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Hair cortisol and work stress: Importance of workload and stress model (JDCS or ERI)

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ABSTRACT

Hair cortisol concentrations (HCCs) are a potential physiological indicator of work related stress. However, studies that tested the relationship between HCC and self-reported stress in a work setting show mixed findings. This may be because few studies used worker samples that experience prolonged stress. Therefore, we compared a high workload sample (n = 81) and a normal workload sample (n = 91) and studied whether HCC was related to: (i) high job demands, low control, and low social support (JDCS model), and (ii) high effort, low reward, and high overcommitment (ERI model). Results showed that self-reported stress related to HCC only in the high workload sample and only for the variables of the ERI model. We found that HCC was higher when effort was high, reward low, and overcommitment high. An implication of this study is that a certain stress threshold may need to be reached to detect a relationship between self-reported stress and physiological measures such as HCC.

1. Introduction

Hair cortisol concentrations (HCCs) might be a potential physiological indicator of work stress exposure. However, a recent meta-analysis has shown that self-reported stress is unrelated to HCC (Stalder et al., 2017). We think there are two main reasons for this null finding. First, many of the reviewed studies did not include samples with high levels of stress exposure (see Stalder et al., 2017). In our estimate, only four studies out of 44 studies measuring self-reported stress and HCC included samples with a high workload indication (e.g., garment factory workers or caregivers to relatives) and only four studies assessed severe stress exposure (e.g., PTSD), see Table 1. Second, the meta-analytic review was unspecific about the sources of stress. Thirty-eight studies out of 44 measured the overall experience of stress without distinguishing between work stress, family stress and other sources of stress (see Table 1).

Among the six studies that focused on work related stress, two commonly proposed stress models were tested in relation to HCC: (i) the Job Demands Control Support (JDCS) model (Johnson and Hall, 1988; Karasek, 1979), and (ii) the Effort Reward Imbalance (ERI) model (Siegrist, 1996). The JDC(S) model theorizes that stress is highest when workers have high work demands, low control, and low social support. Whereas the ERI model theorizes that stress is highest when workers put high effort in their job but receive few rewards, and are also overcommitted. There is no support for a relationship between HCC and the JDC model in the literature. Both in Belgian factory workers (n = 102) and Chinese kindergarten teachers (n = 43), HCCs appeared to be unrelated to high job demands and a low sense of control (respectively: Janssens et al., 2017; Qi et al., 2015). The evidence linking HCC to variables in the ERI model is mixed. Chinese kindergarten teachers (n = 39) had higher HCC when they experienced a higher imbalance between the work efforts they put in and the rewards they received (Qi et al., 2014). However, garment workers in Bangladesh (n = 175) had higher HCC when they perceived more promotion prospects (Steinisch et al., 2014). The authors argued that in those garment factories the possibility of being promoted (i.e., more reward) meant that workers had to meet exceptional standards. Yet, for employees working in the UK public sector (n = 132) and for German factory workers (n = 66), HCCs were unrelated to the effort reward imbalance workers perceived (respectively: Gidlow et al., 2016a, 2016b; Herr et al., 2017).

To address this inconsistency of findings, our research focused on establishing an objective measure of workload that could act as a moderator of the relation between perceived work stress and HCC. Theoretically, an overproduction or underproduction of cortisol must be sustained for a long time period before any changes in HCC would be

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Table 1
Sample description of studies assessing HCC and self-reported stress. To select the articles for this table we used the following procedure. As a first step, we included the articles in Stalder et al. (2017) that measured self-reports of stress and HCC (k = 35). In a second step we searched in google scholar from 2016 with the following keywords: "hair-cortisol" and "perceived stress". Articles found in this search were read and included if they measured self-reported stress and HCC (k = 8). Finally, a reviewer pointed us to another study which we also included.

