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Relationship between effort–reward imbalance and hair cortisol concentration in female kindergarten teachers

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ABSTRACT

Objective: The present study aims to investigate the relationship between effort–reward imbalance and hair cortisol concentration among teachers to examine whether hair cortisol can be a biomarker of chronic work stress.
Methods: Hair samples were collected from 39 female teachers from three kindergartens. Cortisol was extracted from the hair samples with methanol, and cortisol concentrations were measured with high performance liquid chromatography–tandem mass spectrometry. Work stress was measured using the effort–reward imbalance scale.
Results: The ratio of effort to reward showed significantly positive association with hair cortisol concentration.
Conclusion: The cortisol concentration in the system increases with the effort–reward imbalance. Measurement of hair cortisol can become a useful biomarker of chronic work stress.

Introduction

Work stress has received a lot of attention in recent decades since psychosocial working conditions were found to be strong risk factors for several adverse workers' health outcomes. How work characteristics exert their effects on physical and mental health of the workers is the focus of related theoretical and empirical studies. Among several theoretical models, the effort–reward imbalance model has provided a valuable insight into the fact that a combination of high efforts (e.g. psychosocial workload) and low rewards (e.g. salary, esteem, career opportunities, and security) would lead to an enduring work stress state (i.e. the imbalance between effort and reward) evoking continuous negative emotions that trigger repeated and sustained strain reactions of stress-sensitive nervous systems [1,2]. Such long-term re-activations of stress-sensitive nervous systems may contribute to the development of physical and mental diseases [3,4].

The hypothalamic–pituitary–adrenal (HPA) axis is one of the main stress-sensitive systems regulating the organism's long-term adaptation to stress by secretion of hormones, such as cortisol [5]. Cortisol levels in the circulation would rise or be de-regulated under long-term exposure to stressors and associated stress-reactivity and would keep on activating anti-stress and anti-inflammatory pathways. Prolonged exposure to high cortisol levels are thought to harm the brain and body [6,7]. Thus cortisol may be seen as a critical biomarker mediating the effect of stress on activities of the HPA axis and even on physical and mental health.

Some empirical studies have attempted to explore the relationship between work stress and cortisol through concepts included in the effort–reward imbalance model. However, inconsistent evidences have been accumulated so far. Most studies had failed to find an association between effort, reward or the ratio of effort to reward (ERI) [8–12] and cortisol. By contrast, Eller, Netterstrøm, and Hansen [13] were the first to report that both higher effort and higher ERI were associated with more salivary cortisol excretion in both male and female participants. Maina, Bovenzi, Palmas, and Filon [14] found that higher effort and higher ERI were associated with less salivary cortisol excretion and higher reward was associated with more salivary cortisol excretion. Recently, Eller, Nielsen, Blønd, Nielsen, Hansen, and Netterstrøm [15] found that effort and reward were associated with salivary cortisol excretion in women and in the total population including male and female, respectively, and that higher ERI was associated with more salivary cortisol excretion in women. The results of Eller et al. [13,15] were in accord with the hypothesis of the effort–reward imbalance model that higher efforts and lower rewards or more effort–reward imbalance would trigger stronger strain reactions of stress-sensitive nervous systems. However, the results of Maina et al. [14] were exactly the opposite to the hypothesis of the model. Maina et al. [14] explained their results with the two-stage effort–reward imbalance model [16] proposing

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that work stress elevated stress response at the early period of the working life, but in the long run such work stress would in turn reduce the stress response. Maina et al. [14] inferred that the participants in their study were in the second stage, resulting in the decrease of the cortisol response with the prolonged stress. Notably, the participants in Maina's study [14] showed lower average age (31.6 and 42.6 years) than those (46.7 and 49.7 years; 49.1 and 51.7 years) in the studies of Eller et al. [13,15], but the latter did not show negative correlation like the former. In other words, the two-stage model could not make the perfect explanations for the contradiction between the two results. Therefore, the reason for the inconsistency found remains unclear yet.

Because salivary and plasma cortisol were used to assess HPA activity in the above mentioned studies, the main reasons might be found in three possible methodological limitations. Firstly, there is a temporal mismatch between cortisol assessments and the measurements that were used to assess the psychosocial demands at work. Saliva and blood samples are only representative for cortisol concentrations shortly before the samples were taken (from about twenty minutes up to several hours). By contrast, the self-reports about work aspects that are based on the individual's inner experiences may cover a longer period of time, such as one week and one month, depending on what time-period was asked for to reflect upon in each instrument. Secondly, the cortisol concentrations are vulnerable to sampling time and accidental occurrences. As a result, saliva and blood samples cannot reflect the true general cortisol exposure for a period of time if the samples were not collected in uniformly prescribed sampling times or something unexpected happened just before the sampling. Thirdly, cortisol indices used vary between studies. For example, Eller et al. [13] used awakening cortisol response, and Maina et al. [14] used the morning period and diurnal cycle, and Eller et al. [15] used awakening cortisol response and cortisol at awakening.

