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ORIGINAL ARTICLE

Relationship between work strain, need for recovery after work and cumulative cortisol among kindergarten teachers

Xingliang Qi · Yapeng Liu · Jing Zhang · Shuang Ji · Judith K. Sluiter · Renlai Zhou · Huihua Deng

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Abstract
Objectives The purpose of this study was to explore whether work strain (i.e., job demands and job control) and subjective need for recovery (NFR) after work are related to measured concentration of cumulative cortisol.
Methods Participants were 43 teachers recruited from kindergarten. They self-reported their NFR, job demands and job control over the last month. NFR was measured with the NFR scale. Job demands and control were assessed with the Chinese version of the Job Content Questionnaire. Hair cortisol was used to represent cumulative cortisol excretion. Hair cortisol concentration (HCC) was measured with high-performance liquid chromatography–tandem mass spectrometry.
Results No significant correlations were found between job demands or job control and HCC. NFR was significantly and inversely correlated with HCC ($r = -0.41$, $p = 0.006$). The inverse association between NFR and HCC remained significant when age and job demands and job control were controlled for ($p = 0.02$).
Conclusions The activity of the hypothalamic–pituitary–adrenal axis declines with the accumulation of NFR after working time.

Keywords Work strain · Job demands · Job control · NFR · Hair cortisol

Huihua Deng and Judith K. Sluiter are co-principal investigators of this study.

X. Qi · Y. Liu · J. Zhang · S. Ji · H. Deng (✉)
Key Laboratory of Child Development and Learning Science of Ministry of Education (Southeast University), and Institute of Child Development and Education, Research Center for Learning Science, Southeast University, Nanjing 210096, China
e-mail: dengrcls@seu.edu.cn

J. K. Sluiter
Coronel Institute of Occupational Health, Academic Medical Center, University of Amsterdam, PO Box 22700, 1100 DE Amsterdam, The Netherlands

R. Zhou · H. Deng
Beijing Key Laboratory of Applied Experimental Psychology, School of Psychology, Beijing Normal University, Beijing 100875, China

Introduction

Need for recovery (NFR) has been considered as a link in a chain of complicated physiological and psychological procedures between work strain (i.e., high job demands and low job control) and its chronic effects on health (Sluiter et al. 2003). NFR was defined as the need to recuperate from work-induced fatigue (Mejman et al. 1990; Sluiter et al. 1999). It is a kind of short-term fatigue deriving from work strain and also deciding on workers' recovery capability in certain time period (Sluiter et al. 2003). A lack of sufficient recovery under sustained work strain will cause the residual NFR accumulate day by day (Sluiter et al. 2003) and sequentially result in burnout, chronic fatigue or low-energy syndromes (Arnetz et al. 2008, 2014). In terms of psychophysiology, the insufficient recovery from work stress may contribute to irregular activities of individual's biological stress system, thereby giving rise to health problems (Maina et al. 2009). Therefore, NFR and irregular stress response might be two important intermediates between work strain and chronic fatigue or low-energy syndromes. It is essential to explore the relationship between NFR and the biological stress response for understanding the association between work strain and its outcomes.

Accumulation of NFR was thought to reduce workers' response capability to new job demands (Sluiter et al. 2003). In other words, it would weaken the biological response of stress-sensitive system. As the allostatic load theory proposes, repeated stress without complete adaptation over time leads to accumulated physiological wear and tear and multisystem dysregulation state, especially the decreased response in the stress system (McEwen 1998). This gives an implication that lack of recovery from work strain may result in decreased activity of stress system. Additionally, NFR is essentially short-term work-related fatigue (Sluiter et al. 2003). It may manifest as weak stress response (Kumari et al. 2009) as fatigue (e.g., physical weakness and low-energy syndromes) showed the characteristics (Dittner et al. 2004; Arnetz et al. 2008). From the above, NFR may be related to decreased activity of stress system.

