Rydstedt, L.W., Cropley, M., Devereux, J.J., & Michalianou, G. (2008). The Relationships between Long-term job strain and Morning and evening saliva cortisol secretion among white-collar workers. *Journal of Occupational Health Psychology*, 13, 105-113.

The Relationships between Long-term Job Strain and Morning and Evening Saliva Cortisol
Secretion among White-Collar Workers

Leif W. Rydstedt*

University West

Mark Cropley

Jason J. Devereux

Georgia Michalianou

University of Surrey

*Corresponding author: University West, IS-AOP, 461 86 Trollhättan, Sweden;

leif.rydstedt@hv.se

The study objective was to assess long-term job strain impact on morning and evening saliva cortisol secretion. In all 77 white-collar workers (31% females; sample mean age = 42 years) volunteered to sample morning (immediately after waking up) and evening (10 pm) saliva cortisol for seven consecutive days. By median split on aggregated self-reported job strain from three consecutive questionnaires distributed over a period of about 3.5 years the participants were classified into a high or low long-term strain condition. Regardless of strain condition morning saliva cortisol was significantly reduced from the work to the weekend measures. While chronic job strain did not effect morning saliva cortisol secretion, evening cortisol secretion was significantly elevated for participants in the long-term high job strain condition over all the week. Evening saliva cortisol secretion showed no significant weekday variation. The present findings offer further support for the suggested link between long-term distress and elevated evening cortisol secretion.

Key words: Chronic Job Strain, Morning Saliva Cortisol, Evening Saliva Cortisol

Work related stress has been defined as the emotional and psycho-physiological reactions to adverse and noxious aspects of work, work environments and work organisations. It is a state characterised by high levels of arousal and distress (The Advisory Committee for Safety, Hygiene and Health Protection at Work, 1997). The negative effects of work stress are well documented and have been linked to a variety of mental and physical health problems (e.g. Ganster, Fox & Dwyer, 2001; Marmot, Siegrist, Theorell & Feeney, 1999; Steptoe, Cropley, Griffith & Kirschbaum, 2000). It is assumed that these damaging health effects are brought about by prolonged stress exposure. Brosschot, Pieper & Thayer (2005, p.1043-44) conclude that *“a major part of this influence is caused by prolonged physiological activity due to stressors, and not or not alone the activity during stressors.”* The purpose of the present study is to analyse the long-term effects of job strain on what has been identified as a key psycho-physiological component in the stress process, i.e., reactivity and recovery of cortisol secretion.

A conceptual model to predict job strain and work-related health outcome

Peter and Siegrist (1997) claim that the increased awareness the potential impact of work stress on health and well-being has led to an intense conceptual and theoretical development along with empirical validation studies. One of the most prominent conceptual models for the study of health consequences of work stress is the Demand-Control-Support (DC(S)) Model (Karasek, 1979; Karasek, Brisson, Kawakami, Houtman, Bongers & Amick, 1998; Karasek & Theorell, 1990). The DCS model comprises three dimensions of psychosocial working conditions. Psychosocial work demand relates to how hard and intense the job holder has to work and includes for example time pressure and quantitative workload. Control or decision latitude comprises two distinct but closely related components. Task authority reflects the scope of the job holder's authority to make decisions at work while skill

discretion relates to the level and variety of the skill required for the work tasks and the long-term possibilities to acquire new skills in the work role. The third dimension, work-related social support, refers to emotional and instrumental support from colleagues and immediate superiors. The (iso-)strain hypothesis derived by the model claims that adverse long-term psychosocial working conditions, that is high psychosocial demands in combination with low control opportunities (and low social support), will reduce the job holder's self-efficacy and cause high psycho-physiological strain, which in turn will exert a negative impact on health, possibly mediated through neuropsychological pathways (Frankenhaeuser and Johansson, 1986; Karasek and colleagues, 1990; 1998).

By exclusively reviewing longitudinal studies based on the DC(S) model, with a large range of health and well-being outcome measures, de Lange, Taris, Kompier, Houtman and Bongers (2003) concluded that there was good evidence for longitudinal causal main effects between the psychosocial working conditions included in the DC(S) model and health and well-being outcomes, especially for self-reported outcomes. On the other hand, the (iso-)strain hypothesis received a more inconsistent empirical support (de Lange et al., 2003).

