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

Running title: Cortisol levels in construction workers in the Arctic

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

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

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

Keywords: Cortisol, Diurnal rhythm, Extreme environment

INTRODUCTION

We have studied a sample of construction workers at 78° north to see to what extent humans living and working in Polar Regions maintain their diurnal rhythms during midnight sun and midwinter darkness. Maintenance of the rhythm appears to be a prerequisite to function properly, and to avoid health and security risks from working under these exceptional environmental conditions.

Diurnal rhythms in human and animals are set in part by the shift in light from day to night (1), even if habits and behavioural factors also influence the rhythms (2). On the average there is 12 hour light and 12 hour darkness cycle all over the globe. However, there is a marked variance depending on latitude localisations. In the Polar Regions the average is still 12 hours light and 12 hours 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 we have 12 hour darkness and 12 hour daylight per day all over the globe.

For the Antarctic region an “over winter 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 of the diurnal cortisol rhythm in personnel over wintering 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 over wintering syndrome was recorded at the BAS stations may be that the British Antarctic Survey (BAS), that has the logistic responsibility for these stations, keep 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 the BAS Antarctic stations. The Svalbard or Spitsbergen islands have permanent settlements, engaged in tourism, science and mining. Svea is a coalmining community situated at Spitsbergen, 78° north. We have studied the diurnal cortisol rhythm in 25 male workers constructing a tunnel for 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 their homes in mainland Norway and Svea. 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 night shifts or 21-days day shift). During the work hours inside the tunnel, the workers had no or little exposure to external light. In the off hours the workers were exposed to huge differences in external light. During the summer time at 78° north 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 hours rhythm with peak levels usually found in the first 30 to 60 minutes after awakening and decreasing levels thereafter (6). Cortisol measured in saliva is a non-invasive technique favourable for field studies. 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 (7).

Night work interferes with biological and social rhythms and has been associated with health complaints (8). The workers in this study had to adapt to a night rhythm every other working period. The normal pattern is that sleep is reduced by approximately 2 hours when working early morning or night shifts (9). Previous studies have already demonstrated that workers in isolated environments have a complete adaptation to night shift within a week (7, 10, 11). This is a much faster adaptation than what happens in 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) (12), and that the workers experienced few sleep problems and adapted easily to the work schedule (13).

In this study we examined if 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 questions were explored.

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

MATERIAL AND METHODS

Procedure

The workers were tested three times during a 9 month construction period; April/May (24 hours light), September/October (approximately 12 hours light/12 darkness) and November/December 2003 (24 hours darkness). The work schedule was 21 days at work in Svea followed by a 21 day free period. During the work period the workers alternated between

21 days or 21 nights every other work period. The 10-hour day shift was from 0600AM to 0400PM and the10-hour night shift was from 0600PM to 0400AM. All the workers were given orally 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 at all three test periods. Half of the workers collected the first saliva samples during day work, the second during night work and the third during day work. The other half of the workers collected the first saliva samples 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 Actiwatches during the three test periods. Data from the sleep measurements are published in another article (13).

Participants

Complete data set were obtained from 25 Norwegian tunnel workers (all men)(62.5%), that were present at all three data samplings. Data were collected from 40 workers. Of these, 15 workers did not complete the study, three workers left the company, two workers were on sick leave, three workers were transferred to other tasks in the company, five workers refused to participate further in the study and two workers did not collect saliva samples. The workers were screened with a questionnaire and collected saliva three times during a nine month construction period. All of them were working shift 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 no or little exposure to any daylight during their work hours. The tunnel itself was dark, but the blasting and drilling area were lit. Svea is an Arctic area with no, or few other possible activities than work. The off hours were spent in the living quarters close to the tunnel. The sun is continually above the horizon from late April to late August and the polar night last from the end of October to the mid 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 organised in teams of 10-12 workers for each shift. The work tasks were 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 was above 85dB(A). The dust levels inside the tunnel were mostly within recommended limit values. Parts of the work were physically demanding, as they had to climb, crawl and work in different positions and with major use of hands and arms. Meals were served at regularly times in a canteen, which was open also during the night shift.

