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ORIGINAL ARTICLE

Associations between two job stress models and measures of salivary cortisol

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Abstract
Purpose To investigate the association between two job stress models—the job demand-control model and the effort-reward imbalance model—and repeated measures of salivary cortisol among male and female call-centre operators.
Methods Daily cortisol profiles consisting of seven time points were measured across two workdays and one leisure day to determine the cortisol awakening response and the cortisol output in the day in 104 volunteers. The employees completed two self-administered questionnaire—the Karasek's demand-control questionnaire and the Siegrist's effort-reward imbalance questionnaire—to assess psychosocial hazards at work. The relations between the perceived workload measures and salivary cortisol levels were analyzed by means of generalized estimating equations method after adjusting for potential confounders (gender, age, educational level, marital status, morning awakening time, sleep duration and quality, weekdays, work schedule, adherence to sampling procedure).
Results The total cortisol amount excreted in the awakening period was positively associated with the job strain measures (high strain vs. low strain: 1.4 (2.4–0.3) nmol/l). In contrast, individuals scoring higher in effort-reward imbalance at work had both lower cortisol awakening response (high imbalance vs. low imbalance: −0.7 (−1.3 to −0.2) nmol/l) and lower diurnal secretory activity (−9.2 (−17.7 to −0.7) nmol/l). Gender, weekday and adherence to sampling schedule significantly influenced the cortisol excretion in the morning period.
Conclusions Our results indicate that the two work stress models differentially affect salivary cortisol output. This finding suggests that combining the information from two complementary job stress models results in improved knowledge on the psychobiological correlates of the psychosocial work environment.

Keywords Job demand-control model · Effort-reward imbalance model · Salivary cortisol · Psychosocial hazards

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Introduction

In the recent years the adverse psychosocial work environment received increased attention as job stress has been recognised as a risk factor for a number of health outcomes, mainly cardiovascular diseases (Belkic et al. 2004; Bosma et al. 1998), musculoskeletal (Sprigg et al. 2007) and mental disorders (Bonde 2008; Dragano et al. 2008; Stansfeld and Candy 2006).

Although there are a number of ways in which psychosocial workplace environment could be assessed, including rating made though observation, interviews, measures of production such as output, self-reported questionnaires containing questions regarding presence of risk factors in the work environment are the most common type of psychosocial hazard measures. Two theoretical models received particular attention in recent years in the field: the job demand-control (JDC) model developed by Karasek (1979) and the most recent effort-reward imbalance (ERI) model proposed by Siegrist (1996). The former includes two components: psychological demands, which tap quantitative and conflicting demands at work, and decision latitude which measures decision authority and skill utilization over a task. Employees who face high demands and have little control over their job are hypothesized to be at great risk of becoming ill. The ERI model assumes that effort at work is spent as part of a contract based on the norm of social reciprocity where rewards are provided in terms of money, esteem, and career opportunities including job security. The experience of a lack of reciprocity in terms of high costs and low gains elicits negative emotions in exposed workers: thus, in the long run, the imbalance between high effort and low reward at work increases illness susceptibility as a results of continued strain reactions. A further assumption of this model concerns individual differences in the experience of effort-reward imbalance: people characterized by a motivational pattern of excessive work-related commitment and high need for approval (overcommitment) are at increased risk of strain from non-symmetric exchange. There are several similarities between the two models: they both represent general model of work-stress and are operationalised by a standardized self-administered questionnaire, data being analyzed according to predefined procedures. Moreover, clear conceptual and methodological differences exist: the JDC model is restricted to the structural aspects of the psychosocial work environment, when the ERI model includes both extrinsic (situational) and intrinsic (personal) characteristics. Additionally, the two different stress theoretical orientations (control vs. reward) have different implications for policy: whereas the control paradigm points to the division of labour, the reward paradigm addresses the issue of distributive justice and fairness (Siegrist et al. 2004).

