Original article

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Diurnal profiles of salivary cortisol on workdays among construction workers versus white-collar workers

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Objectives The aim of the present study was to test whether construction workers, who are known to have a relatively higher risk of cardiovascular disease (CVD), had higher concentrations of cortisol in saliva and a lower relative variability when compared with white-collar workers.

Methods Data from two groups of male construction workers with physically demanding job assignments, with either regular or extended workhours (N=40) and a group of white-collar workers recruited from both the private and the public sector (N=118) were examined. All of the workers had participated in previous research projects with similar methodology. Saliva was sampled during ordinary workdays at awakening, between 30 and 45 minutes after awakening, and approximately 14 hours after awakening.

Results Compared with the white-collar workers, the construction workers had higher mean concentrations of cortisol in saliva, 36% and 14% for construction workers with regular and extended workhours, respectively. The observed differences weakened when the exact sampling time (time of day) was taken into consideration in the statistical modeling. Compared with the white-collar workers, the construction workers had a lower relative variability in salivary cortisol as measured by the coefficient of variation (CV 76% versus 99%). A detailed analysis revealed that the construction workers with regular workhours had the highest concentration of cortisol in saliva but the lowest relative variability when compared with the construction workers with extended workhours (CV 72% versus 82%).

Conclusions The results suggest that physically demanding construction work is associated with a less variable and increased cortisol excretion when compared with white-collar work.

Key terms cardiovascular disease; hypothalamus-pituitary-adrenal axis; radioimmunoassay; workhour.

In Denmark, epidemiologic studies have shown that male workers in the transportation and construction sector have a relatively higher risk of cardiovascular diseases (CVD) compared with all other occupationally active men (1). Interestingly, there seems to be a gradient among workers in the construction sector as workers with extended workhours on large-scale construction sites (eg, bridge and tunnel construction) have a greater risk of CVD than construction workers with ordinary workhours (2). The etiology of CVD among construction workers is, however, not well known. Although lack of recovery between workshifts and poor lifestyle are probable contributing factors (3), the more precise biological mechanisms have yet to be specified. Because of the well-known nervous interconnection between the heart and the brain (4) and the fact that construction work may often be stressful in terms of work at odd hours, time pressure, and physical- and attention-demanding job assignments, it seems plausible that work stress may contribute to the somewhat higher relative risk of CVD among construction workers.

One commonly suggested biological mechanism behind stress-related poor health is the alteration in the activity of the hypothalamus-pituitary-adrenal (HPA) axis (5). The HPA axis plays a central role in homeostatic processes and is commonly thought to reflect attempts to adjust to daily pressures and joys (6). The principal marker for activation of the HPA axis in field studies and much experimental stress research is cortisol, although several hormones are involved (eg, corticotropin-releasing hormone and adrenocorticotropic hormone). The immediate physiological effects of increased

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cortisol concentrations, for example, increased blood pressure, suppression of inflammation, and precipitate insulin resistance, are well documented (7–9). The long-term effects of minor deviation in the excretion of cortisol are, however, less well-documented even if it is known that prolonged and elevated concentrations of cortisol may lead to the redistribution of body fat characterized by trunk obesity, hypertension, and type 2 diabetes, as seen in Cushing's disease (7, 10).

Cortisol is also of interest in the mounting documentation in support of the view that CVD may be influenced by psychoneuroendocrine mechanisms. Some of the strongest evidence of a psychoneuroendocrine mechanism involved in CVD comes from a recent prospective study, which showed an association between the cortisol-to-testosterone ratio and the incidence of ischemic heart disease (11). In this study, a relatively high excretion of cortisol in relation to testosterone was found to be detrimental, and the authors concluded that the relationship seemed to be mediated through the insulin resistance syndrome. Furthermore, obesity and failure to down-regulate the normally high plasma cortisol levels in the morning were found to be positively associated with indicators of poor cardiovascular health in a cross-sectional population study (10). In another study, low diurnal variability in salivary cortisol was suggested as meditating the association between known risk factors and CVD, type 2 diabetes, and stroke (6).