Psychoneuroendocrinal mechanisms in the stress process

The two major psychoneuroendocrine systems that constitute the main components of physiological stress response are the sympathetic adrenal-medullary system (SAM) regulating the secretion of the catecholeamines adrenaline and noradrenaline - and the hypothalamic pituitary adrenal-cortical (HPA) system controlling cortisol secretion (e.g. Kristenson, Eriksen, Sluiter, Starke & Ursin, 2004). The catecholeamines respond immediately to acute stress exposure and prepares the organism for the "fight-or-flight" response.

Cortisol secretion is associated with increased energy release and with suppression of the inflammatory response and immune response, and one of its most important functions is

to protect the organism against its own self-defence systems (Kristenson et al., 2004). Baum and Grunberg (1995) described cortisol reactivity to stressors as somewhat inconsistent and more difficult to interpret compared to the catecholeamines. The HPA system follows a clear circadian rhythm with highest levels in the early morning and continuous decrease over course of the day to reach its nadir in the late evening around 10 pm (e.g. Kirschbaum & Hellhammer, 1989; Kudielka, Schrommer, Hellhammer & Kirschbaum, 2004).

Cortisol secretion has been found to increase in novel and unfamiliar situations that evoke feelings of uncertainty, anxiety or negative experiences (van Eck and colleagues, 1994; 1996; Kirschbaum & Hellhammer, 1989; Preussner, Hellhammer & Kirschbaum, 1999; Steptoe, Cropley, Griffith and Kirschbaum, 2000). In the same way, Lindfors and Lundberg (2002) found that persons with high psychological well-being had significantly lower saliva cortisol secretion than persons with low psychological well-being. Negative Affect, neuroticism, rumination and emotional inhibition have been associated with increased cortisol secretion as well as with delayed recovery after stress exposure (van Eck, Berkhof, Nicholson & Sulon, 1996; Roger & Narajan, 1998).

Linking mechanisms between work stress and psycho-physiological arousal

Cognitive activation theory (e.g. Ursin and Eriksen, 2004) provides a link between work stress, cognitive activation and psycho-physiological arousal. Stress is defined as physiological alarm in a homeostatic system and occurs when there is something missing or when the organism perceives a discrepancy between “what should be and what is”. Despite the physiological definition of the stress response, the cognitive appraisal of a potential stressor by the individual is given a central role in the theory. When the individual perceives an imbalance of the type described above the physiological stress response is triggered off

which puts the organism in a state of arousal. In the short term this state of arousal is part of an adaptive general alarm system whereas sustained periods of arousal have been associated with potentially harmful consequences (De Croon, 2002; Ursin & Eriksen, 2004). Kristenson et al, (2004) suggest cognitive activation to be affected by the individual's expectancies of the coping outcomes, learned over the life cycle and that negative expectancies tend to be associated with increased or maladaptive psycho-physiological arousal which in turn may be a predictor of long-term ill-health.

Stress and circadian cortisol secretion pattern

Some studies have reported an association between job strain and elevated morning cortisol secretion (e.g. Steptoe et al., 2000; Schultz, Kirschbaum, Preussner, & Hellhammer, 1998; Sluiter and colleagues, 1998; 2001). In a study of full-time working females, Lundberg and Hellström (2002) found a strong significant association between morning saliva cortisol secretion and the amount of overtime worked during the last year. They claimed morning salivary cortisol was a reliable indicator of work-related stress and suggested that it could be used to guide work site interventions aiming to reduce work-related stress. In their study of long-distance coach drivers working three day shifts, with prolonged work hours on shuttle trips, Sluiter, van der Beek, & Frings-Dresen (1998) found elevated urinary cortisol secretion during all the working days compared to baseline and the two days off after the shuttle trip. They also found a "fatigue debt" in cortisol secretion during the days off after the trip, manifested in a slightly distorted circadian rhythm, with later peak secretion due to prolonged sleep on the work-free days. In a recent study Chandola, Brunner and Marmot (2006) found chronic work stress over an extended period to predict metabolic syndrome, a cluster of risk factors which also embraces elevated cortisol secretion.

