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Circadian Rhythm of Heart Rate, Urinary Cortisol Excretion, and Sleep in Civil Air Traffic Controllers

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The examination of Air Traffic Controllers (ATCs) from the Warsaw Airport (Poland) included 24-hr ECG monitoring. The participants were 10 civil ATCs, 9 males and 1 woman. The study was carried out on a group of 19 ATCs during their duty periods, 14 of them working 12-hr shifts and 5 performing 24-hr duties. The participants collected urine every 4 hrs, and cortisol concentration was determined. Further, the survey included the quality and duration of sleep, and subjective fatigue in the 62 participants.

In ATCs, shift work modifies natural rhythms of the circulatory system and decreases the ability for intensified mental work at night. In consequence ATCs experience frequent sleep disorders.

heart rate   cortisol   sleep disorders   circadian rhythm   shift work

1. INTRODUCTION

Air Traffic Controllers (ATCs) have responsibilities for the safety of aircraft and the lives of airline passengers. Difficulties in their working conditions include information overload, intermittent intensive mental effort, and shift

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work including night work. In some papers and manuals of aviation medicine, the view is expressed that these working conditions make them more susceptible to diseases of civilisation, particularly to arterial hypertension and gastrointestinal ulceration (Costa, 1993; Crump, 1979; Hopkin, 1995; International Civil Aviation Organization, 1985; MacLennan & Peebles, 1996).

One approach to the problem of assessing the amount of stress experienced during duty hours is to investigate physiological indices that change when physical or mental loads are present. Several of these indices exist, amongst which are cortisol secretion, heart rate, and the timing and length of sleep (Luna, 1997; Melton, Smith, McKenzie, Wicks, & Saldivar, 1978; Mori, 1982; Price & Holley, 1982; Stammers, 1979) These indices can also be used as markers of the circadian system, and so determine if the pattern of work affects circadian rhythmicity. The potential importance of circadian rhythmicity is that altered rhythms are common in night work and are believed to be causally linked in some way to longer-term problems of health, including chronic sleep loss, gastrointestinal malfunction, and cardiovascular morbidity.

In the current study, changes in these indices have been investigated in ATCs not only during duty periods taken at different times of the 24 hrs but also during rest days, when the participants had no duties. Attention has been focussed on evidence of stress in the workplace and on changes in sleep; in the case of this latter variable, the sample that was used also enabled the effect of the number of years of work experience upon any changes to be investigated.

2. PARTICIPANTS, MATERIALS, AND METHODS

2.1. Heart Rate

The participants were 10 civil ATCs working at the International Warsaw Airport (Poland). Nine of these were males, one, a woman; they were aged 36–44 and had worked as ATCs for 5–21 years. Four of the participants were area controllers and 6 were approach controllers.

Heart rate was recorded over periods of 24 hrs by Holter ECG monitoring. The ECG signal was recorded using MR-14 cassette recorders and analysed by the Medilog MA-14 analyser (Oxford Medical Systems, Abingdon, UK). Recordings were made for each participant three times: during duty hours (12 or 24 hrs on duty), on the day following the duty, and during leisure time.

The mathematical and statistical analysis of the results comprised the following:

- Individual heart rate (HR) chronograms, showing the average heart rate during successive hours of a 24-hr period;
- The parameters of the circadian rhythm of HR for each individual—the mesor, amplitude, and acrophase—using our own version of the cosinor method (Zużewicz, Kwarecki, & Meller, 1979), and the parameters of the group cosinor (Zużewicz, 1991). Evaluation of the significance of a circadian rhythm of HR was by the amplitude test.

The results were compared with two groups of controls. The first was the circadian rhythms of heart rate obtained from 13 males of the same age as ATCs but employed as white-collar workers on day shifts. The second was selected from different occupational groups by using a normogram of the 24-hr profile of HR from 60 healthy males, white-collar workers, belonging to different occupational groups, aged 29–49, who were not employed in a shift system. (In this group we used hourly averages of HR values + 2 *SD*). Both groups worked only on day shifts. The chronograms for individual ATCs were superimposed upon the normogram in order to evaluate the changes of HR profile that had resulted from a particular shift.