The aim of our study was to test whether construction workers, who as an occupational group are known to have a relatively high risk of CVD, had higher concentrations of cortisol in saliva when compared with white-collar workers recruited from occupations with a lower relative risk of heart disease. A possible dose–response relationship for cortisol concentrations was evaluated by including two groups of construction workers, one with regular workhours and a second with extended workhours. Furthermore, because biological variability is always a major concern when groups are compared, the relative intraindividual variability was evaluated.

Study population and methods

Study population

We used data from two previous field studies (12, 13). Demographic characteristics of the participants are presented in table 1. The first study group comprised 40 male construction workers with physically demanding job assignments. Of these, 19 worked regular hours and lived at home. On the average, they reported to work 8.1 (range 4.5–10.5) hours per workday, including lunch, for an average workweek of 40.4 hours. Their mean daily transportation time was 75 minutes. The remaining 21 participants lived in building site camps and worked two consecutive weeks followed by nine days off. On the average, they worked 11.5 (range 5.0–13.5) hours per workday for an average workweek of 38.5 hours in a 3-week period. Their mean daily transportation time was less than 30 minutes. Construction workers with extended workweeks were recruited from three Copenhagen Metro building sites. Construction workers with regular workhours were recruited from three building sites constructing buildings or road bridges (13). The second study group consisted of male white-collar workers (N=118) recruited from both the private and the public sector in the southern part of Sweden (12). The participants in this group were primarily employed as teachers, call-center operators, social security officers, administrators, internal manufacturers, or research and development personnel. All of the participants gave their informed consent, and the local ethics committees approved the study to comply with the Helsinki Declaration.

Salivary cortisol

Collection of saliva samples. The saliva samples were collected during workdays. The participants received written and oral information about sampling details. Saliva samples were collected by self-monitoring by use of polyester Salivette® (Saastedt, Germany) tubes at awakening, between 30 and 45 minutes after awakening, and approximately 14 hours after awakening. At their own discretion, the construction workers collected saliva for the measurement of cortisol on four workdays, Tuesdays and Thursdays in two consecutive workweeks. The group of white-collar workers collected the saliva samples at their own discretion during one workday (typically Wednesday).

Performance of measurement of cortisol in saliva. The assay used for the determination of cortisol in saliva was a competitive radioimmunoassay (RIA) (Spectria Cortisol Coated Tube RIA) purchased from Orion Diagnostica,

Table 1. Demographic data of the study groups. (BMI = body mass index)

Group	N	Age (years)		BMI (kg/m^2)		Smokers (%)
		Mean	Range	Mean	Range	
Construction workers						
Regular workhours	19	39	19–53	25.5	20.0–30.3	64 [a]
Extended workhours	21	42	27–62	26.3	20.7–30.9	
White-collar workers	118	45	19–65	28.3	16.2–42.1	13

[a] Estimated percentage of smokers among Danish construction workers according to Mathiesen et al (1).

Espoo, Finland. A method evaluation of certified reference material in water showed no bias of the method; the recovery was 97% [95% confidence interval (95% CI) 94–100.9]. The limit of detection (LOD) was 1.59 nmol/l. The between-run coefficient of variation (CV) was 19% at 11.5 nmol/l and 16% at 49.2 nmol/l (14). To show equivalence between different runs, natural saliva samples at two levels (11.5 nmol/l and 49.2 nmol/l) were used as control materials and analyzed together with the samples. Westgard control charts were used to document that the analytical method remained under analytical and statistical control, that is, the trueness and the precision of the analytical methods remained stable (15). The ratio between the analytical and within-subject variation (CVa/CVi) was 0.14, indicating that the method was adequate for measurement in healthy subjects (14). The RIA used in this study was recently evaluated in a laboratory comparison (16).

