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Problems related to shift work

A field study of Swedish railroad workers with irregular work hours

by BIRGITTA KOLMODIN-HEDMAN, M.D., and ÅKE SWENSSON, M.D.[1]

KOLMODIN-HEDMAN, B. and SWENSSON, Å. Problems related to shift work: A field study of Swedish railroad workers with irregular work hours. *Scand. j. work environ. & health* 1 (1975) 254—262. A group of 132 engineers from the north of Sweden was included in the study. A subsample of about 50 subjects was selected for further laboratory investigations during a light and warm summer period and a dark and cold winter period. The mean for the hours of sleep noted on the sleep records was significantly lower for night work than for day work. The amount of sleep during night work was significantly less during the light period than during the dark period as was the amount of sleep during the day off. Body temperature measured during work followed a daytime pattern and had a low amplitude. Potassium excretion and the blood levels of cortisol displayed a stable circadian rhythm with a daytime pattern. Many environmental factors made the results of catecholamine data difficult to interpret. The frequency of reported peptic ulcers was higher in the engineer group than in some other groups.

Key words: shift work, catecholamines, sleep, circadian rhythm.

Many different types of shift work, e.g., two-shift and three-shift, and their influence on the health and well-being of workers have been studied. Shift work can be regarded not only as work during two or three 8-h periods in 24 h with a defined rotation of blocks of different shifts but also as regular night work and quite irregular work schemes in which night work is included. These types of work may give rise to special problems with medical, psychological, and social natures. Investigations of workers with regular shift work are numerous. Not many studies of night workers have been made, and only a few investigations of workers with irregular hours have been published (6, 33).

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In an early study of a group of Swedish railroad workers, Bjerner et al. (6) found a higher frequency of peptic ulcers than in the general population. The increase in comparison with the general population was even greater than for groups doing regular shift work (1, 3, 5). The importance of factors other than shift work per se is, however, indicated by the fact that in some investigations no such increase in the frequency of peptic ulcers was demonstrated (12, 34). One important factor in this connection is sleep deprivation. Bjerner et al. (5, 6, 7) found that workers with sleep deprivation complained of many symptoms, such as tiredness, irritability, difficulties in concentration, and headache, when working at night. Wedderburn (36) suggested that a short work period would be more suitable for preventing the development of sleep deficiency. Sleep debts during shift work were also reported by Tune (35).

One of the factors discussed in connec-

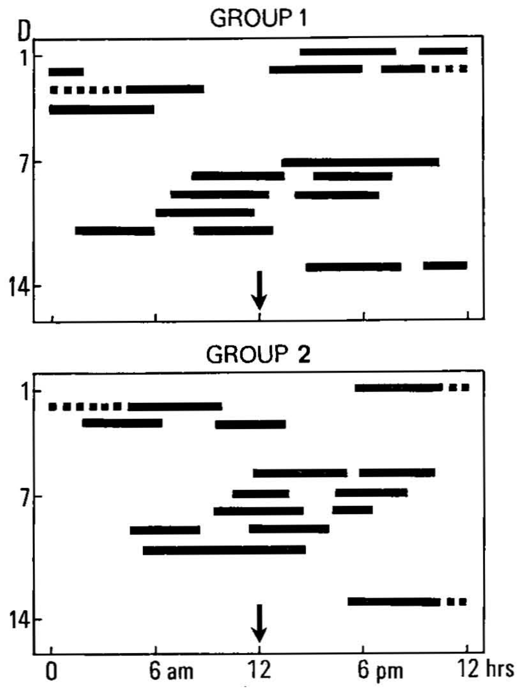

Fig. 1. Work hours for two groups of engineers during a 12-day period.

tion with the ill-effects of shift work and/or nighttime work and/or work at irregular hours is the disturbance of circadian rhythms. In animals the change from light to darkness and from darkness to light is a very strong synchronizer (19) or "Zeitgeber" (4). In man, on the other hand, social relations seem to be still more important (6, 27). A great number of social complications were reported in shift workers when the family and community followed a daytime pattern (32). Many biological parameters, as body temperature (28, 29), sodium and potassium excretion (11, 25, 26), and blood levels of 11-OH-cortisol (10), display rhythmic variations. Urinary excretion of catecholamines also shows rhythmic variations (18, 24). However, when interpreting catecholamine levels, one must remember that many environmental factors affect the levels, e.g., smoking, coffee and tea drinking, physical exercise, and a high or low ambient temperature (2, 16). Stress factors and their relationship to catecholamine excretion have been studied in an industrial group of paper mill workers on a continuous three-shift schedule (18) and also in experimental situations (15, 17).