Inconsistent evidences have been accumulated so far about the relationship between both the models and various health impairments, as well as the identification of biological mechanisms linking exposure to adverse work environment and health is until still unclear. The psychobiological research postulated that the pathways by which work stress influences ill health is mediated by the hypothalamic-pituitary-adrenal (HPA) axis which regulates the long-term adaptation of organism to stress. Disruption in HPA axis functioning, due to chronic stress, is usually examined in ambulatory settings by investigating the salivary cortisol awakening response (CAR) and the diurnal secretory activity (Kudielka and Wust 2008), as this method enables repeated cortisol measures during the day at the workplace and makes the method an obvious choice for measuring a part of the physiological stress reaction. There is a rapidly growing literature relates both the JDC and ERI models to cortisol regulation. A positive association between the early morning cortisol levels in high strain subjects has been reported (Alderling et al. 2006; Kunz-Ebrecht et al. 2004; Steptoe et al. 2000), whereas other studies failed to observe significant relationships (Maina et al. 2008; Steptoe et al. 1998). Similar contrasting results have been obtained for the ERI model with reports on blunted (Bellingrath et al. 2008a; Bellingrath and Kudielka 2008b; Siegrist et al. 1997; Wirtz et al. 2008), as well heightened (Steptoe et al. 2004) salivary cortisol levels or no differences in the HPA axis response (Hanson et al. 2000; Irie et al. 2004). However, to our knowledge, one study only (Hurwitz Eller et al. 2006) so far examined the two models simultaneously with regard to salivary cortisol levels although this approach is important at least for three reasons. Firstly, the models identify complementary aspects of a stressful work environment and, thus, offer the opportunity to evaluate the relative strength of each association with the outcome under study. Secondly, as the several different methodological approaches used to quantify the salivary cortisol levels hamper the comparison of the results reported in literature, thus the choice to use both standardized psychometric measures and salivary cortisol indices could improve validity of the associations between the variables under study. Thirdly, if either model is associated with salivary cortisol, a more comprehensive set of worksite intervention measures needs to be developed for preventive measures, in particular for people whose work environment is characterised by features of the demand-control and the effort-reward imbalance model.

This investigation was designed to examine the following issues. Firstly, what is the nature and direction of the relationship between indices of cortisol production and the two major job stress models? Secondly, are the relationships between psychometric measures and the cortisol indices consistent? Previous studies pointed out that several confounding factors influence the salivary cortisol levels, so we included a considerable number of potentially confounders to test the robustness of our main findings.

Method

Study sample

This pilot study was part of a larger interventional study looking at the well-being promotion in the call-centres of an Italian telephone company. Through e-mail advertisement, the total workforce of front-line call-handlers of two call-centres were informed that they participate in a project investigating the physiological correlates of work stress. By means of on work side meetings subjects were asked to give written informed consent having read a detailed written description of the research protocol. The overall participation rate was 29% (26 and 35% for the two enterprises, respectively) of the total call-handlers employed in the two call-centres and did not differ for gender, age, educational level, marital status and work schedule when compared to the total population performing this job. All participants met the following inclusion criteria: (1) no hormone replacement therapy; (2) no medication for psychiatric disorders; (3) blood glucose level lower than 120 mg %. Eleven employees were excluded on the basis of selection criteria yielding a final study sample of 121 (32 males and 89 females) subjects. The ethical approval for the study was obtained from the local research ethics committee of the University of Torino as well as of the University of Trieste. Participants received a printed report of their salivary cortisol values after completion of the investigation.

Psychometric measures

Participants completed a self-administered questionnaire including background information as measures of gender, age, educational level, marital status, work schedule, and measures of psychosocial job stressors assessed according to the JDC model (Karasek and Theorell 1990) and ERI model (Siegrist 1996).

The former has been tested using the Italian version of the job content questionnaire (JCQ) which contains 11 Likert-scaled items (Cesana et al. 2003): psychological demands were composed of the sum score (range 5–20) of five items (i.e. “Do you have to work very intensively?”), and decision latitude was composed of the sum score (range 6–24) of six items (i.e. “Do you have a choice in deciding how you do you work?”), each of which was rated on a 4-point scale ranging from 1 (“strongly disagree”) to 4 (“strongly agree”). This model predicts that the combination of psychological demands and decision latitude results in different degrees of perceived strain, stress-related risk, and active-passive behavioural correlates of jobs (Karasek 1979). The Cronbach’s α were 0.71 and 0.74 for the scales “psychological demand” and “decision latitude” in the group 1, and 0.80 and 0.82 in the group 2. A job strain variable was constructed by dichotomising the two scales (median) and combining them into one variable with the categories “low strain (low psychological demands and high decision latitude)”, “active work (high psychological demands and high decision latitude)”, “passive work (low psychological demands and low decision latitude)” and “high strain (high psychological demands and low decision latitude)”.

