefficient (Cronbach alpha) computed on a total of 604 shiftworkers was .83 (Vidaček et al. 1989).

The group of tolerant shiftworkers had a good quality of sleep and fewer psychosomatic and digestive complaints. They achieved extremely high scores in the Sleep Quality Scale (average Z score = +1.3) and at the same time low scores on the Psychosomatic-Digestive Complaints Scale (average Z score = −0.8). Their mean score for the Sleep Quality Scale was M = 20.8 (SD = 0.89) and for the Psychosomatic-Digestive Complaints Scale M = 19.8 (SD = 4.36).

The group of intolerant shiftworkers had a poor quality of sleep and more digestive and psychosomatic complaints. They achieved extremely low scores in the Sleep Quality Scale (average Z score = −1.3) and at the same time high scores on the Psychosomatic-Digestive Complaints Scale (average Z score = +0.4). Their mean score computed for the Sleep Quality Scale was M = 12.0 (SD = 1.71) and for the Psychosomatic-Digestive Complaints Scale M = 28.3 (SD = 6.66).
The two groups were matched by age ($M = 39.9$ years, range: 30–52 years, and $M = 39.9$ years, range: 30–53 years).

The third group that took part in the study consisted of non-shiftworkers who were matched to shiftworkers by age ($M = 39.9$ years, range: 29–52 years).

2.2. Instruments and procedure

Oral temperature was recorded by means of an electronic digital thermometer (Kramer-Hatuse, Bologna, Cod 5323) during a period of 5 min. Heart rate was measured by means of a six-channel polygraph, which was made for the study, using three standard Beckman Ag/AgCl electrodes. One electrode was fixed on the left hand and the others on the right hand (one of the latter was grounding electrode).

The study took place in the company recreation centre. Each group of subjects was examined for 3 days. During that time the subjects were separated from their families, friends and other social environment to prevent possible disturbances. They arrived at the centre in the afternoon of the first day of examination. After having been accommodated in their rooms, the subjects received precise written instructions about the procedure and conditions of measurement. Oral temperature and heart rate were taken in conditions identical to those planned for the next day in order to adjust to the experimental situation. They had dinner at 20:30 h, went to sleep at about 22:00 h and woke up at about 06:30 h the following morning.

On the second day measurements of oral temperature and heart rate were performed every hour over a 24-h span in a room especially arranged for the purpose. The first measurement was made at 09:00 h and the last one at 09:00 h the following morning. For a 10-min period before measurement, the subjects were not allowed to drink or smoke. Oral temperature was measured in the sitting position for 5 min.

After the measurement of oral temperature, heart rate was recorded in the same sitting position for a 2-min period. One measurement session for oral temperature and heart rate took about 10 min.

Between the measurement sessions subjects were accommodated in a large room, adjacent to the one where measurements of heart rate and oral temperature were performed. In the large room subjects were allowed light activity only (i.e. playing cards, reading, listening to music) but not to sleep. They were free to smoke, but were not allowed alcohol, coffee or tea. Meals were served immediately after the end of the measurement sessions at 10:00, 14:00, 18:00, 21:00 and 06:00 h.

The ambient temperature in the rooms was approximately constant at 21 °C. During the period of examination continuous artificial lighting at normal interior lighting intensity was provided in all rooms where the subjects stayed. All measurements were performed over a 3-week period in springtime.

2.3. Data analysis

The data of each subject's 24-h measurements of oral temperature and heart rate were analysed by means of COSINA (Monk and Fort 1983) to get the estimates of mesor, amplitude and acrophase of the best fitted cosine curve for a 24-h period.

The estimated parameters were further analysed using one-way analysis of variance in order to find out whether there were reliable differences between the three groups.
3. Results

Average 24-h variations in oral temperature and heart rate for the three groups of workers are presented in figure 1 and cosinor parameters in table 1.

Oral temperature showed evident circadian variations for all three groups of workers. Temperature reached a minimum in the early morning: in the group of intolerant

![Graph showing temperature and heart rate variations over 24 hours for different groups of workers.]

Figure 1. A double plot of 24-h variations in oral temperature and heart rate.

Table 1. Cosinor parameters and the percentage of subjects whose data significantly fit a 24-h cosine function.