No.	Reference	Description	Sex	Age range[a]	Country	High workload[b]	Severe stress exposure	Stress at work	Questionnaire used
1	Boesch et al. (2015)	Healthy army recruits	Men	Young adult	Switzerland	No	No	No	PSS
2	Chan et al. (2014)	Non-obese and obese	Both	Young adult-elderly	Canada	No	No	No	PSS
3	Chen et al. (2015)	Children with disabilities and their primary caregivers	Both	Adolescent-young adult	Chile	No	No	No	PSS
4	Dettenborn et al. (2010)	Employed and unemployed	Both	Young adult-middle age	Germany	No	No	No	TICS
5	Diebig (2016)	Employees	Both	Young adult-middle age	Germany	No	No	No	IS
6	Dowlati et al. (2010)*	Cardiac rehabilitation	Both	Middle age-elderly	Canada	No	No	No	PSS
7	Etwel et al. (2014)	Women living in war zone	Women	Young adult	Libya	No	Yes	No	PSS
8	Feller et al. (2014)	General population	Both	Middle age-elderly	Germany	No	No	No	TICS
9	Gerber et al. (2013)	Health science students	Both	Young adult	Switzerland	No	No	No	PSS
10	Gidlow et al. (2016a)	Public sector employees	Both	Young adult-middle age	UK	No	No	Yes	PSS/ERI
11	Gidlow et al. (2016b)	Public sector employees	Both	Young adult-middle age	UK	No	No	No	PSS
12	Grass et al. (2015)	General population	Both	Young adult	Germany	No	No	No	PSS
13	Herr et al. (2017)	Factory workers	Men	Young adult-middle age	Germany	No	No	Yes	ERI
14	Janssens et al. (2017)	Production workers	Both	Young adult-middle age	Belgium	No	No	Yes	JDC
15	Kaess et al. (2017)	Internet gaming disorder	Men	Adolescent-young adult	Germany	No	No	No	TICS
16	Kalra et al. (2007)	Healthy pregnant	Women	Young adult-middle age	Canada	No	No	No	PSS
17	Karlén et al. (2011)	University students	Both	Young adult	Sweden	No	No	No	PSS
18	Kozik et al. (2014)*	Elderly, community-dwelling	Both	Elderly	Canada	No	No	No	PGCMS
19	Lambert et al. (2014)	Temporomandibular disorder	Both	Young adult-middle age	US	No	No	No	PSS
20	Menning et al. (2015)	Breast cancer	Women	Middle age-elderly	Netherlands	No	No	No	PSS
21	O'Brien et al. (2012)	Students, staff and faculty	Both	Young adult-middle age	US	No	No	No	PSS
22	Pulopulos et al. (2014)*	Study program university	Both	Middle age-elderly	Spain	No	No	No	PSS
23	Qi et al. (2014)	Kindergarten teachers	Women	Young adult	China	Yes	No	Yes	ERI
24	Qi et al. (2015)	Kindergarten teachers	Women	Young adult	China	Yes	No	Yes	JDC
25	Saleem et al. (2013)	Coronary artery disease	Both	Middle age-elderly	Canada	No	No	No	PSS
26	Skoluda et al. (2012)	Amateur endurance athletes	Both	Young adult-middle age	Germany	No	No	No	PSS
27	Stalder et al. (2010a)*	Employed by university and students	Women	Young adult	UK	No	No	No	SACL
28	Stalder et al. (2010b)*	Alcoholics	Both	Young adult-middle age	Germany	No	No	No	PSS
29	Stalder et al. (2012a)	University students	Both	Young adult-middle age	Germany	No	No	No	TICS
30	Stalder et al. (2012b)	Endurance athletes and students	Both	Young adult-middle age	Germany	No	No	No	PSS/TICS
31	Stalder et al. (2014)	Elderly caregivers of relatives with dementia	Both	Elderly	Germany	Yes	No	No	SRRS
32	Steinisch et al. (2014)	Garment factory workers	Both	Young adult-middle age	Bangladesh	Yes	No	Yes	ERI
33	Steudte et al. (2013)	PTSD	Women	Young adult-middle age	Germany	No	Yes	No	TICS
34	Steudte et al. (2011a)	PTSD	Both	Young adult	Uganda	No	Yes	No	PSS
35	Steudte et al. (2011b)	Generalized anxiety disorder	Both	Young adult-middle age	Germany	No	No	No	PSS/TICS
36	Steudte-Schmiedgen et al. (2014)	PTSD	Both	Young adult-middle age	Germany	No	Yes	No	TICS
37	Streit et al. (2016)	Bipolar disorder and schizophrenia	Both	Young adult-middle age	BiH	No	No	No	SSCS
38	Sumra and Schillaci (2015)	Readers health and wellness websites	Women	Child -elderly	Canada	No	No	No	PSS
39	Turner et al. (2016)	Disadvantaged neighborhoods	Women	Child-young adult	Australia	No	No	No	PSS
40	van Holland et al. (2012)	Production workers meat-processing industry	Both	Young adult-middle age	Netherlands	No	No	No	NFR
41	Van Uum et al. (2008)	Severe chronic pain	Both	Young adult-middle age	Canada	No	No	No	PSS
42	Wells et al. (2014)*	Mental health problems	Both	Young adult-middle age	Canada	No	No	No	PSS
43	Wosu et al. (2015)*	Clients of barbershops and hair salons	Both	Young adult-elderly	US	No	No	No	Unknown
44	Younge et al. (2015)*	Structural heart disease	Both	Young adult-middle age	Netherlands	No	No	No	PSS/HADS