The effort-reward imbalance model was measured using the Italian version of the effort-reward imbalance questionnaire, which contains 21 Likert-scaled items. Effort was assessed with 5 items (i.e.: “I am often pressured to work overtime”), and reward with 11 items (i.e.: “Considering all my efforts and achievements, I receive the respect and prestige I deserve at”), each item being rated on a 5-point scale. Items are answered in two steps. First, subjects agree or disagree whether or not the items content describes a typical experience of their work situation. Subsequently, subjects who agree are asked to evaluate to what extent usually feel distressed by this typical experience. The rating procedure is defined as follows: (1) does not apply; (2) does apply, but subject does not consider herself distressed; (3) does apply, and subject considers herself somewhat distressed; (4) does apply, and subject considers herself distressed; (5) does apply, and subject considers herself very distressed. A total sum score based on the five items measuring effort varies from 5 to 25: the higher the score, the more perceived demands are experienced as stressful. Accordingly, a score of 11 indicates the perception of the lowest rewards whereas a score of 55 reflects a very high level of reward. The Cronbach’s α were 0.80 and 0.83 for the scale effort and reward in the group 1 and 0.79 and 0.83 in the group 2. The effort-reward imbalance has been computed for every respondent as ratio according to the formula: $e/(r \times c)$, where “e” is the sum score of the effort scale, “r” is the sum score of the reward scale, and “c” defines a correction factor (0.454545) while the nominator contains five items (5/11). A value close to zero indicates a favourable condition (relatively low effort, relatively high reward), whereas values beyond 1.0 indicate a high amount of effort spent that is not met by the received or expected in turn. Overcommitment was assessed by means of six items measuring the cognitive-motivational pattern of coping with demands characterized by an excessive work-related overcommitment and a high need for approval: given the uni-dimensionality of this scale the six-four-point Likert scaled items are computed to a total score varying from 6 to 24: the higher the score, the more likely a subject is to experience overcommitment at work. The Cronbach’s α for this scale were 0.80 and 0.83 for group 1 and group 2, respectively. Overcommitment was used as a dichotomous variable: high levels of overcommitment were defined by the upper tertile of the total distribution.

Salivary cortisol sampling procedure

Saliva samples were collected using cotton dental rolls held in the mouth for about 60 s, and then stored in Salivette tubes (Sarstedt Ltd., Leicester, UK). Participants were instructed to take 7 samples on two workdays with a weekly interval between sampling, and 1 day off, with measures at awakening, 30, 60 min thereafter, at the start of work-shift and then every 3 h. Subjects were asked to take the first sample while lying in bed, and the second after 30 min without brushing their teeth, eating, drinking or smoking. To ensure the participants’ correct understanding further, we issued each person written information along with three kits of saliva sampling tubes. Participants filled in a diary the actual time of day they had taken each sample, information on the time of going to bed, and the time of awakening. Additionally, subjects were asked to estimate their sleep quality by mean a binary rating scale of 1 (good) and 2 (poor). To facilitate the collection of saliva tubes, each participant received pre-stamped envelopes to be returned after each day of sampling. Subjects stored the tubes in their freezer and then returned the samples to the investigators personally. Individuals with any missing value were excluded (17 subjects), so the sample analyzed totalled 104 individuals, 76 females and 28 males (total salivary cortisol samples considered: no. 2184).

Cortisol analysis

At the arrival to the laboratory, all samples were stored in a freezer (−20°C) until the analyses. Before free cortisol was assayed, the samples were thawed and spum at 3,000 revolutions/min for 5 min to obtain 100 μl of supernatant. Free cortisol levels in saliva were measured by a solid phase radioimmunoassay (RIA) method (Radim Diagnostics, KS18CT Roma, Italy) (LOD = 1.59 nmol/l). All samples from each subject were analysed simultaneously in duplicate. The intra- and inter-assay variability rates were 4.2–8 and 7.2–8.5%, respectively.

Salivary cortisol levels were quantified by means of five indices. The first three involved estimations of the cortisol awakening response (CAR) (the acute increase of the cortisol level in the 60 min after awakening) that has shown to be independent of the general cortisol level and thus provides independent information on HPA axis functioning (Clow et al. 2004). Using the formulas provided by Pruessner et al. (2003), measures of CAR were obtained by computing the area under the curve (AUC) relative to zero (or ground: AUC_t) and the area under the curve with respect to increase (AUC_i); the mean increase (MnInc) was quantified according to Wust et al. (2000). The AUC_t provides information on the basal activity of the HPA axis in the first hour after awakening (Clow et al. 2004), while AUC_i and MnInc provide information on the reactivity of the system during the same period (Wust et al. 2000).The cortisol excretion in the post-awakening period was calculated by means of the area under the curve with respect the ground (AUC_g) using the samples from 4 to 7 ($AUCG_{day}$), and the area under the curve with respect the ground using the sample 1 and the samples from 4 to 7 (Diurnal cycle) (Pruessner et al. 2003). It is well known that compliance with the sampling schedule play a crucial role in the interpretation of the cortisol values, particularly in the morning period when even small deviations from the sampling times could invalidate the cortisol results. Thus, we classified participants as being likely adherent or non-adherent based on whether they showed a difference of more than 2.5 nmol/l (corresponding to the operational guideline value for cortisol-reactivity) between samples collected at +30 min and the awakening sample (Wust et al. 2000).

