Effort-reward imbalance and salivary cortisol in women employed in dentistry

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EFFORT-REWARD IMBALANCE AND SALIVARY CORTISOL IN WOMEN WORKING IN DENTISTRY

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Women working in health care dealing with client interactions may be particularly vulnerable to work-stress. Such work-stress may be related to hypothalamo-pituitary-adrenal (HPA)-axis functioning as reflected in cortisol output. The present study investigated whether an imbalance between effort and reward (ERI) including overcommitment is linked to cortisol in terms of single and aggregate measures. Participants rated work-related factors in questionnaires and sampled saliva at three time points during one working day: 1) at awakening, 2) 30 minutes post-awakening, and 3) at 16.00. The results showed no association between overcommitment and cortisol, and overcommitment did not enhance the effect of effort-reward imbalance. However, the ratio between high effort and low reward was associated with $AUC_G$ and $AUC_I$. These inconsistent finding are partially in line with previous research, and future studies should focus on occupational status as a moderator of ERI and its effect on the HPA-axis functioning.

Work plays a central role to individuals in modern society as it provides a continuous income. Additionally, an occupation provides opportunities for experiencing successful self-regulation in a meaningful social context and thereby promotes health and well-being (Siegrist et al., 2004). However, stressful occupational situations may threaten this self-regulation, which over time may result in health-related problems rather than in health and well-being. The effort-reward imbalance model (ERI-model; Siegrist, 1996) can be applied to a wide range of occupations in research on more or less chronic aspects of work-stress. Lack of reciprocity between effort and reward, is common in occupations within the service, health care and in client-focused sectors. Work within such occupations is usually demanding and require high-level performance but provide few promotion opportunities (Peter & Siegrist, 1999). In main, these sectors employ more women than men, with women being particularly vulnerable to work-stress problems (Lundberg, 2005). However, it is still unclear how work-stress can translate into health problems but some previous research suggests that hypothalamo-pituitary-adrenal (HPA)-axis functioning and its control of cortisol may be a key component of this process (Bellingrath, Weigl, & Kudielka, 2009). Considering this, it is important to investigate if there is an association between perceptions of work stress and HPA-axis functioning in terms of cortisol, as cortisol levels are associated to an individual’s perception of the psychosocial environment and different aversive health outcomes (Chida & Steptoe, 2008; Hansen, Garde, & Persson, 2008; Karlson et al., 2012).

Previous studies on ERI and overcommitment (OC) and their associations with cortisol have yielded inconsistent results (Karlson et al., 2012). The main findings in work-stress research on cortisol measures show non-significant associations. However, there
is no general conclusion what cortisol measure is most appropriate when investigating work-stress (ERI-model) and its association with HPA-axis functioning (Lundberg, Garvin, & Kristenson, 2012). To complement previous research, the present study will examine if there is an association between perceived ERI, or high level of OC and different cortisol measures in working women.

**Occupational stress models**

Theories of stressful work and health are conceptualized in terms of adverse health behavior as a response to psychosocial stressors at work (Lazarus & Folkman, 1984; Siegrist, 2004). Two models often used in research on occupational stress are: the job demand-control-support model (JDCS) and effort-reward-imbalance model (ERI). The job demand-control-support model (developed by Karasek in 1979, extended by Karasek and Theorell in 1990) focuses on psychological demands, job control and social support at work. Demands and control can be used to manipulate the employee’s environment at task level and social support is a buffer against job strain (Karasek & Theorell, 1990). Job demand is measured in terms of time pressure and control as intellectual authority of the daily tasks. Karasek and Theorell (1990) imply that JDCS-model can be used to predict variations in mental strain. The JDCS-model and ERI-model overlap in the demand/effort component, but they differ clearly in that the JDCS-model is restricted to the situational aspects (structural power aspects) of the psychosocial work environment (Karasek & Theorell, 1990; Peter & Siegrist, 1999; Siegrist et al., 2004).

**Effort-reward imbalance model**

The ERI-model is an occupational stress model focusing on a combination of social and psychological dimensions in occupational settings to predict individual adverse health outcomes of chronic occupational stress (Siegrist & Pieter, 1994). Importantly, the ERI-model extends the JDCS-model (Karasek & Theorell, 1990) by including both situational (extrinsic demands and rewards) and personal information (OC) that influence negative emotional experience at a specific workplace (Peter & Siegrist, 1999).

Occupational situations where individuals experience lack of promotion prospects or job insecurity (low status control), high work pressure (high extrinsic demands) or high need of control and approval (high intrinsic demands, OC), lead to high effort and low reward. The experience of an imbalance between effort and reward at work may not be conscious, especially if it is an everyday experience. When employees perceive high effort with low reward they are likely to quit or reduce their efforts, but on the other hand they may also respond by a continuous high effort (OC). The dimensions constituting the ERI-model are extrinsic and intrinsic (OC) effort, and rewards (Siegrist, 1996).

Extrinsic effort can be conceptualized as a quantitative workload like shiftwork, heavy noise, cumulative workload, or work pressure. Daily work pressure is high in all status groups at work, but has been associated more with highly educated groups than groups with lower level of education in previous studies (Siegrist et al., 2004; Siegrist & Peter, 1994).