Note 1: * = Retrieved from Stalder et al. (2017), PSS = Perceived Stress Scale (Cohen et al., 1983), NFR = Need for recovery at work (Braam et al., 2009), TICS = Trier Inventory for the Assessment of Chronic Stress (Schulz and Schlotz, 1999), IS = Irritation scale (Mohr et al., 2006), ERI = Effort reward ratio (Siegrist et al., 2004), JDC = Job Demands Control (Karasek et al., 1998), PGCMS = Philadelphia Geriatric Morale Scale (Lawton, 1975), SACL = Stress Arousal Checklist (Mackay et al., 1978), SRRS = The Social Readjustment Rating Scale (Katschnig, 1980), SSCS = Screening Scale of Chronic Stress of the Trier Inventory for the Assessment of Chronic Stress (Schulz and Schlotz, 1999), HADS = Hospital Anxiety and Depression Scale (Zigmond and Snaith, 1983).

[a] Child: ≤12 yrs., Adolescent: 13–17 yrs., Young adult: 18–39 yrs., Middle age: 40–64 yrs., Elderly: ≥65 yrs.

[b] High workload was operationalized as paid or unpaid activities that require substantial effort over a long time period. Classification was based on the sample description.

expected to relate to subjective stress reports. To test this hypothesis, we recruited a sample of workers that were following an executive management program outside of their normal daily jobs (high workload sample, $n = 81$) and a sample that held regular jobs with no extra work load (normal workload sample $n = 91$). By measuring both the JDC(S) and ERI model variables in these samples we were able to compare the predictive validity of these models for causing work stress. We hypothesized that only in the high workload sample HCC would be related to self-perceived stress.

2. Method

2.1. Participants

One-hundred-and-seventy-two people were included in the final analyses (59 men and 113 women). Mean age was 39 yrs. ($SD = 12$, $min = 20$, $max = 67$) and 79.7% had a university degree. A total of 224 people initially filled out the questionnaire and donated their hair sample. However, we had to exclude 52 people due to the following reasons: failed hormonal analyses (33), allergy medication (8), corticosteroids (3), menopause (5), and breastfeeding (1).

The high workload sample consisted of 81 workers who were all recruited at Nyenrode Business University in the Netherlands. These people were following one of the University's executive management programs and, in addition, held a daytime job. Data collection was done by a Master student (N. Gubbels) who was properly trained in taking hair samples. Recruitment was done by approaching individuals in the executive program directly.

The normal workload sample consisted of 91 workers who only held a daytime job, and were all recruited through the social networks of students. Master students in the course Work and Health at the Vrije Universiteit Amsterdam were trained in taking hair samples and recruited 60 people. N. Gubbels recruited 31 people. Controlling for recruiter did not change the statistical conclusions of this study (see Table 5).

