



## **Original article**

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### **Different levels of work-related stress and the effects on sleep, fatigue and cortisol**

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## Different levels of work-related stress and the effects on sleep, fatigue and cortisol

by Anna Dahlgren,<sup>1</sup> Göran Kecklund, PhD,<sup>1</sup> Torbjörn Åkerstedt, PhD<sup>1,2</sup>

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**Objectives** The aim of the study was to relate different levels of work stress to measures of sleep and the diurnal pattern of salivary cortisol and subjective sleepiness.

**Methods** Thirty-four white-collar workers participated under two different conditions. One workweek with a relatively high stress level (H) and one with a lower stress level (L) as measured through self-rated stress during workdays. The workers wore activity monitors, filled out a sleep diary, gave saliva samples (for cortisol), and rated their sleepiness and stress during one workday and one free day.

**Results** During the week with stress the number of workhours increased and total sleep time decreased. Sleepiness showed a significant interaction between weeks and time of day, with particularly high levels towards the evenings of the stress week. Cortisol also showed a significant interaction, with a more flattened pattern, probably due to increased evening levels during the stress week. Stress (restlessness) at bedtime was significantly increased during the stress week.

**Conclusions** The results demonstrate that a workweek with a high workload and much stress increases sleepiness and workhours, impairs sleep, and affects the pattern of diurnal cortisol secretion.

**Key terms** actigraphy; sleepiness; workhours.

Stress, or increased workload, has been the topic of much recent research and has been implicated as a causal factor of ill health, particularly in relation to metabolic and cardiovascular disease (1–3), but also burn-out (4). The latter has become epidemic in countries such as Sweden (5) and is characterized by extreme fatigue in combination with cognitive impairment and reduced empathy with others (4, 6, 7). The mechanism behind the development of stress-related diseases includes a long-term increase in circulating cortisol levels, leading to an allostatic up-regulation of the hypothalamo-pituitary-adrenal (HPA) axis (8). Cortisol suppresses testosterone and some parts of the immune system, and such suppression may make people more vulnerable to illness (9). Much of this reasoning, however, is based on animal studies, experimental (laboratory) stress, and cross-sectional field studies of groups with various degrees of stress. There seems to be very little data describing the effects of periods of real life stress in longitudinal studies.

Cortisol shows a pronounced variation across the time of day, and it has been argued that stress may alter the pattern. Thus groups with stress or increased workload often exhibit increased cortisol levels, particularly in the morning (10–14). Caplan et al (15), however, failed to find such a pattern, and Preussner et al (16) found lower morning levels of cortisol in persons with burnout. A similar reduction of diurnal cortisol amplitude was found in a large study of groups reporting increased levels of stress (17). It has also been observed that evening cortisol may be elevated in connection with stress (18).

All of the aforementioned studies involved between-group comparisons, which may be difficult to interpret because of selection mechanisms. However, there are also several intraindividual studies showing that cortisol increases in connection with laboratory or real life stress (14, 19, 20), but the only within-person study of real life stress at work (21) failed to find any change in the diurnal cortisol pattern during a period of perceived stress. However, the definition of the stress condition

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was based on an increase in paid overtime rather than on experienced stress, which may make interpretation difficult. Brantely et al (22) did find increased cortisol levels during a stressful period but did not study the diurnal pattern. Another longitudinal study of overtime work (23) found a simultaneous increase in work overload, fatigue, and catecholamine excretion.

Another factor of interest in relation to real life stress is sleep, since primary insomnia is usually considered a result of long-term stress (24) and sleep is usually closely related to stress (25–28). Sleep is also of interest in stress research since, for example, cortisol levels and insulin intolerance are increased after a few days of partial sleep loss (29). Indeed, any awakening from sleep will be associated with a burst of cortisol, and cortisol levels are increased in insomnia (30–34). But, again, there are virtually no studies on the reaction of sleep to periods of increased work stress.

Fatigue appears to be a key characteristic of long-term stress, as demonstrated in the burnout literature (35). However, again, apart from the studies of Piper et al (36) and Rissler & Elgerot (23), there is very little information from field studies on the effects of periods of increased workload. However, in a recent study (37), it was found that young people scoring high on burnout showed a higher diurnal level of rated sleepiness, particularly during days off and particularly in the morning. High sleepiness as a consequence of stress may be counterintuitive, but there is anecdotal evidence that a high workload may raise sleepiness levels. However, no data seem to be available.

