Saliva cortisol levels in construction workers in the Arctic (78°N)

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ABSTRACT

Objectives. The aim was to investigate how working in an extreme and isolated environment in the Arctic affected the diurnal rhythm of saliva cortisol.

Study design. Field study.

Methods. Twenty-five male tunnel workers were screened during 3 different working cycles with different light conditions during a 9-month construction period; April/May (24 hours [h] light), September/October (approximately 12 h light and 12 h darkness) and November/December (24 h darkness). The work schedule was 10 h on/14 h off, 21 days at work/21 days off work. The workers alternated between the day shift in 1 work period and the night shift in the next. Four saliva samples were collected on day 14 in all 3 periods; immediately after awakening, and then 30 minutes, 6 hours and 12 hours after awakening.

Results. Regardless of shift schedule, the workers’ cortisol levels were significantly lower in the period with 24 hours of light per day compared to the period with “normal” light conditions. There were no differences in the cortisol levels of the workers on night shifts in the period with 24 hours of darkness compared to those in the period with “normal” light conditions, but the workers who were on day shifts in the period with 24 of hours darkness had a disturbed cortisol rhythm (lower peak after awakening and lack of the normal decrease during the day).

Conclusions. External light conditions and shift schedule were important factors in regulating the workers’ cortisol rhythm. It seems to be easier to adapt to a night rhythm than an early morning rhythm in an isolated and extreme environment.

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Keywords: cortisol, diurnal rhythm, extreme environment
INTRODUCTION

We have studied a sample of construction workers at 78°N to see to what extent humans living and working in polar regions maintain their diurnal rhythms during midnight sun and midwinter darkness. Maintenance of this rhythm appears to be a prerequisite for functioning properly, and for avoiding the health and security risks that come from working under these exceptional environmental conditions.

Diurnal rhythms in humans and animals are set in part by the shift in light from day to night (1), although habits and behavioural factors also influence these rhythms (2). On average there are daily cycles with 12 hours of light and 12 hours of darkness all over the globe. However, there is a marked variance depending on latitude localizations. In the polar regions the average is still 12 hours of light and 12 hours of darkness; however, in the summer there is daylight for 24 hours per day, and during winter there is no sunlight for 24 hours per day. Around September 23 and March 20 of each year there are 12 hours of darkness and 12 hours of daylight per day all over the globe.

For the Antarctic region an “overwinter syndrome” has been postulated, consisting of depression, irritability, insomnia and cognitive problems (3). In a previous study, Harris et al. (4) did not find any disturbance in the diurnal cortisol rhythm in personnel overwintering at two British Antarctic stations (Rothera 67°S; Halley 75°S). The only registered complaints were reports of subjective sleep disturbance. The reason why no overwintering syndrome was recorded at these stations may be that the British Antarctic Survey (BAS), which has the logistic responsibility for these stations, keeps their workers on a strict, normal day-night schedule in all their stations (4).

In the Arctic, people live and work at latitudes as high as or even higher than those in the BAS Antarctic stations. The Svalbard or Spitsbergen islands have permanent settlements, engaged in tourism, science and mining. Svea is a coal-mining community situated at Spitsbergen, 78°N. We have studied the diurnal cortisol rhythm in 25 male workers in Svea who were constructing a tunnel for the transport of coal from the coal mine to the harbour. Svea is an isolated place where the only activities are mining or transporting coal. The workers shuttled between Svea and their homes in mainland Norway. They spent 21 days at work in Svea followed by a 21 day free period. They changed from day to night shift every other period (21 days working night shifts or 21 days working day shifts). During their work hours inside the tunnel, the workers had little or no exposure to external light. In their off hours the workers were exposed to huge differences in external light. During the summer time at 78°N there are several months with bright daylight for 24 hours per day; during the midwinter (the end of the construction period) the sun never rises above the horizon (polar night).

Cortisol is well known as a marker of diurnal rhythm (5). The hormone follows a 24 hour rhythm with peak levels usually found in the first 30 to 60 minutes after awakening, and decreasing levels thereafter (6). Salivary cortisol levels follow very closely to plasma levels, and like plasma levels they are very sensitive to psychological factors (7). Cortisol measured in saliva is a non-invasive technique favourable for field studies. The cortisol awakening response (CAR), defined as the period of cortisol secretory activity in the first 30 to 60 minutes immediately post-awakening, is presumed to be determined by circadian influences but will also reflect phasic psychophysiological processes specific to the waking-up
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process (6,8). Saliva cortisol sampled immediately after awakening and during the working period is a good indicator for any changes in diurnal rhythm associated with different working schedules (9).