The hypothalamic–pituitary–adrenal (HPA) axis is one of the primary stress response systems, the dysfunction of which can pose a threat to health (Juster et al. 2010). The end product of the HPA axis, cortisol, has been taken as an indicator of HPA axis's response to challenges in the workplace and also been linked to a variety of clinical and subclinical symptoms of health (Anagnostis et al. 2009; Chandola et al. 2010). Several empirical studies have been done on the relationship between scores of subjective NFR and cortisol level. Some studies on the relationship found inverse associations (Sluiter et al. 2001; Rydstedt et al. 2009), which was consistent with the above theoretical hypothesis. However, there were inconsistent results on the relationship, with some studies finding positive associations (Sluiter et al. 2001; Gustafsson et al. 2008) and non-significant associations (Axelsson et al. 2003; Van Holland et al. 2012). The inconsistencies might be partly attributed to some methodological limitations in assessing long-term or basal cortisol level. Most of the above-mentioned studies utilized urinary or salivary cortisol to represent basal cortisol levels. These biomarkers have typical circadian and ultradian rhythms within a day (Van Cauter 1990) and only can provide an assessment of cortisol secretion over a few minutes or a few hours at maximum. The sampling time of saliva or urine may complicate the relationship between subjective measures of NFR and cortisol secretion. For instance, the relationship was inverse during work for early morning salivary cortisol and urinary cortisol secretion (Sluiter et al. 2001; Rydstedt et al. 2009), but was positive in the weekend day following working days for evening salivary cortisol excretion and urinary cortisol excretion (Sluiter et al. 2001; Gustafsson et al. 2008). Additionally, unexpected events happening just before the sampling may cause fluctuations of cortisol level (see review, Russell et al. 2012). This will make the association of NFR with cortisol unstable, especially for salivary cortisol. Thus, salivary cortisol excretions could not reliably represent basal cortisol levels for validating the relationship between NFR and cortisol level.

Recently, hair cortisol is regarded as a promising biomarker to assess long-term cortisol excretion (Russell et al. 2012). Unlike salivary cortisol, hair cortisol opens a new time window of providing a retrospective index of cumulative cortisol excretion or basal cortisol level over several months (Russell et al. 2012). It is now thought to be less affected by circadian rhythm and causal situational factors before sampling (Russell et al. 2012; Stalder et al. 2012). A recent study has attempted to explore the relationship between NFR and cortisol concentration in 3-cm-long hair, but failed to find that the association was significant (Van Holland et al. 2012). In the study, assessment of NFR was representative of several weeks, and cortisol concentration in 3-cm-long hair estimated mean cortisol concentration over about three months if hair growth rate is 1-cm segment per month (Russell et al. 2012). Thus, the insignificant association might be attributed to a temporal mismatch between cortisol assessment and the psychological measurement (Qi et al. 2014a). It inferred that 1-cm-long hair closest to the scalp to estimate the cortisol excretion over one month might more closely match time span of the measurement of NFR over one month. Therefore, using cortisol level in 1-cm-long hair closest to the scalp as biomarker, the present study aims to examine the relationship between NFR and cortisol concentration.

However, work strain can activate HPA activity and induces an increase in cortisol level. Most of empirical studies had shown that workers in high strain jobs (i.e., low control and high demands) had higher cortisol levels compared to those in low strain jobs (i.e., high control and low demands) (Alderling et al. 2006; Kunz-Ebrecht et al. 2004; Steptoe et al. 2000; Maina et al. 2009) although other studies failed to observe significantly positive associations (Maina et al. 2008; Steptoe et al. 1998). The positive association between strain and cortisol may be true for salivary cortisol, but we are not sure whether it is true in the case of hair cortisol. Therefore, one aim of the present study is to explore the relationship between work strain and hair cortisol. On the one hand, we expected the hair cortisol will rise with work strain as salivary cortisol does. On the other hand, work strain has been proven to be resource of NFR (Sluiter et al. 2001, 2003). Thus, the relationship between work strain and cortisol level might influence the relationship between NFR and cortisol level. Therefore, the present study will control the potential confounding variables, job demands and job control, when exploring the relationship between NFR and hair cortisol concentration (HCC). Additionally, there is no research to explore the relationship between work strain and hair cortisol while the effort–reward imbalance in work was found to show positive correlation with HCC (Qi et al. 2014a). Therefore, the present study will explore how the job demands and job control influence hair cortisol.