PURPOSE

In this investigation we studied a group of workers with irregular work hours who did the same type of work during the day and night. As the group chosen could also be studied during a light and warm summer period and a dark and cold winter period, we included a study of the effects of light and darkness on the parameters used. The following questions were posed: (a) Is a circadian rhythm maintained? (b) How does work during the day and at night influence the sleep pattern? (c) Are there differences between summer and winter periods in laboratory test results or in the amount of sleep recorded? (d) Does this type of work influence the state of health and well-being?

METHODS

Questionnaires for information concerning the sense of well-being, social adaptation, lodgings, sleep disturbances, and previous illness were completed at home after oral information had been given by the investigators.

Sleep records were filled out at home for a 12-day working period. Hours asleep and awake were noted for each day and night.

Body temperature was measured every other hour during a work shift with a thermometer placed under the tongue for 10 min. Measurements were not made immediately after physical exercise or coffee drinking. The results were noted on a form by the subject himself.

Sodium and potassium in urine were determined by an atomic absorption method (Perkin Elmer).

Adrenaline and noradrenaline in urine were analyzed according to the method of von Euler and Lishajko (14).

Blood 11-OH-cortisol was analyzed according to Mattingly (31).

A self-rating of symptoms and feelings was made on a 10-grade scale. This was done in the same period as the urine sampling. The items rated were: irritation, fatigue, restlessness, stress, boredom, depression, power of concentration, muscular pain, tension, headache, anger, nervousness, calmness, and sleepiness.

SUBJECTS

One special group of Swedish railroad workers was selected, i.e., railroad engineers and engineer assistants who transported iron ore between Kiruna (a town in the very north of Sweden) and Vassijaure at the Norwegian border. This work is the same during the day and night, unlike other types of industrial work. Two examples of work rotation are shown in fig. 1. The questionnaires were given to 132 engineers and assistants and, for comparison, to 51 persons doing three-shift work (railroad service personnel). From the total group of engineers a sample was chosen for the laboratory investigation so that work hours at different times of the day and night were covered.

The investigation was performed during a warm and light period of the summer (A) and a cold and dark period of the winter (B). During the summer the midnight sun gives light for 24 h, whereas in December and January it is dark for 24 h. Forty-nine persons participated in period A; and 52 persons, in period B. Unfortunately, the same persons could not always be followed during these two periods, and therefore only group results from the various time periods could be evaluated. The subjects served as their own controls during a test day when they were free from work.

EXPERIMENTAL DESIGN

Trains starting early in the morning and returning in the afternoon, trains leaving in the afternoon and returning early at night, and trains leaving around midnight and returning in the morning were followed. Thus the whole cycle of day and night was included (fig. 2).

The train going from Kiruna to the border carries the iron ore. After arriving in Vassijaure the engineers rest for 1—2 h and then return to Kiruna with another train without ore. In the figure the starting point is marked K and the border station Vj.

A control period, when subjects had their day off, comprised the hours 6: 30—9: 30 a.m, 5: 30—8: 30 p.m, and midnight to 3 a.m. The subjects stayed in the examination room but were allowed to walk about indoors, listen to the radio, read, smoke, and drink coffee.

An attempt was made to standardize the effect of caffeine on catecholamine levels. Coffee was prepared in a standardized way, and 150 ml were given to the subjects every hour both during work and during the control periods.

Before the start of the trip, on arrival at the border station, and after the return, a blood sample was drawn into heparinized tubes. Plasma was separated by centrifugation at 2,500 rpm and was then frozen at −20°C until the analyses could be made. Blood samples were taken at the start and at the end of each control period.