The participants in our study were of particular interest since a large proportion (76%) had a worktime system in which they themselves could decide how many hours to work and when to work them. This situation made it possible to relate the number of workhours to the level of workload. Presumably the two would be expected to be related, but it has never been demonstrated in a longitudinal study (38).

The aim of our study was to examine the effects of work-related stress on sleep and overall health, the diurnal pattern of cortisol and sleepiness, and workhours, using a within-person design. For this purpose a group of office workers was followed for a week with high stress and a week with low stress, the stress level being based on the participant's own predictions. The focus was on workdays, but weekends were also included to yield information on possible lack of recovery.

## **Study population and methods**

### *Study population and design*

Our study involved 55 office workers employed by two labor unions in Stockholm, Sweden. It was a part of a

larger project concerning workhours and health. At both workplaces about 50% of those approached agreed to participate in the study. The workers participated under two different conditions. One condition involved a workweek with a relatively higher stress level (H) and another workweek with a relatively lower stress level (L), as predicted by the participants. They were asked to base their prediction on their expected workload, which for some persons had regular peaks each month. During each condition the participants rated their stress and sleepiness six times a day and sleep quality once a day during a week. Saliva was sampled for cortisol analysis six times a day during one workday and one day off.

Eventually, only 34 [23 women and 11 men, mean age 47 (SD 11) years] participants showed a clear difference in subjective stress between the weeks (at least half a scale unit difference). The most common reason for the loss of the remaining 21 persons was that they could not find a period of sufficiently low stress within the time frame of the project. The mean stress level across workdays (Monday to Friday) was calculated and yielded 4.5 (SD 0.2) for the high (H) stress week and 3.5 (SD 0.2) for the low (L) stress week (see the scale below). The mean for the number of ratings of  $\geq 6$  during the high stress week (Monday to Friday) was 8.2 (SD 1.0) and 3.0 (SD 0.6) in the low stress week ( $t=7.6$ ,  $df=33$ ,  $P<0.0001$ ).

The design of the two conditions was counterbalanced, but, due to the 21 dropouts, 16 started with the high stress measurement and 18 started with the low stress measurement. Of the 34 participants, 17 were working in administration, 16 were union representatives, and 1 was a supervisor.

### *Self-ratings*

During both conditions the participants made ratings in a diary at awakening during the day, and in the evening. The ratings of stress were made at 0700, 1000, 1300, 1600, 1900, and 2200 on a 9-point scale. The stress rating scale was inspired by the work of Kjellberg & Iwanowski (39) and their development of the "stress-energy rating questionnaire". They used almost 100 mood adjectives that were factor analyzed. A series of factor analyses was carried out, and the final outcome was a two-factor structure. The factors were labeled "energy" (represented by adjectives like active, energetic, efficient, etc) and "stress" (represented by adjectives like tense, stressed, under pressure, etc). The dimensions included six items each. The "stress-energy scale" has been validated, with good results, against job-strain measures (40). However, since we needed to collect information about stress several (6) times a day over 18 days, it would have been too much of a burden for the

participants to complete the entire questionnaire. Therefore, the items on the stress dimension were integrated into a single rating scale. The scale included nine response categories, of which five included verbal anchors: 1 very low stress (very calm and relaxed), 3 low stress (calm and relaxed), 5 neither low nor high stress, 7 high stress (high tension and pressure), 9 high stress (very high tension and pressure). In the diary, the participants also rated their sleepiness during the day (at 0700, 1000, 1300, 1600, 1900, and 2200) using the Karolinska Sleepiness Scale (KSS 1 very alert – 9 very sleepy, fighting sleep, effort to stay awake). The scale has been validated against physiological and behavioral measures (41). Electroencephalographic (EEG) and electrooculographic (EOG) changes characteristic of sleepiness usually begin to appear at a value of 7 (41).

At the end of the day, the participants reported how their day had been with respect to different symptoms of stress. The questions concerned whether one had felt tense, irritated, exhausted, under time pressure, or had had difficulties concentrating (1= not at all, 5= to a large extent). The participants also answered questions about workload (1=very low, 5= very high) and whether they had enough rest and relaxation during the day (1=definitely enough, 5= far from enough). On the same occasion, the participants also rated how they expected to sleep the coming night (1= very well, 9= very poorly).