In this study, kindergarten teachers were selected as participants because they are a typical population group of chronic work strain. Teaching kindergarten children is complex work, which needs teachers to contribute mentally, physically and emotionally. Thus, kindergarten teachers face high work strain (Larchick and Chance 2004). Additionally, Chinese kindergarten teachers have fixed work and rest time (40 h per week, 8 h per day), and their working timetable is typical among Chinese workers.

Methods

Participants

Participants were teachers who worked in two kindergartens in Nanjing, China. Male teachers were excluded because almost all the employees in the kindergarten were females. Thirty-seven teachers worked in Kindergarten A, which was in charge of both normally developing children and developmental disordered children. Of these teachers, 26 teachers consented to participate in this study. Nineteen teachers worked in Kindergarten B, which was responsible for only normally developing children. Of these teachers, 17 teachers consented to participate in this study. Finally, a total of 43 out of 56 female kindergarten teachers (77 %) participated in this study. Participants gave signed informed consent before participating in the study. This study followed the Declaration of Helsinki and was approved by the Health Science Research Ethics Board of Southeast University.

Participants should meet the following criteria: (a) their body mass index (BMI) was under 28 kg/m^2 since obesity might affect HCC (Stalder et al. 2012), (b) their hair was not dyed and bleached and not treated by permanent waving and straightening, (c) their hair in the posterior vertex was longer than 1 cm, and (d) their age ranged between 20 and 50 years during which they are in the working state in China. All participants self-reported that they had no pre-existing mental diseases or neuroendocrine diseases (e.g., Cushing syndrome and Addison's disease), had no other major life events and received no medical treatment nor used glucocorticoid within the latest one-month period.

Questionnaires and survey

The NFR was measured with the NFR scale developed by Van Veldhoven and Meijman (1994). The NFR scale is a self-report instrument to measure a cumulative fatigue effect of high job demands in relation to a worker's ability to deal with that over last month. The scale consists of 11 dichotomous items, which describe the need of the recovery after work, such as 'Generally speaking, I need over an hour to recuperate after work' and 'I am so tired that I cannot keep up my normal work during the second half of the day.' Answers are provided on a binomial scale, 'yes' or 'no.' The raw score is the total number of 'yes' answers (after reversely recoding Item 4). The raw score (between 0 and 11) is then converted into a standard score from 0 to 100 by multiplying 100/11, with higher scores mean more NFR after work or more work stress. Previous studies recommended that 54.4 in the scale is used as a cutoff point of health surveillance (Boschman et al. 2014; Ketelaar et al. 2013), which may provide a clue on which workers should be treated on excessive chronic stress. Because it had not ever been applied in a Chinese sample, we first validated whether its factor structure was satisfactory in assessing Chinese workers' NFR (Qi et al. 2014b). We modified the scale as follows. First, the scale was reviewed by the English speaker and the specialist after the English–Chinese translation and Chinese–English retranslation. It was suggested that the reviewed scale can reflect the need of recovery, especially during the last hours of work and immediately after work. Second, the scale was filled in by 554 Chinese workers (median age = 34; age range from 20 to 56) who work in a wide series of working fields including teachers for its construct validity. The 11-item scale showed good construct validity as demonstrated by confirmatory factor analysis (CFA) based on maximum likelihood estimation where $\chi^2/df = 2.98$, root mean square error of approximation = 0.06, root mean square residual = 0.01, normed fit index = 0.94, comparative fit index = 0.96, incremental fit index = 0.96 and goodness of fit index = 0.96. Standardized factor loadings of all items were significant, >0.32 in the expected direction. Finally, its Cronbach's alpha coefficient was 0.78 for the 554 workers and 0.86 for the 43 teachers in the present study.

Job demands and control were assessed with the Chinese version of the Job Content Questionnaire (C-JCQ) that is a reliable and valid instrument for measuring work characters among Chinese healthy workers (Cheng et al. 2003). The present study focuses on two subdimensions of the questionnaire: the 5-item psychological demands scale (i.e., 'Is the working time enough for you to finish the work?') and the 9-item job control scale (i.e., 'Do you have a choice in deciding how you do your work?'). Each item was rated on a 4-point scale ranging from 1 (strongly disagree) to 4 (strongly agree). Both raw scores of these scales were converted into a 0–100 score with higher scores meaning higher job demands and higher job control. In the present study, the Cronbach's alpha coefficients of the job demands and job control scales were 0.68 and 0.67, respectively.