Cortisol secretion is normally at its lowest in late evening. Aardal-Eriksson, Eriksson and Thorell (2001) suggest that reliable differences between stress groups can be observed when measures of cortisol are taken at 10 pm. In a sample of long-term unemployed individuals Grossi, Perski, Lundberg and Soares (2001) found elevated evening salivary cortisol secretion among females, but not males, who reported financial strain, compared to financially unaffected participants. On the other hand, Dahlgren and colleagues (2004) found that while some of their participants reacted with increased cortisol secretion during periods of high work stress compared to a low stress period, others reacted with lowered cortisol secretion under same condition. Siegrist, Klein and Voigt (1997) found healthy middle-aged men with chronic high work stress to show reduced cortisol reactivity when exposed to a mental stressor under experimental conditions. Some studies have also reported high burnout scores to be associated with lowered morning saliva cortisol (Morgan, Cho, Hazlett, Coric & Morgan, 2002; Preussner, Hellhammer, & Kirschbaum, 1999).

Comparing healthy subjects who had been involved in a traumatic event Aardal-Eriksson et al. (2001) found those scoring high on the Impact of Event Score had consistently higher concentrations of evening saliva cortisol (10 pm) over a nine months period following the event and evening salivary cortisol correlated to several indicators of mental distress. At the same time the highly impacted participants showed significantly lower morning saliva cortisol concentrations compared to less impacted. In a sample of rescue workers Aardal-Eriksson, Eriksson, Holm and Lundin (1999) found salivary cortisol concentrations at 10 pm to be correlated to anxiety, depression and posttraumatic symptoms. Based on these findings Aardal-Eriksson et al. (2001) concluded that exposure to a traumatic event may be associated by an imbalance in the HPA axis. Furthermore their studies indicated evening cortisol to be sensitive to prolonged psychological distress (Aardal-Eriksson et al., 1999; 2001). Among soldiers scoring high on a burnout inventory Morgan et al., (2002) found a flattening diurnal

variation with reduced morning and significantly elevated evening cortisol, a pattern which these authors claim to have been found among patients suffering from chronic stress. Similarly, Dahlgren and colleagues (2005) suggested the flattened cortisol rhythm during high stress conditions at work for a group of office workers might be caused by a generally higher level of exhaustion. Reduced rather than increased cortisol secretion in relation to stress exposure, so called hypocortisolism has been found mainly in groups exposed to traumatic stress but has also been reported in association with e.g. healthy individuals living under chronic stress or patients with stress-related disorders (Heim, Ehler & Hellhammer, 2000) as well as among children under problematic conditions (Gunnar & Vazquez, 2001). The contradictory findings on cortisol reactivity to stress exposure have been described as a challenge to research and have so far not gained a full explanation (Gunnar & Vazquez, 2001; Heim et al., 2000; Kristenson et al., 2004).

Reactivity and recovery in the stress process

Reactivity refers to the change in a parameter from its baseline value following exposure to a stressor (Linden, Earle, Gerin, & Christenfeld, 1997). Recovery was defined by the same authors *“as the post-stress rest period that provides information about the degree to which the reactivity in the physiological and psychological parameters measured persists after the stressor has ended”* (Linden et al., 1997, p.117). In a more general sense, recovery can also refer to the work-rest ratio (Sluiter, 1999a). The process of recovery from stress exposure is of central interest in contemporary research and it is commonly thought that speed and completeness of recovery may be as important in the aetiology of disease and illness as the acute reactivity in response to the stress exposure (e.g. Bosschot et al., 2005; Linden et al., 1997; Lundberg, 2003). Unwinding following stress exposure is necessary for the physical

and psychological recovery process and persistent failure to unwind is thought to be detrimental to health because it wears down the body's physiological restorative system (McEwen, 1998).