2.1. Urinary Cortisol Excretion

This part of the study was carried out on a group of 19 ATCs during their duty periods, 14 of them working 12-hr shifts (8 working 07:00–19:00 and 6 working 19:00–07:00), and 5 performing 24-hr duties. The participants collected urine every 4 hrs, and an aliquot was saved for later biochemical analysis. Cortisol concentration was measured by the immuno-fluorescent-polarisation method (Abbot and TDX apparatus). Average urinary cortisol concentrations were calculated for each hour of duty.

2.2. Subjective Sleep

Sixty-two controllers answered a questionnaire on subjective sleep evaluation.

This questionnaire required the respondents to provide information on how long they had worked as an ATC, and to estimate the following aspects of sleep as they applied to a duty day and to the day afterwards: the length and quality of sleep, waking episodes, the duration and time of naps, and the extent of feeling relaxed after waking up.

3. RESULTS

3.1. Heart Rate and Sleep Profile

Figure 1 presents (on the left) hourly averaged heart rates over the course of 24 hrs for one controller (aged 37 and who had been working in a shift system for 12 years); results are shown for a rest day after several leisure days, during a day when working the 24 hrs, and on the day following this. On the right hand side of the figure, the same values are superimposed upon the normogram obtained from the 60 control non-shift workers. This normogram shows that, in the case of persons working at fixed times during

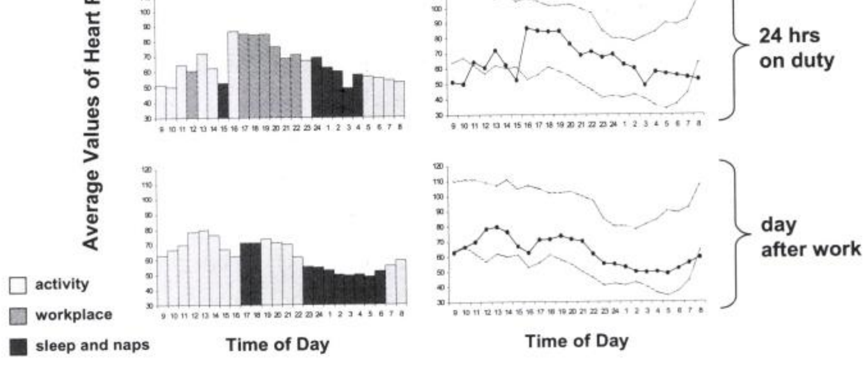

Figure 1. Circadian variation of heart rate (example of Air Traffic Controller: age 37, experience with shift work: 12 years).

the day and living a regular work-rest-sleep cycle, HR reaches maximal values soon after waking, and then shows lower values in the evening and a minimum during the night. This pattern can also be seen in the ATC participant during the hours of duty, indicating the effect of the work load. Comparing the HR records of each ATC during duty hours with the normogram from day-workers indicated that this effect of duty was a general one, and applied whatever the time when the duty took place. During 24-hr duty the effect is visible only during the day. At night, air traffic is far less intense, and therefore the load is much less significant.

All individuals (except one) showed statistically significant circadian rhythms of HR at the level $p < .01$. Table 1 presents the parameters of the group circadian rhythms of the ATCs, and divides them according to whether recordings were made on a day which involved a 24-hr duty, the rest day after the 24-hr duty, or a day of leisure. It also includes the results from the control group, who worked only day shifts. This table shows that there was a higher amplitude and mesor during the leisure day in ATCs compared to the day-workers. There was also a decrease in rhythm amplitude and mesor in the ATCs during a day that involved duty and on the following day.

TABLE 1. Circadian Heart Rate Parameters in the Group of Air Traffic Controllers After 24-Hour Duty and for the Control Group ($N = 13$)

	Mesor (beat/min)		Amplitude (beat/min)		Acrophase (hr:min)	Amplitude Test	
Group	*M*	*SD*	*A*	*SD*	ϕ	*F*	*p* <
24-hr duty	67.8	6.2	9.5	5.5	16:24	46.9	.01
Day following the duty	67.5	6.2	10.9	4.8	15:34	30.9	.01
Leisure day	75.0	1.6	15.8	5.0	15:35	123.1	.01
Control	69.9	6.6	9.5	3.6	14:55	5.6	.01

Investigation of the sleep patterns showed that naps were frequent during the daytime, and that even sleep lasting several hours could take place then. Such changes in the sleep pattern were reflected in a modification of the circadian HR rhythm; during the day immediately following a 24-hr duty, two HR maxima, separated by a fall due to a nap, were observed in all the ATCs (see Figure 1, bottom right).

