



Hair cortisol and self-reported stress in healthy, working adults



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ABSTRACT

Chronic stress can be important in the pathology of chronic disease. Hair cortisol concentrations (HCC) are proposed to reflect long term cortisol secretion from exposure to stress. To date, inconsistencies in the relationship between HCC and self-reported stress have been attributed to variation and limitations of perceived stress measurement. We report data from employees of two large public sector worksites ($n = 132$). Socio-demographic, health, lifestyle, perceived stress scale (PSS), and work-related effort reward imbalance (ERI) were collected at baseline. Participants were asked to respond to mobile text messages every two days, asking them to report current stress levels (Ecological momentary assessment, EMA), and mean stress was determined overall, during work hours, and out of work hours. At 12 weeks, the appraisal of stressful life events scale (ALES) was completed and 3 cm scalp hair samples were taken, from which HCC was determined (to reflect cortisol secretion over the past 12 weeks). Mean response rate to EMA was $81.9 \pm 14.9\%$. Associations between HCC and the various self-reported stress measures (adjusted for use of hair dye) were weak ($\text{all} < .3$). We observed significant associations with HCC for EMA measured stress responses received out of work hours ($\rho = .196$, $p = .013$) and ALES Loss subscale ($\rho = .241$, $p = .003$), and two individual items from ERI (relating to future work situation). In regression analysis adjusting for other possible confounders, only the HCC-ALES Loss association remained significant ($p = .011$). Overall, our study confirms that EMA provides a useful measurement tool that can gather perceived stress measures in real-time. But, there was no relationship between self-reported stress collected in this way, and HCC. The modest association between HCC and stress appraisal does however, provide some evidence for the role of cognitive processes in chronic stress.

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1. Introduction

Chronic stress is an important contributor in chronic disease pathology (Chrousos, 2009; Kristenson et al., 2004). When an individual is stressed, metabolic and physiological changes allow immediate physical exertion (fight-or-flight). However, chronic stimulation of the stress response through daily stress results in allostatic load (McEwen and Stellar, 1993); non-adaptive reactions that alter baseline physiology and increase the likelihood of disease (Brunner and Marmot, 2006; Goldman, 2001). Therefore, stress biomarkers can provide valuable information regarding stress and, in turn, future disease risk.

The present study explored hair cortisol concentration (HCC) as a marker of chronic stress. Cortisol is secreted via the

hypothalamic-pituitary-adrenal (HPA) axis, which is activated in response to stressors, and has become a central marker of stress. Traditional collection through saliva, blood or urine is limited by sensitivity to diurnal cortisol changes, acute stress and consumption. HCC from a 3 cm sample of scalp hair can reflect the past 3 months of cortisol secretion, offering a stable and feasible measure of chronic stress (Gow et al., 2010; Russell et al., 2012; Stalder and Kirschbaum, 2012).

Understandably, there is considerable and growing interest in HCC as an objective biomarker of chronic stress. Evidence is accumulating for the potential application of HCC in clinical and epidemiological studies (Wester and van Rossum, 2015; Wosu et al., 2013) and various relationships have been demonstrated between HCC and, for example, Cushing's Syndrome (Manenschijn et al., 2012), cardiovascular disease (Manenschijn et al., 2013), depression and mood disorders (Dettenborn et al., 2012b), and anxiety (Steudte et al., 2011). However, the association between HCC and subjectively measured stress remains unclear. A review of HCC

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with subjective stress-related psychological measures reported significant associations in less than half of studies (Staufenbiel et al., 2013). Reasons posited by the review authors included heterogeneity of study populations and diverse stress questionnaires (that cover different periods of time), and variable lengths of hair (which also cover different periods of time).

In this paper, we explore the associations between HCC and a number of self-reported stress measures. We used participants in employment as being in work has been shown to be associated with an enhanced cortisol response (Kunz-Ebrecht et al., 2004). There were three aims to our study. First, we address a call for further investigation of HCC with more elaborate stress assessment strategies, such as ecological momentary assessment (Stalder and Kirschbaum, 2012). Ecological momentary assessment (EMA) is not a single research method, but encompasses a range of methods and methodological traditions (Moskowitz and Young, 2006; Shiffman et al., 2008; Smyth et al., 2009). Shiffman et al. (2008) summarised features common to EMA approaches, which help to outline the main advantages:

- 1) Data are gathered as participants go about their lives (i.e. ecologically valid).
- 2) Participants' current state is assessed, rather than relying on recall (i.e. momentary).
- 3) Moments to be assessed can be strategically selected (e.g. specific times, random sampling, or other sampling methods) to suit the particular research enquiry.
- 4) Multiple assessments over time can be used to measure variation in experiences or behaviour, over time and across situations.