Night work interferes with biological and social rhythms and has been associated with health complaints (10). The workers in this study had to adapt to a night rhythm in every other working period. The normal pattern is that sleep is reduced by approximately 2 hours when working early morning or night shifts (11). Previous studies have already demonstrated that workers in isolated environments are able to complete adapt to night shifts within a week (9,12,13). This is a much faster adaptation than what happens with workers in less isolated environments, where the adaptation normally takes between 8–14 days.

In previous studies we have demonstrated that there were no negative health effects of the extended work hours (10 hours on, 14 hours off for 21 days) (14), and that the workers experienced few sleep problems and adapted easily to the work schedule (15).

In this study we examined if the lack of external light during work hours, at this high latitude with different light conditions, had any detrimental effect on the diurnal cortisol rhythm in healthy males living in periodical isolation from home and normal family life. The following research objectives were explored.

1. Comparing the cortisol levels in day shift workers in an Arctic area during periods of 24 hours of light, 24 hours of darkness, and normal light conditions.
2. Comparing the cortisol levels in night shift workers in an Arctic area during periods of 24 hours of light, 24 hours of darkness, and normal light conditions.
3. Comparing the cortisol levels between workers on the day shift and the night shift in an Arctic area in different periods and with different light conditions.

MATERIAL AND METHODS

Procedure

The workers were tested 3 times during a 9-month construction period: April/May (24 hours of light per day), September/October (approximately 12 hours of light/12 hours of darkness per day) and November/December (24 hours of darkness per day). The work schedule was 21 days at work in Svea followed by a 21-day free period. The workers alternated between day and night shifts; they would work 21 days for 1 work period and 21 nights for the next. The 10-hour day shift was from 6:00 a.m. to 4:00 p.m. and the 10-hour night shift was from 6:00 p.m. to 4:00 a.m. All the workers were given oral and written information by representatives from the research group at the first test period. Saliva samples were collected at day 14 in the work period during all 3 test periods. Half of the workers had their first saliva samples collected during day work, the second during night work and the third during day work. The other half of the workers had their first saliva samples collected during night work, the second during day work and the third during night work. The saliva samples were stored in a freezer at the company’s office in Svea until representatives from the research group collected them after each test period. The workers also filled out sleep diaries and used wrist-worn Actiwatchs during the 3 test periods. Data from the sleep measurements are published in another article (15).
**Participants**

Complete data sets were obtained from 25 Norwegian tunnel workers (all men) (62.5%), who were present at all 3 data samplings. Data were collected from 40 workers in total. Of these, 15 workers did not complete the study, 3 workers left the company, 2 workers were on sick leave, 3 workers were transferred to other tasks in the company, 5 workers refused to participate further in the study and 2 workers did not collect saliva samples. The workers were screened with a questionnaire and had their saliva collected 3 times during a 9-month construction period. All of them were working shifts and had been shift workers for an average of 12.6 (SD=8.25) years. The mean age was 42.92 (SD=9.53) with a range from 26 to 60 years.

**Setting**

The workers in the study were constructing a tunnel to transport coal from a coal mine to the nearest harbour in Svea, located on Spitsbergen (78°54N, 18°01E). The work took place inside the tunnel, and they had little or no exposure to any daylight during their work hours. The tunnel itself was dark, but the blasting and drilling areas were lit. Svea is an Arctic area with few possible activities other than work. The workers’ off hours were spent in the living quarters close to the tunnel. In Svea, the sun is continually above the horizon from late April to late August and the polar night lasts from the end of October to the middle of February. In the period from mid-November to the end of January it is always so dark that artificial light must be used at all times. The Arctic climate is characterized by cold winters and cool summers.

The workers were organized in teams of 10–12 workers for each shift. The work tasks included the blasting and drilling of rocks, transport of the blasted rocks out of the tunnel, cement spraying, rock bolting, and scaling cleaning. Ear protection was needed while working because the noise levels inside the cars and the tunnel were above 85dB(A). The dust levels inside the tunnel were mostly within recommended limit values. Parts of the work were physically demanding, as the workers had to climb, crawl and work in different positions, with major use of their hands and arms. Meals were served at regular times in a canteen, which was also open during the night shift.