Instruments

Cortisol was measured in saliva using salivette collection tubes (DPC Norway, Brakkerøya, Drammen). The workers collected four saliva samples on day 14 in three different periods; April/May (24 hours light per day), September/October (approximately 12 hours light/12 darkness per day) and November/December 2003 (24 hours 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 min to obtain the desired amount of saliva and to avoid meals, drink and nicotine for 30 minutes before saliva sample collection. The first sample should be taken while still lying in their beds.

Four single cortisol samples were missing and one cortisol sample was excluded from the analyses due to discrepancy more than three standard deviations.

Analysis

Coat-a-Count RIA kit from Diagnostic Products Corporation (DPC, Los Angeles, CA) was used to assay salivary cortisol. Intraassay and interassay 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 for period (April/May, September/October, and November/December), time of day (0, 0+30min, 0+6hours, 0+12 hours) and the shift (day shift, night shift) of the cortisol. To adjust for multiple observations per individual, we added individual as a random effect in the model (using variance component). We have done sub analyses for time of day and the shift categories.

When exploring the differences in cortisol levels between the three different periods (April/May with 24 hour light per day, September/October with 12 hours light and 12 hour darkness per day, and November/December with 24 hours 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 at day shift were set as reference category.

Age was adjusted for in all models and 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 shift the average wake up time was 4:30AM and the average bed time was 9:30PM.When the workers were working night shift the average wake up time was 2:00PM and the average bed time was 07:00AM (13).

Cortisol levels when the tunnel workers were working day shift

When the workers were working the day shift and the period with ”normal” light conditions (September/October) were set as reference category, the analyses (interaction between period and time of day) showed significantly differences in cortisol levels between the three periods (April/May, September/October, November/December). In average the cortisol levels were significantly lower in the period with 24 hours light (April/May) (Estimate=- .981(SEM=.158), p<.001) and in the period with 24 hours darkness (November/December) (Estimate= - .366(SEM=.173), p<.001) compared to the cortisol levels in the period with “normal” light conditions (September/November)(Figure 1). The shape of the cortisol curve during the period with 24 hours light per day (April/May) looked exactly 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 four measure points (Table 1). In the period with 24 hours darkness (November/December) the shape of the curve were different. The workers showed an increase in cortisol levels after awakening but not the normal decrease during the working period.

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Cortisol levels when the tunnel workers were working night shift

When the workers were on night shift and the period with “normal” light condition (September/October) were 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 light per day (April/May) (Estimate=-.772(SEM=.124,P<.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 light per day (April/May) (Table 1 and Figure 1). There were no significant differences in cortisol levels between the period with “normal” light (September/October) and the period with 24 hours darkness per day (November/December) when the workers were on night shift (Estimate= -.169(SEM=.167),p>.05).

Differences in cortisol levels between day shift and night shift during different light conditions

There were no differences in cortisol levels between the workers who were on night shift and day shift in the period with “normal” light conditions (September/October); cortisol at awakening: (Estimate=- .366(SEM=.350), p>.05), 30 minutes after awakening (Estimate=-. 165 (SEM=.265, p>.05), 6 hours after awakening (Estimate=- .469(SEM=.202), p>.05), and 12 hours after awakening (Estimate=- .340(SEM=.173), p>.05).

In the period with 24 hours light per day (April/May) the workers who were on night shift had significantly higher cortisol levels at awakening (Estimate=1.092(SEM=.423), p<.05), but no differences in cortisol levels 30 minutes after awakening (Estimate=.382(SEM=.244), p>.05), 6 hours after awakening (Estimate=- .642(SEM=.338), p>.05), and 12 hours after awakening (Estimate=.031(SEM=.375), p>.05) compared to those who were working day shift.

In the period with 24 hour darkness per day (November/December) the workers who were on night shift had significantly higher cortisol levels at awakening (Estimate= 1.115(SEM=.287), p<.01), and 30 minutes after awakening (Estimate=.591(SEM=.263), p<.05) compared to those who were on day shift, but there were no significant differences between the shifts 6 hours after awakening (Estimate=- .418(SEM=.299), p>.05), and 12 hours after awakening (Estimate=- .404 (SEM=.292), p>.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 the night shift. This is in itself surprising; even more surprising was the finding that those who were working the day shift showed disturbed cortisol rhythm in the period with 24 hour darkness and had lower activation, especially in the morning hours in all three periods.