Studies by Sluiter and colleagues (1998, 2000; 2001) have shown high job demands to be associated with higher subjective need for recovery as well with elevated cortisol secretion. Sluiter et al. (2001) also showed cortisol reactivity during work as well as cortisol recovery after work to be predictive of subjective health complaints. Depending on the time span and the completeness of the recovery process, Sluiter et al. (2000) distinguish between four categories of recovery. This study is aiming at meta-recovery, the period to recover from task performance that occurs between two periods of work and allowed a detailed assessment of the meta-recovery period after the working week (Sluiter et al., 2000). High levels of job strain have been associated with impaired recovery. In one study, for example, school teachers had their blood pressure monitored throughout the working day, and evening using ambulatory blood pressure equipment. It was found that systolic and diastolic blood pressure did not differ between high and low strain teachers over the working day, but decreased to a greater extent in the evening in individuals reporting low job strain (Steptoe, Cropley & Joeke, 1999)

Although several studies indicate a relationship between job strain and cortisol reactivity, these studies have often been covering much shorter time spans than the present study. The objective of this study was to assess how long-term job strain impacts upon psycho-physiological recovery, here defined as the recurrence to the rest (weekend) value in saliva cortisol secretion. We hypothesise that:

1. Cortisol secretion will be reduced by the transition from work to the weekend

2. Morning as well evening saliva cortisol secretion will be more affected for participants in the chronic high job strain condition compared to participants in the chronic low job strain condition

METHOD

Participants

The participants were ‘white collar’ workers from six organizations across England who had previously participated in a longitudinal epidemiological study on stress and musculoskeletal disorders (Stress and MSD) (Devereux et al., 2004). The Stress and MSD study collected extensive longitudinal data on working conditions, strain reactions and a number of personality traits 3-4 years previously. In the present study letters were sent to 561 potential volunteers inviting them to participate in a study of work rumination and job strain. Eighty-one persons had left their previous jobs and were therefore no longer actual, 56 persons explicitly refused to participate, while 330 persons did not respond to either the initial letter or the reminder. To minimise non-compliance to the instructions for data collection no further efforts were made to involve the non-respondents in the study.

In all 81 people agreed to take part in the study. Four persons were excluded from the study - two failed to complete the saliva sampling and one person was found to have been misclassified in regard to occupational status. Finally, by the diary entries it became clear that one participant had completely misunderstood the procedural instructions for saliva sampling (see below). The final sample thus consisted of 77 persons working in health care, government, technology or consultancy. In all 53 (69%) males and 24 (31%) females participated, ranging in age from 22 to 59 years, with a mean age of 42 years (Sd. 9.21). In terms of occupational classification the majority of the participants (55%) worked in professional occupations, one out of four (25%) were classified semi-professionals, 10% held

managerial positions while the remaining 10% worked in secretarial/administrative professions.

A comparison between the participants in the study and non-participants in the sampling pool revealed that there were no significant differences in age nor were there any differences in perceived job demands, control, social support or negative affect (NA) at baseline. The proportion of females differed significantly ($\chi^2=8.65$, df 1, $P<.01$) between the participating group (31%) and the sample pool (48%).

Independent variables and study condition

The participants were classified into the low or high long-term job strain condition by their perceived job strain assessed using a slightly revised version of the Job Content Questionnaire (JCQ) (Stansfeld, Head & Marmot, 2000) on three different occasions. The first had been completed 3-4 years previously while the third questionnaire was distributed in connection to the field data collection. Demands were measured by four items with an alpha coefficient of 0.66. Work-related control was measured by 16 items with an alpha coefficient of 0.87, ten of which assessed decision authority in the work situation and six items measured skill variety. Work-related social support was measured by seven items with an alpha coefficient of 0.79. Each dimension of the JCQ was finally coded so that a lower value meant a higher psychosocial exposure, and these measures from the three questionnaires were aggregated to a single scale. For the classification into job strain exposure conditions the aggregated measures of demands, control and support from all three occasions was dichotomised at the median.

The high job strain group consisted of 38 persons, 26 (68%) males and 12 (32%) females, with a mean age of 43.7 years. The low job strain group consisted of 39 persons, 27 (69%) males and 12 (31%) females, with a mean age of 40.4 years, the demographical background characteristics were thus fairly similar for the two study conditions. For all the

nine separate job content scales used for grouping to chronic strain condition, t-test showed that the participants in the chronic high strain condition were significantly more exposed to adverse psychosocial working conditions than those in the chronic low strain condition ($p < .001$ for all nine scales)..

Procedure

Each individual was contacted by telephone and/or e-mail and meetings with a research assistant were arranged at the respondents' place of work. At the meetings each participant was given a paper questionnaire, a 7 day paper diary, fourteen saliva collection tubes and instructions on how to use the research materials. After seven days the materials were collected by hand by the research assistant.