Every morning during both weeks the participants filled out the Karolinska Sleep Diary (KSD) (42). It consists of several questions concerning “sufficient sleep”, “early awakening”, “ease of falling asleep”, and “stress or restlessness at bedtime”. The ratings were made on a 5-point scale (1 poor sleep – 5 no problems with sleep). To measure the quality of sleep, a sleep quality index (SQI) was formed of the questions “restless sleep”, “ease of falling asleep”, “sleep quality” (phrased as “how did you sleep”), and “slept throughout”.

At the beginning of each condition, the participants filled out a questionnaire. It contained questions on their present work situation, workhours (1 = <37.5 hours, 2 = 38–40 hours, 3= 41–45 hours, 4 = 46–50 hours, 5 = 51–60 hours, and 6 = >60 hours) the week before the measurement periods, as well as rated health and sleep the preceding month. The questionnaire also contained the HAD (hospital anxiety and depression) scale, which has been developed to measure symptoms of depression and anxiety among physically ill patients (43). The HAD scale has 14 items, of which 7 measure anxiety and 7 measure depression. The ratings are made on 4-point scales, which represent the degree of distress (0= none, 3=unbearable). The participants made ratings for the week preceding the measurement periods. The sum of each subscale can be classified in terms of severity, for which 1–7 indicates normal, 8–10 represents intermediate doubtful cases, and 11–14 stands for definite cases.

Zigmond & Snaith (43) reported good reliability and validity for the HAD scale.

### *Actigraphy and cortisol*

Throughout both conditions, the participants wore an actigraph (Cambridge Neurotechnology Ltd, Cambridge, UK, 2001) measuring wrist activity. The participants were instructed to press an event button when going to sleep (lights out) and at awakening. For scoring the data the Actiwatch Sleep Analysis (2001, version 1.09) was used. The output sleep score corresponds well with polysomnographically recorded sleep for the parameter total sleep time (44). Of all the sleep recordings about 14% was lost due to the participants’ failure to wear the actigraph. The measures obtained were bedtime, wake-up time, actual sleep time (excluding time awake), and sleep efficiency (actual sleep time/total sleep time × 100).

On one workday (Wednesday) and one day off (Saturday) during each condition the participants gave saliva samples for cortisol using Salivette (Sarstedts, Rommelsdorf, Germany) cotton swabs. Wednesday was chosen because it was considered to be the day with the highest stress and workload. The participant kept a swab in his or her mouth for about 1 minute and then put it in a test tube, which was sealed. The samples were obtained 15 minutes after awakening and at 1000, 1300, 1600 and bedtime. The participants were instructed to avoid food for 30 minutes before these time points. There were no differences in the sampling time between the conditions at awakening or at bedtime. About 10% of the samples were lost. When possible, missing data were replaced by a mean value based on adjacent values. Missing data at awakening and at bedtime were not replaced because of the lack of adjacent values. Missing data at 1000 were not replaced either, since using the preceding high morning value probably would have resulted in a mean value that was too high and misleading. The cortisol samples were analyzed by radioimmunoassay, using the Spectria (<sup>125</sup>I) coated tubes radioimmunoassay kit, (Orion Diagnostica, FIN-02101 Espoo, Finland). The within-assay coefficient of variation ranged from 0.5 to 6 and the between-assay coefficients never exceeded 10%.

### *Statistical analyses*

To obtain a measure describing the whole measurement period for each condition, we averaged the values of each variable over the workdays and weekends, separately, for each condition. A two-factor analysis of variance (ANOVA) for repeated measurements was used to detect changes for each participant under the different conditions, but also to examine the differences

in the recovery periods (weekends) through interaction effects. The first main factor was condition (high and low stress) and the second was workdays or weekend. For data concerning only the workweek, a one-factor ANOVA for repeated measurements was used. In order to compare the diurnal pattern of cortisol, stress, and sleepiness ratings under the different conditions, we used a two-factor ANOVA for repeated measurements in which the first factor was condition and the second was time of day. In these analyses, weekday was not added as a factor because of the differences in time for the first measure of cortisol and because of missing data from the ratings of stress and sleepiness at 0700. Instead a separate analysis was performed for workweeks and weekends, respectively. When the ANOVA showed a significant interaction, a comparison at each time point was made using pairwise t-tests in order to explore the different temporal patterns of the conditions. Despite the risk of increasing familywise error, this approach was preferred since our study is one of the first to explore variations in cortisol, sleep, and sleepiness due to work stress, and it may be judicious to retain sensitivity. However, conservative Bonferroni corrections were also carried out for comparison. In order to examine how the mean values of the variables "stress", "workload" and "workhours" were related, we correlated these during each measurement week. The alpha level was set to 0.05 in all the analyses.