During a train run urine was collected in plastic bottles without a preservative. Urine was voided into bottle I immediately before the start of the run (the exact time was noted) so that the subjects would have empty bladders at the exact starting point. Bottle II was used in the middle of the run and represented an approximate time of 90 min; the exact time was noted. Urine was voided into bottle III at the end of the trip, and the exact time was noted. During the control periods, urine was collected for periods of 90 min in each of the subperiods described above. At the stations the laboratory staff received the bottles and recorded volumes, pH, and specific gravity. The samples for catechol-

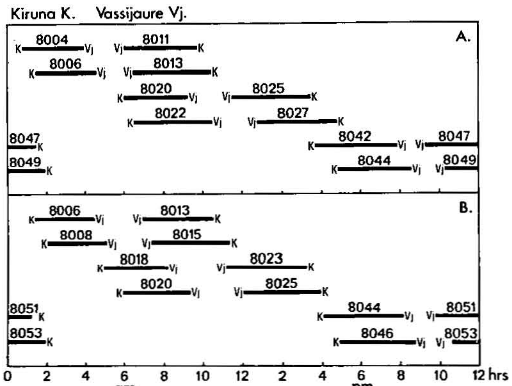

Fig. 2. Schematic diagram of the timetables for the train runs followed during the light period (A) and the dark period (B).

Table 1. Percentage frequency of reports concerning comfort at and attitudes toward work.

Group	N	Wish to change jobs	No wish to change jobs	No decision	Sense of well-being at work	Discomfort at work	No decision
Engineers	121	37	50	12	40	39	12
Workers doing three-shift work	51	69	29	2	41	47	10

Table 2. Percentage frequency of reports on impairment of social functions.

Group	N	Family contacts	Social contacts	Possibility to follow educational courses	Shopping and similar activities	Visits to the theater and the movies
Engineers	121	76	55	81	12	62
Workers doing three-shift work	51	63	53	71	14	61

Table 3. Percentage frequency of reports on present and/or previous illnesses.

Group	N	Coronary heart diseases	Peptic ulcers	Gastritis	Nervousness
Engineers	121	0	13	26	12
Workers doing three-shift work	51	0	8	29	22

Table 4. Percentage frequency of reports on sleep disturbances during the day and night.

Group	N	Undisturbed day sleep	Disturbed day sleep	Undisturbed night sleep	Disturbed night sleep
Engineers	121	24	76	73	27
Workers doing three-shift work	51	20	80	59	33

amine analysis were acidified to pH 3 and then frozen. The urine for the electrolyte analysis was frozen directly and stored frozen at −20°C. An analogous procedure was used for the control periods.

RESULTS

Questionnaire

The questionnaire forms were given to 132 engineers or engineer assistants. The forms were filled out properly by 121,

Table 5. Means ± standard errors of hours of sleep during different time routines for 66 railroad workers.

Time of work	Light period (A)	Dark period (B)
Day off	8.1 ± 0.10	8.7 ± 0.10
Day work	7.5 ± 0.12	7.6 ± 0.15
Afternoon work	7.8 ± 0.14	8.0 ± 0.13
Late afternoon work	6.6 ± 0.16	7.1 ± 0.16
Night work	5.2 ± 0.21	6.3 ± 0.26
Early morning work	5.1 ± 0.20	5.3 ± 0.12

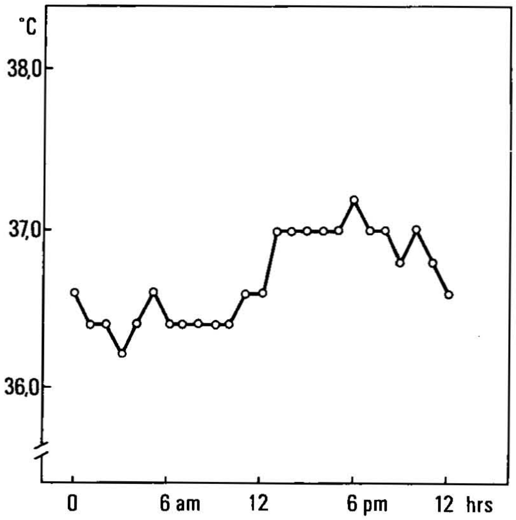

Fig. 3. Mean values of the body temperatures of the engineers during the day and night.

inadequately by 4, and left unanswered by 7. Sixty-eight per cent of the men were between 40 and 50 years of age. Fifty-one subjects doing three-shift work were used as controls. They worked at one station as service personnel. Thirty-nine per cent were between 40 and 50 years of age. Table 1 shows data on comfort at and attitudes towards work. In the engineer group, 40 % felt at ease, but the same percentage did not, and 37 % wanted to change jobs, but 50 % did not. In the three-shift group, 41 % felt at ease, 47 % did not, 69 % wanted to change to work with regular hours, and only 29 % wanted to continue with the same work.