Psycho-physiological measures

Saliva cortisol secretion was used as an indicator of psycho-physiological reactivity and measured over seven consecutive days to include a full working week as well as the weekend. Two measures were taken each day: one in the morning and one during the evening. Saliva samples were collected with salivettes, plastic vitals containing small cotton dental rolls. Participants were asked to place the cotton roll in their mouth until it was saturated with saliva. They were instructed to collect their saliva before bedtime at 10 pm and immediately after waking. The time of going to bed, the time of waking and the exact time of every saliva sampling was recorded in the diaries. Participants were instructed not to brush their teeth or drink tea, coffee, or caffeinated beverages before the morning saliva sampling and were also instructed not to consume alcohol or citrus drinks one hour before the evening saliva sampling. They stored their samples in a re-sealable plastic bag in the freezer compartment of their home refrigerator. The samples were then collected and stored at -20°C (-13°F) until

transported and assayed in the laboratory at Technical University Dresden, Germany. As recommended in the literature (Dressendörfer, et al. 1992), cortisol readings three standard deviations or more away from the group mean were considered as outlying and replaced with the individual mean for the work week readings in accordance with standard protocol.

Data analyses

For the present study Analysis of Variance (ANOVA) with a mixed design was used where chronic job strain was used as “between subjects” condition, and the week cycle, categorized in two levels (aggregated work days and weekend respectively) constituted the “within subjects” conditions. The interaction between “strain condition” and weekday was also analyzed. Morning and evening cortisol readings were analyzed parallel. SPSS version 14.0 (GLM with repeated measures) was used for the statistical analyses.

RESULTS

INSERT TABLE 1 ABOUT HERE

In Table 1 the mean values of the morning and evening cortisol readings for the low and high job strain groups are presented for the aggregated working days and weekend respectively. As shown in Table 1 there was a considerable drop in morning saliva cortisol secretion between workdays and weekend, regardless of strain condition. This shown by the highly significant within subjects morning measure ($df\ 1,75$; $F=46.0$; $p<.001$) in Table 2. The within subjects analysis for evening cortisol secretion was not significant, thus no recovery in evening cortisol from work to leisure was found. Neither were there any significant interaction effects, for either morning or evening saliva cortisol secretion, between the week cycle and chronic job strain conditions.

INSERT TABLE 2 ABOUT HERE

The results of the ANOVA for morning and evening cortisol secretion over the week cycle for chronic low and high job strain groups is presented in Table 2. There were no significant differences in morning cortisol secretion between the strain conditions. However chronic job strain significantly affected the evening measures ($df\ 1/75$; $F=4.28$; $p<.05$) where participants in the chronic high job strain condition had consistently higher mean levels of evening saliva cortisol secretion than participants in the low strain condition, during work days (2.24 and 1.81 nmol/l respectively) as well as during the weekend (2.14 and 1.71 nmol/l respectively).

DISCUSSION

The empirical findings in the present study gave a somewhat mixed support for the suggested hypotheses. The sharp drop of morning saliva cortisol from the working days to the work-free days of the weekend supported the first hypothesis and firmly indicates morning cortisol to be strongly affected by ongoing workload. On the other hand, and contrary to our expectations, the drop in morning cortisol secretion from work to weekend was almost identical regardless of chronic strain condition. Most of the positive findings between job strain and morning cortisol secretion have been reported from cross-sectional studies or studies with a considerably shorter time span between exposure and outcome measures than in the present study. Relatively little is known about the long-term relationship between job strain and morning saliva reactivity and a possible explanation for the failed findings may be that increased morning cortisol reactivity is influenced more by immediate than by chronic strain exposure. As mentioned, the findings reported on the relationship between stress and morning cortisol have been somewhat contradictory and a possible conclusion from this study is that morning cortisol may be more affected by e.g. daily assessed specific job strain changes, Type A behaviour, rumination or sleep quality rather than by chronic strain.