Statistical methods

Data analysis was performed with the statistical software Stata (v. 10.0 SE, Stata Corporation, 2007). Since salivary cortisol data were not normally distributed, a ladder of powers was used to normalize cortisol variables according to Tukey (1977). A chi-square test suggested that square root transformation of cortisol variables was suitable to obtain a normal distribution of data. Data were summarised using the mean or the median as measures of central tendency, and the standard deviation or interquantile range as measure of dispersion. Comparisons between independent groups were made with either the unpaired Student *t* test or the Mann–Whitney test. Categorical data were tabulated in 2×2 or $2 \times k$ contingency tables and the differences between proportions were assessed by the χ^2 test. The correlations between measures of job stress were evaluated by the Spearman rank statistic (ρ). The relation between repeated measures of cortisol and several covariates was assessed by the generalised estimating equations (GEE) method to account for the within-subject correlation of the measures of salivary cortisol over time. We examined the relation between cortisol levels and job strain divided into four categories: high strain, active work, passive work, and low strain. A similar procedure was adopted to assess the relations between cortisol levels and the two dimensions of job strain (psychological demands, and decision latitude). For the ERI model, effort and reward sum scores were divided in tertiles and independently tested to estimate their separate effects on cortisol levels. The effort-reward ratio was used as a binary variable ($\leq$1.0 vs. >1.0) to compare the prevalence of imbalance between groups and divided in tertiles of the logarithmically transformed data to explore the relation between effort-reward ratio and cortisol levels. Several covariates (gender, age, marital status, educational level, work schedule, awakening time, sleep duration and quality, and participant adherence) were included in the analysis. A *P*-value of 0.05 was chosen as the limit for statistical significance.

Results

There were significant differences in sociodemographic characteristics between the two call-handler populations (Table 1). Female gender was prevalent in group 1. Moreover, the number of part-time workers and not-married subjects was greater in group 1 than in group 2. The participants in group 2 were older and had a lower educational level than workers in group 1. The participants in the group 2 were more adherent, woke up earlier and hade a shorter sleep duration than subjects in group 1. Sleep quality not differed between groups.

Table 2 shows the results of the psychometric measures. In the whole sample, high job strain ranged from 25 to 28%.

Table 1 Description of the study population

Characteristics	Group 1	Group 2
Gender		
Male	12 (17.6)	16 (44.4)
Female	56 (82.4)	20 (55.6)[d]
Age (years)	31.6 (9.4)	42.6 (7.0)[b]
Education (years)		
<10	3 (4.4)	7 (19.4)
>10	65 (95.6)	29 (80.6)[c]
Marital status		
Single, separated, divorced or widowed	43 (63.2)	8 (22.2)
Married or cohabiting	25 (36.8)	28 (77.8)[e]
Work schedule		
Full time	34 (50.0)	29 (80.6)
Part time	34 (50.0)	7 (19.4)[d]
Adherence to protocol		
Not adherent	30 (44.1)	7 (19.4)
Adherent	38 (55.9)	29 (80.6)[c]
Morning waking time (hours)	8.03 (1.36)	6.40 (0.6)[b]
Sleep duration (hours)	7.5 (1.6)	6.8 (0.9)[a]
Sleep quality		
Good	45 (66.2)	26 (72.2)
Poor	23 (33.8)	10 (27.8)

Data are given as means and standard deviations or numbers and percentages

Student *t* test: [a]$P = 0.005$; [b]$P < 0.001$

χ^2 test: [c]$P < 0.05$; [d]$P < 0.005$; [e]$P < 0.001$

Proportions of 17.6–22.2% of the call-handlers were above the cut off (1) for the effort-reward imbalance ratio, indicating a disturbed balance of (too much) effort and (too low) reward. There were neither differences between groups with regards to job strain categories, nor for effort-reward imbalance ratio. The populations did differ with regard to decision latitude and effort spent at work dimensions, and subjects in group 2 showed higher values than the group1. Table 3 presents the correlation matrix of the five measures of job stress. As expected, psychological demands and effort showed a positive association, confirming that the two measures operationalised similar aspects of work stress. In contrast, in both populations decision latitude and reward were not correlated. Moreover, the negative correlations between psychological demands, effort, overcommitment and reward, as well as the positive associations between psychological demands, effort and overcommitment, confirmed the theoretical assumptions underlying the two models in group 2. Psychological demands showed no associations with reward and overcommitment in group 1.

The relations between salivary cortisol indices and the JDC and ERI models were examined by marginal linear regressions using repeated measures of salivary cortisol as dependent variable (Tables 4, 5, 6, 7). Since preliminary analysis revealed that cortisol concentrations exhibited a stable pattern across the two sampling workdays for all determinations of cortisol output, the mean values of the two workdays pairs were used in further analyses. Compared to high strain, low strain was negatively associated with the total cortisol amount excreted in the awakening period

Table 2 Distribution of psychological work environment measures in the study population

Characteristics	Group 1		Group 2	
	Median interquantile range and *N* (%)		Median interquantile range and *N* (%)	
Demand-control model				
Psychological demands	34.0	8	36.0	6
Decision latitude	14.5	3	15.0[a]	1
High strain	19	(27.9)	9	(25.0)
Active work	17	(25.0)	16	(44.5)
Passive work	14	(20.6)	7	(19.4)
Low strain	18	(26.5)	4	(11.1)
ERI Model				
Effort	11.0	4	13.0[b]	4
Reward	36.0	10	37.0	6
Effort-reward imbalance ratio				
Low	56	(82.4)	28	(77.8)
High	12	(17.6)	8	(22.2)
Overcommitment	10.0	7	12.5	7