**Instruments**

Cortisol was measured in saliva using salivette collection tubes (DPC Norway, Brakkerøya, Drammen). The workers collected 4 saliva samples on day 14 of 3 different work periods: April/May (24 hours of light per day), September/October (approximately 12 hours of light/12 hours of darkness per day) and November/December 2003 (24 hours of darkness per day). The first sample was taken immediately after awakening (0), the second 30 minutes later (0+30 min), the third 6 hours after awakening (0+6 hour) and the last sample 12 hours after awakening (0+12 hour). The workers were instructed to chew gently on the cotton swab for 1 minute to obtain the desired amount of saliva, and were asked to avoid food, drink and nicotine for 30 minutes before saliva sample collection. The first sample was to be taken while the workers were still lying in their beds.

Four single cortisol samples were missing and 1 cortisol sample was excluded from the analyses due to a discrepancy greater than 3 standard deviations.

**Analysis**

Coat-a-Count RIA kit from Diagnostic Products Corporation (DPC, Los Angeles, CA) was used to
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assay salivary cortisol. Intra-assay and inter-assay coefficients of variance did not exceed 10.3%.

Statistics
PASW (SPSS) statistics for Windows version 17 were used for all the statistic analyses. The mixed model routine was used to model the effect of the work period (April/May, September/October, November/December), time of day (0, 0+30 min, 0+6 hours, 0+12 hours) and the shift (day shift, night shift) on the cortisol levels. To adjust for multiple observations per individual, we added individuals as a random effect in the model (using a variance component). We have done sub-analyses for time of day and the shift categories.

When exploring the differences in cortisol levels between the 3 different periods (April/May with 24 hours of light per day; September/ October with 12 hours of light and 12 hours of darkness per day; and November/December with 24 hours of darkness per day), cortisol levels in September/October (“normal light”) were set as the reference category. When exploring the differences in adaptation between day shift and night shift, cortisol levels during day shifts were set as the reference category. Age was adjusted for in all models and the significance level was set to 0.05. The analyses on cortisol were performed on log-transformed data and geometric means were used in the figures.

Ethics
All participants gave their written consent to participate in the study. Ethical clearance was obtained from the Regional Committee for Medical Research Ethics in western Norway and the study was in accordance with the Declaration of Helsinki. The investigation was conducted in co-operation with The Norwegian Labour Inspection Authority.

RESULTS
Results from the sleep measurements published recently showed that when the workers were working day shifts the average wake-up time was 4:26 a.m. and the average bedtime was 9:29 p.m. When the workers were working night shifts the average wake-up time was 2:58 p.m. and the average bedtime was 7:20 a.m. (15).

Cortisol levels when the tunnel workers were working day shifts
When the workers were working day shifts and the period with “normal” light conditions (September/October) was set as reference category, the analyses (interaction between period and time of day) showed significant differences in cortisol levels between the 3 periods (April/May, September/October, November/December). On average the cortisol levels were significantly lower in the period with 24 hours of light per day (April/May) (Estimate=-0.981[SEM=0.158], p<0.001) and in the period with 24 hours of darkness per day (November/December) (Estimate=-0.366[SEM=0.173], p<0.001) compared to the cortisol levels in the period with “normal” light conditions (September/November) (Fig. 1). The shape of the cortisol curve during the period with 24 hours of light per day (April/May) looked very similar to the curve in the period with “normal” light conditions (September/November), but the sub-analyses showed that the levels were significantly lower at all 4 measure points (Table I). In the period with 24 hours of darkness per day (November/December) the shape of the curve was different. The workers showed an increase in cortisol levels after awakening but not the subsequent decrease that is normally found during the working period.
Table 1. Multilevel estimates and standard error (SEM) of the cortisol levels at different measure points (awakening [0], 0+30min, 0+6h, 0+12h) adjusted for age during different light conditions; April/May (24 hours of light per day), September/October (12 hours of light and 12 hour darkness per day) and November/December (24 hours of darkness per day), where cortisol levels in September/October were set as reference category (0). Separate analyses were performed for day shifts and night shifts.