Questionnaire data were collected in teachers' own work places. Participants self-reported their background information including gender, age, height, weight, working age (years of being a teacher), weekly working time and frequency of hair washing with shampoo and whether their hair was treated during the last 3 months. In the meantime, they also globally evaluated job demands and control during the last 4 weeks with the C-JCQ scale and how often their NFR in the evenings after work was experienced during the last 4 weeks with the NFR scale.

Collection of hair samples and assay of hair cortisol

Collection of hair samples was also done in teachers' own work places immediately after the survey. Hair strands in the posterior vertex region were cut with iron scissors as close as possible to the scalp. The hair strands were stored at -50 degree centigrade and were cut into 1-cm segments prior to use. The 1-cm segment closest to the scalp was used in the following cortisol assay.

The procedures for measuring hair cortisol were described elsewhere (Qi et al. 2014a). Briefly, the hair samples were washed twice with 2 ml methanol for 2 min. The 20-mg clean hair samples were finely cut into pieces and incubated in 1 ml methanol for 2 days at 25 degree centigrade. Cortisol-d4 as internal standard was added at 10 ng/ml in the incubation. The 2-day incubated solution was centrifuged at 10,000 rpm for 1 min. A 400 µl of supernatant was took out and dried with nitrogen at 40 degree centigrade. The dried sample was redissolved in 80 µl methanol for cortisol analysis that was performed in a 3200 QTRAP liquid chromatography–tandem mass spectrometer (ABI, USA). Cortisol was ionized with an electrospray ionization source, identified in negative ion mode using multiple reaction monitoring mode and quantified by internal standard method. The transition of the mass-to-charge ratio was observed from 407.20 to 331.2 for cortisol and from 411.20 to 335.20 for cortisol-d4. The assay method for hair cortisol gave limits of detection and quantitation at 0.5 and 1 pg/mg, and intra-day and inter-day coefficients of variation <10 %, and accuracy of 99.2 ± 8.3 % at 2 pg/mg and 103.1 ± 7.3 % at 20 pg/mg (Qi et al. 2014a) and 102.8 ± 7.2 % at 200 pg/mg, showing good reliability and validity.

Statistic analysis

CFA was performed by Lisrel 8.70. Data were analyzed using the statistical package SPSS 16.0 for Windows. The data distribution normality was examined with one-sample Shapiro–Wilk test. As listed in Table 1, all the data were presented as median (range) for non-normally distributed data and for normally distributed data as M ± SD where M was mean value and SD was standard deviation. Mann–Whitney U test was done for comparison of age, working age, BMI, job control, job demands and HCC between subgroups in charge of different children and between subgroups with NFR scores higher and lower than 54.4. Spearman's rank correlation analysis was conducted to examine association between age, working age, BMI, job control, job demands, NFR and HCC. Furthermore, partial correlation analysis with job demands and control as control variables was conducted to examine whether job demands and control impact the relationship between NFR and HCC. Non-normally distributed data were log-transformed for Pearson's correlation analysis and the hierarchical multiple regression analysis because log-transformation effectively reduced the skewness and kurtosis. A two-tailed p value of 0.05 was used as significance.

Results

Table 1 provides participants' descriptive information regarding sociodemographic data and hair-related characteristics.

Table 1 Descriptive statistical results of sociodemographic data, hair-related characteristics, job demands, job control, need for recovery (NFR) and hair cortisol concentration (HCC) in female kindergarten teachers ($n = 43$)

Characteristics	median, range, $q1$, $q3$	M ± SD	Shapiro–Wilk test
Age (years)	27, 20–46, 24, 30	28 ± 6	$p < 0.001$
Working duration as teacher (years)	5, 1–30, 3, 8	6 ± 5	$p = 0.002$
Body mass index (kg/m^2)	21, 18–26, 18, 23	21 ± 3	$p = 0.135$
Job control	57, 32–73, 53, 60	55 ± 12	$p = 0.046$
Job demands	58, 43–76, 55, 61	58 ± 11	$p = 0.103$
NFR	45, 9–100, 27, 57	45 ± 18	$p = 0.023$
HCC (pg/mg)	12.8, 1.4–108.2, 6.2, 21.0	19.5 ± 22.0	$p < 0.001$