[a] $P < 0.005$; [b]$P = 0.001$

Table 3 Correlation matrix for the job stress measures

	Decision latitude	Effort	Reward	Overcommitment
Group 1				
Psychological demands	0.256	0.013	−0.027	0.188
Decision latitude		0.10	0.172	−0.182
Effort			−0.507[a]	0.745[b]
Reward				−0.509[a]
Overcommitment				
Group 2				
Psychological demands	−0.092	0.434[b]	−0.498[b]	0.513[b]
Decision latitude		−0.007	0.113	−0.023
Effort			−0.600[b]	0.612[b]
Reward				−0.599[b]
Overcommitment				

The Spearman rank correlation coefficients (ρ) are reported

[a] $P < 0.005$, [b] $P < 0.001$

Table 4 Marginal linear regression of salivary cortisol index AUC_t on gender, age, marital status, weekday, adherence to protocol, and job strain categories in the study population

Factors	AUC_t coeff (95% CI)	
	Group 1	Group 2
Gender[1]	0.2 (−0.4 to 0.9)	−1.1 (−1.8 to −0.4)[a]
Age	0.01 (−0.02 to 0.04)	−0.04 (−0.08 to 0.01)
Marital status[2]	0.4 (−0.3 to 0.9)	0.3 (−0.3 to 0.9)
Day off[3]	−0.3 (−0.9 to 0.2)	−0.8 (−1.4 to −0.2)[a]
Adherence to protocol[4]	1.4 (0.8–2.0)[b]	0.5 (0.05–0.9)[a]
Job strain[5]		
Active work	−0.2 (−0.9 to 0.5)	−0.4 (−1.2 to 0.3)
Passive work	0.1. (−0.6 to 0.8)	−0.5 (−1.4 to 0.5)
Low strain	−0.4 (−1.1 to 0.3)	−1.4 (−2.4 to −0.3)[a]
Constant	6.6 (5.2–8.1)	9.9 (7.1–12.7)

Regression coefficients and robust 95% confidence intervals (95% CI), adjusted by work schedule, awakening time, sleep duration and quality, were estimated by means of the GEE method to account for the within-subject correlation between repeated measures of salivary cortisol. Square root transformation was used to normalize cortisol data. See text for the definition of AUC_t

Reference category: female[1], not married[2], workday[3], non-adherence[4], high strain[5]

[a] $P < 0.05$; [b] $P < 0.001$

(AUC_t) although the difference was significant in group 2 only (Table 4). The other cortisol indices were not related to job strain categories, as well as there were no significant associations between indices of cortisol excretion and the two dimensions of JDC model (psychological demands, decision latitude) when separately analysed (data not shown).

Effort spent at work and salivary cortisol levels were negatively associated, with some differences between groups (Table 5). In group 2, higher effort was significantly associated with lower values of total cortisol amount in the morning period (AUC_t). In both groups, diurnal cycle (DC) was inversely related to effort spent at work. No associations were found between effort and indices of cortisol increase in the morning period (AUC_i, MnInc) in both groups, while subjects scoring high in effort showed reduced values of salivary cortisol excreted in the post-awakening period ($AUCG_{day}$), but in group 2 only (−7.0 CI −13.0 to −0.9).

Exploration of the potential association between reward and salivary cortisol revealed that higher reward was significantly associated with greater total cortisol amount in the awakening period (AUC_t) and higher diurnal cycle levels in group 1 (Table 6).

Effort-reward imbalance and indices of cortisol production were negatively associated (Table 7): individuals having higher (upper tertile) effort-reward imbalance ratio showed lower total cortisol amount in the morning period (AUC_t) as well as reduced diurnal cycle (DC) levels, although this association achieved the limit of statistical significance in group 1 solely. Overcommitment and indices of salivary cortisol excretions showed a weak positive association (data not shown).

Both sociodemographic (gender, age, marital status) and situational (weekday, adherence to protocol) factors affected the salivary cortisol indices. Women in the group 2 showed AUC_t values higher than men (median: 67.1 vs. 49.8 nmol/l, $P < 0.05$). In group1, age and diurnal cycle were positively related ($\rho = 0.266$, $P < 0.05$). Not-married subjects showed diurnal cycle values higher than married subjects (median: 13,476 vs. 1,0733 nmol/l, $P < 0.05$).