Siegrist (1996) distinguishes between three types of rewards: immediate in terms of economic pay-off (monetary) or socio-emotional feedback (esteem); and long-term reward in terms of status control (promotion aspects, job stability). Siegrist’ term status
Control is based on theories regarding self and identity. The lack of status control is particularly critical during high workload, because the occupational role is threatened and self-esteem and sense of mastery are impaired (Siegrist & Peter, 1994). Along this line, an experience of low reward and low security can produce sustained and strongly negative emotions like irritation, anger or fear. Status control differs between workgroups, as a low level of occupational status is more costly to cognitively adapt to than a low level of task control (Siegrist et al., 2004).

OC, or intrinsic effort, is a specific cognitive-motivational coping pattern manifested in exaggerating efforts beyond what is expected, striving for approval, esteem and control. This behavioral pattern is explained by the self-gratification elicited by perception of being in control, rather than by extrinsic rewards. Individuals with this attribution style tend to overestimate or underestimate demanding stimuli and an enhanced arousal is triggered, which in the long run makes them vulnerable for exhaustion and physiological breakdown (Siegrist, 1996). OC has been related to high level of education, and especially among women in midlife, in previous studies (Siegrist et al., 2004).

In sum this suggests that a high level of ERI and OC may be associated with work-stress ill health as a subjective stressful experience of unfairness may result in emotional distress, and OC may lead to a sustained autonomic arousal.

Stress models
Stress is typically defined as the adaptive physiological response to an external event (McEwen, 1998). The acute stress response protects against disease and enables resistance to a stressful situation. A prolonged response or a maladaptive response, on the other hand, may cause disease, or a vulnerability to disease, rather than protect the body from it. There are several stress-theoretical perspectives dealing with the interaction between social environments, individual psychological characteristics and processes, as well as physiological indicators reflecting bodily processes. Other theories of stress include a cognitive component, which determine whether a stressful event will lead to sustained arousal and in the long run ill health (Lazarus & Folkman, 1984; Ursin & Eriksen, 2010).

The allostatic load model (McEwen, 1998) explains how repeated use of the stress system yields strain in the long run. Adaption to a stressful situation (allostasis) is natural for human body in the short term. However, if stress systems get overworked or fail to shut down, allocastatic load occurs. McEwen distinguish between three psychological responses that produce allocastatic load: repeated intense stressful events produces heightened blood pressure; failed shut down leading to persistent heightened blood pressure or glucocorticoid elevation leading to neuronal impairment in hippocampus; inadequate response, where other systems (e.g. inflammatory cytokines) than stress systems responds to stress.

Ursin and Eriksen (2010) formulated the Cognitive Activation Theory of Stress (CATS) explaining how an individual’s subjective experience of demands, and the outcome expectancy, in a situation will elicit stress responses or not. Outcome expectancies are defined as positive coping or negative emotions (feelings of hopelessness or helplessness), which are associated with arousal or heightened stress response. Feelings
of hopelessness are related to situations where individuals have the ability to control a situation, however with adversely outcome. A feeling of helplessness relates to inability to control the situation. However, the cause of negative emotions is not necessarily consciously appraised, sometimes people feel anxious without knowing why. When a situation, such as an experience of ERI, produces strong negative emotions there is a risk for chronic stress to develop (Gaillard & Wientjes, 1994, Ursin & Eriksen, 2010).

Ursin and Eriksen (2010) argue that it is the sustained arousal from negative emotions that cause ill health. Sustained arousal is hard to measure because of the homeostatic mechanisms dampening the responses. OC may be involved in driving such prolonged arousal, which in turn may be assessed in terms of biomarkers of stress.

**Cortisol as biomarker of chronic stress**

Long-term outcomes of chronic stress such as cardiovascular disease, type 2 diabetes, reduced immune function, as well as cognitive impairment are linked to the secretion of cortisol in the hypothalamic pituitary adrenocortical (HPA) system (Kristenson, Garvin, & Lundberg, 2012; Lundberg, 2005; McEwen, 1998). These long-term outcomes are preceded by risk factors thought to reflect chronic work-stress. Yet, it is still unclear how work-stress can translate into health problems, but some previous research suggests that HPA-axis functioning and its control of cortisol may be a key component of this process (Bellingrath, Weigl, & Kudielka, 2009).

Typically, cortisol reaches a peak in the blood 30 minutes after an exposure of acute stress followed by a recovery period, a general adaptive short-term response (McEwen, 1998; Lundberg, 2005), as illustrated in Figure 1. However, cortisol also has a pronounced diurnal rhythm with a peak in the morning after awakening (Cortisol awakening response, CAR) and a fall during the day, with the lowest level in the evening (Hansen et al., 2008). Therefore, a challenge within field studies of working individuals is that long-term stress and acute stress differs in HPA-axis functioning and the associated secretion of cortisol (Karlson, et al., 2012).

![Figure 1. Normal cortisol diurnal variation during the day.](image)

Cortisol levels are frequently used as objective biological markers of stress as a supplement to self-reports assessing occupational stress. The most reoccurring method collecting cortisol in work stress research is by saliva samples, which is a non-invasive
method and easy to administer (Garde et al., 2009; Hansen et al., 2008). Chronic work related stress research employs different ways of measuring and analyzing cortisol levels and dynamics. Single time points (including means or sums of several single measurements) are the most frequent way since the early days of the research field. Aggregate measures like deviations/slopes between two or more time points and area under the curve (AUC) calculated from two or more time points are more recently introduced into the research field (Kristenson et al., 2012) and is a way to stabilize findings and deal with confounders.