$q1$ and $q3$ are 1st and 3rd quartiles, respectively

M is mean value and SD is standard deviation

p is statistical significance

Table 2 Summary of regression coefficients of hair cortisol concentrations against need for recovery (NFR)

	B	SE	*p*
Step 1			
Age	0.004	0.012	0.738
Job demands	−0.000	0.006	0.998
Job control	0.000	0.006	0.957
Step 2			
NFR	−0.536	0.217	0.018

Hair cortisol concentrations and need for recovery were log-transformed

B is unstandardized regression coefficient, SE is standard error mean and *p* is statistical significance

Thirteen teachers (30 %) got the scores over 54.4 on the NFR scale, and the other 30 teachers (70 %) got NFR scores below 54.4. There were no significant differences between these two groups in job demands ($Z = -1.95$, $p = 0.68$), job control ($Z = -0.84$, $p = 0.77$) or HCC ($Z = -1.02$, $p = 0.21$). The 13 teachers with high NFR scores were significantly older (median age = 30, range 20–43, $q1 = 5$, $q3 = 12$ versus median age = 26, range 20–46, $q1 = 24$, $q3 = 27$; $Z = -2.57$, $p = 0.01$) and had significantly longer working age (median working age = 6, range 1–20, $q1 = 5$, $q3 = 16$ versus median working age = 4, range 1–30, $q1 = 3$, $q3 = 6$; $Z = -2.28$, $p = 0.02$) than 30 teachers who with normal NFR scores.

NFR showed no significant correlation with age ($r = 0.26$, $p = 0.09$), working age ($r = 0.10$, $p = 0.53$) or BMI ($r = 0.20$, $p = 0.21$). NFR also showed no significant correlation with job control ($r = -0.10$, $p = 0.61$) and job demands ($r = -0.03$, $p = 0.98$). HCC showed no significant correlation with age ($r = 0.06$, $p = 0.71$), working age ($r = 0.06$, $p = 0.97$) and BMI ($r = 0.08$, $p = 0.63$). HCC also showed no significant correlation with job control ($r = -0.01$, $p = 0.84$) and job demands ($r = -0.12$, $p = 0.46$), but did significant and inverse correlate with NFR ($r = -0.41$, $p = 0.006$). Pearson's correlation analysis showed that there was a significant and inverse correlation between log-transformed NFR and log-transformed HCC ($r = -0.35$, $p = 0.02$). Furthermore, the hierarchical multiple regression analysis including age, job demands and control in the first level and log-transformed NFR in the second level was performed. The results revealed that NFR score significantly and inversely predicted hair cortisol level ($p = 0.02$), but age, job demands and control did not significantly predict it ($ps > 0.05$) as listed in Table 2.

Discussion

The current study showed a significant and inverse association between scores of subjective NFR and HCCs among the kindergarten teachers. Such inverse association indicated that workers who experience more NFR over 1 month would have lower cumulative cortisol excretion. To our knowledge, it is the first evidence on the inverse association between work-induced short-term fatigue and cumulative cortisol excretion.

Previously, two studies have shown inverse correlations between the subjective NFR and the salivary cortisol secretion in the evening (Rydstedt et al. 2009) and on the day off (Sluiter et al. 2001), which is similar to our finding. These results may suggest that if an individual has greater amount of NFR, he/she would have a lower level of cortisol secretion when he/she is not at work. In contrast, there were positive correlations between the subjective NFR and the cortisol secretion in the morning (Gustafsson et al. 2008) and during work (Sluiter et al. 2001). These results seem contrary to the present finding, but compatible. Acute cortisol level (e.g., salivary cortisol level) would be affected by work strain in the working time where work strain might induce an increase in cortisol level in the working time (Alderling et al. 2006; Kunz-Ebrecht et al. 2004; Steptoe et al. 2000; Maina et al. 2009). Work strain is considered as source of NFR, so the acute cortisol level in the morning could covary with the NFR from work. Because the total time out of work is more than the time in work, the cortisol excretion in the out-work time would have greater contribution on the cumulative cortisol levels in hair that reflect the cumulative of cortisol excretion in an extended period. It may be the main reason for hair cortisol get the inverse correlations with NFR like the salivary cortisol secretion in the evening (Rydstedt et al. 2009) and on the day off (Sluiter et al. 2001).

