Work stress and overtime work – effects on cortisol, sleep, sleepiness and health

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Anna Dahlgren

In Sweden the National Bureau of Statistics has reported an increase in stress-related disorders and sleep problems since the mid-1990's. They also report that the number of hours of overtime worked has increased. Previous research on work-related stress and overtime work has demonstrated associations with altered physiological arousal, increased risk for stress related diseases, shorter sleep, greater fatigue and impaired performance. However, there is a lack of knowledge on the effects within individuals. The general aim of the thesis was to investigate the effect of overtime work and increased work stress on sleep, the diurnal pattern of cortisol, sleepiness and subjective stress in a within-subject design. In addition, it examined individual differences in the diurnal cortisol response to stress.
We used a combination of methods – questionnaires, sleep and wake diaries, objective measures of sleep, stress hormones (salivary cortisol) and ambulatory measures of heart rate and blood pressure. Studies followed office workers during two different conditions of (**I**) high/low work stress and (**II**) overtime work respectively. The individual differences in the cortisol response to stress from study **I** prompted study **III**. In this study we examined two groups that showed different cortisol responses to stress.
In conclusion, the results (**I**) demonstrated that a week with higher workload and stress affects physiological stress markers such as cortisol, and is associated with increased sleepiness and problems of unwinding at bedtime, shorter sleep duration and longer work hours. Furthermore (**II**) overtime work, under conditions of relatively low workload, was shown to be associated with modest effects on physiological markers of arousal. More pronounced effects were found on sleep and fatigue, with greater problems during overtime work. Study **III** indicated that individual differences in cortisol response to stress maybe related to fatigue and exhaustion.

Key words: work stress, overtime work, cortisol, sleep, sleepiness, fatigue, individual differences, within-subjects design, field study

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Contents

List of papers

The present thesis is based on the following three studies:

I

Dahlgren, A., Kecklund, G., & Akerstedt, T. (2005). Different levels of work-related stress and the effects on sleep, fatigue and cortisol. *Scandinavian Journal of Work, Environment and Health, 31*(4), 277-285.

II

Dahlgren, A., Kecklund, G., & Akerstedt, T. (2006). Overtime work and its effects on sleep, sleepiness, cortisol and blood pressure in an experimental field study. *Scandinavian Journal of Work, Environment and Health, 32*(4), 318-327

III

Dahlgren, A., Åkerstedt, T., & Kecklund, G. (2004). Individual differences in the diurnal cortisol response to stress. *Chronobiology International, 21*, 913-922.

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Introduction

The present thesis is focused on work related stress and long work hours. In 2005 24.4% of the Swedish workforce was experiencing work-related disorders (SCB, 2005). Stress and mental strain were the most common causes of work-related disorders among women and the third most common among men, with 13 per cent of the women having stress related disorders and 7.4 per cent of the men. Stress in working life can be associated with several factors related to work characteristics. This has been the topic of a large body of research and from this several models of work-related stress and health have emerged. What most models have in common is a focus on the balance between work demands and the individual's ability to "cope", for example between the demands/effort and the level of job control and rewards (Karasek & Theorell, 1990; Karasek, 1979; Siegrist, 1996; Siegrist & Peter, 2000). Based on these models, studies have shown a relation between work-related stress and cardiovascular diseases (Alfredsson & Theorell, 1983; Hammar et al., 1994; Siegrist, 2000; Theorell et al., 1998) as well as with burnout (Bakker et al., 2000), and musculoskeletal symptoms (Bongers et al., 1993; Toomingas et al., 1997).

The prevalence of stress-related disorders has increased considerably since the middle of the nineties (SCB, 2005). At the same time there have also been several changes within working life. Some of these workplace developments could be related to the increase in stress related disorders such as the increased use of information technology, the globalization of the economy, more dual earner couples, changing boundaries between work and home, flexibilization and the creation of the 24-hour economy (Kompier, 2005). The two latter trends have had major influences on working life and in particular the way working times are organised. With the 24-hour economy followed increased demands for irregular working hours for professions other than the traditional ones such as workers within the service sector, hence the prevalence of irregular work hours has increased. The traditional "normal" workweek from 9-5, five days a week, is nowadays employed in only half of the work force. Flexibilization of the organisation of work refers to when companies are adjusting the use of means and employees to the variation of demands. Overtime work, part time contracts, shift work, temporary contracts, working at home or hiring workers from temporary employment agencies are all means to do this. In Sweden the number of hours of overtime worked increased in the beginning and middle of 90's (SCB, 2000). However, it also seems like that unpaid overtime has increased (Aronsson & Göransson, 1997). This makes it hard to estimate the actual numbers of hours worked in the population. In a review of long work hours Van der Hulst (2003) showed that long work hours are associated with adverse health effects. Long working hours involve a prolonged period of effort spent on solving work tasks and thereby exposure to potential stressors, which in turn increases the risk of stress-related diseases.

One of the key factors for the development of ill health in relation to stress and long work hours is the quality of recuperation (Buckley & Schatzberg, 2005; Liu & Tanaka, 2002). Disturbed or short sleep has shown to be related to poor health (Spiegel et al., 1999). In Sweden, there has been an increase in not only stress related disorders but also in complaints of fatigue and poor sleep (figure 1). These symptoms have increased by almost 50 per cent since the mid eighties (SCB, 2005). The increase was most pronounced in the mid nineties and early 2000s. Disturbed sleep has been shown to have a clear association with stress and long work hours. However, it is plausible that the relationship between stress and sleep is bi-directional such that the increased arousal due to stress will cause problems of falling asleep, sleep disturbances and early awakenings. But also poor sleep itself can cause an elevation in physiological arousal (Buckley & Schatzberg, 2005). However, there are large individual differences in the effects of work related stress and long work hours. It is not clear which factors are crucial for the development of stress related diseases in the interplay between stress and work hours.

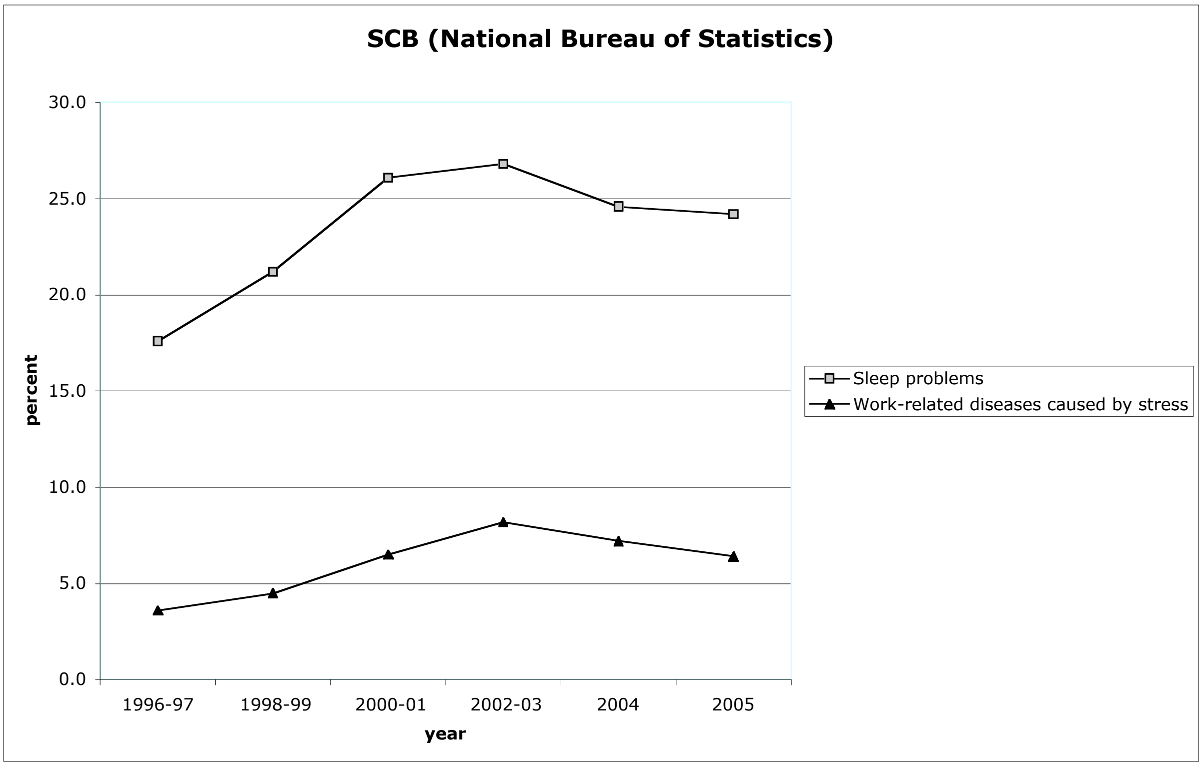

Figure 1. Development of sleep problems and work related diseases caused by stress in the Swedish population.

The studies presented in this thesis will focus on the relation between work hours, work related stress and workload as well as on how individual differences affect physiological reactions to stress. There follows a review of the background knowledge in these areas.

Background

Stress

The concept of stress originally referred to a set of biological reactions. In the 1930's Hans Selye discovered that when an organism is exposed to extreme heat, cold, toxics etc. (i.e. stressors) a set of bodily reactions took place. He came to refer to this as stress, where stress was the result of any demand upon the body (Selye, 1946). Since then stress has become a widely used concept within both the medical and social sciences. However, what some individuals perceive as a stressor causing a stress response might not have the same effect in another individual. The work of Lazarus and Folkman (Lazarus & Folkman, 1984; Lazarus, 1993) offered a more psychological perspective to the stress concept with the transactional approach. The transactional approach defines stress as "a relationship with the environment that the person apprises as significant for his or her well-being and in which the demands tax or exceed available coping resources" (1986). Stress is neither in the stressor nor in the stress response but in the relationship between the two. Ursin and Eriksen (2004) developed a stress model that further developed the relationship between psychological processes and physiology in their " Cognitive Activation Theory of Stress" (CATS). The individual differences in response to stress are, according to CATS, determined by the expectancy of the outcome of stimuli and the expectancy of specific responses available for coping. The former is related to defence mechanisms whereas the latter is related to coping, helplessness and hopelessness. These different responses to stress are furthermore linked to individual variations in ill-health. If the coping behaviour is expected to give positive results stress/arousal is reduced with no negative health effects whereas lack of coping, as in hopelessness and helplessness, may lead to somatic disease through sustained arousal. However, a deficiency within the field of stress research is that there still is no generally accepted definition (Ursin & Olff, 1993).

The stress response

Before Seyle defined the stress concept, Cannon had already described the body's physiological reactions to a danger or threat (Cannon, 1914). These physiological changes prepare us for fight or flight. The first immediate reaction to a stressor is the activation of the sympathetic nervous system, which through the hormones adrenaline and epinephrine cause the blood pressure and heart rate to rise, increase sweat in the palms, improve blood coagulation, reduce sensitivity to pain, dilate the pupils and increase our attention. About ten minutes later the HPA- axis is activated, which uses the hormone cortisol to regulate the metabolism including glucose levels. Cortisol also suppresses the immune system by inhibiting cytokines such as TNF alfa, IL1 and IL2 (Chrousos & Gold, 1992). The biochemical responses to stress are largely catabolic, i.e. a breakdown of metabolic compounds takes place in order to produce energy. At the same time many of the anabolic processes, i.e. processes that promote a build up of the body, are suppressed such as parts of the immune system, growth hormone and testosterone etc. The anabolic processes are instead mainly active during relaxation and sleep.

Cannon described these physiological responses as a way for the body to maintain *homeostasis*. Homeostasis implies that there are narrowly defined optimal levels of activation of the internal milieu of the body and when these levels are changed they are soon regulated back to “normal” levels through negative feedback mechanisms. In other words, there is one optimal level for the bodily functions. These assumptions were mainly based upon early research of isolated organs. However, this model fitted poorly when the whole internal milieu of the body was studied. Neither did it explain why only some groups within society suffered from such things as high blood pressure. Based on these notions Sterling and Eyer (1988) presented a new model of *allostasis* in order to describe the physiological reactions to stress. Allostasis means “stability through change” i.e. in order to maintain stability within an organism all the parameters of its internal milieu must vary in order to match them appropriately to the environmental demands. Furthermore, allostasis is a more complex concept in its regulation since it involves the whole brain and body rather than local feedback circuits. The allostasis model has been valuable for describing the development of stress related diseases and others have contributed further to this model. McEwen and Stellar (1993) expanded the allostasis model by introducing the term *allostatic load* to describe the wear and tear on the body caused by the allostatic regulation under long term or repeated stress, which can predispose the organism to disease. The mechanism behind the development of stress-related diseases under allostatic load includes long-term increase of circulation cortisol and elevated blood pressure, which may lead to a permanent change in the physiological set points or norms. This change can result in cardiovascular, metabolic, immunological and neuronal pathology (McEwen, 1998). For most individuals an acute stress response is not related to any negative effects on health, when stress hormones go back to baseline levels afterwards. For pathology to develop the time span for the stress exposure is crucial but there is no general definition of the timing or magnitude of stress and it is likely that there are large individual variations.

Cortisol is commonly measured in order to get an indication of the allostatic load. This gives an indication of the activity of the HPA-axis. During stress the hypothalamus is activated through inputs from the central nervous system, amygdala and supra chismatic nucleus (SCN) (see figure 2). The hypothalamus releases corticotrophin-releasing hormone (CRH), which in turn stimulates the puitary to release adreno-corticotropin-releasing hormone (ACTH). ACTH’s role is to stimulate the adrenal cortex to release cortisol. The levels of cortisol are regulated by inhibitory feedback mechanisms that work at both these levels by inhibiting ACTH and CRH, but it can also affect the hippocampus, which in turn inhibits the hypothalamus.

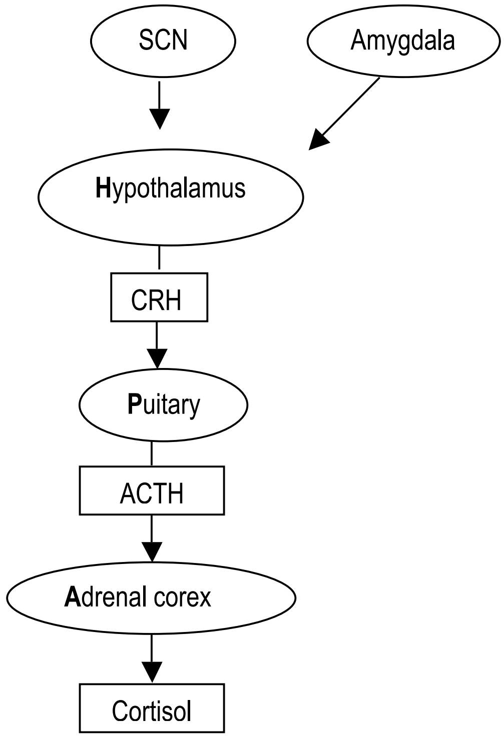

Figure 2. The activation of the HPA-axis and cortisol secretion

The secretion of cortisol

Normally cortisol is secreted in a pulsatile fashion (Chrousos, 1998). Moreover in people with normal sleep-wake cycles the cortisol secretion has a pronounced circadian variation with high levels at awakening, which then increases up to 50-75% within the first 30 minutes (Pruessner et al., 1997) and then levels out and reaches it nadir around midnight. This rhythm has large interindividual variations (Stone et al., 2001) but the intraindividual variations of the morning values have been shown to be stable across days (Clow et al., 2004; Edwards et al., 2001). The physiological role of the awakening cortisol response has been proposed to have a metabolic purpose in mobilising energy reserves in the transition from sleep (Pruessner et al., 1997) or to switch the immune system from night time Th1 domination to daytime Th2 domination (Petrovsky & Harrison, 1997). It may well be possible that the role of the awakening cortisol response includes both these functions. Although its exact role is not clear several studies have linked the awakening cortisol response to physiological health and psychological well-being.