Statistical methods

P-values below 0.05 were considered statistically significant. To gain comparable sets of data from the two studies, we averaged the construction workers' three daily salivary cortisol measurements across days to yield an average estimate of three time points on an average workday. Repeated-measures models were thereafter specified in order to account for the correlation between measurements within days using the Proc Mixed procedure in SAS (version 8.02, SAS Inc, Gary, NC, USA). The dependent variable was salivary cortisol. The initial model included group [three levels: construction workers with normal 8-hour workdays ($con_{8\text{-hour}}$), construction workers with extended workdays ($con_{extended}$), and the reference group of white-collar workers], as well as time of sampling (three levels: awakening, between 30 and 45 minutes after awakening, and 14 hours after awakening) as categorical predictors. The interaction term group × time of sampling was specified. Models were solved using a restricted maximum likelihood (REML) method. Residual analyses revealed negatively skewed distributions with increasing variances for increasing concentrations of cortisol. The cortisol data were therefore transformed to a normal distribution by means of a logarithmic transformation. For all of the analyses, age and body mass index (BMI) were entered as continuous covariates. The covariates were retained in the model if $P < 0.20$. The relative intraindividual variability was calculated as the coefficient of variation (CV) of the logarithmically transformed concentration of cortisol in the three samples from each person. The coefficient of variation expresses the standard deviation as a percentage of the sample mean (SD/mean×100). A Levene test was used to test the homogeneity of variance across the occupational groups constituting the total sample of white-collar workers.

Results

Figure 1 presents the concentration of cortisol in saliva from awakening to approximately 14 hours after awakening for each group. A repeated-measures analysis showed a statistically significant difference between the groups (P=0.02) and a statistically significant effect of time of day (P<0.01). The interaction between group and time of day was not statistically significant; therefore it was indicated that the groups had a similar diurnal pattern of cortisol concentrations. Posthoc comparisons showed that the construction workers with regular workhours had higher mean concentrations of cortisol in saliva than the white-collar workers (36%, 95% CI 8–72, P<0.01). There was no statistically significant difference between the construction workers with extended workhours and the white collar workers (14%, 95% CI -12–47, P=0.32) (table 2, model 1). The inclusion of age

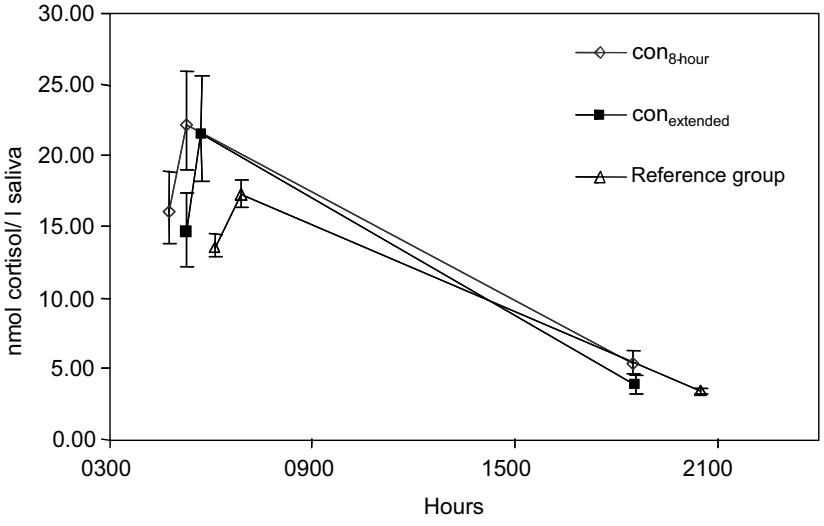

Figure 1. Mean concentration and 95% confidence interval for cortisol in saliva from the construction workers working regular (N=19) ($con_{8\text{-hour}}$) and extended (N=21) ($con_{extended}$) workhours and the reference group of white-collar workers (N=118).

Table 2. Estimated concentrations of cortisol in saliva from the construction workers working regular (N=19) and extended (N=21) workhours and the white-collar workers (N=118). (95% CI = 95% confidence interval)

	Construction workers				White-collar workers	
	Regular workhours		Extended workhours			
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Model 1						
At awakening	18.22	14.43–23.01	15.22	11.78–19.65	13.40	12.00–14.96
+45 minutes	23.78	21.30–26.56	19.86	17.79–22.18	17.49	15.66–19.53
+14 hours	4.68	4.08–5.37	3.91	3.41–4.48	3.44	3.00–3.95
Model 2						
At awakening	17.23	13.12–22.63	14.09	10.68–18.60	13.32	3.15–24.59
+45 minutes	21.64	18.82–24.88	17.70	15.39–20.35	16.72	14.54–19.23
+14 hours	7.76	2.23–26.95	6.35	1.83–22.04	6.00	1.73–20.82

and BMI did not influence the differences between the groups.