3.2. Urinary Cortisol Excretion

The results are shown in Figure 2. During 24 hrs on duty, the maximum concentrations of urinary cortisol were observed in the morning hours just after waking (ca. 09:00), with uniformly lower concentrations from about 14:00 to 06:00. During the 12-hr daytime shift (07:00–19:00), cortisol excretion was modified; the concentrations were higher than in the group performing 24-hr duty, particularly during the final part of the shift (17:00–19:00). By contrast, when working on a night shift (19:00–07:00), urinary cortisol concentrations were significantly lower than those at the same times in the group performing a 24-hr duty.

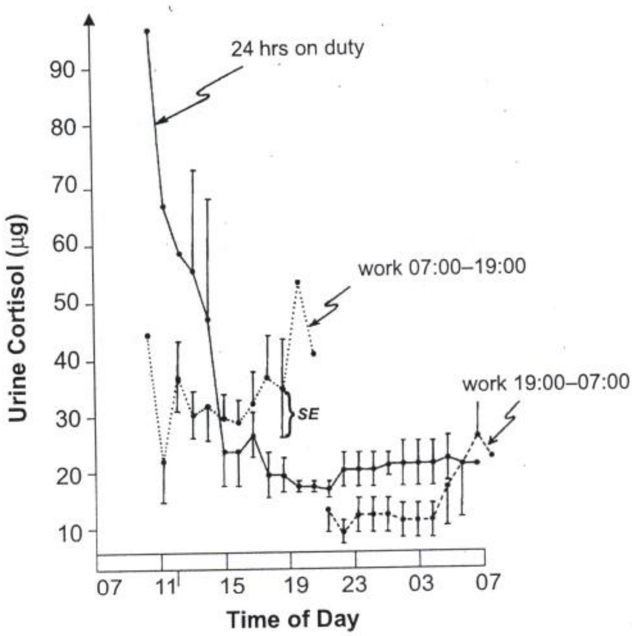

Figure 2. Cortisol excretion with urine in Air Traffic Controllers working different duties. Points mark average values for every hour, vertical lines mark standard error (*SE*).

3.3. Subjective Sleep and Work Experience

Sleep patterns during leisure time were analysed from the 62 ATCs (see Figure 3). Sleep duration fell with increase in experience as an ATC, this fall amounting to about 40 min between the least and most experienced groups. Just under half of this fall could be attributed to sleep latency.

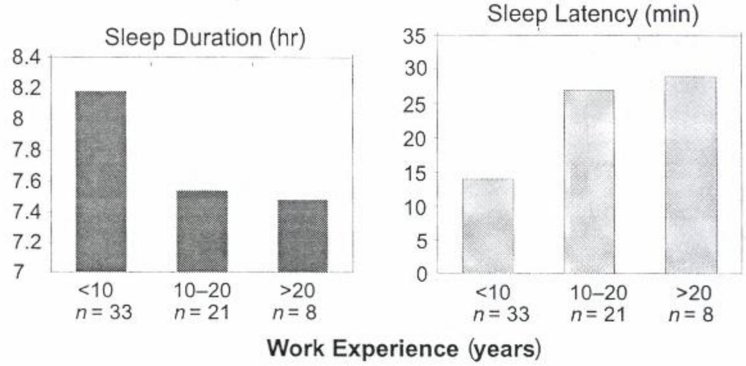

Figure 3. Sleep duration and the time of falling asleep in Air Traffic Controllers with different work experience.

Thirty respondents (48% of the total) reported sleep problems, including 12 (36%) of those who had been ATCs for more than 10 years. Thirty-five (56%) respondents complained of waking episodes in the middle of the night; this group included 13 (39%) of those who had been ATCs for up to 10 years and 22 (76%) of those who had been working as ATCs for more than 10 years.

Twelve percent of those who had been working as ATCs for up to 10 years did not feel relaxed after waking up; this compared with 19% of those who had worked for 11–20 years and 50% of those who had worked for more than 20 years.