Hair cortisol has in recent years been used as a novel approach to cumulative cortisol exposure over several months. Hair cortisol was thought to be less affected by circadian rhythm, short-term fluctuations of the HPA axis or situational factors just before sampling [18]. It has now been used as a stable and reliable biomarker of chronic stress [17,18]. Some recent studies have consistently reported that there was significantly higher hair cortisol level in individuals in the stressful state [19–25]. Furthermore, several studies have explored the association of higher hair cortisol concentration with the hypothesized higher perceived stress measures [20,21,26,27]. A significant correlation coefficient was found in two studies where Kalra et al. [26] showed a positive correlation between the perceived stress (PSS) and hair cortisol concentration in 1–1.5 cm-long hair among pregnant women, while Karlén et al. [27] showed a negative correlation between the PSS and hair cortisol concentration in 3 cm-long hair among young adults. Additionally, significantly positive correlation between serious life event and hair cortisol concentration was reported [23,27].

To our knowledge, only one study has explored the relationship between self-reported stress and hair cortisol concentration in 3 cm-long hair among workers [28], but found that it was insignificant. One explanation might be a temporal mismatch between cortisol assessments and the measurements where assessment of self-reported stress levels was representative of several days or weeks while the 3 cm-long hair estimates cortisol exposure over 3 months. The present study will use 1 cm-long hair to estimate the cortisol exposure over 1 month, which may match the time span better in the measurement of the work stress.

Additionally, teaching has been identified as one of the most stressful occupations. Occupational stress of teachers was proven to predict their health and well-being [29]. Teachers are often taken as a typical population group to perform work stress research on. The present study recruited kindergarten teachers who taught normally developing children or developmentally disordered children. The present study focused only on females because most of the employees in the kindergarten were women.

The main aim in the present study is to examine whether hair cortisol can be used as a biomarker of chronic work stress, that is, to investigate whether ERI value is significantly positively associated with hair cortisol concentration (HCC). Based on the literature above, we predicted that effort scores and ERI values would be positively associated with HCCs, and reward scores negatively with HCCs.

Methods

Participants

Participants were 39 female teachers from three kindergartens in Nanjing, China. Of these, 25 teachers were recruited from two integrated kindergartens specific for normally developing children and developmentally disordered children (e.g., autistic children), and 14 teachers were from one kindergarten for only normally developing children. Participants agreed and 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, (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, (d) hair weight was more than 20 mg, and (e) their ages 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 last one-month period.

Questionnaire measurements and hair collection

Work stress was measured using the effort–reward imbalance scale—the Chinese version [31]. The effort–reward imbalance scale with 17 items contains effort and reward subscales that include 6 items (e.g. I often have to work overtime) and 11 items (e.g. I am less likely to get promoted), respectively [30]. Each item is rated according to: does not apply (scored as 1); does apply, but subject does not consider herself distressed (2); does apply, and subject considers herself somewhat distressed (3); does apply, and subject considers herself distressed (4); does apply, and subject considers herself very distressed (5). The effort and reward subscales of the effort–reward imbalance scale have good validity and reliability in the Chinese population [31]. The present study used raw total scores of effort and reward subscale and ERI, which were calculated according to the formula: $ERI = 1.83\ E/R$ where E is the sum score of the effort subscale and R is the sum score of the reward subscale [31]. In the present study, Cronbach's alpha coefficients of effort and reward subscales were 0.83 and 0.86, respectively.

Simultaneous collections of questionnaire data and hair samples were done in the teachers' own work places. Participants self-reported their background information including gender, age, working duration, height, weight, and frequency of hair washing with shampoo and whether hair was treated during the last three months. At the same time, they also self-reported their work stressors over the last month with the effort–reward imbalance scales. Hair strands in the posterior vertex region were cut with iron scissors as close as possible to the scalp and were stored in dry tubes at −50 °C for cortisol analysis. The hair strands were cut into 1-cm segments prior to use. The 1-cm segment closest to the scalp was used in the subsequent incubation.

Hair cortisol analysis

Before the hair samples were incubated in methanol, the hair samples were washed twice with 2 ml methanol (2 min for each) and