Methodological issues in the assessment of cortsiol

There are some methodological concerns in the assessment of cortisol. The cortisol level in saliva corresponds well to the serum free cortisol (Kirschbaum & Hellhammer, 1994). The subjects themselves can easily take saliva samples. This method makes collection of cortisol data in the daily environment easy and provides an ecologically valid measure. However, it is essential that subjects follow some basic instructions in relation to the saliva sampling. These include no food or tooth brushing 30 minutes before sampling. Moreover, due to the pronounced circadian variation in cortisol it is crucial that subjects make the sampling at the instructed time points. In a recent study Kudielka et al (2003) used electronic monitoring in order to examine the subjects compliance with the saliva sampling protocol. Their results showed that 74 % (32 subjects) of the subjects complied with the instructions. The other 26% failed to take at least one of the samples at the instructed time point. Moreover, the non-compliant group showed significantly lower morning values compared to the compliant group. Jacobs et al (2005) also used electronic monitoring and found that the compliance was higher (81%) and there was no significant difference between compliant and non-compliant subjects, though the morning values were not measured. These results highlight the importance for subjects to follow the given protocol, especially for the morning samples. Electronic monitoring is one way of controlling subjects' compliance though it is not sufficient for measures of the first sample upon awakening since that is still dependent on self-reports of awakening times. One way to get around this problem would be to combine electronic monitoring with other objective measures of sleep such as EEG or actigraphy in order to identify time of awakening.

Cortisol levels sampled at the same times of day differ between studies (for example see overview tables in Clow et al (2004) and Kirschbaum & Hellhammer (1989)). The large variation in absolute values can be explained to some extent by inter individual differences but is also due to differences in analysis assays (Kirschbaum & Hellhammer, 1989) and lack of control of confounding factors (se below). Hence it is not feasible to compare the absolute levels between different studies (Kirschbaum & Hellhammer, 1989). Furthermore individual differences in cortisol levels are problematic when between subject designs are used.

Several studies have identified a set of potential confounding factors in the measurement of cortisol secretion. However, the results are not consistent and more research is needed to fully illuminate theses factors roles in the regulation of cortisol levels. One of these potential confounding factors is *gender*, women have been shown to have a larger increase of the morning levels of cortisol in some studies (Pruessner et al., 1997) whereas others have failed to find such differences (Edwards et al., 2001; Kudielka & Kirschbaum, 2003; Kunz-Ebrecht et al., 2004). *Age* has so far not shown any major impact upon cortisol secretion (Edwards et al., 2001; Pruessner et al., 1997; Wust et al., 2000). However, in a recent study by Kudielka and Kirschbaum (2003) age showed a positive correlation with cortisol levels immediately after awakening and a negative correlation with the amount of increase after awakening. Another central question has been whether the *time of awakening* affects the cortisol levels and diurnal pattern. Some studies have not shown any effect of time of awakening upon cortisol (Kunz-Ebrecht et al., 2004; Pruessner et al., 1997; Wust et al., 2000) whereas others have shown a more pronounced response in early awakeners (Kudielka & Kirschbaum, 2003). Fredrenko et al (2004) studied the awakening cortisol response in nurses on their early, late and evening shifts. They found that the awakening cortisol response in the early shift was more pronounced. However, in a similar study by Williams et al (2005), station staff in the London underground was followed during early- and late shifts and control days. They also found an association with the early shifts and a significantly more pronounced increase in the awakening cortisol response. However, the early morning shifts were also associated with more stress and sleep disturbance. When controlling for stress and sleep disturbance the effect of awakening time disappeared. It is likely that early awakening, stress and sleep disturbances often coincide and further systematic research is needed to clarify role of time of awakening. The *mode of awakening* (alarm or spontaneous) does not seem to have any influence on cortisol levels or the awakening cortisol response (Pruessner et al., 1997). But the anticipation of awakening at a certain time can increase the cortisol levels before awakening but not affect the awakening cortisol response (Born et al., 1999). *Personality traits* and their potential effects on the cortisol response to stress have been the focus of a number of studies. No significant relationships have been found during stress tests such as public speaking (Kirschbaum et al., 1992; Roy et al., 2001; van Eck et al., 1996) or during one workday (Hanson et al., 2000). However, van Eck et al (1996) found that trait anxiety and depression were associated with elevated cortisol levels. They followed their subjects in their daily life for five days collecting daily ratings and saliva samples. It is possible that personality traits are not related to the immediate reaction to a stressful situation. Preussner et al (1997) showed that the correlation between personality traits and cortisol rose considerably when data was aggregated. They reason that novelty may mask the influence of personality traits when examining a single stressful situation.

Studies of the HPA-axis in response to stress

By studying the HPA-axis it is possible to get an insight in the allostatic processes that take place in response to stress. Stress has indeed been found to alter the pattern of cortisol secretion during the day. Groups with stress or increased work load often exhibit increased cortisol levels, particularly in the morning (De Vente et al., 2003; Härenstam & Theorell, 1990; Kirschbaum et al., 1992; Schulz et al., 1998; Steptoe et al., 2000). However, Caplan (Caplan et al., 1979), failed to find such a pattern. In a study by Preussner et al (Pruessner et al., 1999) they found lower morning levels of cortisol in a group of subjects with burnout. A similar reduction of diurnal cortisol amplitude was seen in a large study of groups reporting increased levels of stress (Rosmond et al., 1998). There are also a number of *intra-individual* studies showing that cortisol increases in connection with laboratory or real life stress (Brantley et al., 1988; Kirschbaum et al., 1992; Lundberg & Frankenhaeuser, 1980; Mason, 1968).

It is quite clear that a stressful situation affects cortisol. Some research has examined factors that might modulate the cortisol response to stress. It has been shown that the feeling of control over the situation influences cortisol secretion. Low control is associated with elevated cortisol levels (Henry, 1992; Lundberg & Frankenhaeuser, 1980). Furthermore, a number of studies have explored the association between mood and affect and cortisol. The results have revealed some support for an association between negative affect/mood and increased levels of cortisol (Buchanan et al., 1999; Smyth et al., 1998). The same relation has been shown for anxiety (Benjamins et al., 1992; Curtis et al., 1978; Vedhara et al., 2003). But there are also studies that do not support the relation of negative affect or anxiety to elevated cortisol. For example van Eck (van Eck et al., 1996) showed no relation between these variables under stress exposure. However, at baseline and after stress exposure, groups with high and low affect differed, with higher levels of cortisol in the group with high negative affect. The authors suggest that it might be more important to determine the differences in current distress than perceived stress level to be able to understand cortisol secretion, which they see as measure of more chronic distress. Smyth et al (Smyth et al., 1998) interpreted their data on the relation between cortisol and momentarily evaluated stress and negative affect somewhat differently, stating that negative affect might have a mediating role in the relation of stress and cortisol. Moreover, when looking at relationships between cortisol levels and subjective ratings of stress it seems that retrospective ratings of recent stressful events agrees quite poorly with cortisol levels (Gaab et al., 2005; Smyth et al., 1998; van Eck et al., 1996). Rather, it is the ratings of current stress and in particular the anticipation of stress that show a relationship to corisol with higher levels (Gaab et al., 2005; Smyth et al., 1998; van Eck et al., 1996).

Stress and the cardiovascular system

The cardiovascular system is very responsive to a range of psychological and behavioural states (Krantz & Falconer, 1995). It consists of the heart and blood vessels, which primarily maintain adequate blood flow through bodily tissues. The circulation of blood is maintained by a contraction of the heart muscle during which blood pressure peaks as blood is forced from the heart, referred to as systolic blood pressure, then the heart muscle relaxes and blood pressure reaches its lowest value, referred to as diastolic blood pressure. The blood pressure and the heart rate are regulated in relation to each other through the so-called baroreceptor reflex. It makes sure that if blood pressure suddenly would drop the heart rate would increase, i.e. they are inversely related. During stress, however, the baroreceptor reflex is diminished. This allows an increase in both heart rate and blood pressure during stressful events. By ambulatory measurement it has been shown that blood pressure and heart rate increases in relation to negative mood and stress (Andreassi, 2000; Pickering et al., 1996; Shapiro et al., 2001; Steptoe, 2000). However, it has been noted that the cardiovascular response to stress seems to have large individual differences (Sherwood & Carels, 2000). This makes comparisons between groups less suitable when studying the reactions in the cardiovascular system in relation to stress.

Apart from stress, blood pressure and heart rate have been shown to be influenced by other factors. First of all blood pressure seems to show a circadian variation although it is strongly influenced by the activities undertaken (Mann et al, 1979; Millar-Craigh et al., 1978; Schneider & Costiloe, 1975). Blood pressure has been shown to be higher during work, while lower at home and lowest during sleep (Pickering et al., 1982; Sherwood & Carels, 2000). Body posture and physical activity have great effects on blood pressure and heart rate, which increase during activity (Pickering, 1997). This implies that one needs to have control over the type of activities undertaken when interpreting blood pressure measurements. Other non-psychological factors that influence the cardiovascular system are alcohol, salt intake, caffeine and nicotine (Papillo & Shapiro, 1990; Pickering, 1997; Robertson & Curatolo, 1984). Also these factors need to be controlled for in the assessment of blood pressure.

Sleep

A general definition of sleep is that it is “a reversible behavioural state of perceptual disengagement from, and unresponsiveness to, the environment (Carskadon & Dement, 2000 p. 3). Sleep is divided into five different stages depending on amplitude and frequency of brain activity. Stage 1 is characterized by small amplitude and high frequency and in stage 4 the brain activity shows low frequency and high amplitude (Rechtschaffen & Kales, 1968). The fifth sleep stage is characterised by small amplitudes and short frequency in combination with Rapid Eye Movements and is hence called REM sleep. These stages appear in a cyclic fashion during sleep, with each cycle lasting for approximately 90 minutes.

The different stages of sleep can be measured by polysomnography, which is a combination of measures of brainwave activity (elelctroencephalography-EEG), eye movements (electrooculography-EOG) and muscle activity (electromyography-EMG). However, polysomography is mostly used in clinical and laboratory settings since it is an expensive and time demanding technique (Bloch, 1997). A less invasive and cheaper way of measuring sleep is by identifying periods of activity and rest through a wrist worn device (actigraph). From this it is possible to obtain objective measures of sleep length, time awake and sleep efficiency. Actigraphy has been shown to have a reasonable good relationship to polysomographic measured sleep (Cole et al., 1992; Sadeh et al., 1995) and subjective ratings of sleep (Lockley et al., 1999). Furthermore it is a suitable method to use when following subjects for a longer period of time, which makes it preferable in longitudinal field studies. However, actigraphy does not give any information on the different stages of sleep. Another method for measuring sleep is the use of sleep questionnaires, which have shown good correlations with polysomographic measured sleep (Åkerstedt et al., 1994; Kecklund & Åkerstedt, 1996).

Both homeostatic processes and the circadian rhythm control sleep. The latter is regulated by the suprachiasmatic nuclei (SCN) of the hypothalamus, which signals to the pineal gland to release melatonin during darkness. Hence, our circadian rhythm is largely synchronized by light although other factors such as social interaction also have been shown to have influence. However, sleep is also regulated by a homeostatic drive, which increases with the duration since the end of the previous sleep. Prior time spent awake and the quality of prior sleep is closely related to the need for nocturnal sleep (Åkerstedt & Gillberg, 1986). In a recent review by Tononi and Cirelli (2006) it is suggested that slow wave sleep (SWS i.e. sleep during stages 3 and 4) plays an important role for maintaining synaptic homeostasis. The regulation of SWS is thus tied to the amount of synaptic potentiation that has occurred during previous wakefulness. Furthermore, this seems to be regulated locally, i.e. brain areas that have been highly active during wakefulness will show increased power during SWS. It is suggested that this might be a way for the brain to both save energy and space and also promote learning and memory.

Whereas stress is a catabolic process, sleep is highly linked to anabolic processes. For example, the anabolic hormones growth hormone and testosterone are released during SWS (Weitzman, 1975). At the same time a set of catabolic hormones e.g. cortisol is suppressed during sleep (Vgontzas et al., 1999). Furthermore, sleep has been shown to be linked to the immune system (Kreuger et al., 1999), activating specific parts of the immune system during sleep. During sleep the body also conserves energy by decreasing the body temperature and metabolism (Mills et al., 1978). In addition, on a synaptic level in the cortex, sleep plays an important role in promoting synaptic downscaling and thereby enhancing learning and memory (Tononi & Cirelli, 2006). Thus, sleep seems to be crucial for rest and recuperation from the day's wear and tear on several levels.

The interaction between stress and sleep

There are several findings indicating an interaction between sleep and stress, which consequently affects the regulation the immune system along with anabolic and catabolic processes. There are results suggesting that the HPA-axis interacts with sleep, probably in a bidirectional way (Buckley & Schatzberg, 2005). An exogenous increase of CRH has been shown to result in lighter sleep with more awakenings and a decrease in deep (SWS) sleep (Holsboer et al., 1988), although this effect seems to be dependent on the level of CRH. Various levels of cortisol bind to different receptors, which seem to affect sleep in different ways. A low level of cortisol might therefore enhance deep (SWS) whereas a high level of cortisol has the opposite effect with decreased deep (SWS) sleep (Buckley & Schatzberg, 2005). However, deep sleep in itself has an inhibitory effect on the HPA-axis at the same time as growth hormone (anabolic hormone) is stimulated (Vgontzas et al., 1999). A disruption of sleep will alter the cortisol secretion during the night by attenuating the feedback mechanism of cortisol regulation (Späth-Schwalbe et al., 1991). Furthermore, elevated cortisol levels in the evening have been observed after exposure to partial sleep deprivation (Spiegel et al., 1999). Similar results have been shown in insomnia patients. Vgontzas et al (2001) showed that patients suffering from insomnia showed an increase in serum cortisol during the evening and the first hours of sleep. Also morning cortisol has been shown to increase in relation to fragmented sleep (Ekstedt et al., 2004).

Need for recovery, sleepiness and fatigue

In relation to the allostatic model, sleep and recuperation are crucial in order to prevent a chronic allostatic up regulation in response to stress. Disturbed sleep is suggested to be one of the mechanisms involved in the development of pathology from long-term stress (Buckley & Schatzberg, 2005). From this perspective sleepiness or need for recovery can be seen as a signal of an imbalance between the anabolic and catabolic processes where there is a need to promote sleep and recuperation. Thus, the need for recovery (time required to return to baseline) could work as a measure of the severity of stress (Amelsvoort et al., 2003).

Sleepiness is defined as the tendency or drive to fall asleep (Carskadon & Dement, 1982) whereas fatigue is a more vague concept and lacks accepted definition. Generally fatigue is indicating reduced energy and passes after a resting period, whereas sleepiness passes after sleep. Sleepiness follows the circadian rhythm with low levels of sleepiness during the morning and midday and higher levels during the evening and night (Åkerstedt & Gillberg, 1990).

There are only a few studies that have measured sleepiness and fatigue in relation to stress. However, findings indicate increased levels of sleepiness in relation to stress (Söderström et al., 2004). Also the need for recovery has been shown to be strongly associated with high work demands (Sluiter et al., 2003) as well as overtime work (Jansen et al., 2003). In a study by van Amelsvoort et al (2003) the need for recovery was linked to stress related disease.

They showed that the need for recovery after work was a strong predictor of subsequent cardiovascular disease. Sleepiness could be seen as a drive towards recovery (Piper, 1986), indication an imbalance between activity and recovery, or between catabolic and anabolic processes.