## Results

Tables 1–3 show the significant differences between the high- and low-stress week for total sleep time, stress at

bedtime, workhours, workload, sufficient recuperation, mean sleepiness, time pressure, being exhausted, work situation, and anxiety (on the HAD scale). The high-stress week essentially showed higher load, stress, fatigue, and anxiety and less sleep, but no differences in sleep quality and sleep efficiency. Virtually all of the variables showed a significant difference between the workweek and the weekend, except for sleep efficiency. Significant interactions were found for mean stress, being tense, being irritated, being under time pressure, and the prediction of sleep quality. The workweek–weekend difference was smaller during the low-stress week.

The correlation analysis of the mean values of stress, workload, and workhours showed that, during the high-stress week, there was a significant correlation between stress and workhours ( $r=0.37$ ,  $P<0.05$ ) and between workhours and workload ( $r=0.36$ ,  $P<0.05$ ). During the low-stress week, there was a significant correlation ( $r=0.37$ ,  $P<0.05$ ) between workhours and workload.

The diurnal pattern of the mean levels of sleepiness (KSS) and stress is shown in figure 1. The former showed a significant effect of time of day, for the workweek, as well as an interaction (table 4). Pairwise t-tests showed significantly higher sleepiness at the end of the day (time 1600:  $t=2.1$ ,  $P<0.05$ ; time 2200:  $t=4.0$ ,  $P<0.05$ ) during workdays in the high-stress week. During the weekend, sleepiness was significantly higher in the high-stress condition, but there were no differences in the diurnal pattern. Rated stress during the workdays showed a significant effect for condition, for obvious reasons, and also for time of day. Stress ratings during the weekend were significantly higher in the high-stress condition.

The ANOVA for cortisol secretion (table 4) on Wednesday in each measurement week showed a significant

**Table 1.** Results from the two-way analysis of variance for repeated measurements on the data from the actigraphy measurements.

Factor <sup>a</sup>	Actigraphy							
	Sleep start		Sleep end		Total sleep time		Sleep efficiency (%) <sup>b</sup>	
	Mean <sup>c</sup>	SE	Mean <sup>c</sup>	SE	Mean <sup>c</sup>	SE	Mean <sup>c</sup>	SE
High stress								
Workdays <sup>c</sup>	2323	0009	0623	0006	0621	0009	90.3	1.1
Weekend <sup>c</sup>	2408	0011	0803	0010	0705	0015	89.7	1.2
Low stress								
Workdays <sup>c</sup>	2314	0008	0630	0008	0637	0008	91.2	0.8
Weekend <sup>c</sup>	2403	0012	0818	0011	0730	0013	90.7	1.0
F-values								
High versus low stress		0.7		2.5		8.2 <sup>d</sup>		2.6
Workdays versus weekend <sup>c</sup>		34.9 <sup>e</sup>		169.1 <sup>e</sup>		29.1 <sup>e</sup>		2.0
Interaction		0.03		0.3		0.3		0.07

<sup>a</sup> Responses ranged from 1 (difficulties) to 5 (no problems) if not otherwise stated.

<sup>b</sup> Total sleep time/sleep length  $\times$  100.

<sup>c</sup> Values represent means over the week (Monday to Friday) and the weekend (Saturday-Sunday).

<sup>d</sup>  $P<0.01$ .

<sup>e</sup>  $P<0.001$ , the degrees of freedom varied between 31 and 33.