2.2. Procedure

All participants provided informed consent before their participation. After this, they donated a hair sample and then filled out an online questionnaire up to one week after the hair donation. In the questionnaire it was specifically mentioned at each question that their response should reflect their work experiences over the last three months. The study was approved by the Ethics Committee of the Faculty of Behavioral and Movement Sciences of the Vrije Universiteit Amsterdam (VCWE) and was registered under VCWE-2014-060.

2.3. Hormonal analyses

HCCs were determined with a liquid chromatography tandem mass spectrometry method (LC–MS/MS) (Gao et al., 2013) by the lab of the Biological Psychology Department at the Technical University of Dresden. Intra- and inter-assay coefficients of variation are between 3.7 and 8.8% and the limits of quantification (LOQ) are below 0.09 pg/mg. Experimenters tied three strands of hair together with a thread and then cut it with a scissors. Each strand had a minimal length of 3 cm and was cut from the posterior vertex region of the head. Hair strands were placed in aluminum foils that were put in envelopes. The envelopes were placed in a box and sent to the laboratory.

2.4. Questionnaires

2.4.1. General questionnaire

Participants provided information on their work situation (e.g., income, work hours) and health (e.g., disease, alcohol use).

2.4.2. Job demands control support model (JDCS)

Participants filled in the Dutch translation of the Job Content Questionnaire (Karasek et al., 1998) to measure Job demands (4 items, Cronbach's $\alpha = .74$), Control (9 items, Cronbach's $\alpha = .79$), and Social support (8 items, Cronbach's $\alpha = .82$). For Job demands one of the original 5 items was removed ("I am free from conflicting demands others make") as with this item the scale had a Cronbach's α of .69. Participants indicated for each item in how far they agreed with it from 1 (strongly agree) to 4 (strongly disagree). An example of Job demands items is: "My job requires working very hard". An item example of Control is: "I have a lot to say about what happens on my job". To calculate Job demands and Control, items for each scale were averaged. Social support was measured with two scales (4 items each): coworker support (item example: "People I work with take personal interest in me") and supervisor support (item example: "My supervisor is concerned about the welfare of those under him"). Both social support scales were averaged to obtain a single social support measure. Job strain was calculated by log transforming Job control/Job demands, and Job strain with social support was calculated by log transforming Job control/Job demands × Social support (see Courvoisier and Perneger, 2010).

2.4.3. Effort reward imbalance (ERI)

Participants filled in the long version of a Dutch translation of the Effort Reward Imbalance Questionnaire (Hanson et al., 2000) to measure Effort (5 items, Cronbach's $\alpha = .76$), Reward (10 items, Cronbach's $\alpha = .79$), and Overcommitment (6 items, Cronbach's $\alpha = .80$). For Effort one of the original 6 items was deleted ("My job is physically demanding") as participants did not do any physically demanding work (original Cronbach's $\alpha = .72$). Participants indicated for each item in how far they agreed with it from 1 (strongly agree) to 4 (strongly disagree). An item example of Effort is: "I have constant time pressure due to a heavy work load". An item example of Reward is: "My job promotion prospects are poor". An item example of Overcommitment is: "When I get home, I can easily relax and "switch off" work". To calculate Effort, Reward, and Overcommitment the items for each scale were averaged. Effort-reward-imbalance (ERI) was calculated by log transforming Effort/Reward and ERI with overcommitment was calculated by log transforming Effort/Reward × Overcommitment.

2.5. Statistical analyses

First, we performed separate ANOVA's to investigate if the high versus normal workload samples differed in HCC, Number of subordinates, Gross income, Age, Workhours, and the variables of the JDC(S) and ERI model, while controlling for Sex and Age.[1]

Second, we ran moderator regression analyses to investigate if the relationships between HCC and the JDC(S) and ERI models were different for the high workload and normal workload sample. In Step 1 we included Sex and Age as covariates, in Step 2 we included one of the variables from the stress models and Sample (main effects), in Step 3 we included the interaction between stress variable and Sample. For those significant interactions we performed simple slope analyses to interpret the interaction. The statistical conclusions of this study did not change when not including any covariates in Step 1 (see Table 5).