Work related stress

Much of the research on work related stress has focused on describing stressors within the workplace. For example, it has been shown that both too much work as well as too little work is associated with a physiological stress response (Frankenhaeuser, 1980). From this a number of models have developed, which seek to describe the relationship between work, stress and health. Most of these models are based on the work of Lazarus and his definition of stress as a transactional process.

Measuring work related stress

One of the leading work stress models was out lined by Karasek and Theorell who developed the job strain model (Karasek & Theorell, 1990; Karasek, 1979). Since the 1980's the job strain model has been one of the most influential models of work related stress and health, in particular in relation to cardiovascular problems (Kristensen, 1996). It is a two-dimensional model of the relation between job demands and job control. Job strain occurs when the demands are high and the worker has low control. Control in this context refers to the workers decision latitude or ability to influence the work situation. Later the model was extended to also include the dimension of social support that seems to work as a buffer in a situation with high job strain (Johnson, 1986).

Another influential model of work related stress was developed by Sigerist et al, called the Effort-Reward Imbalance (ERI) model (Siegrist, 1996). According to the ERI model a stress response in relation to work is determined by the balance between effort and reward. Conditions of an imbalance between high-cost and low-gain are likely to elicit feelings of threat, anger and depression or demoralization, which in turn evoke sustained autonomic arousal. Conditions of high effort are thought to have both extrinsic sources, such as high demands and workload as well as intrinsic sources such as coping. Coping in this respect is mainly focused on the need for control as a personal pattern of coping with demands at work. The differences in need for control explain why different individuals may spend different amounts of energy mobilisation and job involvement under the objectively same conditions.

The ERI and the demand/control model have both been very influential in the research on work related stress. However, these are just two examples of the several other theoretical models of the relationship between work, stress, health and well-being (for a further discussion on other examples of the most prominent of these models see chapter 9 in Cooper, 2005). In general these kinds of models have provided definitions of stressors or events that will increase the probability of stress reactions. They have become a useful tool for evaluating stress within working life. However, one should bear in mind that models are just models and do not predict stress reactions in every individual. Furthermore, none of them is generally accepted as a standard for the measurement of work stress and they have both been criticised for weaknesses. For example the issue of how to measure demands was discussed in a review by Kristensen (1996). He point out that the different scales measuring demands might give different results depending on which group is investigated. Moreover, the demand scales separate between work pace and working hours and there are a high score on one of these factors may occur in one group and not in another. This means that the way in which demands are measured is crucial for the results. There are several other more or less serious criticisms of the different work stress models.

In order to measure work related stress Kjellberg and Iwanowski (1989) developed a "Stress-energy rating questionnaire" by using almost 100 mood adjectives. Through factor analysis they found that these adjectives formed a two- factor structure. These were labelled "energy" (represented by six adjectives like active, energetic, efficient) and "stress" (represented by six adjectives like tense, stressed, under pressure). The "stress-energy scale" has been validated, with good results, against job-strain measures (Kjellberg & Wadman, 2002).

Other ways of assessing work or real life stress, not using the different work stress models, have involved asking subjects how stressed they have been within a defined time period. The Perceived Stress Scale (PSS) is one example of this, which asks subjects to report how frequently they have experienced stressful situations in the past month (Cohen et al., 1983). Other ways of assessing real life stress has been through measuring the number of work hours (Steptoe et al., 1998), measures of burnout symptoms (Pruessner et al., 1999) etc. Moreover there are some studies, though relatively few as yet, that have used self-ratings of momentarily experienced stress. Hanson et al (2000) applied momentary ratings of stress by measuring momentary demand and satisfaction throughout the day. Their results showed no relation between the momentary ratings and physiological arousal (cortisol). Van Eck et al (van Eck et al., 1996) provided their subjects with beeping devises and asked the subjects to report any stressful events since the last beep and to rate the severity on a likert scale. They showed that stressful daily events were associated with increased cortisol secretion. This relationship was especially strong if the stressful event was still going on at the time of cortisol sampling. In a study with a similar approach and method Smyth et al found that the physiological arousal, measured by increase in cortisol, was more related to the anticipated stress (in the coming hour) than to current or past experience of stress (Smyth et al., 1998). The importance of the time aspects of the ratings was also demonstrated by (Gaab et al., 2005) who showed that the subjects' ratings of anticipated stress before a public speaking task was more closely related to their physiological responses than the ratings after the experiment. It has been argued that retrospective ratings of stress are influenced by other factors such as the outcome of performance (Gaab et al., 2005).

The wide range of scales used in the measurement of stress is related to the lack of any generally accepted model of work related stress or standardised subjective rating scale or indeed any generally accepted definition of stress.

Work related stress and stress related diseases

Stress within working life has been implicated as a casual factor of ill health, particularly in relation to metabolic and cardiovascular disease (Alfredsson et al., 1985; Hammar et al., 1994; Siegrist, 1996; Theorell et al., 1998). Recent data from a Japanese prospective study estimates the risk for a cardiovascular event to be 2.89 in groups with high job strain (Uchiyama et al., 2005) Results from a study by Amelsvoort et al (2000) indicated that one of the mechanisms behind the increased risk of myocardial infarction might be a shift in the cardiac balance; subjects with higher job strain had a shift towards sympathetic dominance. Changes in the cardiovascular system in relation to job strain were also found in a longitudinal study by Schnall et al (1998). High job strain was associated with higher blood pressure (both systolic and diastolic) during work, after work and during sleep (only systolic blood pressure differed). In addition they showed that the change in job strain between different time points could predict change in blood pressure. It is not only on overall increase in blood pressure that is associated with high job strain. It also seems that high job strain prevents subjects from unwinding after work (Steptoe et al., 1999). In terms of allostatic load, results suggest that a work situation with high job strain is a risk factor for chronic allostatic load (McEwen, 1998).

Stress at work may also be a contributing factor for the development of musculosketal disorders (Toomingas et al., 1997). In a study by Lundberg et al (1999) it was shown that cashiers who experienced more stress than others had greater problems with neck and shoulder pain although they had the same workload with respect to the total weight of the groceries they handled.

Also burnout has been shown to be related to work related stress (Maslach & Jackson, 1981). Burnout has become epidemic in countries such as Sweden (RFV, 2003) and is characterized by extreme fatigue in combination with cognitive impairment and reduction of empathy with others (Cherniss, 1980; Freudenberger, 1983; Maslach & Jackson, 1981). Groups with burnout have shown a lowered cortisol response in the morning (Pruessner et al., 1999).

Work related stress in relation to sleep, fatigue and performance

Another factor of interest in relation to real life stress is sleep, which usually has a close relationship with stress (Åkerstedt et al., 2002; Kecklund & Åkerstedt, 2004; Marquié et al., 1999; Urponen et al., 1988) and primary insomnia is usually seen as resulting from long-term stress (Kryger et al., 1994). In relation to work related stress it may result in problems unwinding and disturbed sleep. Åkerstedt et al showed that it was the inability to stop worrying about work during free time that disturbed sleep (2002). This factor showed a stronger relation to sleep disturbances than work demands. Also apprehension of the next day has shown negative effects on sleep. Apprehension of a difficult next day was shown to be associated with more shallow sleep (less SWS and more stage 2) and more difficulties awakening (Kecklund & Åkerstedt, 2004; Torsvall & Åkerstedt, 1988). To date there are only a few studies of the reaction of sleep to periods of increased work stress. However, as mentioned before, sleep and stress are related in a bidirectional way. For example reduced sleep has been shown to be associated with changes in cortisol levels (Backhaus et al., 2004; Buckley & Schatzberg, 2005; Meerlo et al., 2002; Morin et al., 2003; Späth-Schwalbe et al., 1991; Spiegel et al., 1999).

Fatigue appears to be a key characteristic of long-term stress, as demonstrated in the burnout literature (Melamed et al., 1999). However, again, apart from studies by Piper (1986) and Rissler and Elgerot (1978), there is very little information from field studies on the effects of periods of increased workload. However, in a recent study (Söderström et al., 2004) it was found that young subjects 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 high workload may raise sleepiness levels. However, no data seem to be available.

Work time control as moderator of work stress

In a series of studies Ala-Mursula et al (Ala-Mursula et al., 2002; Ala-Mursula et al., 2005; Ala-Mursula et al., 2004) have examined the effects of work time control in relation to health and work stress. Work time control was measured by six items concerning abilities to influence; start and ending times of the workday, taking of breaks, handling of private matter during the workday, scheduling of shifts, scheduling of days off and taking of unpaid leave. In a cross sectional study they showed that poor work time control was associated with adverse health problems in women but not in men (2002). The gender difference was interpreted as an effect of the greater workload experienced outside work by women, suggesting that work time control may help in managing the balance between working and private life. These results were further confirmed in a prospective cohort study (2004). It showed that a low level of work time control was associated with increased risk of future health problems, especially in women. The results were less strong among the men. Ala-Mursula et al (2005) also showed that work time control mediated the levels of sickness absence in relation to high work stress. Once again the results were less strong for men. Together these studies imply that increasing the employees control over working times would help to improve health and buffer them from negative effects of high work stress.

Summary

To summarize the previous research one can conclude that stress within working life is related to the development of a set of different diseases such as cardiovascular diseases, musculosketal problems, burnout, sleep disturbances and fatigue. The mechanism is thought to go through a set of physiological changes such as elevated blood pressure, sleep disturbances and up-regulation of the HPA-axis. However, there are some problems with previous research. Much of this research has used group comparisons, exploiting the different work stress models for categorizations of stressed and non-stressed individuals. Although this approach gives valuable information it does not render any possibilities to follow the mechanisms involved in different levels of work related stress within an individual. Moreover, the studies of physiological variables in relation to stress have mainly focused on short acute stress situations such as public speaking. Only a very few studies have focused on stress in working life with longer periods of increased stress. Furthermore, the factors behind the individual differences in physiological response are not yet clear. These factors may be important for understanding of development of stress related diseases. The present thesis will address these issues.

Overtime work and long work hours

One way of coping with a demanding work situation is to work longer hours. Research has shown that the organization of work hours will have different implications on workers health, safety and performance. This thesis will mainly discuss the extending length of work shifts by means of overtime work.

The aim of the European Working Time Directive (EWTD) is to restrict working hours in order to optimise health and safety among workers. The directive includes stipulation of a maximum of 48 hours of work per week, allthough this is calculated as an average across several months. This means that there might be periods that exceed 48 hour per week. Another regulation is that there should be 11 hours of rest for every 24 hours, which means that the maximum length of a shift can be 13 hours. However, it is possible to “opt out” if both partners (employers and employees) find an agreement. This possibility makes it feasible to violate the directives and work for longer shifts than 13 hours and for more than 48 hours per week.

The prevalence of long work hours was examined in the third European survey on work conditions (Boisard et al., 2002). Results showed that about 17 percent of fulltime employees work 45 hours or more per week. In Sweden about 30 percent of the working population work overtime every week but the prevalence varies between occupational groups (SCB, 2004). In particular white-collar workers constitute a group that frequently works overtime. For example, 70 percent of those with managerial positions work overtime every week, as do 45 percent of academics.

Work schedules differ in many ways, and more than 10,000 schedules are in use worldwide (Knauth, 1998). Hence, long work hours exist in various different forms. Compressed working weeks (CWW) are one working time model that is quite common when scheduling shiftwork. In a CWW schedule a few longer shifts are followed by a longer sequence of consecutive days off. The mean number of work hours per week is mostly still around the “normal” 40 hours per week although there are some cases where the total number of work hours per week exceeds 40h. The longer period of days off makes these kinds of schedules quite popular among workers (which might influence subjective reports). The longer time off may also allow greater recuperation to take place. Long working hours in non-shiftwork mostly take the form of overtime work. Overtime work is work done outside of the contracted hours. Overtime work often coincides with a peak in workload although there are also people who constantly work overtime. Overtime can result in longer shifts but may also occur as weekend work.

Research on long work hours (>8h/per day) has mostly been using cross sectional group comparisons, prospective studies or applying a before- after design when changing the work schedule from 8h to 12h. However, there are also a few longitudinal studies that have studied people during peak periods of overtime work. In the following review of long work hours and overtime work, studies of a change from 8h to 12h have been separated from other studies of long work hours and overtime work. The main reason for this is that the research on a change from 8h to 12h days has mostly been done on shift workers and often there are more factors than the actual length of the shifts that change. This is in itself interesting and important for the area of working hours. However, this thesis mainly focuses on long work hours and overtime work in day workers and therefore factors unique to shiftwork will not be discussed or reviewed in any detail. Moreover, it would be worth striving for a distinction between studies on overtime work and studies on long work hours. However, this is not always feasible due to inadequate descriptions of the work schedules.

There are also other key factors in the organization of work hours that will be mentioned briefly here. The timing of the start and end of the shifts will have effects. *Early morning* work has been shown to have strong associations with shorter and more fragmented sleeps (Kecklund et al., 1997; Torsvall & Åkerstedt, 1988). The mechanism behind this seems to be the anticipation of the very early rise time (Kecklund & Åkerstedt, 2004). A *late finishing time* of the shift will increase the likelihood of sleepiness at the end of shift (Tucker et al., 1998). Moreover, a late finishing time might also interfere with the following sleep due to less time for other duties and also less time for unwinding before bedtime. The timing of *rest brakes* is another factor known to be related to the number of accidents during the shift (Tucker et al., 2003). Also the *time between shifts* is crucial for the recuperation between shifts (Axelsson et al., 2004). When designing work schedules it is important to take these factors into consideration when striving for a system that will allow the workers to be alert through out the shift and to get sufficient recuperation between shifts.

Long hours in shiftwork

Many studies of long work hours have examined shift workers and the effects of a change from 8-hour shifts to 12-hour shifts. There is only modest consistency between studies, which might be due to methodological problems that these kinds of studies suffer from. For example Lowden et al (1998) studied control room operators who changed from an 8h to a 12h shift system. Results showed that the 12 h shift system was associated with positive effects such as greater satisfaction with work hours and less sleepiness. However, as the authors discuss in their paper, the old 8h schedule was suboptimal (for example, it featured backwards rotation) which makes it hard to interpret whether the results were an effect of the actual length of the shifts or other factors. When changing a shift system there might also be other factors changing. This may be one of the reasons for the diversity of results. When going from an 8h shift system to a 12 h system some have found positive effects on alertness (Lowden et al., 1998) and health (Williamson et al., 1994) whereas other have found negative effects on these variables (Rosa, 1991; Kogi et al., 1989). However, this research is based on shiftwork studies, which imply that there are also other factors unique to shiftwork that may account for some of the effects or lack of effects. Since the present thesis will focus on long work hours in relation to daytime work such factors will not be reviewed here.

Overtime work and long hours in relation to stress and stress related diseases

Whether working overtime or long hours affect health has been the topic of a number of studies. However, the results are inconclusive, with some studies showing negative and some showing positive effects on health whereas others have found no effect at all. One of the hypotheses is that overtime work will prolong high workload and thereby increase stress hormones and blood pressure. Such physiological changes are associated with an increased vulnerability to stress related diseases such as myocardial infarction, diabetes and increased body mass index, as discussed previously.

One of the relatively few studies that have examined overtime work in relation to stress hormones was that of Rissler and Elgerot (1978). In a longitudinal design, they followed a group of white-collar workers during a period of high overtime work and high workload. Epinephrine and norepinephrine was measured in urine during the day and evening. The results showed that the levels of adrenaline and epinephrine increased during the overtime period. The effects were shown during both the working day and during the evening. After the overtime period, levels went back to baseline values. It was also observed that there were individual differences in when the overtime was occurring. The mean working day was 1 hour longer and most people extended their workday with one hour per day but some of them started one hour earlier instead. Most of the overtime work occurred during the weekend. Steptoe et al (1998) also used a longitudinal design in order to study the relation between different amounts of work hours and cortisol (in saliva) in workers within the retail industry. Measures were made at 4 time points during which work hours ranged from 32.6h to 48h (mean values). Results showed no significant difference in cortisol levels. However, the study appeared to involve only one sampling of cortisol and it is not clear at what time of day samples were taken. Furthermore, the range in work hours was relatively small and the amount of overtime was relatively moderate. Persson et al (2003) examined cortisol in relation to performance of a cognitive test in a study in which construction workers on a 12h schedule were compared with workers on an 8h schedule. However, none of these studies have examined the diurnal secretion of cortisol.