**Table 2.** Results from the two-way analysis of variance for repeated measurements on the data from the diary ratings.

Factor <sup>a</sup>	Diary ratings															
	Sleep Quality Index	Ease of falling asleep	Stress or restlessness at bed time	Sleepiness (KSS) at awakening <sup>b</sup>	Work-hours	Work-load <sup>c</sup>	Sufficient recuperation <sup>d</sup>	Mean sleepiness (KSS) 0700–2200 <sup>b</sup>	Mean stress 0700–2200 <sup>e</sup>	Tense	Irritated	Time pressure	Exhausted	Difficulties to concentrate	How will your sleep be tonight <sup>e</sup>	
	Mean SE	Mean SE	Mean SE	Mean SE	Mean <sup>f</sup> SE	Mean SE	Mean SE	Mean SE	Mean SE	Mean SE	Mean SE	Mean SE	Mean SE	Mean SE	Mean SE	
<b>High stress</b>																
Workday <sup>g</sup>	3.9 0.1	3.9 0.1	3.9 0.1	5.7 0.3	9;23 0;14	3.8 0.1	3.0 0.1	4.6 0.2	4.5 0.2	3.8 0.1	4.0 0.1	3.4 0.2	4.3 0.1	4.3 0.1	3.2 0.2	
Weekend <sup>g</sup>	4.2 0.1	4.4 0.1	4.3 0.1	4.7 0.3	.. .	.. .	3.9 0.1	4.5 0.2	3.5 0.2	4.7 0.1	4.6 0.1	4.6 0.1	4.6 0.1	4.8 0.1	2.7 0.2	
<b>Low stress</b>																
Workday <sup>g</sup>	4.0 0.1	4.2 0.1	4.3 0.1	5.2 0.3	8;44 0;08	3.4 0.1	3.4 0.1	4.4 0.2	3.5 0.2	4.2 0.1	4.3 0.1	3.9 0.2	4.5 0.1	4.3 0.1	2.8 0.2	
Weekend <sup>g</sup>	4.3 0.1	4.5 0.1	4.6 0.1	4.6 0.1	.. .	.. .	3.9 0.1	3.9 0.2	2.7 0.2	4.6 0.1	4.5 0.1	4.6 0.1	4.8 0.1	4.7 0.1	2.8 0.2	
<b>F-values</b>																
High versus low stress	1.2	4.0	14.5 <sup>h</sup>	2.5	8.6 <sup>i</sup>	7.7 <sup>i</sup>	4.9 <sup>j</sup>	17.6 <sup>h</sup>	55.7 <sup>h</sup>	3.2	1.2	9.4 <sup>i</sup>	4.5 <sup>j</sup>	0.03	1.2	
Workday versus weekend <sup>g</sup>	9.2 <sup>i</sup>	11.0 <sup>i</sup>	12.7 <sup>i</sup>	16.6 <sup>h</sup>	..	..	61.0 <sup>h</sup>	5.6 <sup>j</sup>	94.9 <sup>h</sup>	49.1 <sup>h</sup>	19.2 <sup>h</sup>	54.5 <sup>h</sup>	13.8 <sup>h</sup>	28.9 <sup>h</sup>	7.0 <sup>i</sup>	
Interaction	0.02	0.5	1.5	0.9	..	..	3.1	3.3	6.2 <sup>j</sup>	13.7 <sup>h</sup>	5.1 <sup>j</sup>	7.9 <sup>i</sup>	1.0	1.4	6.6 <sup>i</sup>	

<sup>a</sup> The responses ranged from 1 (difficulties) to 5 (no problems) if not otherwise stated.  
<sup>b</sup> 1 = alert, 9 = very sleepy.  
<sup>c</sup> 1 = very low, 5 = very high.  
<sup>d</sup> 1 = not sufficient, 5 = sufficient.  
<sup>e</sup> 1 = very good, 9 = very poor.  
<sup>f</sup> Number of hours; number of minutes.  
<sup>g</sup> Values represent means over the week (Monday to Friday) and the weekend (Saturday-Sunday).  
<sup>h</sup> P<0.001; degrees of freedom varied between 31 to 33.  
<sup>i</sup> P<0.01.  
<sup>j</sup> P<0.05.