Compliance with the sampling procedure and weekday significantly affected the awakening cortisol response

Table 5 Marginal linear regression of salivary cortisol indices AUC_t, and DC on gender, age, marital status, weekday, adherence to protocol, and effort in the study population

Factors	AUC_t coeff (95% CI)		DC coeff (95% CI)	
	Group 1	Group 2	Group 1	Group 2
Gender[1]	0.2 (−0.4 to 0.7)	−0.9 (−1.4 to −0.3)[a]	13.5 (4.0–23.1)[a]	−6.6 (−13.6 to 0.4)
Age	0.01 (−0.02 to 0.04)	−0.04 (−0.1 to 0.01)	1.1 (0.6–1.5)[b]	−0.5 (−1.0 to 0.1)
Marital status[2]	0.3 (−0.4 to 0.9)	0.2 (−0.5 to 0.9)	−9.1(−17.9 to -0.2)[a]	−3.4 (−12.5 to 5.6)
Day off[3]	−0.3 (−0.8 to 0.2)	−0.8 (−1.4 to −0.2)[a]	−20.5 (−30.5 to −10.4)[b]	2.8 (−5.4 to 10.9)
Adherence to protocol[4]	1.4 (0.81–1.9)[b]	0.5 (0.1–0.9)[a]	−8.0 (−16.2 to 0.2)	−3.4 (−11.4 to 4.5)
Effort[5]				
2nd tertile	−0.5 (−1.1 to 0.02)	−0.9 (−1.5 to −0.3)[a]	−8.9 (−17.5 to −0.2)[a]	−7.8 (−15.3 to −0.3)[a]
3rd tertile	−0.4 (−1.0 to 0.3)	−0.8 (−1.6 to 0.02)[a]	−2.5 (−10.7 to 5.7)	−1.8 (−11.5 to 7.9)
Constant	6.9 (5.4–8.4)	9.9 (7.2–12.7)	101 (64.5–137)	124 (92.1–156)

Regression coefficients and robust 95% confidence intervals (95% CI), adjusted by work schedule, awakening time, sleep duration and quality were estimated by means of the GEE method to account for the within-subject correlation between repeated measures of salivary cortisol. Square root transformation was used to normalize cortisol data. See text for the definitions of AUC_t, and DC

Reference category: female[1], not married[2],workday[3], non-adherence[4], 1st tertile[5]

[a] $P < 0.05$; [b]$P < 0.001$

Table 6 Marginal linear regression of salivary cortisol indices AUC_t and DC on gender, age, civil status, weekday, adherence to protocol, and reward in the study population

Factors	AUC_t coeff (95% CI)		DC coeff (95% CI)	
	Group 1	Group 2	Group 1	Group 2
Gender[1]	0.2 (−0.4 to 0.8)	−0.8 (−1.4 to −0.2)[a]	14.2 (4.5–23.9)[a]	−4.9 (−11.5 to 1.8)
Age	0.01 (−0.02 to 0.04)	−0.03 (−0.1 to 0.03)	1.0 (0.6–1.4)[b]	−0.3 (−0.9 to 0.3)
Marital status[2]	0.4 (−0.2 to 1.1)	0.1 (−0.7 to 0.9)	−7.1 (−15.8 to 1.5)	−2.9 (−12.9 to 7.1)
Day off[3]	−0.3 (−0.9 to 0.2)	−0.8 (−1.5 to −0.2)[a]	−20.4 (−30.6 to −10.3)[b]	3.1 (−4.8 to 11.1)
Adherence[4] to protocol	1.4 (0.8–2.0)[b]	0.5 (0.01–0.9)[a]	−7.4 (−16.3 to 1.5)	−3.6 (−11.7 to 4.6)
Reward[5]				
2nd tertile	0.3 (−0.4 to 0.9)	−0.1 (−1.0 to 0.8)	2.6 (−7.8 to 12.9)	−0.3 (−10.1 to 9.4)
3rd tertile	0.7 (0.1–1.3)[a]	−0.1 (−1.0 to 0.8)	10.5 (2.9–18.2)[a]	3.5 (−6.3 to 13.2)
Constant	6.4 (5.0–7.8)	9.1 (6.0–12.2)	94.5 (60.7–128)	113 (78.1–148)

Regression coefficients and robust 95% (95% CI), adjusted by work schedule, awakening time, sleep duration and quality, were estimated by means of the GEE method to account for the within-subject correlation between repeated measures of salivary cortisol. Square root transformation was used to normalize cortisol data. See text for the definitions of AUC_t and DC

Reference category: female[1], not married[2], workday[3], non-adherence[4], first tertile[5]

[a] $P < 0.05$; [b]$P < 0.001$

(AUC_t), adherent subjects having higher values than non-adherents (median: 63.1 vs. 41,8 nmol/l in group 1, $P < 0.001$; median: 61.1 vs. 44.7 nmol/l in group2, $P < 0.05$), and workday having higher values than leisure day (median: 52.5 vs. 45.7 nmol/l in group 1, $P < 0.05$; median: 58.8 vs. 45,7 nmol/l in group2, $P < 0.001$).

Discussion

The aim of this investigation was to explore possible HPA axis dysregulation related to psychosocial work environment described by means of the demand-control (JDC) model and the effort-reward imbalance (ERI) model.