Blood pressure and heart rate variability (HRV) are other examples of physiological parameters that have been shown to change in overtime work, indicating a higher strain and arousal. Hayashi et al (1996) studied ambulatory blood pressure for 24h in white-collar workers. They showed that subjects with mild hypertension who worked overtime (mean 84h/month) had higher blood pressure, shorter sleep and were more fatigued before and after work compared to subjects with a mild hypertension who had a low amount of overtime (mean 26h/month). In this study they also followed a group of individuals for 24h during a period with long hours (busy period) and a period of short hours (control period). The busy period (96h/month) was characterised by higher blood pressure, shorter sleep and greater fatigue compared to the control period (26h/month). However, this is one of many examples where overtime work often coincides with a busy period involving high workload and stress. It is not clear whether it is the working hours per se that cause the higher blood pressure or whether it is the higher stress and workload or if they interact. Also Kageyama et al (1998) studied the associations between HRV and overtime in male white-collar workers. HRV was measured at rest and when standing up. Their results showed that the group working 60h of overtime per month exhibited a sympathodominant state, but only for measures taken standing up. Together, these studies indicate that overtime is associated with altered blood pressure, which might be contributing to stress related diseases. Studies of stress related diseases have shown an association with overtime work. In a case-control study by Liu et al (2002) they showed, after controlling for shift work and job demand, that patients treated for acute myocardial infarction the previous year and month had worked longer hours (48.8h/week vs. 45.1h/week). Results from another case-control study by Sokejima et al (1998) showed that working longer hours (>11h/day) increased the risk for acute myocardial infarction (AMI). However, working less than 7h/day was also associated with an increased risk. The authors explained their findings of the increased risk associated with long hours as a result of workers being under high stress and strain, which affects the blood pressure. The authors suggested that the increased risk of AMI in the group working short hours might have reflected existence of a pre morbid condition or being unemployed. However, both the study by Liu et al (2002) and Sokejima et al (1998) were studies of long work hours, based on a mean value for the past month, i.e. it is not clear how much overtime work was undertaken in relation to contracted hours. Furthermore in the study by Sokejima et al (1998) shiftwork was not controlled for.

Another disease that has been shown to have an association with overtime work is diabetes. In a prospective cohort study by Kawakami et al (1999) the risk was 3.7 times higher for the development of diabetes in a group working 50h of overtime per month. It is possible that the development of diabetes is related to diet, with high levels of overtime being related to longer times between meals and over eating. This is to some extent supported by the findings from a study by Nakamura et al (1998). They found an association between overtime work and increase in Body Mass Index. However, their results were rather weak and overtime only explained 5% of the variance in BMI.

All these studies point to a negative association between overtime and health. However, as mentioned, there are also studies that fail to show these associations or even show the opposite effects. In a prospective cohort study Nakanishi et al (2001) studied long work hours and the relation with hypertension among white-collar workers. Subjects who reported working >11h per day had reduced risk of hypertension compared to the reference group, which consisted of subjects working <8h per day. Since the company's regular work hours were 40h/week one has to assume that those who reported that they worked longer than 11h per day must be working overtime. Nakanishi et al (2001) has in another study, within the same company, examined the relationship between work hours and diabetes. Their results showed that the risk of developing diabetes decreased in a dose response manner with an increase in number of work hours per day. Others have failed to show any association between longer work hours/overtime work and reported health symptoms (Steptoe et al., 1998; Van Der Hulst & Geurts, 2001).

Overtime work and long hours in relation to sleep, fatigue and performance

When working overtime or long hours the time left for recuperation will be reduced. At the same time overtime work is associated with an increased need for recovery, especially if the overtime work is perceived as being troublesome (Jansen et al., 2003). Despite the increased need for recovery there are data showing an association between short sleep times and overtime work. From subjective ratings of required sleep length and actual sleep length, Kageyama et al (2001) showed that overtime work was associated with shorter sleep and sleep deprivation (defined as actual sleep divided by required sleep). Short sleep has also been shown to be associated with long work hours. In a questionnaire survey of intermediate managers Maruyama et al (1996) showed that less than 6h of sleep was more common among those working >10h per day within. Moreover, it was not clear whether this included overtime work. In the study by Hayashi et al (1996) subjects were followed during a period of large amounts of overtime. The busy overtime period was associated with shorter sleep (5.6h vs. 6.8h) and greater fatigue both before and after work as compared to a period with less overtime. These studies indicate that overtime work and long work hours are associated with short sleep. However these findings are only based on subjective data and little is known about the physiological mechanisms behind these results. It is possible that the shorter sleep is either due to not allowing as much time for sleep or due to problems of unwinding before bedtime. None of these studies examined if the quality of sleep was affected.

Stress and disturbed sleep are two well-known factors in the promotion of fatigue and impairment of performance (Wimmer et al., 1992). Subjective ratings of fatigue and performance testing are rare within studies of overtime. However there are some data from questionnaire studies indicating greater fatigue in relation to overtime work (Hayashi et al., 1996; Park et al., 2001; Proctor et al., 1996). A questionnaire study by Park et al (2001) found that the group with a greater number of work hours per week reported more fatigue before going to work than those with shorter hours.

Proctor et al (1996) carried out one of the few studies that have employed cognitive measures. They showed that overtime work was associated with impaired performance on tests measuring attention and executive functions. The impairment was mainly demonstrated in longer response times. There are also studies that have looked at injury rates in relation to overtime work. Dembe et al (2005) showed that overtime work increased the risk of suffering an occupational injury or illness. Similar results have been shown for long work hours, indicating an exponentially increased accident risk beyond the 9th hour at work (Hänecke et al., 1998). However, once again there are also other studies failing to find a relation between overtime and fatigue (Beckers et al., 2004) and in a questionnaire study by Åkerstedt et al (2004) overtime work was associated with lower fatigue.

Overtime work and the home-work balance

The interplay between work stress and private life has been the topic of only a few studies, which have focused on the work-home interference. A conflict between work and family roles might arise when there are limited *time* and *energy* resources due to a demanding work situation. Working long hours will not only decrease the time for recuperation, there will also be less time for other obligations (e.g. picking up children from school). Long work hours, overtime work, shift work and long commuting times have been shown to be the main predictors of work-home interference in both men and women (Geurts et al., 1999; Jansen et al, 2003; Jansen et al 2004; Simon et al., 2004). However, work related factors have also been shown to be associated with work-home interference (Geurts et al., 1999; Krantz et al., 2005). A demanding work situation may result in depletion of the energy sources needed to fulfil duties within the home. The effects of work-home interference are associated with increases in symptoms of ill health and health complaint (van Hooff et al., 2005; Krantz et al 2005), elevated need for recovery (Jansen et al., 2003) and higher rates of sickness absence (Vaananen et al., 2004). There are a few studies that have indicated that men respond especially negatively to long work hours (> 50 h/week) (Krantz et al., 2005; Vaananen et al., 2004). Although there are still very few studies within this area, it seems that the interplay between demands at work and at home may be important in the understanding of the development of ill health.

Methodological problems in the study of overtime work

The reason behind the diversity in results may be attributed to some of the methodological problems that studies of overtime and long work hours in general suffer from. Many studies use a cross-sectional design and in several of these cases it is hard to control for individual differences as well as for the influence of different work characteristics. In the prospective cohort study by Nakanishi et al (2001), which showed a decreased risk for hypertension in relation to overtime, there might be other things unique to the different groups of working time that caused the effects. It is possible that those working long hours have different job characteristics that buffer from work related stress for example more influence over their jobs. Nakamura et al discuss this in their paper and point out that the longer overtime group consisted of more researchers and architects as compared to the 8h group that had a larger proportion of clerks. Similarly, those who work much overtime are often in a work situation with high demands but also high decision latitude and control as well as a high work motivation (Åkerstedt et al., 2004; Beckers et al., 2004). It is not clear how the different job characteristics may moderate the effects of overtime work. In a study by Van der Hulst and Geurts (2001) they showed that overtime work was associated with negative health effects, but only for those who had low job rewards. They conclude that overtime did not necessarily have adverse health effects. However, if there is low rewards even a moderate amount of overtime work was associated with adverse health complaints. Furthermore, this effect was exacerbated when employees were pressured to work overtime by supervisors. This means that when comparing groups with different amounts of overtime one needs to control for job rewards. The diversity of results can probably partly be explained by the differences between groups, which makes it hard to differentiate the effects of work hours per se from other factors. In a recent paper by Tucker et al (2005) it was shown that individual differences in social support buffered the negative effects of working long hours. Moreover, they showed that those who had high social support had less health problems the longer hours they worked. The authors speculated that if one has a good social support and wants to work longer hours (for motives like additional money) it might be negative for health if not allowed to do so.

To avoid these problems it would be preferable to use a within-subject design. However, to date relatively few studies that has done this (Hayashi et al., 1996; Rissler & Elgerot, 1978; Steptoe et al., 1998). The results from Rissler and Elgerot (1978) and Hayashi et al (1996) both found that overtime work was associated with higher stress and physiological arousal, greater fatigue and reduced sleep. Steptoe et al (1998) did not find any changes in physiological arousal as measured in cortisol. However, their measurement methods were not optimal since they only used one sample of cortisol, taken before or after work or during breaks. Although time was constant within individuals, the sampling time varied greatly between individuals. This may have obscured effects during certain time points of the circadian rhythm. Furthermore the study only compared rather moderate lengths of work hours. However, although these studies applied a within-subject design they also suffered from methodological problems when comparing periods with high and low overtime work. In these cases, stress is often a confounder, since overtime work often coincides with a high workload. This makes it hard to distinguish the effects of working time from the effects of high workload and stress. While it is probable that workload and work related stress are two of the most crucial factors moderating the impact of long hours, their precise role remains unclear.

Summary

Overtime work and long work hours are associated with greater stress, increased risk for stress related diseases, shorter sleep, greater fatigue and impaired performance. However, the diversity in results calls for some caution when generalising the results. It should also be noted that there are no studies that have shown any clear relationship between sleep disturbances and stress in relation to overtime work. Furthermore, methodological problems make it hard to distinguish the effects of long work hours from a stressful work situation.

General aim of the thesis

Previous research on work-related stress and overtime work has shown an association with altered physiological arousal, increased risk for stress related diseases, shorter sleep, greater fatigue and impaired performance. However, there is a lack of knowledge on the effects within individuals during periods of high workload and stress or overtime work. The previous research has largely been based on between group comparisons and therefore suffers from difficulties of confounding factors relating to characteristics unique to individuals or groups. This may be one of the reasons for some of the inconsistencies in earlier findings. Moreover, it is still not clear how high workload and stress are related to overtime work.

Studies of stress and work hours have established that there are large individual differences in physiological reactions, such as cortisol secretion, to stress. However, it is still not clear which factors may contribute to these differences.

The general aim of the thesis was to investigate the effect of increased work stress on sleep, work duration and the diurnal pattern of cortisol, sleepiness and subjective stress in a within-subject design. In addition, it examined individual differences in the diurnal cortisol response to stress. Following on from initial findings that stress led to increased duration of work later studies also aimed to experimentally investigate the effect of extended work hours on the same variables as in the first study.

Study I

The aim of study **I** was to examine the effects of work-related stress on sleep and overall health, sleep, the diurnal pattern of cortisol and sleepiness and work hours, using a within subject design.

Study II

In study **II** the effects of overtime work were explored when workload and stress was held constant. The aim was to study how overtime work affects sleep, fatigue and physiological arousal using a within subjects design. We also wanted to examine the effects on life outside of work and to identify which activities people would be most likely to cut down on.

Study III

Study **III** focused on individual factors influencing the levels of cortisol and its circadian pattern. The aim was to further explore the large individual differences in cortisol secretion in relation to stress and to examine if they were associated with individual differences.

Method

Design of the studies

Table 1 gives an overview of the samples, measures, designs and statistical methods used in the three studies. They were all field studies. A within subject design was applied in study **I**, and **II** whereas study **III** used a between subject design. In study **I** and **II**, participants were followed during two different conditions. Study **III** were based on mainly the same subjects as in study **I** but in this study it was of interest to examine different groups during the two different conditions.

Table 1. Overview of methods in studies **I-III**

Study	**Sample**	**Measures**	**Design**	**Statistical method**
I	Office workers	• actigraphy • diary • background questionnaire • saliva samples for cortisol	Within subjects	Repeated 2 factor ANOVA Paired t-tests Correlations
II	Office workers	• actigraphy • diary • background questionnaire • saliva samples for cortisol • heart rate and blood pressure	Within subjects	Repeated 2 factor ANOVA Repeated 3 factor ANOVA
III	Office workers	• actigraphy • diary • background questionnaire • saliva samples for cortisol	Between groups, Within subjects	Repeated 2 factor ANOVA Paired t-tests

Participants and settings

All the participants were white-collar workers. In study **II** participants were recruited through information letters and phone calls to work places close to Karolinska Institute. They had positions as technicians, administrators, researchers etc. The main reasons for not participating in the study were not working full time or not being able to extend the work hours as requested due to either factors at work and/or family arrangements. Study **I** and **III** formed part of a larger project concerning work hours and health. The participants worked as union representatives or administrators at two unions in Stockholm, Sweden, and were recruited via information letters and phone calls. Some of the reasons for not participating in the study were working part time, no variation in workload, being unable to predict workload or medical conditions. In all three studies we aimed at recruiting an equal proportion of women and men. Table 2 provides information about the number of subjects in each study, their age and sex.

Table 2. Descriptive data of participants in studies **I-III**

	Subjects invited	Subjects participating	Subjects analyzed	Women	Men	Mean age	Age range	% With children
Study **I**	110	55	34	23	11	47	27-60	32 %
Study **II**	38	18	15	9	6	46	27-65	27 %
Study **III**	110	55	24	11	9	46	27-60	33 %

Procedure

In study **II** 18 participants were followed during one work week (Monday to Sunday) with "normal" working hours (8h) and one week with overtime work with 4 extra hours of regular work tasks (12h). Participants wore an actigraph, filled in questionnaires and made daily ratings of sleep, stress, sleepiness and work. On Monday and Thursday they took saliva samples for the measurement of cortisol. On these days ambulatory heart rate and blood pressure were also measured for 24h in 1h intervals during the day and 2h intervals during the night. One participant dropped out of the study, and two participants were excluded because of irregular working patterns.

Studies III and I had a very similar designs to study **II** where the participants were followed during two different conditions. In these studies different levels of stress characterized the conditions. In study **I** 55 participants were followed during one workweek with relatively high stress and workload and another workweek with relatively low stress level, as predicted by the participants themselves. In each measurement week participants wore an actigraph, filled in questionnaires and made daily ratings of sleep, stress, sleepiness and work. On Wednesday and Saturday in each week they took saliva samples for measurement of cortisol. Only 34 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. In study **III** the 34 subjects from study **I** were divided into two groups, based on their morning cortisol levels. One group consisted of subjects who, in their cortisol response to the high stress condition, showed a higher morning level compared to morning levels in the low stress condition (Group 1). For the other group, cortisol levels were lower in the morning under the high stress condition (Group 2). Another four subjects were excluded due to a lack of exhibited variation in morning levels of cortisol (<1.0 nmol/L) and another five subjects had missing morning values.