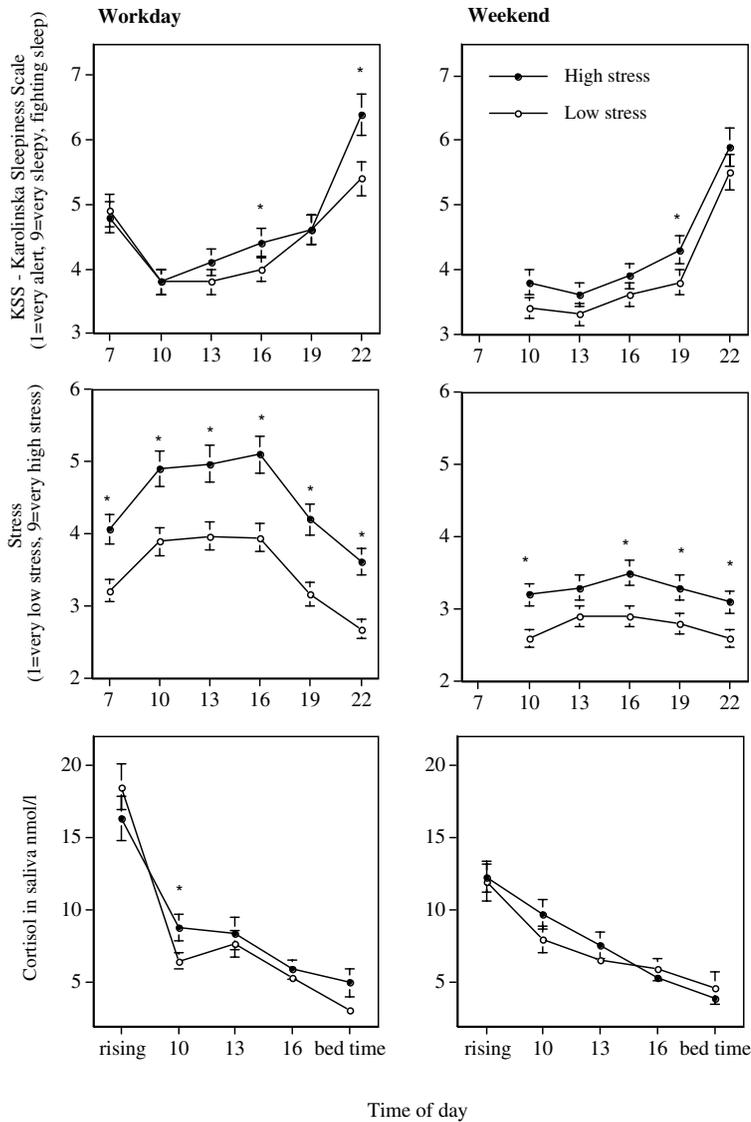
**Table 3.** Results from the two-way analysis of variance for repeated measurements on the data from the questionnaire, analyzed with the paired t-test. (HAD = hospital anxiety and depression)

Factor <sup>a</sup>	Questionnaire											
	Work situation		Overall health		Sleep quality		Workhours (week before) <sup>b</sup>		HAD anxiety		HAD depression <sup>c</sup>	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
<b>High stress</b>												
Workday <sup>d</sup>	3.3	0.1	3.6	0.1	3.2	0.2	2.8	0.2	7.8	0.6	5.5	0.6
Weekend <sup>d</sup>	..	.	..	.	..	.	..	.	..	.	..	.
<b>Low stress</b>												
Workday <sup>d</sup>	3.6	0.1	3.6	0.2	3.4	0.2	2.3	0.2	6.4	0.6	5.2	0.6
Weekend <sup>d</sup>	..	.	..	.	..	.	..	.	..	.	..	.
<b>F-values</b>												
High versus low stress	-2.2 <sup>e</sup>		-0.5		-1.1		1.6		7.1 <sup>c</sup>		0.3	
Workday versus weekend	..		..		..		..		..		..	
Interaction	..		..		..		..		..		..	

<sup>a</sup> The responses ranged from 1 (difficulties) to 5 (no problems) if not otherwise stated.  
<sup>b</sup> 1=<37.5 hours, 6>60 hours.  
<sup>c</sup> 1=low, 14=high.  
<sup>d</sup> Values represent means over the week (Monday to Friday) and the weekend (Saturday to Sunday).  
<sup>e</sup> P<0.05

effect of time of day and interaction between week and time of day. The interaction indicates a more flattened pattern, compared with that of the low-stress condition, with higher values at 1000 and a tendency towards higher values in the evening (see figure 1). There was no difference between the conditions for wake-up time on

the day of the sampling [high stress: 6 minutes 39 seconds (SE 0:08); low stress: 6 minutes 45 seconds (SE 0:09); t=0.2; df=28; P>0.05]. Pairwise t-tests at each time point showed a significant difference at the time of 1000 with higher cortisol levels in the high stress condition [high stress: 8.8 (SE 0.9); low stress: 6.5 (SE 0.6);



**Figure 1.** Means and standard errors of the means for the workday and weekend values of cortisol, sleepiness, and stress. \* P<0.05 with the pairwise t-test. Cortisol at rising was taken 15 minutes after the participant awakened.