Some negative effects of the work at irregular hours, as reported by the two groups, are listed in table 2.

Table 3 shows the frequency of previous and present illnesses in the two groups. None of the persons questioned had had anginal chest pain or a myocardial infarction. Peptic ulcers, verified by X-ray, were found in 13 % of the engineers and in 8 % of the three-shift group. In addition 40 % of the engineers and 21 % of the three-shift workers had or had had incapacities due to joint disorders and back trouble.

As pointed out in the introduction, problems often arise when a man has to sleep in the daytime. Table 4 gives the results of the questionnaire investigation for the engineer and the three-shift groups. Sleep during the day was disturbed for 76 and 80 %, respectively, as against 27 and 33 %, respectively, for night sleep. The major disturbing factors were traffic in general, railroad traffic, and the noise from playing children.

Sleep records

It can be seen from table 5 that the mean of the sleep hours calculated from the sleep records kept during night work and work with the starting point late at night or early in the morning differed significantly ($p < 0.001$) from the mean of the sleep hours recorded for daytime work or on a day off. It was also found that the amount of sleep before starting night work was less than that before work in the daytime. Sleep during the daytime and during the day off in the light summer period was significantly less than that during the dark winter period ($p < 0.001$ and $p < 0.001$, respectively). It should be noted that there were no differences in the mean number of sleep hours between dark and light periods when the workers did daytime work.

Body temperature

A diagram of the mean body temperature during day and night for a work period is given in fig. 3. It can be seen that a daytime pattern is obtained. However, the amplitude is low. Physical activity may have had an influence on the temperature during the night.

Electrolyte excretion

Fig. 4 shows the 24-h excretion curve for potassium calculated for all the data (periods A and B), followed both for the periods of work and for the day off. A circadian rhythm is clearly seen in the data. This was not the case for the sodium and chloride excretion data.

Excretion of adrenaline

The results of the excretion of adrenaline are summarized in fig. 5, which gives the pooled data from periods A and B for

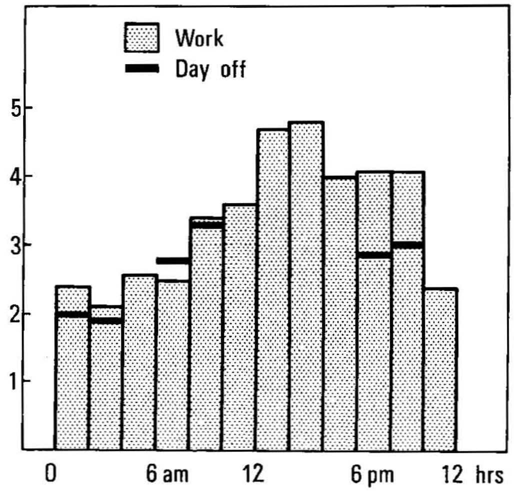

Fig. 4. Mean values for the excretion of potassium in urine (mg/min) followed for 24 h during a work period and during a day off. Data from periods A and B are pooled.

hours of work and the described periods of the day off. The most striking effect is the high level as a whole and the higher value for the corresponding control period. However, the differences are not statistically significant. We could not find any difference in the adrenaline excretion between the summer and winter investigations. The mean ambient temperature was + 9.5°C, and −9.3°C, respectively.

Excretion of noradrenaline

The results of the excretion of noradrenaline are recorded in tables 6 and 7 for periods A and B, respectively. Generally, the noradrenaline levels were higher in the winter than in the summer period. There were generally no differences between the excretion values during the work period and the day off.

Levels of cortisol (11-OH-cortisol)

The results are summarized in fig. 6. A circadian rhythm of a daytime pattern was found with the highest level at 6 a.m. and the lowest at midnight. No difference could be found between the values from work periods and from leisure time. In spite of the fact that railroad workers also work during night hours a daytime pattern is retained.

Rating of symptoms and feelings

The only two parameters which showed measurable variations were sleepiness and fatigue. As expected, the subjective feeling of sleepiness and fatigue was highest at night from 12 p.m. to 5 a.m., whether rated during the control period or during work. The same was the case when the train started early in the morning or returned after a night period of work. Thus a discrepancy was found between the rated degree of fatigue and the excretion level of adrenaline in urine, which was generally high.

A comprehensive description and more details have been given in a Swedish report (23).