Measurements

Sleep diary

In studies **I**, **II** and **III** the subjective aspects of sleep were measured using the Karolinska Sleep Diary (KSD) (Åkerstedt et al., 1994; Åkerstedt et al., 1997). This was filled in every day upon awakening and consisted of several questions concerning the previous nights sleep, such as having "sufficient sleep", "early awakening", "ease falling asleep", "stress or restlessness at bedtime". The ratings were made on a five-point scale (1 poor sleep – 5 no problems with sleep). A sleep quality index was formed of the questions "restless sleep", "ease of falling asleep", "sleep quality" (phrased as "how did you sleep") and "sleep throughout". In study **I** a second index reflecting the ease of awakening was formed using the items "ease awakening" and "fully rested". The KSD has been validated against polysonography measures and shows good correlation with objective measures (Åkerstedt et al., 1994; T. Åkerstedt et al., 1997; Kecklund & Åkerstedt, 1997).

Wake diary

In all studies (**I-III)** participants rated their sleepiness and stress throughout the day. Sleepiness was measured 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 behavioural measures (T. Åkerstedt & Gillberg, 1990). Electroencephalographic (EEG) and electrooculographic (EOG) changes characteristic of sleepiness usually begin to appear at a value of 7 (Åkerstedt & Gillberg, 1990). The stress rating scale measured subjective physiological activation. Response categories ranged from 1 to 9, of which 5 included verbal anchors: 1 very low stress (very calm and relaxed), 3 low stress (calm and relaxed), 5 neither low or high stress, 7 high stress (high tension and pressure), 9 high stress (very high tension and pressure). The stress rating scale was inspired by the work of Kjellberg and Iwanowski (1989) and their development of the "Stress-energy rating questionnaire". They used almost 100 mood adjectives that were factor analyzed. A series of factor analyses were carried out and the final outcome was a two- factor structure. The factors were labelled "energy" (represented by adjectives like active, energetic, efficient etc.) and "stress" (represented by adjectives like tense, stressed, under pressure etc.). The dimensions included 6 items each. The "stress-energy scale" has been validated, with good results, against job-strain measures (Kjellberg & Wadman, 2002). However, since we needed to collect information about stress at six times of the day during 18 days, it would have been too much of a burden for the participants to complete the entire questionnaire. Therefore, the items of the stress dimension were integrated into a single rating scale. Wang et al (2005) used a similar scale, ranging from 1 to 9, and their results showed that ratings of stress increased as well as heart rate and cortisol in relation to a highly stressful task. In study **II** participants also rated mental fatigue throughout the day. The scale varied from 1 to 9, of which 5 included verbal anchors: 1 very active, very high energy, 3 high energy, 5 neither energetic or slow, 7 fatigue but not too hard to make a mental effort, 9 very slow, low energy, inactive.

At the end of the day subjects rated how their day had been with respect to work and different symptoms of stress (**I**, **II**, **II**). The questions concerned whether one had felt "tense", "irritated", " exhausted", "under time pressure", "worn out", "persistent fatigue", "had had difficulties thinking" (1 to a large extent – 5 not at all) and whether they had enough recuperation during the day (1 definitely enough – 5 far from enough). The questions about work concerned work hours, workload, work pace (1 very low – 5 very high) and satisfaction with own work performance (1 very dissatisfied – 5 very satisfied).

In the diary participants also reported what they did after work. They noted in the diary what kind of activity they had been involved in for the past 30 minutes. In order to make it easier to fill in the diary different activities were classified into different categories such as "household work", "caring for children/relatives", leisure activities", "rest/sleep", "spending time for your self", "watching television" etc. This was based on the Swedish Statistic's survey on time spent on different activities within the Swedish population (SCB, 1992).

Questionnaire

At the beginning of each measurement week, subjects filled in a questionnaire that included working hours the previous week (1- <37.5, 6- >60h) and how they had felt the previous week. It contained questions about "work situation" (1 very bad – 5 very good), "persistent fatigue", "mentally exhausted", "sleep quality" and "overall health" (1 difficulties – 5 no problems).

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 (Zigmond & Snaith, 1983). It consists of fourteen items of which seven measure anxiety and seven depression. Ratings are made on 4- point scales, which represent the degree of distress (0= none, 3=unbearably). The sum of each subscale can be classified in terms of severity, where 1-7 indicates normal, 8-10 intermediate doubtful cases and 11-14 definite cases. Zigmond and Snaith (1983) reported good reliability and validity for the HAD scale.

Actigraphy

During all three studies participants wore an actigraph (Cambridge Neurotechnology Ltd., UK), which measured wrist activity, throughout the whole measurement period. Participants were instructed to press an event button when going to sleep (lights out) and at awakening. The Actiwatch Sleep Analysis program (version 1.09) was used for scoring the data. The output sleep score has a high correspondence with polysomnographically-recorded sleep for the parameter total sleep time (Sadeh et al., 1995). The measures obtained were bedtime, wake-up time, actual sleep time (excluding time awake) and sleep efficiency (actual sleep time/total sleep time * 100).

Cortisol in saliva

In studies **I** and **III** saliva samples were taken on Wednesday and Saturday. Saliva samples were taken on Monday and Thursday in each condition week in study **II**. The participants gave saliva samples using Salivette (Sarstedts, Rommelsdorf, Germany) cotton swabs. The participants kept a swab in his/her mouth for about one minute and then put it in a test tube and sealed it. The samples were obtained fifteen minutes after awakening and at a number of time points during the day as well as one sample just before going to bed. The participants were instructed to avoid food for half an hour before these time points.

About 10 percent of the samples were lost in studies **I** and **III** and about 8 percent in study **II**. When possible, missing data was replaced by a mean value based on adjacent values. Missing data at awakening and bedtime was not replaced because of the lack of adjacent values. Missing data at the first measurement after the morning sample was not replaced either, since using the preceding high morning value probably would have resulted in a too high and misleading mean value. The cortisol samples were analyzed by RIA, using the Spectria (^{125}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%.

Ambulatory heart rate and blood pressure

On Monday and Thursday (**II**) in each condition ambulatory blood pressure and heart rate were measured for 24 hours. This was done in one- hour intervals during the day and two-hour intervals during the night, using an ambulatory blood pressure monitor (Spacelabs Medical Inc). The amount of missing data was about 14 percent during the day (between 8h and 22h) and about 19 percent during the night (between 24h and 7h). Missing data was either due to not wearing the ambulatory blood pressure monitor or due to being physical active, which interrupts the measurements. Some participants did not want to wear it during the night and deliberately took it off before going to bed. A mean for values at work, after work and during sleep was calculated in order to reduce the effects of physical activity and to overcome the problem of missing data points.

Statistics

In studies **I, II** and **III** a two-factor ANOVA for repeated measurements was used in order to detect differences in diary ratings between conditions (**I**, **II**) and between groups (**III**). In all studies one factor was condition, whereas the second was workdays (Monday to Friday) in study **II**, weekend in study **I,** and group in study **III**. The cortisol samples were analysed in a three-factor ANOVA for repeated measurements in study **I** and in study **II,** and in **III** with a two factor ANOVA. Correction for sphericity, using the Huyhn-Feldt procedure, was performed when necessary in study **II**. The heart rate and blood pressure data in study **II** were also averaged for values taken at work, after work and during sleep.

Results – summary of studies

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

Work related stress has been shown to be related to ill health. However, most of the previous studies have been based on experimental studies 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. In study **II** we sought to relate different levels of work-related stress to measures of sleep, sleepiness and cortisol using a within subject design. It involved office workers employed by two labour unions in Stockholm, Sweden. They participated during two different conditions, one workweek with higher stress and one workweek with lower stress, as predicted by the participants.

Participants wore actigraphs, made daily diary ratings, gave saliva samples for cortisol on Wednesday and Saturday and filled in a short questionnaire at the beginning of the measurement week.

Results showed significant differences between the high and low stress week for total sleep time, stress at bedtime, work hours, workload, sufficient recuperation, mean sleepiness, time pressure, being exhausted, work situation and HAD anxiety. The high stress week essentially showed higher load, stress, fatigue, anxiety and less sleep, but no differences in sleep quality and sleep efficiency.

The diurnal pattern of the mean levels of sleepiness (KSS) and stress showed significant effects of time of day as demonstrated in figure 3. The ratings of sleepiness (KSS) also showed an interaction between condition and time of day, sleepiness was higher at the end of the day in the high stress week (16h; $t=2.1$; $p<0.05$; 22.00h; $t=4.0$ $p<0.05$). Rated stress during workdays showed a significant effect of condition, for obvious reasons.

The analysis of the cortisol data showed that there was no main effect in cortisol levels. However, there was a significant interaction effect that indicated a more flattened pattern during the high stress week ($F=3.8$, $p<0.05$). Pairwise t-tests indicated significantly higher levels at 10h and a trend towards higher levels at bedtime.

Virtually all variables showed a significant difference between the working week and the weekend, except for sleep efficiency. Significant interactions were seen for mean stress, being tense, being irritated, being under time pressure and prediction of sleep quality. The workweek - weekend difference was smaller during the low stress week. During the weekend, sleepiness was significantly higher in the high stress condition but there were no differences in the diurnal pattern. Stress ratings during the weekend were significantly higher in the high stress condition.

The results demonstrate that a week with high workload and stress is associated with increased sleepiness, longer work hours, impaired sleep and an alteration of the diurnal pattern of cortisol.

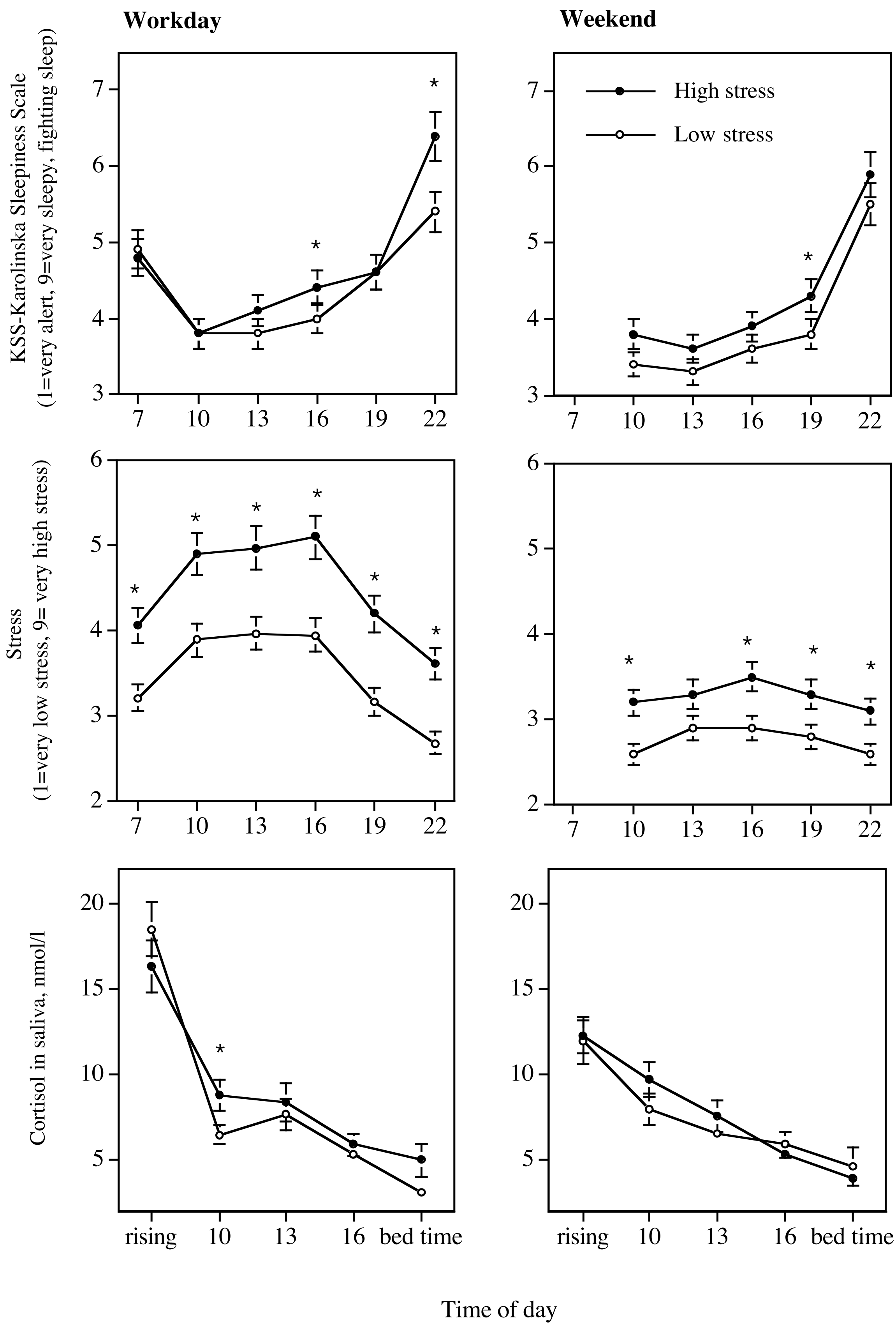

Figure 3. Means and standard errors of the workday and weekend values of cortisol, sleepiness and stress. * P<0.05 with pairwise t-test. Cortisol at rising was taken 15 minutes after the participants awakened.

Study II- Overtime work and its effect on sleep, sleepiness, cortisol and blood pressure

Previous studies of overtime work show inconclusive results, which may be partly due to methodological problems such as the use of between group comparisons or having stress as a confounder. The aim of study **I** was to examine how overtime work affects sleep, fatigue and physiological arousal using a within subjects design without any external stress. We also wanted to examine the effects on life outside of work and to identify which activities people would be most likely to cut down on during the period with overtime work. One hypothesis was that overtime work would lead to higher physiological arousal, more disturbed sleep and greater fatigue.

The study involved an experimental field study in which participants were followed for one workweek with normal work hours (8h) and one workweek of overtime with 4 extra hours of regular work (12h), without any external stress. It was only the working time that was manipulated while workload and stress was held constant. In other words, there was no external pressure to increase work pace. Work hours were simply extended in time and work was performed at normal pace. This was done in order to optimise the possibility of detecting effects of work hours per se rather than stress or high workload.

In each measurement period participants wore an actigraph and made daily ratings of work, stress and fatigue. On Monday and Thursday in each condition subjects gave saliva samples for measurement of cortisol. On these days ambulatory heart rate and blood pressure was also measured.

Inspection of figure 4 indicates that overtime work was associated with greater sleepiness at the end of the working week as demonstrated by a significant interaction effect ($F=4.2$, $p<0.05$) between conditions and weekday. Furthermore, the analysis of the Friday in each condition showed that sleepiness was significantly higher throughout the whole day in the overtime condition ($F=35.2$, $p<0.05$). The participants also reported more symptoms of fatigue during the overtime week such as being more irritated, exhausted, worn out and having more difficulties thinking. Furthermore, participants reported less sufficient recuperation during the overtime week.

The data from the actigraphs showed a shorter total sleep time in the overtime condition (6h24min versus 6h42min) but there was no indications of effects on subjective or objective sleep quality.

There were no differences between conditions in ratings of stress or workload, indicating that the work situations were fairly similar under both conditions. However, the start of the workday differed between conditions with an earlier start of approximately 28 minutes in the overtime week.

The measurement of cortisol, heart rate and blood pressure showed no main effect of condition. However, as illustrated in figure 5 there was a trend towards higher cortisol levels in the morning on Thursday of the overtime week ($F=3.2$, $P<0.10$).

There were no differences in overall health or pain symptoms but there was a significant difference in coffee consumption, which increased in the overtime condition.