Chronic stress and its effects on the HPA-axis functioning is complex, it can either increase or decrease cortisol levels (Jonsdottir et al., 2012; Miller, Chen, & Zhou, 2007). A dysregulation of the HPA-axis is thought to elicit flat diurnal curves, with low levels of cortisol in the morning and higher levels than normal in the evening – producing a high level of daily output (Miller et al., 2007). Consequently, heightened cortisol levels characterize a flattened curve during the day, instead of a decline with the lowest level in the evening. According to Lundberg et al. (2012) this pattern may be related to CATS in terms of helplessness and hopelessness (Ursin & Eriksen, 2010), as well as chronic or repeated stress as in the Allocastic Load Model (McEwen, 1998). Low levels of cortisol and non-reactivity to acute stress may also indicate a dysregulation of the HPA-axis (Jonsdottir et al., 2012). Total output of cortisol during the day and diurnal curves could be aggregated in terms of slope or AUC (Preussner et al., 2003; Rotenberg et al., 2012).

Previous research has shown that CAR (the awakening response) and single time point measures at awakening, but not higher total output throughout the day (Miller et al., 2007), is associated with threats to the social self (controllable stress due self-regulation). A high CAR has also been associated with worrying among women (Gustafsson et al., 2008). A greater CAR is possible on working days in individuals who are stressed as compared to a day off work. This means that CAR can be used to assess anticipation of the day (Clow et al., 2004).

When studying chronic stress in terms of cortisol measures it is important to consider various covariates. Biological sources to variability in cortisol levels throughout the day are thought to include age and menstrual cycle. Findings show that cortisol levels tend to increase with age (Garvin et al., 2012). Other findings suggest a low level of cortisol response association with a high waist ratio (Lundberg et al, 2012). Socioeconomic (SES) differences in cortisol levels throughout the day has been shown by higher cortisol levels among high SES individuals, and a lower AUC from ground throughout the day (Garvin et al., 2012). Physical diseases have been related to low morning cortisol levels, high evening cortisol levels, low CAR and flattened diurnal curves over the day (Kristenson & Lundgren, 2012).

**Effort-reward imbalance and cortisol**

Studies that have investigated the association between ERI-model and cortisol have yielded inconsistent results. Eller et al. (2006) found an association between high ERI and a high level of CAR for women on a working day in a cross-sectional study on academics and non-manual workers. However, for the men OC and ERI was associated with CAR. Eller et al. (2012) showed that ERI was associated with low levels of cortisol at awakening as well as with high CAR. Another cross-sectional study on
schoolteachers (Bellingrath et al., 2008) did not find any association between ERI and the diurnal curve, neither on workdays nor on a day off work. Liao et al. (2014) found that low reward and high ERI was associated with a flatter diurnal decline (slope), which may indicate that HPA-axis responsiveness has adapted to chronic stress.

Ota et al. (2014) found no associations between ERI and AUC\(_G\) (three samples during a working day) in women teachers. Steptoe et al. (2004) found an association between OC and average cortisol levels throughout the day in men, but not in women. Hanson et al. (2000) were unable to find any association between high ERI and high levels of cortisol during the day (AUC\(_G\)) or a flattened slope, and did not find any interaction effect between OC and ERI. Harris et al. (2007) did not find any associations between ERI and CAR, slope or awakening levels of cortisol.

Taken together, only a few studies have shown an association between ERI (including OC) and cortisol measures, with the associations being inconsistent. The ways in which salivary cortisol is sampled (i.e. time between samples) along with different ways of analyzing salivary cortisol (single vs. aggregate measures) are likely to be related with differences between study findings for chronic work stress and cortisol. Variability in salivary cortisol levels can be of both biological and methodological sources and it is of interest to take into account of the systematic influences on sampling when measuring stress reactions in occupational field studies (Hansen et al., 2008). Lundberg et al. (2012) concludes that some types of cortisol measurements (single time points vs. aggregated measures) seem to be more informative than others, but for psychosocial work-stress there are no conclusions what measure is most appropriate.

**Aim**

The overall aim of this study is to investigate associations between ERI, OC and cortisol measures reflecting HPA-axis functioning. Specifically, linkages between ERI (including OC) and different ways of measuring cortisol will be examined. Salivary cortisol measures including commonly used ways of operationalizing cortisol, including single points in time along with aggregate measures will be used to investigate linkages between ERI and HPA-axis functioning among working women.

Specifically, the research questions were:

1. Is there an association between effort-reward imbalance and cortisol, in particular cortisol levels associated with ill health (CAR, AUC\(_G\), AUC\(_I\), and slope anchored in awakening) among women employed in dentistry?

2. Is there an association between overcommitment and cortisol, in particular cortisol levels associated with ill health (CAR, AUC\(_G\), AUC\(_I\), and slope anchored in awakening) among women employed in dentistry?

3. Is there an interaction effect between high overcommitment and high imbalance between effort and reward associated with even higher vulnerability to ill health (CAR, AUC\(_G\), AUC\(_I\), and slope anchored in awakening), than overcommitment and high imbalance between effort and reward alone among women employed in dentistry?
Method

Setting
The data used in present study were collected as part of a research project focusing on working schedules, health and well-being in Swedish dental health care workers (von Thiele Schwarz, Lindfors, & Lundberg, 2008). Data used in the present study were collected in the first of three waves of data collections, in September/October 2004.