NFR is considered as the prelude of chronic fatigue (Sluiter et al. 2003). In a previous study, low waking salivary cortisol and a flat slope in cortisol secretion are associated with fatigue in non-clinical populations (Kumari et al. 2009). Additionally, diminished adrenal steroid production was regarded to be typical characteristics of chronic fatigue (Werbel and Ober 1993). The present results, hair cortisol showing inverse correlation with NFR, may provide collateral evidence for the notion that NFR is a kind of short-term fatigue and is an early symptom of work-related chronic fatigue (Sluiter et al. 2003).

The present result, inverse association between NFR and hair cortisol, provides a basis for the allostatic load theory in the work stress area. As predicted by the allostatic load theory (McEwen 1998), consistently uninterrupted stress response would decrease or suppress the physiological function of the stress response system. The accumulative process of NFR is just such a process. If an individual has not enough time or possibilities to recover from NFR and return to a normal or pre-stressor level of functioning after work, the residual NFR will accumulate day by day. The present study showed the more experienced NFR is associated with the lower level of cortisol excretion. It may suggest the more accumulate NFR the lower cortisol activity. It is consistent with the allostatic load theory's predictions.

The present study did not find significant correlations between job demands or control and HCC. One reason may be the fact that work characteristics might play an impact on the HPA axis's activity at certain time points or a short period rather than for all the time of daily life (Qi et al. 2014a), while hair cortisol reflects the total cortisol excretion for a long time. Another reason may be that the present homogeneous populations may give rise to a narrow window of variation in job demands and job control. The narrow distribution does not well match the wide variation in hair cortisol level, resulting in a lack of association between work characteristics and hair cortisol. Additionally, previous studies did not always find the direct and significant correlation between NFR and the job demands or control (Sluiter et al. 2001; Sonnentag and Zijlstra 2006) although high job demands and low job control are the sources of the NFR. The effect of work characteristics on association between NFR and hair cortisol level might also be ignorable by the unstable relationship between NFR and the job demands or control.

The 43 kindergarten teachers in this study showed a relatively high median NFR score and high proportion at (30 %) of high NFR scores over the cutoff point compared with that in previous research (De Croon et al. 2003; Kiss et al. 2008; Sluiter et al. 1999, 2001, 2003). Notably, the teachers with the high NFR scores were significantly older and had significantly longer working age than those with NFR scores. Additionally, the 43 teachers had significantly higher NFR score ($Z = -4.83$, $p < 0.001$) than another sample of 554 Chinese workers from various working fields recruited for the validation of NFR scale. At the same time, the workers in this study were significantly older than the 554 workers ($Z = -2.08$, $p = 0.04$) and had significantly longer work age ($Z = -2.02$, $p = 0.04$). A previous study showed that older workers had higher NFR than younger workers (Sluiter et al. 2003; Kiss et al. 2008). Therefore, the reason that the 43 teachers in this study show relatively high NFR scores might be that they are relatively older and have associated longer work exposure.

This study has some limitations. First, cross-sectional data in this study were not enough to understand dynamic effects of NFR accumulation on the HPA axis. Therefore, it needs a longitudinal design to detect the dynamic process. Second, the participants in this study were all female. Gender differences have been found in the relationship of recovery and cortisol secretion (Rydstedt et al. 2009; Eek et al. 2012). Future researches should explore whether the present result will also appear in male workers.

In conclusion, the present study found that NFR over 1 month was significantly and inversely associated with the accumulated cortisol over 1 month. The activity of the hypothalamic–pituitary–adrenal axis declines with the accumulation of NFR after working time.

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Conflict of interest The authors have no competing interests to report.

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