Second, we considered stress appraisal. An individual's resilience or their ability to cope with stressors, can influence their stress response. For example, psycho-physiological responses to stress are different depending on whether an individual views the stress positively, as challenge, compared with negatively, as a threat (Blascovich and Mendes, 2000; Seery, 2011), with individuals able to change their psycho-physiological response to stress based on the task instructions they are given (e.g. Seery et al., 2009; Turner et al., 2014). Further, primary cognitive appraisal of a stressor has been found to account for 26% of variance in the stress response assessed by cortisol (Gaab et al., 2005). To date, there has been little consideration of such factors in relation to HCC.

Finally, we explored the relationship between the work environment and HCC through assessment of the effort-reward. The effort-reward imbalance (ERI) concept was developed in the context of cardiovascular disease prediction (Siegrist et al., 1986). It is based on the principle of reciprocity; that employee investment of effort in the absence of perceptibly adequate reward, promotes a stress response. Continued activation of this stress response has deleterious health effects, with ERI being linked with negative outcomes for mental health (Ndjaboué et al., 2013) and physical health (Kuper et al., 2002; van Vegchel et al., 2005). There is no consistent evidence linking ERI with salivary cortisol measures (Eller et al., 2012). Only two studies to date have linked ERI with HCC; one in Chinese kindergarten teachers (Qi et al., 2014), and another study that found the perceived promotion prospects item within ERI was negatively associated with HCC in Bangladeshi garment workers (Steinisch et al., 2014).

To address the above aims we measured associations between HCC and: (i) EMA-measured stress; (ii) general perceived stress; (iii) stress appraisal; and (iv) the effort-reward imbalance, in generally healthy, adult employees.

2. Methods

2.1. Participants

Participants were recruited from two large public sector employers in the West Midlands region of the UK. Workplace 1 was a higher education establishment and Workplace 2 was a local authority organisation. Exclusion criteria were: non-ownership of a mobile phone; hair typically shorter than 2 cm; conditions known to affect cortisol levels (including pregnancy, Cushing syndrome, Addison disease). With a power of .8 and an alpha level of .05, a target sample 150 was deemed sufficient to detect relatively weak correlations ($r > .2$) between HCC and perceived stress measures.

Out of the 153 participants recruited, 132 were included in most inferential statistics with HCC (although fully adjusted linear regression was possible for 122). This final sample comprised more women than men (107 vs. 25), with an overall mean age of 41.4 ± 11.4 (range 21–69 years).

2.2. Procedure

Employees were invited to take part through an email, which included a link to a brief online screening questionnaire, with accompanying information sheets. Screening questions included: smoking status; mobile phone ownership (yes/no); currently pregnant (yes/no); length of your head hair (less than 1 cm, 1–2 cm, typically longer than 2 cm). Participants were offered £15 in retail vouchers on completion of the project as an incentive. All eligible individuals who completed the screening survey were contacted to arrange appointments for baseline data collection at the work-site. Participants were then sent text messages at random times, every other day for 12 weeks, after which, follow-up data collection appointments were arranged. This study was approved by the University ethics committee.

2.3. Measures

2.3.1. Baseline

- Demographic: age, gender, ethnicity, deprivation (rank based on Index of Multiple Deprivation of home neighbourhood, where higher rank indicates less deprivation).
- Hair-related: washing frequency (from 1 to >7 times/week), use of hair dye/treatment (yes/no).
- Mobile phone-number (for text message follow-up).
- Stress: perceived stress scale, PSS-10 (Cohen et al., 1983), as a measure of general stress.
- Effort-reward imbalance (ERI): 16-items that provide summary scores for effort (3–15), reward (7–35) and over-commitment scale (6–24), and the effort-reward ratio, where higher ERI indicates greater stress potential (Leineweber et al., 2010). Sensitivity analysis was also run for individual ERI items.

2.3.2. Three-month follow-up

- Stressful life event appraisal: appraisal of life events scale (ALES) (Ferguson et al., 1999), where individuals were asked to 'describe briefly the most stressful event that you experienced in the last three months' and then appraise it by rating 16 items using a 6-point scale (where 0 = not at all to 5 = very much so). Summary scores were calculated for 3 primary appraisal dimensions of threat, challenge and loss.
- Holiday periods: Any days in the past 3 months when participants were on annual leave (holiday) from work were identified to be classified as 'non-work' periods (for EMA data processing).
- Hair sample: at least 3 cm of hair were taken from the posterior vertex position of the scalp. Based on an average hair growth rate

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