Study sample
In total, 197 employees at the six dental care centers were invited to participate in the study, 195 volunteered. Male employees and administrative personnel were excluded in the present study, giving a sample of 159 females working with dental client-interaction. Further exclusion concerned 4 women reporting diabetes and 6 women reporting being pregnant. One woman had not reported time of first saliva sample on the working day and four women on medication had single cortisol measures above 100 nmol/l suggesting extreme values and effects of medication on HPA-axis functioning, and they were consequently excluded.

The final sample consisted of 144 women, with a mean age of 46.45 years (S=10.68 years, range 21-64). Fifty-seven percent of the women had completed secondary school or elementary school, and 43% had a university degree or higher. Thirty-nine women worked as dentists, 86 as dental nurses, and 19 as dental hygienists. Fifty-four women reported a chronic disease, 64 were on medication (for example antihypertensive agents, Levaxin, Methotrexate, migraine medicine, epilepsy medicine, estrogens), whereas 9 medicated temporarily during the data-collection.

Materials
In addition to demographic factors (gender, age, current occupation, and education), the questionnaire also included measures of ERI and health related factors.

A Swedish version of the ERI instrument (Siegrist et al., 2004) was used to assess effort and reward. Extrinsic effort was measured with 6 items concerning time pressure, interruptions, physical load, and increasing demands. High scores indicate demands at work that are experienced as stressful. Reward was measured with 11 items concerning three types of reward: esteem (5 items) were related to respect from colleagues and superiors; monetary gratification (1 item) were related to adequate salary; status control (5 items) was reflected in promotion prospects, expected negative change in work conditions and job insecurity. A high score indicates a perception of a high level of reward (Siegrist et al, 2004). Cronbach’s alpha for the effort scale was .69 and alpha for reward scale was .81.

Each item was rated in a two-step procedure, the first part regarding apprehension and the second level of distress. The rating was on a 5-point scale (0 = “does not apply”, 1 = “does apply, but no distress”, 2 = “distressed to some degree”, 3 = “distressed”, 4 = “very distressed”). Some of the items were reversed where “very distressed” represented unexposed and “does not apply” exposed. Accordingly, the lowest possible score on the effort scale is 0 and highest is 30. The lowest possible score on the reward scale is 0 and the highest 55. To examine effort-reward imbalance a ratio between the
two scales, were computed, using the formula \( e/(r \times c) \) where \( e \) = extrinsic effort score (high extrinsic effort), \( r \) = reward score (low reward), and \( c \) = correction factor (6 effort items/11 reward items \( \times 0.5454 \)) for the difference in the number of items in the nominator and denominator. A standardized ratio above 1.0 indicates a high perception of imbalance between effort and reward and a ratio close to zero indicates no imbalance between effort and reward (Siegrist et al., 2004).

OC was measured with a six-item abbreviated and tested Swedish ERI-instrument (Siegrist et al., 2004). The questions concerned inability to withdraw from work, for example “As soon as I get up in the morning I start thinking about work problems”. The response format was a 4-point scale (1 = Strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). One item was reversed. One item (“When I get home, I can easily relax and ‘switch off’ work.”) was excluded from the scale due to low reliability (alpha = .40). The final Chronbach’s alpha for the scale was .61.

Missing values (Raaijmakers, 1999) were replaced by single imputation mean of nearby points, for effort (2.7% missing values), reward (4.2% missing values) and OC (2.7% missing values). The scores were indexed by dividing the scores with number of items. High scores indicate high effort, high reward, and OC to work.

Whether family matters interfere with work, Home-work interference, was assessed by the two items subscale from the SWING questionnaire (Geurts et al., 2005; Frone, Russel, & Cooper, 1992). Both items were rated on a 7-point scale, (1 = “very seldom” – 7 = “very often”). 2.1% missing values were replaced by single imputation mean by nearby points. An index was calculated from the sum scores and number of items, with high scores indicating high level of interference. High level of involvement in the family/home may lead to preoccupation sustained negative emotions not directly related to current work. Cronbach’s alpha for the scale was .58.

Procedure
The participants completed the questionnaire at home, attended a health examination and provided saliva samples. The saliva samples were collected to measure the stress hormone cortisol 3 times during a workday. The participants were instructed in writing how and when to perform the sampling. They also received two plastic bags with three plastic tubes (Salivettes®), each containing a cotton roll. They were told to put the roll in their mouths for 2 minutes in order to wet it thoroughly. The tubes were marked with a coding system to make sure that the tubes were used in the right order. Following standard procedures for saliva sampling, a saliva-sampling diary was to be kept in order to control that instructions were followed.