In general the construction workers were awake approximately 1 hour before the reference group. For this reason the exact time of sampling and the squared time of sampling were entered as covariates in the next step of the statistical modeling. This adjustment of the statistical modeling weakened the previously observed group difference between construction workers with regular workhours and the white-collar workers to 29% (95% CI -1–70, P=0.06), and further reduced the non-statistically significant difference between the construction workers with extended workhours and the white-collar workers to 6% (95 CI -20–40, P=0.68) (table 2, model 2).

The relative intraindividual variability was statistically significantly lower for the construction workers (76%, 95% CI 65–92) than for the white-collar workers (99%, 95% CI 91–108, P=0.004). The construction workers with regular workdays had a lower variability than the construction workers with extended workdays (72%, 95% CI 57–95, versus 82%, 95% CI 64–112, respectively, P=0.043), although this difference was not statistically significant (table 3). No statistically significant discrepancy from homogeneity in the relative variation of salivary cortisol was found among the different occupational groups constituting the total sample of white-collar workers (P=0.14).

Table 3. Relative variability—the standard deviation expressed as a percentage of the sample mean (coefficient of variation) of each individual's coefficient of variation during the day of sampling. (95% CI = 95% confidence interval)

Group	Coefficient of variation [a, b]	
	%	95% CI
Construction workers	76	65–92
Regular working hours	72	57–95
Extended working hours	82	64–112
White-collar workers	99	91–108

[a] P-value 0.043, difference between construction workers in general and white-collar workers.
[b] P-value 0.004, difference between construction workers with regular and long workhours and white-collar workers.

Discussion

Compared with the white-collar workers, the construction workers showed signs of increased HPA activation, as reflected in their generally higher mean concentrations of salivary cortisol. However, all three groups displayed the expected diurnal pattern of cortisol concentrations with markedly higher concentrations 30–45 minutes after awakening and low concentrations in the evening. Despite differences in the absolute values, the relative increases and decreases within the groups were similar among the three groups. The cortisol concentrations in saliva from the present white-collar group were highly similar to that of a Danish reference population sampled with the similar methodology and during a similar time span as that of the present group of white-collar workers (14). In view of the construction workers' relatively higher risk of CVD, the results partly agree with the results from previous studies, which identified higher cortisol values as associated with an increased risk of CVD (8, 11). However, we did not find the expected gradient between construction workers with extended or regular workhours. Contrary to our expectations, the construction workers with regular workhours, rather than the construction workers with extended workhours, had the highest concentrations of salivary cortisol when compared with the white-collar workers. The differences could not be explained by differences between the groups with respect to BMI or age. However, when the exact time of sampling was accounted for in an analysis of covariance, the observed group differences decreased by about 7% to 8%, and the previously observed statistically significant difference between the construction workers with regular hours and white-collar workers weakened (P=0.06). Nevertheless,

the changes in the estimates and P-values suggest that the time of sampling, or awakening time, is a determinant of the overall mean concentration of cortisol. The apparent time dependency of mean cortisol concentrations emphasizes the importance of putting biological processes in relation to time of day. But, since construction workers by societal convention start work early in the morning, it is possible to argue that the higher cortisol concentration is a consequence of the occupation to which a person belongs.

Variability in morning and night cortisol may be a measure of plasticity in the HPA axis (17). The relative intraindividual variability, as measured by the coefficient of variation of the logarithmically transformed concentration of cortisol in the three samples from each person in the present study, differed between the study groups. The construction workers, in general, had a lower relative intraindividual variability in salivary cortisol concentrations during the workday when compared with the white-collar workers (table 3). The relative intraindividual variability among the white-collar workers was similar to the observed coefficient of variation in a Danish reference population that was sampled with a similar methodology (14).

There are, of course, several factors that may contribute to the variability of cortisol concentration, including, for example, age (18) and smoking (19). The inclusion of age did not influence the conclusions. With respect to smoking, it is very likely that there were more smokers among the construction workers. While heavy smoking just before sampling may increase the concentration of cortisol in saliva (19), habitual smoking does not seem to influence concentrations of cortisol in saliva in normal sampling settings and in field studies (14). For this reason, smoking can, in this study, be considered a potential confounder that may have blurred the result by adding variance to the model.

To summarize, the results suggest that physically demanding construction work is associated with less variable and increased cortisol excretion when compared with white-collar work.

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