**Table 4.** F-values and significance levels of the two-way analysis of variance of the repeated measurements. (df= degrees of freedom)

	High/low stress			Time of day			Stress × time		
	F-value	P-value	df	F-value	P-value	df	F-value	P-value	df
<b>Karolinska Sleepiness Scale</b>									
Workday	3.7	0.06	1,31	38.3	0.0001	5,155	6.8	0.0001	5,155
Weekend	6.7	0.01	1,31	38.3	0.0001	4,124	0.2	0.96	4,124
<b>Stress</b>									
Workday	185.7	0.0001	1,31	34.9	0.0001	5,155	0.57	0.73	5,155
Weekend	11.5	0.002	1,31	2.4	0.05	4,124	0.2	0.94	4,124
<b>Cortisol</b>									
Workday	0.5	0.49	1,20	72.6	0.0001	4,80	3.8	0.008	4,80
Weekend	0.2	0.67	1,21	29.2	0.0001	4,84	1.0	0.41	4,84

t=2.3; P=0.035], although this difference would not be significant if a Bonferroni correction were used. A separate paired t-test of the stress ratings on Wednesday showed a significantly higher level in the high-stress

week [high stress: 4.9 (SE 0.3); low stress: 3.4 (SE 0.3); t=5.5; df=32; P<0.001]. Cortisol samples from the weekend (Saturday) showed no significant differences between the conditions or in the diurnal pattern.

Table 3 also presents the analyses from the questionnaire, which showed that there was a significant difference in the HAD ratings. The participants reported more anxiety before the high-stress condition but no differences in depression. Questions concerning the number of hours worked the week before the measurement or the participants' health and sleep the month before did not differ between the conditions. The participants had, however, perceived their work situation as less good the week before the high-stress condition.

## Discussion

The results showed that a workweek with higher ratings of perceived stress was characterized by more sleepiness, more sleep problems, and more hours of work when compared with a workweek with lower stress. Some of these effects carried into the subsequent weekend. The effect on cortisol was expressed as a more flattened pattern under the high stress condition.

As discussed in the introduction, previous work on stress and cortisol has mostly involved interindividual studies with stressed and nonstressed groups. Most of them show increased (morning) cortisol (10, 12–14), even if reduced levels have also been found (15, 16). The reason for the discrepancy in the results is not clear, but the risk of confounding due to selection is high when groups are compared rather than conditions being compared.

There was a significant interaction between the stress levels and time of day in the analysis of the cortisol secretion, a reduction in diurnal amplitude being reflected during the stress week. This result lacks any directly comparable findings in previous studies, but Rosmond et al (17) found a flattened diurnal pattern when a high-stress group was compared with a low-stress group. Steptoe et al (21) compared different levels of workload within persons but found no effects on cortisol. The procedure and results of cortisol measurements were, however, not very well described. Brantley et al (22) studied cortisol levels in urine (between 1400 and 1600) during days with high stress compared with days with low stress. Their results showed that mean cortisol levels were higher in the high-stress period. They did not, however, examine the circadian pattern of cortisol.

Other studies examining groups with signs of job strain or burnout have focused on repeated measures of cortisol in saliva within the first hour after awakening (12, 16). Our study had only one morning measure (15 minutes after awakening), and it was therefore not possible to examine the morning rise in cortisol. In the study by Schulz et al (12), however, no differences between groups of high or low job strain were shown for this

morning value, but rather in the following morning measures, when the group with high strain showed elevated levels. It is possible that more measurement points in the morning would have given us additional information on cortisol secretion under different stress levels. It should also be noted that, since the measurement of cortisol took place in the middle of the week, we do not have any information on accumulation effects.