Conditions were made regarding the working day being at least the third working day in a row. The participants were told to sample saliva immediately after awakening (latest 8.00), the second sample 30 minutes after awakening (latest 8.30) and the third sample at 16.30 or around that time. The participants were instructed to avoid physical activity the day before sampling. They were also told not to eat, drink coffee or tea, smoke or brush their teeth one hour before sampling.
The diary and saliva samples were to be put in a plastic bag and returned together with the self-reports at the health check-up or sent to Stockholm University. The saliva samples were transported to the laboratory where they were stored in a freezer (-20°C) until analyzed. Cortisol was determined using competitive radioimmunoassay (Spectria Cortisol RIA, Orion Diagnostica, Espoo, Finland; intraassay precision < 5%, 1.7-4.1% and inter-assay precision < 10%, 4.3-9.0%). Each sample was analyzed twice and in randomized order.

Clow et al. (2004) point to the fact that Time of awakening and current menstrual phase are important to control for when doing research on cortisol measures and were included as covariates. Waist-hip ratio (life style factor), medication and chronic disease (may effect the cortisol levels) were included as covariates.

**Biological stress-marker: Salivary cortisol**

In order to address that complexity of the HPA axis and psychosocial stress at work, both single time point measures and dynamic cortisol levels through the day will be computed during a working day (Karlson et al., 2012; Pruessner et al., 2003). Single time point measures are: Sample 1 (at awakening), Sample 2 (30 minutes post-awakening), Sample 3 (at 16:00).

**Aggregate cortisol measures**

*Area under the curve* (AUC) is calculated to evaluate curve values from repeated measures for a whole day as an aggregate measure (Pruessner et al., 2003). The curve during the day is individual but is considered abnormal when there is a deviation from the norm. While the time intervals between samples in the present study vary, formula $AUC_G$ (Table 1) was used to compute the overall level during the day. To compute dynamic increase of cortisol from repeated measures during a day formula $AUC_I$ (Table 1) was used as an index of change. $AUC_I$ is the difference in area under and above the curve with reference to baseline. If the increase is smaller than the decrease, $AUC_I$ takes a negative value (Fekedulegn et al., 2007).

*The cortisol awakening response* (CAR) – the difference between cortisol levels at awakening and a peak occurring 30 – 45 minutes after awakening was used to assess anticipation of the day (high CAR) as well as high emotion and stress (blunted CAR). CAR is normally characterized as an increase in cortisol (Clow et al., 2004). The CAR has a minimal loss in precision compared to repeated measures over the day (Fries et al., 2008). $CAR_{AUC}$ was calculated by overall cortisol secretory activity (AUC) between awakening and 30 minutes post-awakening (Table 1). Normal cortisol CAR should be 50%-160% increase in the time between awakening and 30 minutes post-awakening (Hansen et al., 2008) 3.6 – 35.1 nmol/L awakening, 7.6-39.4 nmol/L peak level post-awakening, Late afternoon samples (17:00-19:00 10.3 nmol/L).

*Slope*$_{first\rightarrow last}$ is calculated to evaluate the diurnal slope, the difference between awakening sample and last sample divided by the time between sampling (Table 1). A normal diurnal slope declining over the day is manifested in negative values; blunted slopes (flattened curve) are characterized with values close to zero (Rotenberg et al., 2012).
Table 1

Aggregated cortisol measures formulas

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Measure</th>
<th>Formula Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUC&lt;sub&gt;G&lt;/sub&gt;</td>
<td>Area under the curve with respect to ground. Overall level over the day. Sample 1-3.</td>
<td>( \sum_{i=1}^{n-1} \frac{(m_i + m_{i+1}) \cdot (t_{i+1} - t_i)}{2} )</td>
</tr>
<tr>
<td>AUC&lt;sub&gt;I&lt;/sub&gt;</td>
<td>Area under the curve with respect to increase. Dynamic increase over the day. Sample 1-3.</td>
<td>( AUC_G - m_1 \cdot \sum_{i=1}^{n-1} (t_{i+1} - t_i) )</td>
</tr>
<tr>
<td>CAR&lt;sub&gt;AUC&lt;/sub&gt;</td>
<td>Area under the curve from ground. Overall awakening response for sample 1-2.</td>
<td>( \sum_{i=1}^{n-1} \frac{(m_i + m_{i+1}) \cdot (t_{i+1} - t_i)}{2} )</td>
</tr>
<tr>
<td>Slope&lt;sub&gt;awake to last&lt;/sub&gt;</td>
<td>Diurnal slope over the day, anchored to awakening using rise over run.</td>
<td>( \frac{m_l - m_1}{2} )</td>
</tr>
</tbody>
</table>

Note. n denotes number of samples; l denotes last sample

<sup>A</sup> Formula based on Preussner et al. (2003), <sup>B</sup> Formula based on Rotenberg et al. (2012)

Consumption of coffee, nicotine and food one hour prior to saliva sampling was controlled for when calculating aggregate measures. All participants had complied with instructions, thereby no one were excluded according to those criteria’s. When calculating AUC<sub>G</sub> and AUC<sub>I</sub>, 8 individuals in the sample were excluded due to inadequate reporting of saliva time of sampling in Sample 2 or Sample 3. With respect to calculation of CAR, 4 individuals in the sample were excluded due time between sampling was outside the range (30-45 minutes + awakening). When calculating Slope<sub>awake to last</sub>, 7 participants were excluded due to inadequate reporting of saliva time of sampling in Sample 2 or Sample 3.