The diary data showed that after work, participants spent less time socializing, doing household work and spent less time for themselves during the overtime week. The participants continued making diary ratings during the following weekend. Results showed no differences between conditions.

The results showed that one week of overtime work with a moderate level of workload was not associated with any main effects in physiological stress markers. Nevertheless, sleep was negatively affected, with shorter sleeps during overtime work, and greater problems with fatigue and sleepiness.

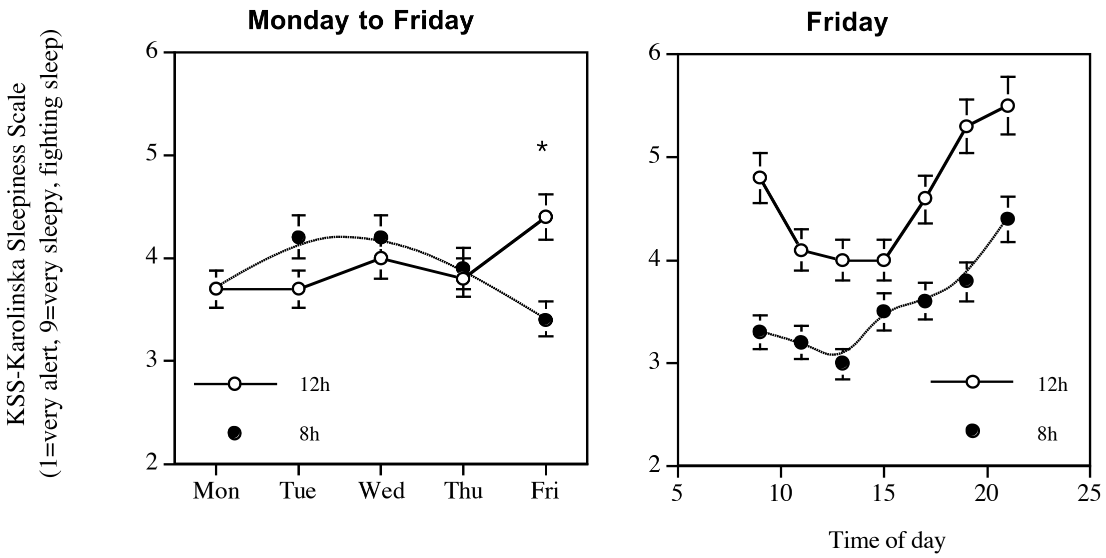

Figure 4. Means and standard errors of the means for sleepiness from Monday to Friday during each condition and for sleepiness throughout Friday an each condition (right). *P<0.05 with pairwise t-test

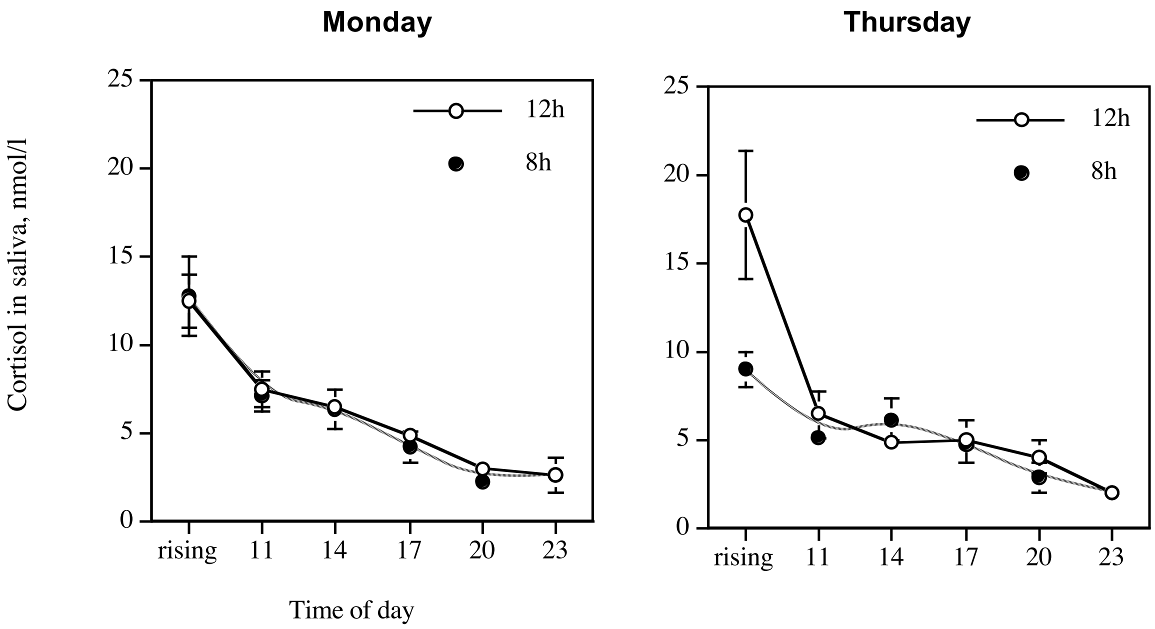

Figure 5. Means and standard errors of the means for the cortisol level during Monday (left) and Thursday (right) in each condition. Cortisol ar rising was taken 15 minutes after the participants awakened.

Study III - Individual differences in the diurnal cortisol response to stress

The large individual differences in the cortisol response to stress from study **I** prompted study **III**. In this study we examined two groups that showed different cortisol responses to stress. The aim was to explore which individual differences might be associated with the difference in cortisol response to stress. Group 1 consisted of individuals that showed a higher morning cortisol value during stress as compared to a period with lower stress. The other group, group 2, consisted of people that showed the opposite pattern, with lower morning values during the high stress period.

Both groups were followed during one week with relatively higher workload and stress and one week with lower workload and stress. Participants wore an actigraph and made diary ratings of sleepiness, stress and work each day. During Wednesday in each measurement period participants gave saliva samples for measurement of cortisol. Samples were taken 15 minutes after awakening, at 10h, 13h, 16h and at bedtime.

Figure 6 shows the pattern of cortisol secretion under the high and low stress week for the two groups. ANOVA did not show a significant difference between groups in the high stress week ($F=2.1$; $p>0.05$; df 1,16). Under the low stress week the ANOVA showed significantly higher levels of cortisol for group 2. They also had significantly higher levels of cortisol in the morning ($t=4,5$;$p<0.001$; df 22) and at 13h ($t=3,2$;$p<0.01$; df 22).

Within-group analyses revealed that, apart from morning cortisol values, group 2 showed no significant differences between the high and low stress weeks. Group 1 had significantly higher levels of cortisol in the high stress week at all clock times sampled except for 16h.

Results showed that group 2 had a higher workload, more persistent fatigue, were more tense and exhausted and experienced greater stress and restlessness at bedtime compared to group 1. Furthermore, group 2 reported having a worse work situation, being more mentally exhausted and having more persistent fatigue the previous week.

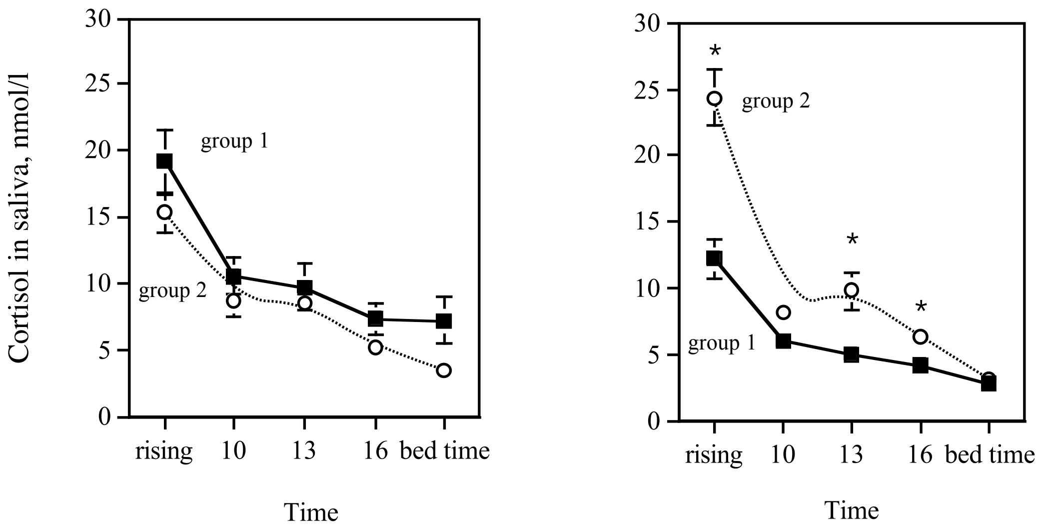

Figure 6. Group differences in cortisol excertion during the day for the two groups under high stress week (left) and low stress week (right). *=p<0.05 with pair wise t-test.

In conclusion the results suggest that there are individual differences in cortisol response to stress. Group 2, with reduced morning cortisol during the week of stress, experienced higher levels of exhaustion/fatigue and stress, as ell as a worse work situation. These results indicate a relationship between suppression of morning cortisol and exhaustion.

Discussion

The main findings from studies **I-III** (table 3) show that work related stress is associated with greater symptoms of sleepiness and fatigue, shorter sleep and altered cortisol secretion. Similar effects were shown in association with overtime work although the symptoms were not as pronounced. Furthermore, the individual differences in cortisol response to work stress were shown to be associated with symptoms of fatigue and exhaustion.

The following discussion will consider whether everyday work stress affects work hours, sleepiness, sleep and cortisol secretion. Moreover, the discussion will consider what characterises the individual differences in the cortisol response to stress. Also evaluated is the question whether either overtime work or extended work hours per se are stressors. Thereafter studies **I-III** will be compared in order to seek increased understanding about sleepiness, sleep and cortisol secretion. Finally the discussion will highlight methodological considerations and weaknesses, as well as the implications of the results for future research.

Table 3. Summary results study I-III

Study	Wake diary I	Wake diary II	Sleep diary	Actigraphy	Cortisol	ABM	Questionnaire
I	⇑ Work hours ⇑ Workload ⇑ KSS both condition and interaction with time of day ⇑ Stress	⇑ Exhausted ⇓ Sufficient recuperation ⇑ Time pressure	⇑ Stress/restlessness at bedtime	⇓ Total Sleep Time	More flattened pattern in high stress		⇑ Anxiety HAD ⇓ Work situation
II	⇑ Work hours KSS: interaction with higher sleepiness at the end of the week ⇓ Household work ⇓ Time fore oneself ⇓ Socializing	⇑ Worn out ⇑ Irritated ⇑ Exhausted ⇑ Difficulties thinking ⇓ Sufficient recuperation	⇑ Coffee	⇓ Total sleep time ⇓ Sleep end	Tendency towards higher morning value at the Thursday in overtime week	Inter-actions	
III	⇑ Workload	⇑ Tense ⇑ Persistent fatigue ⇑ Exhausted	⇑ Stress/restlessness at bedtime		L; higher cortisol morning, 13h, 16h + interaction (group2 higher morning value)		⇓ Work situation ⇑ Persistent fatigue ⇑ Mentally exhausted

Work stress

One week of high work load and work related stress was associated with increased sleepiness, impaired sleep, altered cortisol secretion and longer work hours (**I**). In the discussion that follows, each of these effects will be considered in turn.

Work stress and physiological and psychological stress symptoms

Subjective ratings

Previous research has failed to show consistency between measures of work-related stress and physiological correlates. This could be due to some methodological problems. We have addressed these in various ways. Firstly, the most common approach has been to measure job strain (Karasek, 1979; Theorell & Karasek, 1996) or effort-reward imbalance (Siegrist, 1996). However, although these models of work stress apply to most individuals there is the notion that not all individuals respond with a stress reaction in those situations. This may be due to individual differences or mediating factors buffering from a stress response (Cooper, 2005; Johnson, 1986). In the present thesis we have measured the psychological and physiological experience of stress instead of using such indirect measures of stress. This assures us that the subjects actually perceive a higher stress in the high stress condition. Secondly, when studies have measured the perceived stress this has been done through one measure where subjects are asked to estimate the stress levels for the last week, weeks or month (Cohen et al., 1983). However, retrospective ratings of stress can be dependent on how well one have been able to deal with the stressful situation (Gaab et al., 2005). We have avoided such problems by measuring the perceived stress at several time points throughout the day. Thirdly, we asked the subjects to pick out a week that would be characterised by a high workload. This method made it clear that the measured stress was associated with a concurrent increase workload. By doing this we avoided the problem of including subjects who were not finding the increased work demand stressful. Such problems may be contributing to the lack of support for the assumption that higher workload is generally related to higher levels of stress hormones (Sonnentag & Fritz, 2006). Finally, we applied a within-subject design in order to limit the influence of individual differences. When using a between subject design this is harder to control for and might sometimes obscure the results.

During the week with high workload and stress in study **I** subjects also reported other symptoms of stress such as feeling more exhausted and more time pressure during the day as well as being more stressed at bedtime. This gives some validation to the used stress scale and provides further support that we managed to follow the subjects during a period with high stress.

Cortisol

The high work stress week in study **I** was associated with a change in the pattern of cortisol secretion. Specifically, there was a reduction in the diurnal amplitude during the high stress week. The higher morning levels at 10h and the somewhat elevated levels in the evening probably contributed to this flattened pattern during the high stress week. This result lacks any directly comparable findings in previous studies since there is no other studies that have used both a within subject design and measured the diurnal secretion of cortisol. However, Rosmond et al (1998) have measured the diurnal secretion of cortisol in relation to groups with different stress levels. They found a difference in the diurnal secretion of cortisol between subjects with high stress and subjects with low stress. The high stress group showed a more flattened pattern.

There are a few other studies that have applied a within-subject design when exploring the relationship between stress and cortisol levels. In a study of different levels of workload Steptoe et al (1998) failed to find any effects on salivary cortisiol. However, the timing of the cortisol measurements were not very well described and might not have been optimal. Another study using a within-subject design showed that urine levels of cortisol were higher during days with high stress compared to low stress (Brantley et al., 1988). Another study using mean levels of cortisol during the day showed a small, but significant, association between workload and cortisol (Rose et al., 1982). However, none of these studies examined the circadian pattern of cortisol.

Other studies have focused on repeated measures of cortisol in saliva within the first hour after awakening in groups with signs of job strain or burnout (Pruessner et al., 1999; Schulz et al., 1998). The present study had only one morning measure (15 minutes after awakening) and it is therefore not possible to examine the morning rise in cortisol. In the study by Schulz (1998) no differences between groups of high/low job strain were shown for this morning value, but rather in the measurements taken the following morning. The group with high strain showed elevated levels. It is possible that more measurement points in the morning would have given us further information of 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.

It has been shown that short sleep length is associated with elevated evening levels of cortisol (Spiegel et al., 1999). The high stress week in study **I** was also associated with shorter sleep length and a trend towards higher cortisol in the evening. However, we did not find any significant correlation between the two.

Although we did not find any main effect of cortisol levels in study **I** the highly significant interaction effect indicate that some time points were associated with an elevated level of cortiosl and that these time points altered the diurnal pattern of cortisol secretion. This implies that it is of importance to use several measuring points when examining cortisol.

Work stress and sleep

One week with high stress and workload was associated with some sleep disturbances, expressed as problems falling asleep and shortened sleep length (**I**). These results are consistent with other findings where work related stress has been shown to be associated with sleep problems (Åkerstedt et al., 2002; Marquié et al., 1999; Urponen et al., 1988). Similar results were also demonstrated in a study by Meijman et al (1992), which showed that driving examiners reported more trouble falling asleep during the night after an intensified working day. It is known that high job strain could cause problems of unwinding (Steptoe et al., 1999), which could explain why subjects have more problems falling asleep although they report feeling more sleepy. Problems unwinding after work has been shown to be associated with sympato-adrenal activation which in turn may increase the risk for cardiovascular disease

(Kuiper et al., 1998). In sum the present research indicates that high work demands may be associated with an elevated physiological arousal that prevents individuals from falling asleep.