|                     | April/May (24h light) Estimate (SEM) | September/October (12h light + 12h darkness) Estimate (SEM) | November/December (24h darkness) Estimate (SEM) |
|---------------------|--------------------------------------|---------------------------------------------------------------|--------------------------------------------------|
| Day shift           |                                       |                                                                |                                                  |
| Awakening           | -1.189 (0.250)***                    | 0                                                             | -0.709 (0.327)*                                 |
| 0 + 30 min          | -0.524 (0.209)*                      | 0                                                             | -0.529 (0.250)*                                 |
| 0 + 6 hour          | -0.711 (0.293)*                      | 0                                                             | -0.378 (0.271)                                  |
| 0 + 12 hour         | -1.522 (0.268)*                      | 0                                                             | 0.107 (0.261)                                   |
| Night shift         |                                       |                                                                |                                                  |
| Awakening           | -0.642 (0.304)*                      | 0                                                             | -0.137 (0.348)                                  |
| 0 + 30 min          | -0.345 (0.206)                       | 0                                                             | -0.166 (0.242)                                 |
| 0 + 6 hour          | -0.885 (0.196)***                    | 0                                                             | -0.290 (0.270)                                 |
| 0 + 12 hour         | -1.123 (0.245)***                    | 0                                                             | 0.037 (0.278)                                   |

* p<0.05.  
** p<0.01.

Figure 1. Cortisol levels (geometric mean and standard error of the mean) at different measure points when the tunnel workers were on day shifts and night shifts during the 3 different work periods. The light conditions differed: 24 hours of light per day in April/May; approximately 12 hours of light and 12 hours of darkness per day in September/October; and 24 hours of darkness per day in November/December.
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Cortisol levels when the tunnel workers were working night shifts
When the workers were on night shift and the period with “normal” light conditions (September/October) was set as reference category, the analyses (interaction between period and time) showed that the cortisol levels were significantly lower in the period with 24 hours of light per day (April/May) (Estimate=-0.772[SEM=0.124], p<0.001). Results from the sub-analyses showed that the cortisol levels were significantly lower at awakening, 6 hours after awakening and 12 hours after awakening in the period with 24 hours of light per day (April/May) (Table I and Fig. 1). There were no significant differences in cortisol levels between the period with “normal” light (September/October) and the period with 24 hours of darkness per day (November/December) when the workers were on the night shift (Estimate=-0.169[SEM=0.167], p>0.05).

Differences in cortisol levels between day shift workers and night shift workers during different light conditions
There were no differences in cortisol levels between the workers who were on night shifts and day shifts during the period with “normal” light conditions (September/October). Cortisol at awakening: (Estimate=-0.366[SEM=0.350], p>0.05); 30 minutes after awakening: (Estimate=-0.165[SEM=0.265], p>0.05); 6 hours after awakening (Estimate=-0.469[SEM=0.202], p>0.05); and 12 hours after awakening (Estimate=-0.340[SEM=0.173], p>0.05).

In the period with 24 hours of light per day (April/May), the workers who were on night shifts had significantly higher cortisol levels at awakening (Estimate=1.092[SEM=0.423], p<0.05), but no differences in their cortisol levels 30 minutes after awakening (Estimate=0.382[SEM=0.244], p>0.05), 6 hours after awakening (Estimate=-0.642[SEM=0.338], p>0.05) and 12 hours after awakening (Estimate=0.031[SEM=0.375], p>0.05) compared to those who were working day shifts. In the period with 24 hours of darkness per day (November/December), the workers who were on night shifts had significantly higher cortisol levels at awakening (Estimate=1.115[SEM=0.287], p<0.01) and 30 minutes after awakening (Estimate=0.591[SEM=0.263], p<0.05) compared to those who were on day shifts, but there were no significant differences between the shifts 6 hours after awakening (Estimate=-0.418[SEM=0.299], p>0.05) and 12 hours after awakening (Estimate=-0.404[SEM=0.292], p>0.05).

DISCUSSION

Our main finding is that in spite of the isolation, the extreme external environment and the lack of daylight during work hours, we did not observe any disruption of the diurnal cortisol rhythm in the workers when they were working night shifts. This is in itself surprising; even more surprising was the finding that those who were working day shifts showed disturbed cortisol rhythm in the period with 24 hours of darkness and had lower activation, especially in the morning hours, during all 3 shift periods.