<table>
<thead>
<tr>
<th></th>
<th>Mesor</th>
<th>Amplitude</th>
<th>Acrophase</th>
<th>Significant cosine fits (p &lt; .05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td><strong>Temperature (°C)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tolerant shiftworkers</td>
<td>36.63</td>
<td>0.16</td>
<td>0.36</td>
<td>0.11</td>
</tr>
<tr>
<td>Intolerant shiftworkers</td>
<td>36.64</td>
<td>0.17</td>
<td>0.31</td>
<td>0.10</td>
</tr>
<tr>
<td>Non-shiftworkers</td>
<td>36.62</td>
<td>0.16</td>
<td>0.30</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Heart rate (beats/min)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tolerant shiftworkers</td>
<td>71.39</td>
<td>7.57</td>
<td>3.87</td>
<td>2.22</td>
</tr>
<tr>
<td>Intolerant shiftworkers</td>
<td>70.92</td>
<td>9.56</td>
<td>3.21</td>
<td>1.79</td>
</tr>
<tr>
<td>Non-shiftworkers</td>
<td>68.51</td>
<td>8.72</td>
<td>3.66</td>
<td>2.06</td>
</tr>
</tbody>
</table>
shiftworkers at about 05:00 h and in the groups of tolerant shiftworkers and non-shiftworkers at about 06:00 h. Temperature increased over most of the day to reach a maximum in the late afternoon at about 19:00 h in all three groups.

There were no differences in mesor and acrophase of temperature between the groups of workers ($F(2, 84) = 0.14$ and $F(2, 84) = 0.06$, respectively). There was a tendency of tolerant shiftworkers to have larger amplitudes than other subjects, but the difference was not statistically significant ($F(2, 84) = 2.50, p = .08$).

The circadian variations in heart rate were not as distinct and large as in oral temperature. This could be expected since variations in heart rate are more influenced by environmental factors than temperature. An increase in heart rate following the meals taken after measurements at 06:00, 10:00, 14:00, 18:00 and 21:00 h is noticeable with all the three groups.

All the differences in mesor, amplitude or acrophase of heart rate between the three groups of workers were low and statistically non-significant ($F(2, 84) = 0.92, F(2, 84) = 0.79$ and $F(2, 84) = 1.46$, respectively).

4. Discussion

Results indicate that there are no reliable differences in circadian rhythms of oral temperature between the tolerant shiftworkers, intolerant shiftworkers and workers who never worked in shifts. The findings do not support the results of early studies (Andlauer and Reinberg 1979, Reinberg et al. 1980) that intolerant shiftworkers have a smaller amplitude of temperature rhythm in comparison to tolerant shiftworkers. Likewise, the authors could not find any reliable difference in circadian phase position between the tolerant and intolerant shiftworkers. Therefore, our expectation that the measures could be used as an index of long-term tolerance to shiftwork was not met. The circadian rhythm of the other physiological variable examined, heart rate, which has a strong exogenous component, did not differentiate the examined groups either. The question is how the differences between these findings and those of the other can be explained.

There are several important differences in approach to the study of the relationships between characteristics of circadian rhythms of physiological variables and long-term tolerance to shiftwork between this study and the studies of other authors. In other studies measurements were performed in field conditions where many factors could not be properly controlled. In field studies levels of physical and mental activities during measurements were not kept constant although this is basic requirement for valid measurement of circadian variations of the physiological functions. Data were usually collected by workers' self-measurements in various situations and at various points of time over 24-h periods. Such data were not reliable for mathematical derivation of valid estimates of circadian parameters. In other words, data depended on various psychological, social, economic and other aspects of shiftworkers' everyday life. In this study the subjects were isolated from such influences during the measurement period so that data were not affected.

Generally, in field studies of shiftworkers, many psychological, social and economic factors are involved that affect the results of measurements. These factors are not necessarily directly connected with inter-individual differences in tolerance to shiftwork. Therefore, if one wishes to assess inter-individual differences by measuring oral temperature and heart rate one needs more reliable estimates of parameters of their circadian variations. These can only be obtained in well-controlled conditions. Unfortunately, these results indicate that the circadian variations of oral temperature and heart rate cannot be used as indices of
tolerance to shiftwork when data are collected in well-controlled conditions. In an earlier study (Vidaček et al. 1993), where circadian variations of oral temperature and heart rate were measured in comparable conditions in young subjects, future shiftworkers, before they started to work in shifts, the authors could not find many significant relations between these measurements and subjects’ tolerance to shiftwork after 3 years of exposure to shiftwork.

The data of two recent studies of relations between circadian characteristics and shiftwork tolerance (Costa et al. 1989, Knauth and Harmā 1992), although performed in field conditions, were in agreement with the present results.

Results of both our studies indicate that circadian variations of oral temperature and heart rate measured in well-controlled conditions do not have prognostic or concurrent validity as indicators of tolerance to shiftwork. However, if measurements are performed in conditions of everyday life, where many factors affecting workers’ behavioural arousal level are not controlled so that workers can behave spontaneously as they do in field studies, the parameters of circadian rhythms of oral temperature and heart rate are more likely to be related to shiftwork tolerance.

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