In contrast to morning cortisol secretion the evening cortisol readings were stable over the week and did not change by any significant degree between workdays and days off, which

indicates that evening cortisol may be less sensitive to ongoing stressor exposure. On the other hand, evening cortisol secretion was found to be significantly affected by chronic job strain. This result is in concordance with the findings by Dahlgren et al. (2005), where evening cortisol was shown to be affected by work stress, and by Morgan et al. (2002) where evening saliva cortisol secretion was found to be related to long-term burnout reactions among military personnel. Furthermore, based on their findings on reactivity to traumatic events Aardal-Eriksson and colleagues (1999; 2001) suggest elevated evening cortisol to be an indicator of the long-term stress process. The study by Aardal-Eriksson et al. (2001) covered a period of nine months while the period in the present study covered a period of almost 4 years between the baseline questionnaire and the cortisol readings and thus further adds evidence to the suggested long-term relationship between stress exposure and evening cortisol reactivity. To conclude, the findings from this study suggest that morning and evening cortisol secretion may be indicative of different types of stress exposure or stress processes. Possible differences in the pathways between immediate and chronic stress exposure and reactivity ought to be of high priority for future research in the field.

In regard to the recovery patterns from work to leisure there was also a marked difference. While morning saliva cortisol secretion dropped markedly at the first day off and remained stable over the weekend, evening cortisol secretion remained unaffected by the transition from work to leisure, which seems to further support the suggested differential pathways between exposure and reactivity for morning and evening cortisol secretion.

There were a number of limitations to the study. Due to a high number of non-respondents to our invitation to participate in the study, and a high attrition of our baseline sample, we recruited less than the 100 intended participants. This meant that we could not fully implement our intended research design, that initially was to select only participants in the highest or lowest baseline job strain quartiles and to gender and age-match participants for

the strain conditions. This of course reduced the power of the study. On the other hand since age, perceived working conditions and baseline NA did not differ between the sample and the sample pool there is no reason to assume that our sample was biased in any crucial way.

A problem with studies that collect field data is the lack of control for when samples are taken and this may have interfered with the within-subjects drop in morning cortisol at the weekend. Some participants took readings when they awoke from sleep, which may have been different to their regular time during the week. Considering the diurnal pattern of cortisol this may to some extent have inflated the work days-off difference in morning cortisol secretion. Since the participants were instructed to take the evening sample at 10 pm regardless of bedtime there is probably less of a risk that their diurnal pattern interfered with the measures. But even though the within measures, that is the difference between work and weekend cortisol secretion may have been influenced by non-compliance to the instruction, there seems to be less of a risk that this may have affected the elevated evening cortisol differences due to the chronic job strain condition.

Despite these study limitations no other study to our knowledge has been conducted with such a long follow-up between job strain and cortisol outcomes (morning and evening) over a full week cycle. This study will contribute to the debate concerning the recovery process from stressful exposure to working conditions, and has also identified important areas for further research.

REFERENCES

Aardal-Eriksson, E., Eriksson, T. E., Holm, A-C., & Lundin, T. (1999). Salivary cortisol and serum prolactin in relation to stress rating scales in a group of rescue workers. *Biological Psychiatry*, 46, 850-855.

Aardal-Eriksson, E., Eriksson, T.E., & Thorell, L.H. (2001). Salivary cortisol, post-traumatic stress symptoms, and general health in the acute phase and during 9-month follow-up. *Biological Psychiatry*, 15, 986-993.

Baum, A., & Grunberg, N. (1995). Measurement of stress hormones. In S. Cohen, R. C. Kessler & L. U. Gordon (Eds.) *Measuring Stress: A Guide for Health and Social Scientists*. New York and Oxford: Oxford University Press.

Bishop, G. D. (1994). *Health Psychology: Integrating Mind and Body*. Boston: Allyn and Baker.

Brosschot, J. F., Pieper, S., & Thayer, J. F. (2005). Expanding stress theory: Prolonged activation and preservative cognition. *Psychoneuroendocrinology*, 30, 1043-1049

Chandola, T., Brunner, E., & Marmot, M. (2006). Chronic stress at work and the metabolic syndrome: Prospective study. *British Medical Journal*, 332, 521-524.

Dahlgren, A., Kecklund, G., & Åkerstedt, 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.

Dahlgren, A., Åkerstedt, T., & Kecklund, G. (2004). Individual differences in the diurnal cortisol response to stress. *Chronobiology International*, 21(6), 913-922

de Lange, A. H., Taris, T. W., Kompier, M A J., Houtman, I. L. D., & Bongers, P. M. (2003). "The very best of the millennium": Longitudinal research and the Demand-Control-(Support) model. *Journal of Occupational Health Psychology*, 8(4), 282-305.