During the night shift the workers had the normal peak level of cortisol in the “morning,” and the normal and gradual fall of cortisol levels towards the end of the night shift. To explain this we have to describe their routines in greater detail. The workers on night shift ended their working period at 4:00 a.m., returned to the barracks, washed, took their last (0+12 h) saliva
samples, had a meal and then went to sleep. They woke up around 4:30 p.m., took their “morning” samples and prepared for their work period, which started at 6:00 p.m.

During the day shift the workers woke up at 4:30 a.m. and took their “morning” sample, at a time when they probably would still be sleeping during their off-work periods. They started their work period at 6:00 a.m. and worked until 4:00 p.m., when they returned to the barracks, washed, took their last saliva samples (0+12 h) and had their evening meal and a social period before going to bed. Because the day shift started as early as 6:00 a.m., they may have gone to bed later than required for a normal, 7- to 8-hour sleep period. Previously published measurements (Actiwatch and sleep/wake diaries) showed significantly shorter total sleep length (1/2 to 1 hour) when the workers were on day shifts compared to night shifts (15). This may be explained by higher amounts of social activity with co-workers in the hours after work when the workers were on day shifts compared to night shifts.

All in all it was the workers on the day shifts that paradoxically had the most disturbed rhythm (lower in the morning and higher in the afternoon). This may indicate that, while working and living in isolated and extreme environments, it is easier to adapt to a night rhythm than an early morning shift. This is in accordance with existing knowledge showing that for most people it is easier to phase delay than to phase advance the endogenous circadian system (16). However, the disturbed cortisol rhythm during day shifts in the period with 24 hours of darkness differs from a previous study showing that day workers in Antarctica keep the diurnal cortisol rhythm during the winter (4). The darkness and the extremely cold winter were similar in these 2 studies, but there are also several differences, especially in the types of work and the organization of the day-night rhythm. The most important difference is probably that the workers in the study from Antarctica kept a normal day-night rhythm while the workers in this study did not. Differences in awakening time may also be considered since the workers in Antarctica got up approximately 3 and a half hours later than the day shift workers in Svea. However, previous findings on the association between awakening time and cortisol are relatively inconsistent (17,18), and both a higher cortisol awakening response (19) and no association between cortisol and awakening have been shown (8,20).

The day shift workers had shorter sleep lengths and lower cortisol levels at awakening compared to the night shift workers. These results are in accordance with previous studies showing a positive association between sleep duration and higher cortisol levels at awakening (21–23). However, since there were no differences in cortisol levels after awakening between the workers on day shifts and the workers on night shifts in the period with “normal” light conditions, it seems that the external light conditions are more important than time of awakening and sleep duration. This supports the hypothesis that an absence of solar light during midwinter will affect the diurnal cortisol rhythm in healthy men working in an extreme and isolated environment. It also implies that the maintenance of regular day-night routines may be more important in environments with an absence of daylight than in environments with normal light conditions. This assumption is in accordance with a previous study from a Greenpeace expedition in Antarctica, which found that during the Antarctic summer the circadian rhythm of cortisol, melatonin, sodium
and potassium was synchronized with the clock time, while during the winter all measures ran free in each individual (24). Seasonal variation in cortisol levels in Antarctic-area personnel was also found in an earlier study performed by Grif-fiths et al. (25). However, it is difficult to compare these studies since they give no information on work schedule or day-night routine.

One of the strengths of the present study is that all the workers involved lived in the same environments during their work period, both while working and during their time off. This offers good control over their eating, sleeping and social habits. However, we were not able to use a within-subject design since we were unable to measure all the workers in both shift schedules during all 3 periods. To minimize the effects of this problem, individuals were added as a random effect in our statistical model. In this study, we could not find any indication of negative health effects after alterations of circadian rhythms. The study is limited to a follow-up observation at 9 months, and we do not know if there are any negative long-term effects. Generalization to other populations of workers should be done with caution, since our workers were highly selected and had a preference for this work schedule.

In conclusion, daylight conditions and shift schedules were of importance in measuring cortisol levels. Regardless of shift schedule, the cortisol levels were lower at all measure points in the period with 24 hours of light compared to the period with normal light conditions and the period with 24 hours of darkness. Surprisingly, the day shift workers showed disturbed cortisol rhythms. In an extreme and isolated environment, without an organization or leader that reinforces a normal day-night schedule, it appears to be easier to adapt to a night rhythm than a day rhythm.

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Conflict of interest
None declared.

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