During the night shift the workers had the normal peak level of cortisol in the “morning”, and the normal and gradual fall 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 0400AM, returned to the barracks, washed and took their last (0+12h) saliva samples and went to sleep after having a meal. They woke up around 0430PM, took their “morning” samples, and prepare for their work period that started at 06:00PM.

During the day shift the workers woke up at 4:30AM and took their “morning” sample, at a time where they probably would still be sleeping during their off-work periods. They start their work period at 6:00AM and work until 4:00PM, when they return to the barracks, wash, take their last saliva samples (0+12h), have their evening meal and a social period before going to bed. Because the day shift starts as early as 06:00AM, they may go to bed later than required if they really want a normal 7 to 8 hour sleep period. Previously published measurements (Actiwatch and diaries) showed significantly shorter total sleep length (1/2 to 1 hour) when the workers were on the day shift compared to the night shift (13). This may be explained by higher social activity with co workers in the hours after work when the workers were on day shift compared to night shift.

All in all it was the workers working the day shifts that paradoxically have 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 already existing knowledge showing that for most people it is easier to phase delay than to phase advance the endogenous circadian system (14). However the disturbed cortisol rhythm on day shift, in the period with 24 hours darkness, differs from a previous study showing that day workers in Antarctica keeps the diurnal cortisol rhythm during the winter (4). The darkness and the extreme cold winter are similar in these studies but there are several differences, especially in type of work and organization of the day-night rhythm. The most important difference is probably that the workers in the study from Antarctica keep a normal day-night rhythm while the workers in this study are not. Differences in awakening time may also be considered since the workers in Antarctica get up approximately three and a half hours later then the day shift workers in Svea. However, previous findings on the association on awakening time and cortisol are relatively inconsistent (15, 16) and both higher cortisol awakening response (17) and no association between cortisol and awakening have been shown (18, 19).

The day shift workers had shorter sleep length and lower cortisol levels after awakening compared to the night shift workers. These results are in accordance with a previous study showing a positive association between sleep duration and cortisol levels after awakening (20). However, since there were no differences in cortisol levels after awakening between the workers on day shift and the workers on night shift 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 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 seem to be more important in environments with absence of day light than in environments with normal light conditions. The assumption is in accordance with a previous study from a Greenpeace expedition in Antarctica where they 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 time all measures free ran in each individual (21). Seasonal variation in cortisol levels in personnel in an Antarctic area has also been found in an early study performed by Griffiths et al (22). However it is difficult to compare these studies since they give no information on work schedule or day-night routine.

In conclusion, day light conditions and shift schedules were of importance. Regardless of shift schedule the cortisol levels were lower at all measure points in the period with 24 hours light compared to the period with normal light conditions and in the period with 24 hours of darkness. Surprisingly, the day shift workers showed disturbed cortisol rhythm. In an extreme and isolated environment, without an organisation 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 statement

None declared.

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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 hour midnight sun), September/October (12 hour light and 12 hour darkness) and November/December (24 hour darkness) when cortisol levels in September/October were set as reference category (zero). Separate analyses were performed for day shift and night shift.

	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 (.250)**	0	-.709 (.327)*
0 + 30 min	-.524 (.209)*	0	-.529 (.250)*
0 + 6 hour	-.711 (.293)*	0	-.378 (.271)
0 + 12 hour	-1.522 (.268)*	0	.107 (.261)
Night shift			
Awakening	-.642 (.304)*	0	-.137 (.348)
0 + 30 min	-.345 (.206)	0	-.166(.242)
0 + 6 hour	-.885 (.196)**	0	-.290 (.270)
0 + 12 hour	-1.123 (.245)**	0	.037 (.278)

* p<.05
** p<.01

Fig 1. Cortisol levels (geometric mean and standard error of the mean) at different measure points when the tunnel workers were on day shift and night shifts in the three different work periods. The light conditions differed; 24 hours light in April/May, approximately 12 hours light and 12 hours darkness in September/October and 24 hours darkness in November/December.