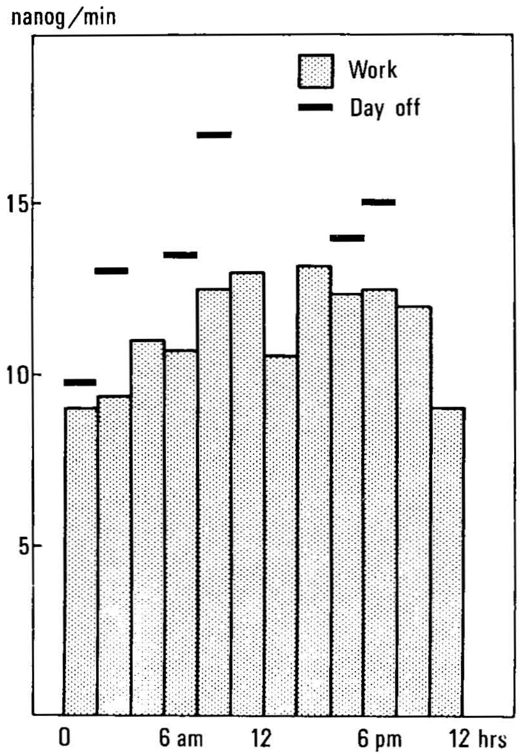

Fig. 5. Mean values for the excretion of adrenaline in urine (nanog/min) during the day and night. Data from periods A and B are pooled.

DISCUSSION

A discrepancy in the frequency of the wish to change jobs and discomfort at work indicates that other factors might be components of satisfaction with this type of work. Furthermore, access to other types of work is limited in such a small town. Economic factors, such as extra pay for traveling work, might also compensate to some extent for negative factors.

Concerning the information about previous or present illness, the frequency of joint disorders and back trouble is low when compared with that reported for other Swedish materials (20, 21). The engineers had more symptoms in the loco-

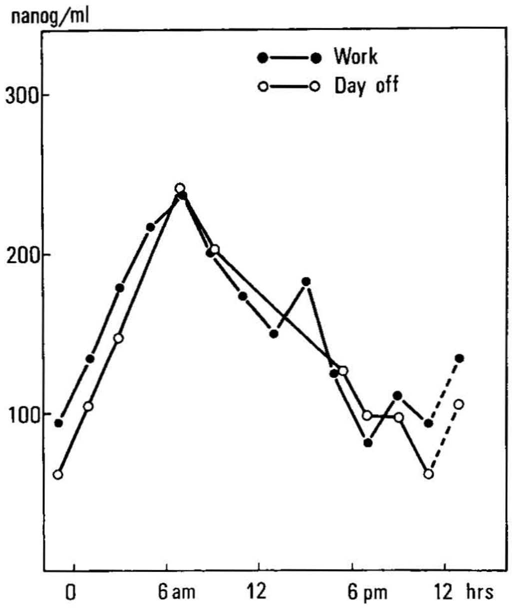

Fig. 6. Mean values for the levels of cortisol in blood (nanog/ml) during the day and night. Data from periods A and B are pooled.

Table 6. Means and standard errors (M ± SE) for the excretion of noradrenaline in urine (nanog/min) during a work period and a day off in 2-h sampling periods (Summer—period A).

Hours	Work period		Day off	
	N	M ± SE	N	M ± SE
12 p.m. — 0.1:59 a.m.	21	29.1 ± 2.1	44	32.1 ± 2.0
2:00 — 3:59 a.m.	26	31.7 ± 1.7	44	32.2 ± 1.9
4:00 — 5:59 a.m.	15	35.9 ± 7.2	—	
6:00 — 7:59 a.m.	12	32.0 ± 3.4	42	34.7 ± 2.6
8:00 — 9:59 a.m.	27	36.2 ± 2.0	42	34.5 ± 2.2
10:00 — 11:59 a.m.	18	32.6 ± 2.7	—	
12 a.m. — 1:59 p.m.	2	21.2 ±	—	
2:00 — 3:59 p.m.	4	30.8 ± 7.3	—	
4:00 — 5:59 p.m.	21	33.7 ± 3.2	—	
6:00 — 7:59 p.m.	13	28.4 ± 2.0	42	36.8 ± 2.3
8:00 — 9:59 p.m.	15	25.7 ± 1.5	42	34.1 ± 2.1
10:00 — 11:59 p.m.	—			

Table 7. Means and standard errors (M ± SE) for the excretion of noradrenaline in urine (nanog/min) during a work period and a day off in 2-h sampling periods (Winter—period B).