Results

After calculating descriptive statistics for all participants, chronic disease/healthy group and high occupational status/low occupational status, correlations between all variables were computed for all participants. To test the research question, hierarchical multiple regression analyses were performed for each cortisol measure (single time points and aggregated measures). In contrast to the automated stepwise regression procedure, hierarchical multiple regression is guided by theory (Aiken & West, 1991). These analyses were performed controlling for biological factors (age, awakening time, chronic disease, medicine, menstrual phase, waist-hip ratio), demographic factors (occupational status, education), and family stress (home work interference) in separate steps. The main effects of ERI and OC were included in the fourth step to clarify their associations with each cortisol measure. Finally, the interaction between ERI and OC were included in the last step to allow examination of research question 3.
Table 2 presents descriptive statistics for all study variables, with means and standard deviations.

Table 2

Means and Standard Deviations of the Outcome Variables (N=144)

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single time point cortisol variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample 1, at awakening</td>
<td>13.67</td>
<td>8.04</td>
</tr>
<tr>
<td>Sample 2, 30 min+ awakening</td>
<td>21.00</td>
<td>9.80</td>
</tr>
<tr>
<td>Sample 3, around 16.00</td>
<td>4.30</td>
<td>3.60</td>
</tr>
<tr>
<td><strong>Aggregated cortisol variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUC₉ (Total output)</td>
<td>8057.48</td>
<td>3394.15</td>
</tr>
<tr>
<td>AUC₁ (Increase)</td>
<td>-275.35</td>
<td>5256.74</td>
</tr>
<tr>
<td>CARₐUCₐ (Awakening response)</td>
<td>529.27</td>
<td>221.61</td>
</tr>
<tr>
<td>Slopeₙₙ₀ₙ₀ₙ₀ (diurnal curve)</td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td><strong>Work stress variables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERI ratio</td>
<td>.67</td>
<td>.32</td>
</tr>
<tr>
<td>OC</td>
<td>.47</td>
<td>.10</td>
</tr>
<tr>
<td><strong>Covariate variables</strong></td>
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<td></td>
</tr>
<tr>
<td>Age</td>
<td>46.46</td>
<td>1.69</td>
</tr>
<tr>
<td>Awakening time</td>
<td>06:05</td>
<td>00:45</td>
</tr>
<tr>
<td>Home work interference</td>
<td>2.76</td>
<td>1.41</td>
</tr>
<tr>
<td>Menstrual phase</td>
<td>56.66</td>
<td>43.31</td>
</tr>
<tr>
<td>Waist-hip ratio</td>
<td>.81</td>
<td>.08</td>
</tr>
</tbody>
</table>

*Note.* Cortisol unit: nMol/l; Time of awakening unit: hh:mm; OC = overcommitment

Table 3 presents Pearson correlations between all variables and shows that ERI ratio had a positive and significant association with CARₐUCₐ. Additionally, the ERI-ratio showed a positive correlation with education, occupational status, single time point cortisol levels 30 minutes post-awakening, home work interference, as well as a negative and significant correlation with OC. ERI ratio did not correlate to any other single time point, or aggregated cortisol measure. OC did not correlate significantly to any single time point or aggregated cortisol measure.

The hierarchical multiple regression analyses in Table 4 show that biological factors, demographic factors and family related stress did not have any significant association with any of the aggregated cortisol measures. However, when adding work-stress variables in step 4 the amount of explained variance increased significantly with 6%. ERI ratio was associated with AUC₉ (F₁₂,12₃=1.91, p < .05) and AUC₁ (F₁₂,12₃=1.92, p < .05), explaining 7% of the total variance, but OC was not. Finally, the interaction term added in step 5 was not statistically significant.

Regarding the single time point measures, neither ERI ratio nor OC were associated with the awakening sample (Sample 1, Table 4). However, biological factors in step 1 added...
12% of explained variance in Sample 1 (at awakening). The covariates awakening time and chronic disease were associated with Sample 1, explaining 8% of the total variance (F_{12,131}=1.78, p < .05).

Further hierarchical multiple regressions with single time points, CAR_{AUC} and Slope_{first to last} as dependent variables were not significant (CAR_{AUC}: F_{12,127}=1.41, p > .05; Slope: F_{12,124}=1.42, p > .05; Sample 2: F_{12,131}=1.57, p > .05; Sample 3: F_{12,129}=1.62, p > .05).
Table 3
Bivariate correlations matrix between all variables (Dentists = 39, Dental nurses = 86, Dental hygienists = 19)

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<td>.80**</td>
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</table>

Note. *p < .05; **p < .01; ***p < .001 (2-tailed)
Chronic disease: 1 = yes; Medicine: 1 = yes; Menstrual phase: days since last menstruation; Education: 1=elementary school - 4 = university or higher
Occupational status (1=dentist/hygienist); HWI= Home work interference; OC= overcommitment;
Table 4
Hierarchical multiple regression analyse including effects of psychosocial work characteristics and interaction between ERI ratio and OC, controlling for biological factors, demographics, and family related stress on aggregated measures of cortisol