TABLE 2. Sleep Patterns in Air Traffic Controllers After 24-Hour Duty Considering Working Period

Working Period (years)	Sleep Duration After 24-Hr Duty During Daytime					"Short" Sleep Duration After 24-Hr Duty During Daytime				
	Sleep (hr:min)			Time of Falling Asleep (min)		Sleep (hr:min)			Time of Falling Asleep (min)	
	N	$\bar{X}$	*SD*	$\bar{X}$	*SD*	*N*	$\bar{X}$	*SD*	$\bar{X}$	*SD*
< 10	8	10:15	1:42	15	12	4	3:30	1:06	9	6
11–20	3	8:50	2:45	18	10	9	3:06	1:06	27	16
> 20	0	—	—	—	—	5	3:06	1:30	33	25

With regard to sleep patterns during days with 24 hrs on duty (29 respondents), duration and the latency to falling asleep are presented in Table 2. Eighteen (62%) of the total number of ATCs reported sleeping on coming home during the daytime; this number comprised 33, 75, and 100% of those who had worked as ATC for up to 10, for 11–20, and for more than 20 years, respectively. Among these 18 people, only 3 felt relaxed. By contrast, half of those ATC who did not sleep during the day on finishing duty felt relaxed; none of those who did not feel relaxed had worked as ATC for more than 20 years.

With regard to sleep patterns during the day following the night duty (54 respondents), 30 (55%) of these slept during the day.

4. DISCUSSION

The current results indicate that the circadian HR rhythm of ATCs was modified by work, particularly when it was performed at the time of particularly intense traffic—that is, during the daytime—and that this applies also to those on duty for 24 hrs. The changes often consisted of small rises in HR when on duty, and only small changes in the cosine parameters were found. However, it must also be realised that, in presenting the results as hourly means, short-lived but large increases in HR value would have been overlooked.

Changes like these have been reported before, as in the studies where two peak values occurred in the parameters of the circadian rhythms of the circulatory system (Hildebrandt, 1980), and where there were decreases in HR amplitude and arterial blood pressure in shift workers, particularly those employed at night shifts (Fritz et al., 1991; Halberg et al., 1990).

A study on ATCs similar to ours (carried out at the Air Control Regional Centre of Rome, Italy) showed that, even during periods of intense air traffic (983 aeroplanes per 24 hrs in summer compared with 679 in winter), physiological and biochemical parameters did not exceed the accepted maxima. This was interpreted to indicate that stress associated with ATC work did not go beyond acceptable limits, and it is suggested that this contributes to safety at work (Costa, Battisti, Munafo, Pinchera, & Pistilli, 1987). The present results support this view.

The results with urinary excretion of cortisol were equivocal. Thus, those from participants on 24-hr duty showed circadian rhythms that were normally phased, and those from participants working the 12-hr night shift showed low cortisol concentrations; neither of these findings indicated that the workplace was associated with stress. By contrast, however, those working 12-hr shifts in the daytime showed raised concentrations, particularly towards the end of the shift. Whether this was caused by an increased work load or by missing evening social activities at this time is not known.

Our results (Figure 3) indicate that the duration of sleep of ATCs becomes shortened with experience, in part due to an increased latency of falling asleep. Similar changes are associated with the process of ageing in the population as a whole, and might contribute to the present finding. However, the results are compatible with the views that the ability to survive on less sleep is one of the coping mechanisms that is developed by the workforce, or that there is a process of self-selection by which those who cannot develop such a mechanism choose to leave this kind of work, or both (Luna, French, & Mitcha, 1997).

Daily naps were found quite frequently among the workforce, on leisure days as well as on duty days and days following duty days (Table 2). Again, this is often found in older participants in general, but in the case of the present ATCs appears to be associated with a decreased sense of relaxation, and might indicate the presence of some forms of stress.

In summary, it seems that there is evidence that the work load of ATCs produces some changes in HR, urinary cortisol excretion, and sleep patterns. These changes appear to be comparatively minor and not to alter circadian rhythms in a major way. Even so, the changes are likely to persist for years and, in the case of sleep disturbances, worsen for some individuals with time spent as an ATC.

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