HCC and gross income were log transformed due to their skewed distribution (no. subordinates was sqrt transformed since it contained zero's). Following guidelines by Pollet and van der Meij (2017), we detected four HCC outliers that were both more than 3 standard deviations (SD) from the mean and more than 3 times the interquartile range (IQR). Outlier removal did not change the statistical conclusions of this study (see Table 5).

[1] In the Supplementary material: see Table S7 for the relationship between age and the study variables and see Table S8 for sex differences in the study variables.

Table 2
Sample differences in HCC, No. subordinates, Gross income, Weekly work hours, Age, Sex, and Educational level.

	High workload sample				Normal workload sample				Sample difference			
	Median	*Range*	*Q1*	*Q3*	*Median*	*Range*	*Q1*	*Q3*	η_p^2	*F*	*df*	*p*
HCC	7.34	51.45	5.60	12.21	6.59	22.39	4.80	9.60	.024	4.15	1,168	.043
No. subordinates	4	80	0	11	0	20	0	3	.084	15.35	1,168	< .001
Gross income	70,000	296,500	40,000	85,000	33,000	129,964	20,802	50,000	.109	19.83	1,162	< .001
	Mean	*SD*	*Q1*	*Q3*	*Mean*	*SD*	*Q1*	*Q3*	η_p^2	*F*	*df*	*p*
Age	41.25	9.84	35	47	37.51	13.67	25	51	.024	4.07	1,169	.045
Work hours	43.74	10.43	38	50	38.35	8.02	32	41	.061	10.86	1,168	.001
		Count		*Count*	*Count*		*Count*		X^2		*df*	*p*
Sex		34 men		47 women	25 men		66 women		4.00		1	.054
Educational level		71 university		10 no university	25 university		66 no university		6.05		1	.015

Note: The statistics comparing the sample differences were calculated with the log transformed values of HCC and Gross income, and No. subordinates was sqrt transformed. In the ANOVA sample difference analyses we controlled for Sex and Age.

Table 3
Sample differences in the JDC(S) and ERI model.

	High workload sample		Normal workload sample		Sample difference			
	M	*SD*	*M*	*SD*	η_p^2	*F*	*df*	*p*
JDC(S) model								
Job Demands	2.82	.52	2.83	.53	.001	.10	1,168	.757
Control	3.22	.42	3.02	.40	.041	7.16	1,168	.008
Support	2.86	.41	2.95	.44	.006	.97	1,168	.326
Job strain	.06	.09	.03	.10	.019	3.29	1,168	.071
Job strain with social support	.52	.12	.50	.14	.005	.81	1,168	.369
ERI model								
Effort	2.94	.56	2.87	.57	.002	.34	1,168	.561
Reward	2.76	.48	2.84	.41	.007	1.17	1,168	.281
Overcommitment	2.47	.57	2.47	.57	< .001	.07	1,168	.792
ERI	.03	.12	< -.01	.13	.007	1.26	1,168	.264
ERI with overcommitment	.40	.19	.38	.22	.002	.29	1,168	.593

Note: In the sample difference analyses we controlled for Sex and Age.

In the Supplementary materials we included the following analyses: results moderator regression analyses when using the variables from the stress models as separate predictors (Table S1), when analyzing the samples separately (Tables S2–S3), when combining samples (Table S4), or when using work hours as moderator (Table S5), variable skewness and kurtosis (Table S6), a correlation matrix of all study variables (Table S7), and sex and educational differences in the study variables (Tables S8–S9).