| Predictors | AUC<sub>G</sub> (n=136) | | | AUC<sub>I</sub> | | | Sample 1 (n=144) | | |
|------------|--------------------------|-----------------|------------------|--------------------------|-----------------|------------------|----------------|--------------------------|-----------------|------------------|------------------|
|            | β   | t    | p    | ΔR² | R² adj. | β   | t    | p    | ΔR² | R² adj. | β   | t    | p    | ΔR² | R² adj. |
| Step 1     |     |      |      |     |        |     |      |      |     |        |     |      |      |     |        |
| Age        | .06 | .48  | .63  | .13 | 1.08   | .28 | -.13 | 1.08 | .28 |
| Time of awakening | -.07 | -.79 | .43  | -.06 | -.71  | .48 | .19* | 2.28 | .02 |
| Chronic disease | -.18 | -1.62 | .11  | .09 | .79  | .43 | -.21* | -2.04 | .04 |
| Medicine   | -.08 | -.82  | .42  | -.18 | -1.70 | .09 | .09  | .89  | .37 |
| Menstrual phase | .05  | .48  | .63  | -.10 | -9.4  | .35 | .16  | 1.49 | .14 |
| Waist-hip ratio | -.09 | -.99  | .32  | -.04 | -.42  | .68 | -.04 | -.41 | .68 |
| Step 2     |     |      |      |     |        |     |      |      |     |        |     |      |      |     |        |
| Occupational status | -.11 | -.52 | .60  | -.25 | -1.17 | .24 | .17  | .92  | .36 |
| Education  | -.02 | -.11  | .91  | .01  | .04  | .97 | -.09 | -.5  | .62 |
| Step 3     |     |      |      |     |        |     |      |      |     |        |     |      |      |     |        |
| HWI        | -.14 | -1.46 | .15  | -.12 | -1.28 | .20 | .07  | .73  | .46 |
| Step 4     |     |      |      |     |        |     |      |      |     |        |     |      |      |     |        |
| ERI ratio  | .31* | 3.02  | .00  | .25* | 2.49  | .01 | -.02 | -.19 | .85 |
| OC         | .17 | 1.69  | .09  | .14  | 1.40  | .16 | -.05 | -.48 | .63 |
| Step 5     |     |      |      |     |        |     |      |      |     |        |     |      |      |     |        |
| ERI ratio x OC | -.12 | -1.42 | .16  | -.12 | -1.41 | .16 | .06  | .75  | .45 |

Note. *p < .05; **p < .01; ***p < .001 (2-tailed); AUC<sub>G</sub>: F<sub>12,123</sub>=1.91, p < .05; AUC<sub>I</sub>: F<sub>12,123</sub>=1.92, p < .05; Sample 1: F<sub>12,131</sub>=1.78, p < .05

Education: 1=university or higher; Occupational status: 0=dental nurses; Menstrual phase=days since last menstrual period
HWI = Home Work Interference
Discussion

The present study examined whether different aspects of the ERI-model had any associations with single and aggregated measures of cortisol respectively. The results showed that ERI ratio was associated with AUC_G and AUC_I, but not with Slope, CAR nor any single time point measure in the present study. Therefore research question 1 was supported when it comes to total output (AUC_G) and increase in cortisol (AUC_I) throughout the day. This is opposed to findings from Ota et al. (2014) who did not find any associations between ERI and AUC_G. However, their sample was female school-teachers and in the present study there are differences in occupational status as dentists and dental hygienists have higher incomes than dental nurses. The difference might also be explained by the rather secure environment in dentistry, compared to the environment in schools. Additionally, they did not collect any sample at awakening. Liao et al. (2013) did find a predictive value for ERI ratio on Slope, but not for CAR. However, they derived the Slope from regressing cortisol of 5 samples over a day, and excluded the second sample. The present study used difference between first and last sample to calculate Slope and included the second sample (peak). The results in the present study indicate a bivariate correlation between a high level of ERI and high level of CAR_AUC. The correlation was not supported when trying to predict a high level of ERI on CAR_AUC when controlling for biological, demographic and family stress related confounders. Therefore research question 1 was not supported when using CAR_AUC as independent variable. This finding is similar to what was reported by Harris et al. (2007) where ERI did not predict the awakening response. This supports the findings of with Chida and Steptoe (2009), who found in a meta-analysis that CAR_AUC was positively related to general life stress but not with work-stress. On the other hand, the result in the present study is opposed to findings of Eller et al. (2006, 2012). However, although controlling for medication, Eller and colleagues did not control for chronic disease. Taken together, the results in the present study follows some of the previous research, but not other. In particular the there is inconsistency in the measures of the awakening response.

OC did not show associations with any of the single time points nor aggregated measures of cortisol. Therefore research question 2 was not supported. Yet, the result in the present study replicates earlier findings (Eller et al., 2006, 2012; Hanson et al., 2000; Steptoe et al., 2004). They found that OC was associated with cortisol levels in men, but not in women. In the present study, ERI ratio had a positive significant correlation with both occupational status and education. In order to avoid further risk of type-I error no group differences were investigated in the present study. Yet, it would have been interesting to investigate the effects of occupational status among women as this sample includes different status among women, and Siegrist et al. (2004) implies that it is more costly to adapt to a lower occupational status. Earlier gender difference might be related to differences in occupational status, therefore group differences between women in different occupational status would be interesting to investigate in future research.

The results did not show an interaction effect between ERI ratio and OC on the cortisol measures. Therefore, research question 3 was not supported. Nevertheless, ERI ratio and OC had a significant bivariate negative correlation, suggesting that individuals high
in OC tend to underestimate demanding stimuli in line with the argumentation by Siegrist et al. (2004).