The shorter sleep in study **I** was probably a result of both the somewhat later sleep start, earlier awakening and lower sleep quality. However, none of these variables showed any significant effect of higher workload and stress. Moreover, the present reduction of sleep length was relatively moderate and there was no accumulation of sleepiness over the week, which indicated that the subjects 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 (Hall et al., 2004; Kripke et al., 2002). The mechanism leading to ill health might be through a suppression of many of the anabolic processes that take place during sleep, leading to an allostatic up regulation (Buckley & Schatzberg, 2005; McEwen, 2006). The results from this study imply that a period of high stress may have negative health effects due to short sleep

No significant effects were shown on sleep efficiency in relation to the higher stress levels (**I**). Other studies have shown sleep to change during stress with less deep sleep and more stage 2 sleep, arousals and awakenings (Ekstedt et al., 2004; Lester et al., 1967; Torsvall & Åkerstedt, 1988). One of the mechanisms might be a shift towards sympathovagal balance during NREM sleep (Hall et al., 2004). The lack of significant effects in sleep efficiency in the present study may imply that the perceived stress levels were not severe enough to give these kinds of effects. However, one should bear in mind that we lack information on variables such as EEG or heart rate variability. It is possible that there were changes in the sleep structure or of the arousal levels during the night that were not detected by measurements of actigraphy.

Work stress and sleepiness

Acute stress is usually associated with increased attention and alertness and a decrease in sleepiness. However, in study **I** sleepiness increased in the afternoon and evening during the week of high workload and stress. This supports the findings from Horne et al (1985) showing that sleepiness before bedtime increased after a behaviourally active day. It is possible that the increase in sleepiness during the evening in response to higher stress indicated a greater need for recovery. Previous studies have shown a strong association between the need for recuperation and high work demands (Jansen et al., 2003; Sluiter et al., 2003). Amelsvoort et al (2003) demonstrated that the need for recovery predicted subsequent risk for cardiovascular disease within the next 32 months. Their results indicated that the need for recovery is an intermediate factor between job stressors and cardiovascular disease. One possible mechanism underlying the association between increased sleepiness under stress could be the effect of increased cognitive effort. For example Tononi and Cirelli (2006) suggested that a greater activation in the cortex was related to a promotion of sleep in order to maintain synaptic homeostasis. However, stress cannot only induce sleepiness due to increased activation. Stress can also result in sleep problems (Bonnet et al., 2005; Cartwright & Wood, 1991; Kecklund & Åkerstedt, 2004; Morin et al., 2003; Torsvall & Åkerstedt, 1988) and thereby induce greater sleepiness the following day. The increased sleepiness in study **I** could both be due to more time spent in a high effort work situation as well as a shorter total sleep time.

Work stress and the balance of rest and activity

The results from study **I** point towards a change in the balance between stress and recovery during the period with high work stress. The change in cortisol levels, the higher arousal at evening and bed time, the less sufficient amount of rest and relaxation during the day and the shorter sleep during the night might combine to suppresses anabolic processes. The higher levels of fatigue and sleepiness may be an expression of this imbalance. Simultaneously as there is a greater need for recuperation, the time available is reduced during the week with high work stress since subjects work longer hours.

The results from study **I** also indicated that some of the effects of higher work stress carried on into the weekend with more problems with stress/restlessness at bedtime and shorter sleep duration. It is noticeable that after a period of high workload and stress some of the effects are still present during the time off, when recuperation should take place. The numbers of studies that have focused on the effects of work stress during weekends are few. However, in a study on working hours within construction workers it was shown that it took longer time to recover from symptoms of fatigue after an 84-hour workweek as compared to those working a 40-hour workweek (Persson et al., 2003). It might be the case that a longer period of recuperation is needed when working under a high load.

Overtime work

The results of study **I** showed that that high workload and stress was associated with increased sleepiness, impaired sleep and altered diurnal cortisol secretion. However, participants also worked longer hours during the period with high workload and stress. It is possible that the effects were partly related to the longer work hours as well as the higher workload. The aim of study **II** was to further explore the effects of work hours per se, when stress levels were constant. The results are discussed below.

Overtime work and sleep

Study **I** showed a relationship between overtime work and sleep and this was supported in the experiment in study **II**. A few previous studies have also found this link (Kageyama et al., 2001; Liu & Tanaka, 2002). However most studies have used questionnaires and the mechanisms behind the shorter sleep are not clear. Since overtime work has been related to increased stress (Ahlberg et al., 2003; Ettner & Grzywacz, 2001; Rissler & Elgerot, 1978) there is reason to believe that stress could be one of the mechanisms behind the shorter sleep. Stress can affect several aspects of sleep, such as the ability to go to sleep, the sleep quality and early awakenings (Ekstedt et al., 2004; Lester et al., 1967; Torsvall & Åkerstedt, 1988). However, in relation to overtime work it is also possible that people voluntarily reduce sleep length as a way of coping with demands both at work and in their private life. The shorter sleep in study **II** may partly be related to the somewhat earlier awakening times during overtime work, even if the phase advance was only 28 minutes. However, we do not know whether this reflects an active strategy by the participants or whether the earlier awakenings were an effect of stress. Neither sleep efficiency nor subjective sleep quality showed any effects of overtime work (**II**). However, impaired sleep quality in relation to stress probably mainly occurs when there is a very high arousal, which can prevent deep sleep and induce more awakenings. In study **II** there were no clear signs of any altered physiological arousal during overtime work.

Overtime work and sleepiness

Study **II** showed that overtime work led to higher sleepiness. This has also been shown in other studies (Kageyama et al., 2001; Maruyama & Morimoto, 1996; Rissler & Elgerot, 1978). However, there are also previous studies that do not show any increase in fatigue during overtime work (Beckers et al., 2004) or even show a decrease in fatigue (Åkerstedt et al., 2004). However, most of these results are based on questionnaire data and between group comparisons. One exception is the study by Rissler and Elgerot (1978) who followed employees at an insurance company during a period of much overtime work. However, there were variations between individuals regarding when the overtime occurred, with some starting earlier or later or worked during the weekend. This makes it harder to interpret whether the increase in sleepiness was due to overtime work per se, or to a lack of recovery during the weekend. In study **II** the increase in sleepiness did not occur until the Friday, when subjects were sleepier through out the whole day. However, we cannot know whether the increase in fatigue and sleepiness is due to the work hours per se or if it is an effect of the shorter sleep and longer time awake.

Overtime work and physiological and psychological stress symptoms

Subjective ratings

In study **II** stress ratings were not increased in connection with overtime work. In some studies overtime work has been shown to be associated with greater symptoms of stress (Ahlberg et al., 2003; Hayashi et al., 1996; Rissler & Elgerot, 1978). However, it is not clear whether this is due to overtime work being the result of high workload or whether it is an effect of work hours per se. In study **II** the workload and work pace were constant and the results indicate that overtime work per se does not affect the subjective ratings of stress. However, interpretation should be made with caution since the workload was relatively moderate in both conditions.

Cortisol

Studies of overtime work and the effects on cortisol are scarce. The cortisol data from study **II** did not show any significant main effect of overtime. However, the interaction effect from the three-way ANOVA and the trend towards an interaction effect in the analysis of the morning values suggest that the overtime week was associated with an increase in the morning value at the end of the week, on the Thursday, This might indicate that working overtime induced higher arousal, which is supported by previous research that has found an association between high arousal and high morning cortisol (Ekstedt et al., 2004). However, since the effect is rather weak, these data should be interpreted with caution. The reasons for the rather weak effect could possibly be that there are individual variations in the cortisol response, such that some individuals reacted with an increase in cortisol whereas others did not. This has been shown to be the case in other studies (**I**). Due to the relatively small size of the present sample it is not possible to explore this issue any further.

Heart rate and blood pressure

The main finding from analyses of the heart rate and blood pressure data in study **II** is that the overtime condition did not show any elevated effects on any of the ambulatory blood pressure (ABP) measurements during either work, after work or during sleep. This contrasts with the findings of Hayashi (1996) who demonstrated that a period of intense overtime work was associated with elevated blood pressure and heart rate. However, in Hayashis' study it is unclear how many hours of overtime were worked on the days when ABP measurements were taken, making comparisons between studies difficult, and stress was clearly present. In the present study the significant interactions between condition and weekday indicated that blood pressure during work was higher at the beginning of the week in the overtime condition, whereas the opposite pattern was shown for the 8-hour week. There were no such effects on workload, work pace or stress ratings. One possible explanation of this interaction might be that the values on the Monday of the overtime condition reflected apprehension at the prospect of working a whole week with 12-hour shifts. The elevated levels on the Thursday in the 8-hour condition could reflect a greater need to get things done before the week is over. However, we have no other data to support these speculations and the significant effects in the blood pressure and heart rate data are rather weak and should be interpreted with caution. Moreover, the lack of information about posture, physical activity and emotional state in connection with the blood pressure recordings makes interpretation of these data ambiguous. It is hard to differentiate an effect of physical activity from psychosocial stressors. However we assume that during work and sleep the participants physical activity levels were somewhat constrained and thus remained relatively constant, whereas activity after work is more likely to vary from day to day. Thus one interpretation of the interaction in the analysis of heart rate after work might be that it was simply due to different levels of physical activation.

Overtime work and the balance of rest and activity

Study **II** showed some indications of an imbalance between rest and activity manifested in shorter sleep times and greater sleepiness by the end of the week. The fact that sleepiness did not show any significant increase until the Friday may indicate an accumulation of sleep debt that did not show until then. Increasing sleepiness may signal that overtime work undertaken under the reported workload and stress levels may not be detrimental to the balance between rest and activity for a period shorter than four days. However, there were also other indications of a drive towards recuperation expressed in greater reported symptoms of irritation, exhaustion, being worn, difficulties thinking and less sufficient recuperation. Although these variables did show a change they were still quite moderate.

There are no studies examining the effects of overtime work on recovery during the weekend. Of the present studies there are indications that the effects of the overtime week do not extend into the weekend (**II**). This may be compared to study **I** in which naturally occurring overtime work (average workday 9h 23 minutes), resulted in negative effects on stress, stress/restlessness at bedtime and sleep durations, which continued into the following weekend. This comparison suggests that moderate overtime work in combination with work-related stress has more negative effects on recuperation during weekends compared to extreme overtime work in the absence of elevated stress and workload. However, apart from the sleep ratings, the data loss in the study **II** was quite large during the weekends and therefore there is a risk of a Type II error.

Individual differences in the cortisol response to work stress

The results from study **I** showed large individual variations in cortisol secretion in response to high stress and workload. Moreover, study **III** demonstrated that there were a group of individuals (group 2) that did not react with elevated cortisol levels in response to stress. Instead they had lower levels as compared to a week with lower work stress. Rose et al (1982) who studied the cortisol response in relation to objective workload among air-traffic controllers demonstrated similar findings. They found a sub sample, which showed decreased levels of cortisol in relation to workload. There follows a discussion of factors that might contribute to the individual differences in cortisol response to stress and also further inspection of cortisol levels and the relation to every day work stress.

Cortisol and fatigue/exhaustion

The results (**III**) showed that group 2, with reduced morning cortisol during the week of stress, showed higher levels of exhaustion/fatigue and stress, as well as a worse work situation. There are a few previous studies that have observed a link between morning cortisol levels and exhaustion. For example, lower morning levels have been observed in subjects with burnout and stress (Pruessner et al., 1999; Rosmond et al., 1998; Yang et al., 2001) and the central characteristic of burnout is exhaustion (Maslach & Jackson, 1981; Melamed et al, 1992). Also chronic fatigue seems related to the suppression of morning cortisol (Nicolson & van Diest, 2000). One might speculate that the higher level of exhaustion in group 2 may be reflected in a flattened cortisol rhythm (low morning values) under levels of high stress, and that a lower stress level might permit normal high amplitude cortisol patterns.

With respect to negative affect or mood there is some support for an association with increased levels of cortisol (Buchanan et al., 1999; Smyth et al., 1998). The same relation has been shown for anxiety (Benjamins et al., 1992; Curtis et al., 1978; Vedhara et al., 2003). But there are also studies that do not support the relationship between negative affect or anxiety and elevated cortisol. For example Van Eck et al (1996) showed no relation between these variables under stress exposure. However, at baseline and after stress exposure, groups with high and low affect differed, with higher levels of cortisol in the group with high negative affect. The authors suggest that it might be more important to determine the differences in current distress than perceived stress in order to understand cortisol secretion, which they see more as measure of chronic distress. Smyth et al (1998) interpret their data on the relation between cortisol and momentarily evaluated stress and negative affect somewhat differently, stating that negative affect might have a mediating role in the relation of stress and cortisol.

From other experimental research it has been shown that the feeling of control over the work situation influences cortisol secretion. Low control is associated with elevated cortisol levels (Henry, 1992; Kunz-Ebrecht et al., 2004; Lundberg & Frankenhaeuser, 1980). It is possible that job control could have played a role in study **III** but data such data were not available.

Workplace characteristics (apart from job control) have received little or no attention in the research of cortisol levels in relation to workload. Objectively high workloads will not necessarily result in a stress reaction in all individuals. Factors such as job control, work time control and social support are known to mediate the stress reactions (Ala-Mursula et al., 2005; Johnson, 1986; Karasek, 1979). When examining the effects of workload in group comparisons it is important to have control of these factors. However, to understand which individual factors determine a cortisol response in relation to high workload it is fruitful to further investigate the role of other mediating factors.

Sleepiness, sleep and cortisol secretion in relation to work stress and overtime work

As demonstrated in study **I** and **II**, manipulation of work hours and workload affected psychological and physiological symptoms of stress, fatigue and recuperation. However, the effects were somewhat different and taken together they reveal some important issues concerning the research on long work hours and work stress. First of all, the results suggest that the length of work hours is not always correlated with the stress reactions. In study **I** subjects worked a moderate amount of overtime whereas the amount of overtime in study **II** was considerably larger. However, the stress levels were higher and there were greater negative effects upon recuperation in study **I**. If one would just compare the different working times in the two studies it would appear that shorter work hours had more severe effects with respect to stress and recuperation. This highlights the importance of controlling for workload and work stress when examining the effects of work hours per se. Secondly, both overtime work and work stress affects sleep, sleepiness and cortisol. However, the effects of work stress and overtime work on these variables differ and they will be discussed separately below. Furthermore, as demonstrated in study **III** there are some concerns when using cortisol as a stress marker. There are large individual variations in cortisol secretion in response to stress and it seems that some individuals will react with a lower cortisol response in relation to higher work stress. This may be important in understanding tolerance of work stress and how it might be related to health.

Comparisons of work stress versus overtime work

Sleep

Sleep might be one of the key factors in the development of stress related diseases in connection with both overtime work and work stress. Results from both studies **I** and **II** showed shorter sleep times in association with increased work stress and overtime. However, it seems that the mechanisms might be somewhat different in the two studies. In study **I** subjects reported more problems with stress/restlessnes at bedtime and also showed a tendency towards elevated cortisol levels during the evening, Whereas study **II** did not show any tendencies towards elevated physiological or psychological stress levels during the evening. Instead the shorter sleep was due to earlier awakenings.

To sum up, the present findings indicate that work stress is related to shorter sleep due to problems unwinding after work. However, the shorter sleep during overtime work was due to anticipation stress or an active strategy to wake up earlier. It is possible that overtime work in combination with a high workload and stress would result in shorter sleep due to a combination of problems unwinding and earlier awakenings due to anticipation stress.