3. Results

3.1. Difference between high and normal workload sample

Compared to the normal workload sample, workers in the high workload sample had higher HCCs, worked more hours, had more subordinates, had a higher income, were better educated, and were on average 4 years older (see Table 2). Also, there were more men in the high workload sample than in the normal workload sample (see Table 2). Workers in both samples did not differ in Job demands, Social Support, Job strain with Social support, Effort, Reward, Overcommitment, ERI, and ERI with Overcommitment (see Table 3). However, workers in the high workload sample indicated to have more control over their work, and to a marginally significant extent, experienced less job strain than the workers in the normal workload sample (see Table 3).

3.2. JDC(S) model

In the high and normal workload sample, HCCs did not relate differently to Job demand, Control, Social support, Job strain, and Job strain with Social support (see Table 4).

3.3. ERI model

In the high and normal workload sample, HCC related differently to Effort, Overcommitment, and ERI with and without Overcommitment, but not Reward (see Table 4). Outlier removal, not including covariates, and including the following covariates did not change the statistical conclusions of these significant results: hormonal contraception, alcohol use, smoking, medication, hair dye, recruiter, university education, work hours, number of subordinates, and gross income (see Table 5).

As we predicted, only in the high workload sample were higher

Table 4
Results of the moderator regression analyses with HCC as outcome, Sample (high vs. normal workload) as moderator, and variables from the JDC(S) or ERI model as predictors. Reported are the change statistics when going from step 2 (main effects) to step 3 (interaction effect).

Moderator regression analyses: high vs. normal workload				
Predictors	Δr^2 (%)	ΔF	*df*	*p*
JDC(S) model				
Job Demands × Sample	.6	1.04	1,166	.310
Control × Sample	> .1	.01	1,166	.909
Support × Sample	1.1	2.00	1,166	.160
Job strain × Sample	.4	.74	1,166	.391
Job strain with Social support × Sample	1.1	2.05	1,166	.155
ERI model				
Effort × Sample	3.4	6.38	1,166	.012
Reward × Sample	1.0	1.79	1,166	.183
Overcommitment × Sample	3.4	6.50	1,166	.012
ERI × Sample	4.3	8.30	1,166	.004
ERI with Overcommitment × Sample	4.9	9.38	1,166	.003

HCCs related to more Effort ($\beta = .259$, $t_{166} = 2.41$, $p = .017$), higher Overcommitment ($\beta = .228$, $t_{166} = 2.13$, $p = .035$), higher ERI ($\beta = .329$, $t_{166} = 2.97$, $p = .003$), and a higher ERI with Overcommitment ($\beta = .335$, $t_{166} = 2.96$, $p = .004$). Yet, in the normal workload sample, HCCs were unrelated to Effort ($\beta = -.114$, $t_{166} = -1.14$, $p = .258$), Overcommitment ($\beta = -.146$, $t_{166} = -1.45$, $p = .148$), ERI ($\beta = -.098$, t_{166} = -1.01, $p = .316$), and ERI with Overcommitment ($\beta = -.119$, t_{166} = -1.25, $p = .213$). See Figs. 1 and 2 for the relationship between HCCs and ERI with and without Overcommitment in both samples.

4. Discussion

In line with our hypothesis, results of this study showed that workload intensity is a crucial moderator of the relationship between physiological and psychological indicators of stress exposure. Only in the high workload sample did we find a relationship between self-reports of work stress and HCC. This finding is in line with research in Chinese kindergarten teachers who taught both normally developing and developmentally disordered children (Qi et al., 2014). In the Chinese sample, HCC was also related to self-reported job stress and this was related to variables from the ERI model (Qi et al., 2014) and not the JDC model (Qi et al., 2015). Our study corroborates their finding. This means that factors associated with an effort-reward imbalance (ERI Siegrist, 1996) are better at predicting HCC than variables from the JDC(S) model (Johnson and Hall, 1988; Karasek, 1979). Our results showed that high effort combined with low reward (ERI) and high ERI combined with high overcommitment are related to increased basal hypothalamus-pituitary-adrenal (HPA) axis activity (i.e., high HCC); yet only in the high workload sample (medium effect sizes: $\beta = .33$ and .34). Of further interest is that perceived effort was also related to HCC levels ($\beta = .26$) but explained less variance than ERI with or without overcommitment. On the other hand, job strain with and without social support (JDCS) was unrelated to basal HPA axis activity in either workload sample. This suggests that physiological health related outcomes, such as basal cortisol levels, may change when people feel they work hard but get little compensation for their efforts and are very committed to their job. We did not find that the combination of high job demands, low job control, and low social support were associated with differences in HCC. This could mean that these factors are less important in experiencing prolonged stress levels, at least at a physiological level. Another possibility for this null effect could be that job control was relatively high among the workers across the entire high workload sample ($M = 3.2$ on a 4 point scale), which could have produced a null effect due to restriction of range. This is perhaps not surprising as these people were allowed by their employer – and sometimes they were sponsored too – to follow an executive study program outside their normal job.