In our sample the prevalence range of job strain and effort-reward imbalance varies from 25 to 28% and from 17.6 to 22.2%, respectively. Normative data (Siegrist 1998) reported that between 10 and 40% of the workforce suffer from some degrees of job strain or effort-reward imbalance. The relatively low prevalence of job strain found in the present study is likely due to the low percentage of the subjects scoring high in psychological demands. The prevalence of the low decision latitude is comparable with a cohort of 2,130 French call-handlers (Croidieu et al. 2008)

Table 7 Marginal linear regression of salivary cortisol indices AUC_t and DC on gender, age, marital status, weekday, adherence to protocol, and effort reward imbalance in the study population

Factors	AUC_t coeff (95% CI)		DC coeff (95%CI)	
	Group 1	Group 2	Group 1	Group 2
Gender[1]	0.09 (−0.5 to 0.6)	−1.0 (−1.6 to −0.4)[a]	12.3 (2.8–21.8)[a]	−7.7 (−16.1 to 0.8)
Age	0.01 (−0.02 to 0.04)	−0.03 (−0.1 to 0.02)	1.0 (0.6–1.4)[b]	−0.4 (−0.9 to 0.1)
Marital status[2]	0.3 (−0.3 to 0.9)	0.2 (−0.6 to 0.9)	−9.1 (−17.6 to −0.5)[a]	−3.5 (−12.9 to 6.0)
Day off[3]	−0.3 (−0.9 to 0.2)	−0.8 (−1.5 to −0.2)[a]	−20.6 (−30.7 to −10.5)[b]	3.1 (−5.0 to 11.2)
Adherence to protocol[4]	1.4 (0.9–2.0)[b]	0.5 (0.1–0.9)[a]	−6.9 (−15.0 to 1.2)	−3.3 (−11.1 to 4.6)
Imbalance[5]				
2nd tertile	−0.7 (−1.2 to −0.2)[a]	−0.7 (−1.4 to 0.1)	−11.1 (−20.1 to 2.1)	−6.4 (−15.8 to 3.0)
3rd tertile	−0.7 (−1.3 to −0.2)[a]	−0.6 (−1.5 to 0.3)	−9.2 (−17.7 to −0.7)[a]	−1.6 (−12.1 to 8.9)
Constant	7.3 (5.8–8.7)	9.6 (6.9–12.4)	107 (69.8–143)	122 (90.0–155)

Regression coefficients and robust 95% (95% CI), adjusted by work schedule, awakening time, sleep duration and quality, were estimated by means of the GEE method to account for the within-subject correlation between repeated measures of salivary cortisol. Square root transformation was used to normalize cortisol data. See text for the definitions of AUC_t and DC

Reference category: female[1], not married[2], workday[3], non-adherence[4], first tertile[5]

[a] $P < 0.05$; [b] $P < 0.001$

and only slightly lower than another Swedish study (Norman et al. 2004) on 57 call-centres operators. With respect to the ERI model, our sample had a percentage of effort-reward imbalance ratio in line with the results found in 949 German teachers (Unterbrink et al. 2007), but higher than in 146 Japanese medical resident (Wada et al. 2008).

The main finding of our research indicates that the two stress models show different associations with the salivary cortisol indices. In the JDC model, a significant positive association was found with the total cortisol amount excreted in the morning period in high strain when compared to low strain call-handlers, while no differences between the four categories of the Karasek's model were observed with regard to the other indices of cortisol excretion. On the other hand, the extrinsic part of the ERI model and indices of salivary cortisol were negatively related, while overcommitment and indices of cortisol production were positively although not statistically associated. The finding that the cortisol awakening response is sensitive to psychosocial stress measured by mean of the Karasek's model (i.e. high strain subjects having a higher cortisol levels in the early morning period) has been previously reported although in no consistently way. Our findings, however, should be interpreted with caution because the relation was observed only in one of the two populations examined in this study. The differences in both sociodemographic and situational characteristics between the two populations could be a plausible explanation of the conflicting results observed in the present investigation, as well as in the literature. Indeed, the population showing the positive association between the total cortisol amount in the morning period and job strain was older, with more married individuals, had lower educational level and more hours worked per day, all factors (Clow et al. 2004; Englert et al. 2008; Kunz-Ebrecht et al. 2004; Dahlgren et al. 2006) deemed positively associated with the cortisol production in the awakening period. Furthermore, since the compliance to the sampling procedure play a crucial role in the cortisol awakening response (Kudielka et al. 2003), the fact that the adherence to protocol was significantly lower in the group not showing the expected association could obscured the actual positive association in this population.