The high-stress condition was associated with some sleep disturbances, expressed as problems falling asleep and a shortened sleep length. It is known that high job strain can cause problems with unwinding (45) and, therefore, could explain why the participants had more problems falling asleep although they reported feeling sleepier. These results indicate that a situation with high workload and stress may lead to transient insomnia and, possibly, to chronic insomnia in the long run. These results are consistent with other findings showing work-related stress to be associated with sleep problems (25–27). There were no significant signs of altered sleep efficiency or quality between the two conditions. On the other hand, the reported stress levels were rather moderate. Under higher and longer lasting stress, one could expect sleep to be more fragmented, but these hypotheses could not be examined in this study. The reduction of sleep length in our study was relatively moderate, and there was no accumulation of sleepiness over the week. This finding indicated that the participants did not build up a sleep debt during the workweek. However, short sleep length has been shown to be a risk factor for ill health and mortality (46). The results from this study imply that a period of high stress may have negative health effects due to short sleep. Short sleep length has also been shown to be associated with elevated levels of evening cortisol (29); however, we did not find any significant correlation between sleep length and cortisol values in our study.

The differences in the diurnal pattern of sleepiness on workdays were pronounced at the end of the day. This result supports findings from other studies showing that participants with high workload or stress or activity will express more sleepiness than those with low stress (47, 48). Sleepiness or fatigue can be seen as a drive towards recovery (36) to maintain homeostasis. From that point of view, the differences between sleepiness levels at the end of the day may demonstrate a greater need for recovery after a day with a high workload and stress. However, one should also bear in mind that the total sleep time is reduced in a week with high stress, which also may contribute to elevated sleepiness.

The results of our study also showed that a workweek with high stress and workload was associated with longer workhours. This finding raises the problem of determining whether long hours per se increases stress or whether a stressful work situation makes a person work

longer. In this case it seems reasonable to assume that increased work demands caused a need for extra hours, although extra workhours, in turn, also prolonged the time for exposure to the stressful work situation. Unfortunately, it was impossible to separate the effects of stress versus the effects of long workhours in our study since we did not keep any of the variables constant. Instead, the aim was to investigate how participants who could influence their own workhours handled a situation of high workload and stress. Other studies of participants working overtime and long workhours have indicated an increased risk for stress-related diseases (38) and impaired performance (49); however, most of these studies were based on between-group comparisons.

One of the limitations of our study was the lack of information of nonoccupational stressors. However, there is no reason to suspect that there would have been any systematic difference in the occurrence of nonoccupational differences. Nevertheless, the relation between occupational and nonoccupational stressors is of great interest for further research and may explain why some people handle high workload or long hours better than others. Another limitation was the lack of an objective measure of sleep with information on sleep content. It has been shown that people with high stress levels, as reflected in elevated burnout scores, have more micro arousals during sleep (37).

The effects of the high-stress week, with higher stress ratings, more problems with stress or restlessness at bedtime and shorter sleep duration, carried into the weekend. This finding indicates that, during a period of high workload and stress, the effects are still present during the time off, when recuperation should take place. This result suggests that a longer period of high stress and workload could have negative effects on the quality of recuperation, and, therefore a longer period away from work is possibly needed.

The week with a high workload of stress did not seem to be part of a longer period with constant high workload since neither workhours nor subjective health nor sleep differed between the conditions during the week before the measurement. Nevertheless, the ratings of anxiety on the HAD scale showed that the participants experienced more anxiety the week before the high-stress condition. This occurrence may have been due to the apprehension of the following week of high workload.

It should be emphasized that participants under constant high pressure were excluded from these analyses since the purpose was to study intraindividual short-term variation. The results can therefore not be generalized to groups with a permanent high workload. An interesting, but more logistically difficult approach would be to carry out a long-term intraindividual study, spanning up to years of stress alternating with periods of normal load.

In conclusion, our results demonstrate that a week with higher workload and stress affects physiological stress markers such as cortisol and also causes increased sleepiness and problems to unwind at bedtime, a shorter sleep duration, and longer workhours. These results indicate that stress impairs the quality of recuperation. It is possible that the balance between anabolic and catabolic processes is disturbed, and this disturbance leads to negative consequences for health. It may be that the quality of recuperation is critical in determining whether stress has negative health effects or not. Additional studies are needed if the relation between stress, recuperation, and health is to be fully understood.

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