Devereux, J. Rydstedt, L. W., Kelly, V., Weston, P & Buckle, P. (2004). *The Role of Work Stress and Psychological Factors upon the Development of Musculoskeletal Disorders*. HSE Books RR 273.

Dressendörfer, R.A., Kirschbaum, C., Rohde, W., et al. (1992). Synthesis of a cortisol-biotin conjugate and evaluation as a tracer in an immunoassay for salivary cortisol measurement. *Journal of Steroid Biochemistry and Molecular Biology*, 43, 683-692.

Frankenhaeuser, M., & Johansson, G. (1986). Stress at work: Psychobiological and psychological aspects. *International Review of Applied Psychology*, 35, 287-299.

Ganster, D. C., Fox, M.L., & Dwyer, D. J. (2001). Explaining employees' health care costs: A prospective examination of stressful job demands, personal control and physiological reactivity. *Journal of Applied Psychology*, 86(5), 954-964.

Grossi, G., Perski, A., Lundberg, U., & Soares, J. (2001). Associations between financial strain and the diurnal salivary cortisol secretion of long-term unemployed individuals. *Integrative Physiological and Behavioral Science*, 36(3), 205-219.

Gunnar, M. R., & Vazquez, D. M. (2001). Low cortisol and a flattening of expected day rhythm: Potential indices of risk in human development. *Development and Psychopathology*, 13, 525-538.

Heim, C., Ehlert, U., & Hellhammer, D.H. (2000). The potential role of hypocortisolism in the pathophysiology of stress-related bodily disorders. *Psychoneuroendocrinology*, 25, 1-35.

Karasek, R., Brisson, C., Kawakami, N., Houtman, I., Bongers, P., & Amick, B. (1998). The Job Content Questionnaire (JCQ): An instrument for internationally comparative assessments of psychosocial job characteristics. *Journal of Occupational Health Psychology*, 3(4), 322-355.

Karasek, R.A., & Theorell, T. (1990). *Healthy Work: Stress, Productivity and the Reconstruction of Working Life*. New York, NY: Basic Books.

Kirschbaum, C., & Hellhammer D.H. (1989). Salivary cortisol psycho-biological research: an overview. *Neuropsychobiology*, 22, 150-169.

Kristenson, M., Eriksen, H. R., Sluiter, J. K., Starke, D., & Ursin, H. (2004). Psychobiological mechanisms of socioeconomic differences in health. *Social Science & Medicine*, 58, 1511-1522.

Kudielka, B. M., Schrommer, N. C., Hellhammer, D. H., Kirschbaum, C. (2004). Acute HPA axis responses, heart rate and mood changes to psychosocial stress (TSST) in humans at different times of day. *Psychoneuroendocrinology*, 29, 983-992.

Linden, W., Earle, T. L., Gerin, W., & Christenfeld, N. (1997). Physiological stress reactivity and recovery: Conceptual siblings separated at birth? *Journal of Psychosomatic Research*, 42 (2), 117-135.

Lindfors, P., & Lundberg U. (2002). Is low cortisol release an indicator of positive health? *Stress and Health*, 18, 153-160.

Lundberg, U. (2003, May). *Is Lack of Recovery from Work more Important for Health than Stress During Work?* Oral Presentation at XIth European Congress on Work and Organizational Psychology, Lisbon, Portugal.

Lundberg, U., & Hellstrom, B. (2002). Workload and morning salivary cortisol in women. *Work and Stress*, 16(4), 356-363.

Marmot, M., Siegrist, J., Theorell, T., & Feeney, A. (1999). Health and the psychosocial environment at work. In M. Marmot and R G Wilkinson (Eds.) *Social Determinants of Health*, (pp 105-131). Oxford University Press: Oxford.

McEwen, B. S. (1998). Stress, adaptation, and disease: Allostasis and allostatic load. *Annals of the New York Academy of Sciences*, 840, 33-44.