The results showed an association between chronic disease and the awakening sample (Sample 1). This could indicate group differences in a perception of ERI (including OC) and CAR_{AUC} between healthy participants and participants with chronic disease. The association was negative, which is in line with arguments from Kristenson and Lundgren (2012). Kristenson et al. (2012) recommend intergroup comparisons to compensate for inter- and intra-individual variations. This could explain the rather large standard deviations for Sample 1 and Sample 2. The sample in the present study was rather homogenous, only consisting of women employed in dentistry. Life style factors, like waist-hip ratio was normal, with a mean value of .81, suggesting a quite healthy life style.

In the present study there was an association between time of awakening and Sample. This result is in line with Clow et al.’s (2004) argumentation of time of awakening as an important confounder when investigating associations with the cortisol awakening response (CAR). When it comes to the different ways to analyze cortisol, Kristenson et al. (2012) implies that aggregated measures could be indicators of HPA-axis functioning while single time point measures may have little relevance when investigating HPA-axis functioning. The aim of the present study included investigation of that implication and the results go in line with that, clearly showing that work-stress seems more related to aggregated measures and chronic disease and time of awakening seems more related to single time points.

In the present study, ERI ratio and OC was not dichotomized into high versus low-level individuals. Some earlier studies use continuous ERI ratio and OC variables (for example Liao et al., 2013) and others use categorical variables (Ota et al., 2013). Additionally, the Likert scale answer format measuring effort and reward has previously been changed to a one-step procedure due higher response rates (Siegrist, Li, & Montano, 2014), while the present study used the two-step procedure. The results in the present study might have been affected by the rather complex two-step procedure. Further research on ERI might enhance number of response rates by using the one-step procedure.

In order to address the complexity of psychosocial stress at work and the HPA-axis, although enhancing risk of type-1 error, both single time point measures and aggregated cortisol measures throughout the day were computed during a working day (Karlson et al., 2012; Pruessner et al., 2003) and investigated in the present study. The aggregated measures used in the present study (diurnal Slope anchored in awakening, CAR_{AUC} and AUC_{G}) have been considered to be more stabile measures than AUC_{I} (Hellhammer, 2007). The present study utilized all of these aggregated measures to investigate differences when investigating HPA axis functioning in relation to work related stress. The hierarchical multiple regressions showed that the bivariate correlation between ERI ratio and CAR_{AUC} could be explained by the covariates chronic disease and time of awakening. However, ERI ratio was associated with AUC_{G} and AUC_{I}.

The mean value of the Slope anchored in awakening in the present study was relatively close to zero, indicating that the diurnal slopes in the sample are flattened (Rotenberg et
However, in the present study there was no sample of cortisol in the evening. The latest sample was to be taken at 16.00, and the slope measure may not be relevant to investigate when not including late evening samples. The mean value of the single time points show that the diurnal variation for all participants was within the normal range (Clow et al., 2004), with a peak 30 minutes post-awakening and a fall during the afternoon. Still, it would have been interesting to investigate group differences as earlier research has shown socioeconomic differences both in perception of ERI, OC (Siegrist et al., 2004) and cortisol output throughout the day (Garvin et al., 2012).

Cortisol samples were collected during one working day only. This may affect the reliability of the present study. Common guidelines for collecting cortisol by saliva sampling are to collect at least 3-4 saliva samples per day, and ideally for several days, although this is seldom feasible (Hellhammer et al., 2007; Kristenson et al., 2012). Collections of saliva samples were complemented with a diary in line with earlier recommendations to control for compliance (Clow et al., 2004; Karlson et al., 2012). Use of electronic monitoring might have strengthened reliability and validity by enhancing compliance with the protocol (Kudielka et al., 2003). Still, electronic monitoring might require additional burden and compliance, and they are far from perfect.

Subjective health complaints should complement biological stress markers in chronic stress research according to Ursin and Eriksen (2004). Self-rated health might be included as a covariate as rating of current health status compared with others of the same age is known to be an independent predictor of mortality beyond biological data (Eriksson, Undén, & Elofsson, 2001; Idler & Benyami, 1997).

Importantly, work-stress may not be considered as highly intense, and as the cortisol response reduces negative feelings it may lead to an underestimation of everyday stressors (Karlson et al., 2012; Ursin & Eriksen, 2010). Dentistry could be seen as a rather secure occupational environment, and the client-interaction might not be as demanding as in other client-interaction occupations.

Concluding remarks

Previous research on work-stress (e.g ERI) and HPA-axis functioning has shown inconsistent results. The present study adds to this inconsistent field by investigating a homogeneous sample of working women (Karlson et al., 2012) as the individual differences may be smaller than between group differences. A dainty contribution to the research field, is that both single time point measures and aggregated measures of cortisol was investigated in order to establish which cortisol measures should be included in research on work-stress and cortisol as an indicator of HPA-axis functioning.

Overall the findings show no consistent effects between different aspects of the ERI-model and different cortisol measures. Nevertheless, there may be some finding of interest as ERI ratio was associated with total cortisol output ($AUC_G$), as well as with dynamic increase in cortisol ($AUC_I$) during the working day. Yet, additional research is needed on other samples also including differences between women with chronic disease and healthy women, and ERI’s association with CAR in women. Differences between
women that differ in occupational status may also moderate the effect of ERI ratio and OC on the HPA-axis functioning.
References