The high and normal workload samples differed in objective measures of workload such as weekly working hours, number of subordinates, and income, but high work loaders did not report more subjective self-reported stress (measured via ERI). Of interest is that job strain (control/demands) was marginally lower in the high workload sample, probably due to high levels of job control experienced by the high workload sample. Indeed, job control alone explained more variance between samples than job strain. Interestingly, HCCs were higher in the high workload sample than in the normal workload sample. This is an important result. Future studies could test if physiological indicators of prolonged stress exposure appear before any psychological stress is experienced. An interesting hypothesis to test is if increased cortisol secretion functions as an active coping strategy of the body to help cope with an intense workload. If high cortisol secretion is maintained and workload stays high for a longer time period this could then eventually lead to psychological complaints. When stress becomes

Table 5
The impact on the *p* values of the significant interaction effects in 3.3 when including no covariates, removing HCC outliers, and adding additional covariates.

	Covariates	Variable × Sample			
		Effort *p*	Overcommitment *p*	ERI *p*	ERI with Overcommitment *p*
Main result study	Sex and Age	.012	.012	.004	.003
No covariates	–	.045	.021	.021	.010
No HCC outliers[a]	Sex and Age	.041	.028	.049	.024
Controlling for Sex and Age	Hormonal Contraception[b]	.012	.012	.004	.003
+ adding covariates one at a time	Alcohol[c]	.012	.012	.005	.003
	Smoking[d]	.013	.012	.005	.003
	Medication	.013	.011	.004	.002
	Hair dye	.008	.009	.001	.001
	Recruiter[e]	.016	.018	.004	.003
	University education	.013	.012	.004	.003
	Work hours	.016	.01	.005	.003
	No. subordinates (sqrt)	.011	.009	.004	.002
	Gross income (log)	.006	.017	.004	.003

[a] Four HCC outliers were identified that were both more than 3 standard deviations (SD) from the mean and more than 3 times the interquartile range (IQR).
[b] Use of hormonal contraceptives (yes/no).
[c] Drinking 3 or more alcoholic units a day for men and 2 or more alcoholic units a day for women (yes/no).
[d] Smoking more than 5 cigarettes a day (yes/no).
[e] By N. Gubbels or other Master students.