Sleepiness and symptoms of fatigue

An alteration in sleepiness has been shown in relation to both work stresss (**I**) and overtime work (**II**). Regarding the former, the average levels of sleepiness during the high stress week were elevated mainly during the afternoon and the evening. An elevation of sleepiness in the overtime week was not observed until the end of the week, on the Friday. On that day sleepiness was higher throughout the whole day. Very few studies have examined the diurnal variation in sleepiness in relation to work stress and overtime work. However, Soderstrom et al (2004) showed an elevation in the diurnal ratings of sleepiness among young people with high burnout scores, especially in the morning. Sleepiness signals a need for sleep, which in turn is determined by previous sleep length and quality, as well as the level of activity (e.g. high work load and demands). Results from study **I** and **II** showed a decreased sleep length but the stress levels were considerably higher in study **I** (figure 7). This might explain the elevated levels of sleepiness in the afternoon during the week with high work stress as compared to the week with overtime work. One possibility is that if the overtime work took place under a period of higher work stress, sleepiness levels would increase considerably.

Although overtime work did not have any great effects on sleepiness, subjects reported greater symptoms of fatigue during the overtime week. Fatigue might in this context be a sign of a weariness from work and can be viewed as a state that protects the individual from overwork (Piper, 1986). But it is also highly plausible that the shorter sleep legnth contributes to the increased fatigue (**II**). However, the concepts of fatigue and sleepiness are not always clearly defined and it is not obvious whether they are separate phenomena or expressions of variations on the same continium.

Stress - subjective ratings

By inspection of figure 7 it becomes evident that the highest ratings of subjective stress occured during the week with high stress and workload in study **I**. Even the ratings in the week with lower stress and work load in study **I** are slightly higher than the ratings in any of the conditions in study **II**. These results suggests that overtime work, without extra workload, is not associated with the same stress levels as work during a period with high workload.

Stress – cortisol

The differences in ratings of stress between studies **I** and **II** were also reflected in the patterns of cortisol secretion with no differences during overtime but a more flattened pattern during high work stress. This suggests that overtime work without higher workload is neither associated with lack of changes in subjective stress nor in cortisol secretion.

Work stress, overtime work in relation to the balance between rest and activity

One week with relatively high workload and work stress was associated with elevated stress and impaired recuperation between workdays and also during the following weekend (**I**). However, overtime work showed only fairly moderate effects on recuperation between workdays and no effect during the weekend (**II**).

In study **I** subjects had both less free time (i.e. less time for unwinding and relaxation) and a higher arousal during the afternoon and evening. Both these factors are likely to contribute to sleep disturbances and consequently an imbalance between rest and activity. Furthermore study **I** implies that after one week with high work load and stress a regular weekend break with two days off might not be enough. The lack of effects during the weekend in relation to overtime work (**II**) implies that the weekend effect is related to work stress than work hours per se.

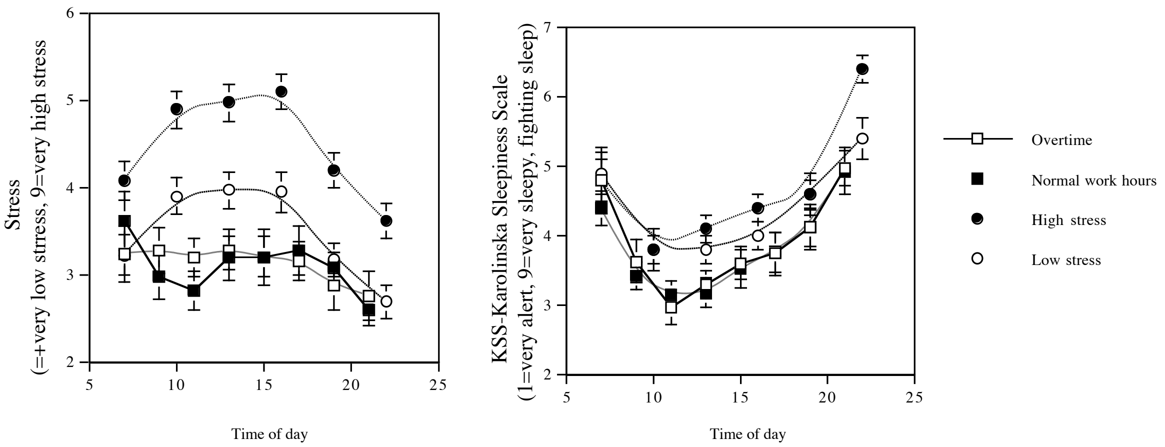

Figure 7. Means and standard errors of the means for stress (left) and sleepiness (right) during the day in each condition for study **I** and **II**.

Individual differences in physiological markers of stress

The ability to endure stress varies between individuals and some may develop stress related diseases from stressful work conditions. However, the mechanisms behind these individual differences are not fully understood. It is thought that stress hormones such as cortisol may play an important role in the development of ill health. Cortisol has been shown to be closely related to the immune system in a bidirectional fashion (McEwen & Seeman, 1999). In the present studies, large individual differences in cortisol secretion were shown in relation to work stress (**I**) and overtime respectively (**II**). The further examination of individual differences reported in study **III** indicated that fatigue and exhaustion might be associated with reduced cortisol response during stress. This might indicate differences in tolerance to stress. It would be of interest to examine if a similar difference exists in tolerance to overtime work. However, the study in the present thesis (**II**) did not have enough participants to explore this issue any further.

The work-home balance during work stress and overtime work

Previous research has shown that overtime work is associated with increased conflict between work and family life (Jansen et al., 2003). Study **II** showed that participants cut down on time spent on household work, time for themselves and time socialising with others. However, there are some limitations in the generelasisability of these results due to the characteristics of the present study group. There were only 4 participants that had children and none had children of less than 7 years of age. One could expect that people with small children and greater family responsibilities would find it harder to cut down on household work. They might instead be tempted to cut down on sleep.

Work stress and workload have also been shown to be related to work-home interference (Krantz et al., 2005) but no differences in time spent on different activities were observed in study **I**. However, only measuring the time spent on different activities does not capture how much effort is required to perform those activities. It is possible that after a workday with high workload and stress there is less energy left over for free time activities. The higher ratings of sleepiness during the evening in study **I** implies that such an effect might have been present.

Work time control and stress and overtime work

Work time control was not measured in any of the studies in the present thesis. However, it is worth noticing that a large proportion of the subjects in the stuies **I-III** could control their own work hours. This might have influenced the results to some extent. Ala-Mursula et al (2004) showed that a greater level of work time control moderated the level of sickness absence in association with high stress (2005). It is possible that the subjects in study **I** managed to cope with the increase in stress and workload better than they would have done if they had not had the possibility to influence their own working times. This may limit the generelasisability of the results to other groups that have less possiblity to influence their work hours. There are a few studies that have looked upon the ability to control ones working hours in relation to overtime work. Findings indicate that the negative effects of overtime work in combination with low rewards is exaberated if the employees are pressured to work overtime by supervisors (Van Der Hulst & Geurts, 2001). Furthermore, among train drivers a high pressure to work overtime in combination with low support was shown to be associated with a positive relationship between weekly hours and physical health symptoms (Tucker & Rutherford, 2005). In study **II** subjects who were used to being able to influence their working times were asked to keep the start and end times of the working day constant during the experimental weeks. This might have caused extra stress for the subjects and also lead to a less naturalistic setting of the study.

Limits and weaknesses

There are some general limits and weaknesses that concern all three studies in the thesis. First of all the number of participants is relatively small which increases the risk for type II error. It is therefore possible that effects were not detected due to the small sample size. Another problem related to the small sample size is the increased risk of our samples being unique by chance, and thereby is the possibilities to generalize the results to other populations lower. Moreover, the small sample size does attenuate the statistical power, i.e. the study increases the risk of not having the precision that is needed in order to obtain reliable results.

In both study **I** and **II** there was approximately a 50% response rate to the first invitation to participate in the study. The reasons for not participating have already been described in the method section. However, it could be argued that we should have done an analyze of the drop-outs. However, the intra-individual design of the studies means that the relatively low response rate is less of a problem.

Furthermore, it is not possible to draw any conclusions on long term effects of either high work stress or overtime work since the present studies followed the participants for only one week of exposure.

Another limitation is the lack of information regarding non-occupational stressors. However, there are no reasons to suspect that there would be any systematic difference in the occurrence of such non-occupational differences. Nevertheless, the relationship between occupational and non-occupational stressors are of great interest for further research and might explain why some individuals handle high workload or long hours better than others.

The lack of polysomnographic measures of sleep restricted the possibilities to draw conclusions on sleep. Thus, we do not know if there was any alterations in sleep architecture or effects on micro arousals.

A methodological issue concerns the use of the stress scale, which was inspired by the work of Kjellberg and Iwanowski (1989). The original validated scale was modified in order to suit the use of several ratings throughout the day. This modified version of the scale lacks validation studies. It is therefore possible that it does not measure stress in an adequate way. However, other variables that also measures stress showed the same variation as the stress scale, suggesting that the scale is a reliable and sensitive instrument for variations in psychological stress.

Another methodological weakness of studies **I-III** concerns the timing of saliva samples for measurement of cortisol. Since cortisol has such strong circadian variation it is crucial that subjects gives samples at the instructed time points. However, we do not have any indication on how rigorously they followed this instruction. This weakness may also refer to the diary ratings. Thus, we do not know if the participants filled in the questions according to the instructions, i.e. several times during the day.

Apart from these weaknesses and limitations there are some more specific related to each of the studies. There follows a discussion of studies **I-III**.

Study I

We cannot be sure that the rated stress was work related. It is possible that there were other things outside of work that caused a higher stress response. One major limitation of study **I** is that we do not have any information about this. However, the subjects were asked to identify weeks in which they would be likely to have a high workload and it therefore seems reasonable to assume that the higher stress ratings are related to the more strenuous work situation.

It should be emphasized that in study **I** subjects under *constant* high pressure were excluded from these analyses since the purpose was to study intra-individual short-term variation. 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 intra-individual study, spanning up to years of stress, alternating with periods of normal load.

The majority of the participants probably could control their own hours, which might have reduced the adverse effect of work stress. However, it would have been a strength if working time control was properly measured.

Study II

Study **II** suffers from some limitations that may diminish the effects of the overtime week. Since the participants could choose the weeks in which to participate, it is feasible that they selected weeks with no major commitments during their free time. In addition, the participants had only moderate family responsibilities. It is possible that the work-home balance was less disturbed than it would have been in another group with greater family responsibilities.

Furthermore, there is a possibility that some effects of fatigue were masked by the increase in coffee consumption. Fatigue symptoms might have been greater in the overtime week if coffee intake had been held constant between conditions. Any of these effects could have confounded the comparison between conditions. Thus, results from study **II** may therefore constitute underestimations.

Generalisation of the results from study **II** is also limited to situations with a moderate workload. The perceived workload in both conditions was relatively moderate and we do not know what the effects would have been in a more demanding work situation.

It could be argued that the lack of objective measures of workload or the amount of work carried out by the participants' limits the findings in study **II**. Instead the participants' perception of workload and work pace was measured. Since there were no differences in the ratings of these two we assume that the work demands experienced by participants did not differ. Hence we achieved our objective of controlling for what in previous studies has been a confounder, i.e. overtime work has been associated with increased work demands. However, objective measures of workload and work performance would have made it possible to ensure that the subjective ratings were valid.

Study III

The grouping criterion in study **III** was applied to the morning values of cortisol since this seems to be a reliable marker of the reactivity of the HPA- axis (Schmidt-Reinwald et al., 1999). This has been used in several other studies as a marker of cortisol response to various stressors (for overview see Clow et al (2004)). The minimum difference between conditions was set to 1 nmol/l, but it is possible that larger differences are needed to discover factors influencing morning levels.

Another weakness concerns the extent to which subjects followed the instructions. Kudielka et al (2003) showed that a significant number of subjects did not follow instructions, and that the non-compliant subjects did not show as strong increase in morning values of cortisol as compliant subjects. We do not, however, have any information of whether the current study suffers from these problems.

Study **III** also suffers from lack of information regarding moderating factors such as the level of control over the work situation. The level of job control might explain the difference in cortisol response to stress. However, no information on job control was obtained in study **III**.

Implications

The results of studies **I -III** indicate that an increased need for recuperation, sleep problems, symptoms of fatigue and sleepiness may be a sign of a need for recovery. The results of study **I** suggest not only that the need for recovery is increased during a period of high workload and stress, but also that recovery might be impaired. This might lead to transient insomnia and, possibly, chronic insomnia in the long run. It is therefore of importance to be vigilant of symptoms of impaired recovery between workdays. Furthermore, results indicate that a week of high workload and stress should be followed by at least two days off (**I**); the results also imply that even longer time might be needed in order to reach baseline levels in stress and sleepiness. However, little is known about recuperation during weekends or vacation.

The results (**I**) imply that during high work stress, sleepiness occurs during the afternoon and evening. This might be something to take into consideration with respect to health and safety when designing work schedules for jobs with high workload. The results imply that long work hours or overtime work should be avoided when the workload is high, and that there should be scheduled brakes in the afternoon in order to prevent sleepiness and thereby promote sustained performance. Furthermore, fatigue and exhaustion may be related to individual differences in the cortisol response to stress (**III**), which have implications for future research, when using cortisol as a stress marker. Cortisol measures should be used in combination with subjective ratings of stress and fatigue, preferably in a within subject design.

With respect to overtime work the results (**II**) do not show any major disadvantages as long as the workload and work stress are not too high. However, it is hard to quantify the optimal amount of workload for long work hours since there are individual variations in the ability to cope with a high work load. Furthermore, previous studies indicate that factors other than workload per se influence work stress, such as control and social support (Tucker & Rutherford, 2005; Van Der Hulst & Geurts, 2001).

Conclusions

In conclusion, the results (**I**) demonstrated that a week with higher workload and stress affects physiological stress markers such as cortisol, and is associated with increased sleepiness and problems of unwinding at bedtime, shorter sleep duration and longer work hours. Furthermore overtime work (**II**), when having a rather low workload, was shown to be associated with modest effects on physiological markers of arousal. More pronounced effects were found on sleep and fatigue, with greater problems during overtime work. Study **III** indicated that the individual differences in cortisol response to stress maybe related to fatigue and exhaustion.

The thesis demonstrates that both work stress (**I**) and overtime work (**II**) impairs the quality of recuperation, although overtime work produced somewhat weaker effects. However, the results imply that it is possible that the balance between anabolic and catabolic processes are disturbed, which may lead to negative consequences for health. It may well be that the quality of recuperation is critical in determining whether work stress or overtime work will have negative health effects or not. One symptom of a disturbed balance between anabolic and catabolic processes is fatigue and sleepiness. Fatigue may also be related to individual differences in cortisol (**III**).

Further studies are needed to fully understand the relationship between stress, recuperation and health. In order to fully understand how the effects of overtime work are related to work demands it would be preferable to manipulate both work hours and workload. In study **I** there was a natural occurrence of moderate overtime work and results indicated negative effects upon sleepiness, sleep, stress and physiological stress markers. Similar effects have been shown in other studies of overtime work, whereas study **II** failed to show negative effects on stress related variables. If it is the demanding work situation per se that gives rise to negative effects, it might not be enough to limit the amount of overtime work or length of work hours in order to promote health. Instead it might be more fruitful to focus on the work hours in combination with the work situation. However, the results from the current studies imply that long work hours alone are associated with negative effects on variables related to fatigue and recuperation. These negative effects may diminish people's abilities to cope with a more stressful work situation. Nevertheless, these results are a step in the exploration of the relationship between work hours, workload and stress. More research is needed to fully understand how work hours interact with other factors such as work characteristics, workload, stress and life outside of work. This is of great importance in order to help employers to optimise work hours with regard their impact on workers health and safety.

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