Morgan III, C. A., Cho, T., Hazlett, G., Coric, V., & Morgan, J. (2002). The impact of burnout on human physiology and on operational performance: A prospective study of soldiers enrolled in the combat diver qualification course. *Yale Journal of Biology and Medicine*, 75, 199-205.

Peter, R., & Siegrist, J. (1997). Chronic work stress, sickness absence, and hypertension in middle managers: General or specific sociological explanations? *Social Science and Medicine*, 43(7), 1111-1120.

Preussner, J. C., Hellhammer, D. H., & Kirschbaum, C. (1999). Burnout, perceived stress, and cortisol responses to awakening. *Psychosomatic Medicine*, 61, 197-204.

Roger, D., & Narjarian, B. (1998) The relationship between emotional rumination and cortisol secretion under stress. *Personality and Individual Differences*, 24(4), 531-538.

Schultz, P., Kirschbaum, C., Preussner, J., & Hellhammer, D. (1998). Increased free cortisol secretion after awakening in chronically stressed individuals due to work overload. *Stress Medicine*, 14, 91-97

Siegrist, J., Klein, D., & Voigt, K-H. (1997). Linking sociological with physiological data: The model of effort-reward imbalance at work. *Acta Physiologica Scandinavica*, 161 (640), 112-116.

Sluiter, J.K., van der Beek, A.J., & Frings-Dresen, M. H.W. (1998). Work stress and recovery measured by urinary catecholamines and cortisol excretion in long distance coach drivers. *Occupational and Environmental Medicine*, 55(6), 407-413.

Sluiter J.K. Frings-Dresen, M.H.W., van der Beek, A.J., Meijman, T. & Heisterkamp, S.H. (2000) Neuroendocrine reactivity and recovery from work with different physical and mental demands. *Scandinavian Journal of Work Environment and Health*, 26(4), 306-316.

Sluiter, J. K., Frings-Dresen, M.H.V., van-der-Beek, A. J., & Meijman, T. (2001). The relation between work-induced neuroendocrine reactivity and recovery, subjective need for recovery, and health status. *Journal of Psychosomatic Research*, 50(1), 29-37

Stansfeld, S., Head, J., & Marmot, M. (2000). *Work-Related Factors and Ill-Health: The Whitehall II Study*. Norwich, UK: HSE Books 266/2000

Steptoe, A., Cropley, M., Griffith, J., & Kirschbaum, C. (2000). Job strain and anger expression predict early morning elevations in salivary cortisol. *Psychosomatic Medicine*, 62, 286-292.

Steptoe, A., Cropley, M. & Joeke, K. (1999). Job strain, blood pressure, and response to uncontrollable stress. *Journal of Hypertension*, 17, 193-200.

Ursin, H & Eriksen, H. R. (2004). The cognitive activation theory of stress. *Psychoneuroendocrinology*, 29, 567-592

Van Eck, M., & Nicholson N. A.. (1994). Perceived stress and salivary cortisol in daily life. *Annals of Behavioral Medicine*, 16(3), 221-227.

Van Eck, M., Berkhof, H., Nicholson, N. A., & N., Sulon, J. (1996). The effects of perceived stress, traits, mood states, and stressful daily events on salivary cortisol. *Psychosomatic Medicine*, 58, 447-4

Table 1

Cortisol secretion (nmol/l) over a week cycle for the chronic low (n=39) and high (n=38) job strain groups. Means and Standard Deviations

	Workdays		Weekend	
	<u>M</u>	<u>Sd</u>	<u>M</u>	<u>Sd</u>
<u>Morning</u>				
Low strain	21.16	5.51	15.99	6.12
High strain	21.44	6.16	16.89	7.16
<u>Evening</u>				
Low strain	1.81	0.86	1.71	0.83
High strain	2.24	1.18	2.14	1.24

Table 2

Analysis of Variance for saliva morning and evening cortisol secretion (nmol/l) over the week cycle for chronic low and high job strain groups

	Morning		Evening	
	df	F	df	F
Between subjects				
Chronic job strain (A)	1	0.25	1	4.28*
Error	75	(56.64)	75	(1.64)
Within subjects				
Weekday (B)	1	46.00**	1	0.77
A x B	1	0.19	1	0.02
Error	75	(19.77)	75	(0.55)

Note. Values enclosed in parentheses represent mean square errors.

* $p < .05$ ** $p < .001$