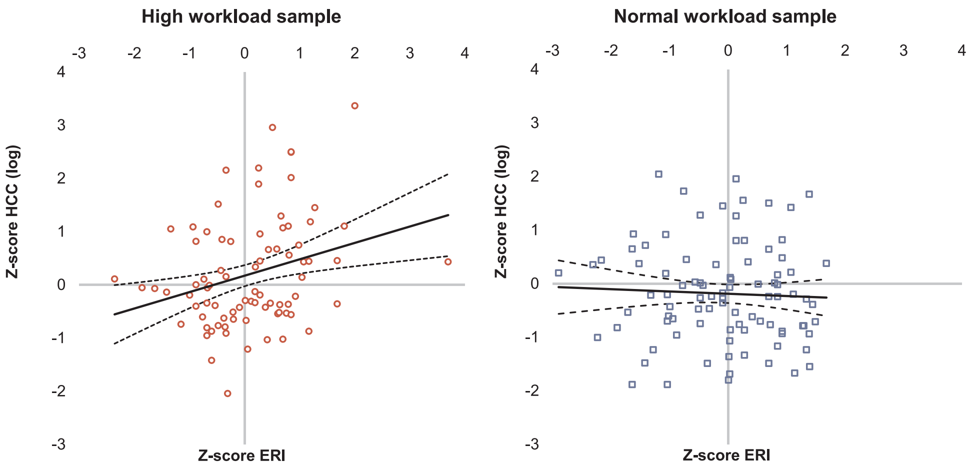

Fig. 1. Scatterplots of HCC and ERI for the high and normal workload sample. Also plotted are the regression lines with their 95% confidence interval.

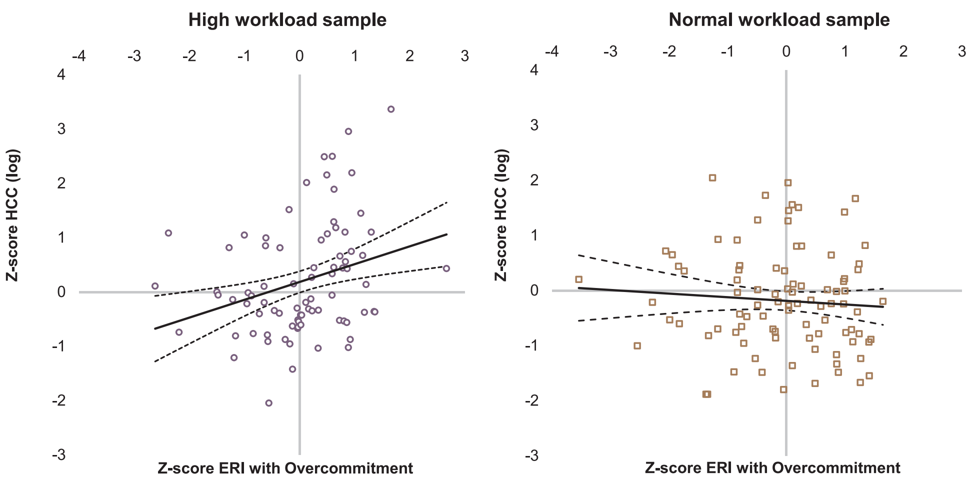

Fig. 2. Scatterplots of HCC and ERI with Overcommitment for the high and normal workload sample. Also plotted are the regression lines with their 95% confidence interval.

chronic (e.g., type II allostatic overload) and cortisol levels are elevated for longer periods of time, cortisol receptors become desensitized, which leads the organism to cope by excessive cortisol production, which again leads to the onset of physiological disease and psychological disorders such as depression or burnout (McEwen, 2003).

The main limitations of this study were that we only had access to cross-sectional data and that work stress was measured retrospectively. Thus, from our study we cannot infer whether the experience of work stress caused HCC to change or that HCC changed the way stress was experienced. Also, we did not assess the impact of major life events (e.g., divorce, promotion) so we could not investigate how these events affected perceived work stress and HCC. Future studies could use longitudinal designs to address these interesting possibilities. Another limitation was that workers in our high and normal workload sample differed in several ways (e.g., sex, age, education). Some of these differences may have arisen due to chance whereas others were inherent to the two samples we selected. For example, workers in the high workload sample probably had a higher socio-economic status than workers in the normal workload sample, because they had jobs with higher responsibility and higher income. We controlled statistically for these sample differences and this does not change the statistical conclusions (see Table 5). Nonetheless, these differences have to be taken into account when interpreting our results.

In sum, our study shows that when assessing the relation between prolonged stress exposure and HCC in a working population it is important to take into account workload factors. It is possible that a certain stress threshold may need to be reached to detect a relationship between self-reports of stress and changes in cortisol. Additionally, we show that it is important which work-related stress model (i.e., questionnaire) is used to measure prolonged stress exposure. A final contribution of our research is that by combining psychological and physiological indicators one can better assess which job conditions produce stress and potentially produce good or bad employee health.

Conflict of interests

None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.psyneuen.2017.12.020.

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