In the ERI model, both effort and reward were related to some cortisol indices in our study and the associations showed opposite directions as expected according to the model construct. However, the direction of the associations between the two component of the extrinsic part of the Siegrist's model and the neuroendocrine stress response pattern indicates that individuals scoring high in effort-reward imbalance at work show lower cortisol excretion. This finding well agrees to the framework of a two-stage model reactivity (Siegrist and Klein 1990): an initially heightened cortisol stress response results from prolonged stress due to effort-reward imbalance at early stages; in the long run, as consequence of chronically high work stress, the stress response is no longer heightened but lowered as functional adaptation to excessive stimulation mediated by the down-regulation of the regulatory receptors or by means of enhanced tissue sensitivity. The conflicting results previously reported, documenting both hyper and hypo-activity of the HPA axis associated with the components of ERI model, may reflect differences in the stress response stage or could be explained as consequence of methodological differences between studies (i.e.: sampling designs/times, in/exclusion or control of potentially confounding factors, invalidation by sampling non-compliance, etc.).

The finding that the two theoretical work stress models are differentially associated with the cortisol indices is perhaps not surprising since conceptual and methodological differences exist between the two models. Components of the extrinsic part of the ERI model (salaries, career opportunity, job security) are linked to macro-economic market conditions, while the Karasek's major focus is on workplace characteristics (Siegrist et al. 2004). Thus, the job strain model might be related more to objective measures of stressors, while the effort-reward model approaches more cognitive levels of perceived job stress. The results of this investigation further support the above mentioned differences, as the correlation matrix (see Table 2) documented no associations between decision latitude and reward in both study populations. The observation of statistically independent associations of the two theoretical models suggests to combine the two complementary approach for the identification of the potential differences in the HPA axis involvement related to the psychosocial work environment. This could allow to identify different aspects of the adverse psychosocial environment in order to implement interventional studies and stress prevention programmes.

This study documented that, in each stress model, the cortisol awakening response was also associated with gender, weekdays and compliance with the protocol. Previous studies reported that gender differences can influence the CAR (Alderling et al. 2006; Kunz-Ebrecht et al. 2004), women reacting with more morning saliva cortisol output to the expectation of a stressful work day than men. This finding should be interpreted with adequate caution, as the females demonstrated higher morning cortisol levels in one group only, and our measurements not take into account hormonal differences (menstrual cycle phase and intake of oral contraceptives) that could have contributed to the observed between-groups differences of cortisol reactivity among females. Differences between working days and leisure day, as observed in this study, are in line with earlier reports of higher cortisol awakening response on working day compared to non-working days (Kunz-Ebrecht et al. 2004; Maina et al. 2008; Schlotz et al. 2004). The finding that the cortisol awakening response was also influenced by the compliance with the protocol is supported by previous researches (Kudielka et al. 2003). Non-adherence to the protocol ranged from 19 to 44% in this investigation, confirming that compliance to the sampling schedule is a common problem in field research when samples are collected under free-living conditions: this finding strengthen the need to control this confounding factor to avoid potential misinterpretation of results. In group 1, the diurnal cycle levels were significantly associated with marital status (not married excreting more cortisol than married subjects) and weekdays (the cortisol excretion being greater in workday than in day off). We have no adequate explanation for these associations, since there are no investigations that explored the relationships between the overall daily cortisol production and these variables. All we can say is that these associations have to be taken with caution because found in the group 1 only.

There are some limitations in this study which may have influenced the results obtained and the conclusions drawn. Firstly, the cross-sectional design does not permit any inferences about the observed associations between psychometric measures and cortisol indices. From a psychobiological perspective, it is unlikely that the differences in cortisol indices can drive the perception of the psychosocial work environment. Secondly, the low response rate, likely due to engagement requested in taking 7 salivary samples in 3 different days, might also have limited the validity of this study. However, there were no differences in sociodemographic variables between participants and non participants, so it is unlikely that selection bias had a large effect on the results. Thirdly, the relatively small size of the sample and the homogeneity of the population may be behind the low variation of the psychometric measures observed in this study; therefore, the strength of the associations could be underestimated and only partially capture the relationship between work stress measures and HPA axis disregulation. A further limitation is the lack of a comprehensive analysis that includes intractions between work and family life, an issue of remarkable interest in future explorations, as it is becoming increasingly apparent that stress research cannot concentrate solely on working environment. Finally, to identify suspected non-adherence to protocol, we excluded subjects who had a small cortisol rise in the morning period (<2.49 nmol/l). Since it is known that some people are non-responders (Stone et al. 2001), this may be questionable as subjects with a true flat CAR could have been classified as not adherents.

In conclusion, this study provides some support to the hypothesis that adverse psychosocial work environment and perturbations of the HPA axis regulation are associated, and underlines the usefulness of testing various models to evaluate psychosocial work environment. Our findings support the hypothesis that the two complementary job stress models independently influence the indices of cortisol excretion, suggesting that the different theoretical constructs of JDC and ERI models result in different associations with this biomarker of stress. In this study, however, sociodemographic and situational data showed important influence on salivary cortisol output, possibly leading to some conflicting results for the associations between cortisol indices and psychometric measures. Prospective studies are need to confirm our results and the clinical implications of our findings.

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