Hours	Work period		Day off	
	N	M ± SE	N	M ± SE
12 p.m. — 01:59 a.m.	32	39.1 ± 3.7	48	36.1 ± 2.4
2:00 — 3:59 a.m.	32	39.0 ± 3.2	48	42.4 ± 3.4
4:00 — 5:59 a.m.	26	42.7 ± 2.4	—	
6:00 — 7:59 a.m.	26	49.0 ± 4.2	47	39.6 ± 2.3
8:00 — 9:59 a.m.	46	46.7 ± 3.1	48	47.9 ± 3.9
10:00 — 11:59 a.m.	22	39.0 ± 3.5	—	
12 a.m. — 1:59 p.m.	10	53.0 ± 8.8	—	
2:00 — 3:59 p.m.	24	47.3 ± 4.7	—	
4:00 — 5:59 p.m.	21	44.1 ± 3.7	—	
6:00 — 7:59 p.m.	20	43.7 ± 3.2	48	39.0 ± 2.6
8:00 — 9:59 p.m.	24	37.3 ± 3.7	48	41.3 ± 2.9
10:00 — 11:59 p.m.	7	46.6 ± 13.9	—	

motor system than the three-shift control group. Draft, a common complaint from the engineers, is a possible explanation. There was no report of anginal chest pain or myocardial infarction. This result might be due to selection in the engineer group. The factors of selection could not be studied in the present investigation. The same frequency of peptic disorders was reported by Jörgensen (22) in an investigation of miners from the same town, Kiruna. There 20 % of the persons had long-standing peptic disorders, and 10 % had been away from work for this reason. We found peptic ulcers in 13 % and gastritis in 26—29 %, respectively. This frequency is higher than what has been found for other groups, e.g., dock workers (30), but it is in accord with the findings of Bjerner et al. (6), who found that traveling railroad personnel had more peptic ulcers than Swedes in general.

The reported decrease of sleep during work at night may be a risk factor with respect to safety at work, as a decreased amount of sleep is expected to affect the alertness of the subject (8, 9). Bjerner et al. (5) found longer reaction times on a multiple-choice reaction test and an increase in error-making after sleep deprivation.

The measurements for studying a circadian rhythm showed a daytime pattern. This held true for body temperature, potassium excretion, and 11-OH-cortisol in blood. Conroy et al. (10) found a reversed pattern in which the highest value occurred at 1 p.m. just before awakening in workers with constant night work. Whether the daytime pattern of blood cortisol is of any disadvantage in work during the night is not known at present. Van Loon (29) found that night work for 1 week gave an inverse pattern at the end of the week and noted individual differences in such a response. Furthermore, he found that a very rapid return to a daytime pattern occurred after 1 or 2 days away from work. The pattern of potassium excretion in urine follows a stable circadian rhythm with a lower excretion during the night than during the day (11, 25, 26). This rhythm is not so easily affected by the intake of food and beverages as is that for sodium and chloride excretion.

Many environmental factors may affect catecholamine excretion. Åstrand et al. (2) showed that coldness evoked an increased adrenaline excretion in fishermen. An increase in adrenaline and to some extent noradrenaline, due to coffee drinking, was reported by Fröberg et al. (16). Indubitably the effect of caffeine increased the adrenaline level in our investigation in both test situations. The unfamiliar test situation on the day off and the extra load of work on the train run under study might also have had a stressor effect and might have raised the adrenaline values. In laboratory investigations, in which the same technique of analysis was employed, the adrenaline excretion level was 5—10 nanog/min (18); and under resting conditions, 2—3 nanog/min (13). The same technique was used in the different test periods, and it is therefore unlikely that a method artifact would have caused abnormally high values. One critical point is that sampling should ideally be done at an acid pH. In the present investigation the urine was acidified at the end of the sampling period. (The delay was 1.5—2 h.) One effect of this delay, however, would be lower catecholamine values.

A somewhat astonishing fact was that the rated amount of fatigue and the adrenaline levels did not correlate. A correlation between intensity in emotions and adrenaline excretion has been described by Fröberg and his coworkers (17, 18, 24) and by Frankenhaeuser (15).

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