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Hair cortisol reflects socio-economic factors and hair zinc in preschoolers

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Summary This study examined the relationship between children's hair cortisol and socioeconomic status of the family, as measured by parental education and income. Low family socioeconomic status has traditionally been considered a long-term environmental stressor. Measurement of hair cortisol provides an integrated index of cumulative stress exposure across an extended period of time. The present study is the first to examine the relationship between hair cortisol and parental education as well as parental income in a representative sample of preschoolers.

Data on hair cortisol, family income, and parental education were collected for a representative sample of 339 children (*Mean* age = 4.6 years; SD = .5 years) from across 23 neighbourhoods of the city of Vancouver, Canada. As maternal education was shown previously to be associated with hair zinc level, hair zinc measurements were included as well in order to explore potential relationships between hair zinc and hair cortisol. The relationship between hair cortisol and parental education was examined using hierarchical regression, with hair zinc, gender, age, and single parenthood included as covariates.

Maternal and paternal education both were correlated significantly with hair cortisol ($r = -0.18$; $p = .001$). The relationship remained statistically significant even after controlling for all demographic covariates as well as for hair zinc and after taking the neighbourhood-level clustering of the data into account. Parental income, on the other hand, was not related significantly to children's hair cortisol.

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This study provides evidence that lower maternal and paternal education are associated with higher hair cortisol levels. As hair cortisol provides an integrated index of cortisol exposure over an extended time period, these findings suggest a possibly stable influence of SES on the function of the hypothalamic—pituitary—adrenal (HPA) axis. Cumulative exposure to cortisol during early childhood may be greater in children from low socio-economic backgrounds, possibly through increased exposure to environmental stressors.

1. Introduction

Childhood experiences may have a life-long influence on the function of the hypothalamic—pituitary—adrenal (HPA) axis and thus on the regulation of cortisol. In children, differences in cortisol levels have been reported in relation to mother's depressive symptoms (Lupien et al., 2001; Essex et al., 2002), childhood adversity (Carlson and Earls, 1997; Gunnar et al., 2001), and stressful neonatal (Grunau et al., 2007) and childhood (Flinn and England, 1997; Gunnar and Vazquez, 2001) environments. Moreover, socioeconomic status (SES) in childhood has been shown to influence cortisol secretion patterns (Lupien et al., 2000, 2005; Li et al., 2007). Both direct and indirect effects of factors such as pre- or post-natal nutrition, stress, early life adversity, maternal depression and/or environmental (school, home, neighbourhood) variables on HPA development could mediate the association between childhood SES and cortisol. Several studies have shown that cortisol levels are also associated with adult SES (Brandtstädter et al., 1991; Steptoe et al., 2003; Kristenson et al., 2004; Kunz-Ebrecht et al., 2004; Cohen et al., 2006a,b) and, in fact, gradients in cortisol levels have been shown according to income, education, and occupational status in adult life (Kunz-Ebrecht et al., 2004; Cohen et al., 2006b). Interestingly, one life course study suggested that associations between cortisol secretion patterns and SES in adulthood can be attributed, at least in part, to SES gradients in cortisol in childhood (Li et al., 2007).

Overall cortisol levels or secretion patterns in childhood are important because they are related to trajectories of physical, cognitive and socio-emotional development. Although the direction of association may vary, it has been demonstrated that growth and adiposity trajectories from age 7 to 45 years are associated with cortisol secretion patterns (Power et al., 2006). Moreover, associations between cortisol and childhood cognition have been observed in several studies including the 1958 British Birth Cohort (Power et al., 2008) and in a cross-sectional sample of 53 Spanish children aged 9—12 years (Maldonado et al., 2008), reflecting the fact that the brain is a major target for the glucocorticoid hormones. Importantly, the relationship is bidirectional, with effects of cortisol on cognitive function and, conversely, effects of cognitive processing on cortisol secretion (Lupien et al., 2002, 2005). The HPA axis is also thought to play a role in socio-emotional development and psychological state (Goodyer et al., 2001; Herbert et al., 2006). Associations between emotional state and cortisol have been observed in infancy (Gunnar and Nelson, 1994; van Bakel and Riksen-Walraven, 2004; Lewis and Ramsay, 2005) and childhood (McBurnett et al., 2000; Shirtcliff et al., 2005; Herbert et al., 2006; Brummelte et al., 2010). One longitudinal study found that preschoolers exposed to high levels of maternal stress had elevated cortisol levels and, in turn, exhibited greater mental health symptoms in first grade (Essex et al., 2002). Over the life course, the HPA axis may become dysregulated due to social stressors (Power et al., 2010), as suggested by studies of low SES and of maltreatment in childhood (Carlson and Earls, 1997; Lupien et al., 2000; Cicchetti and Rogosch, 2001; Gunnar et al., 2001; Gunnar and Vazquez, 2001; Ranjit et al., 2005; O'Connor et al., 2009). In turn, dysregulation of the HPA axis may lead to either hypo- or hyper-secretion of cortisol, carrying increased risk of depression and other mental health problems (Bremmer et al., 2007).

Taken together, this research on the determinants of HPA axis function, cortisol secretion patterns, and life course health and development has generated a tantalizing glimpse of the 'life' of a key stress response pathway in human society. However, our understanding of the significance of the HPA axis for human health and development has been hindered to some extent because of limitations in the available methods of cortisol measurement. Accordingly, a principal challenge for studies that seek to understand the relationships among HPA axis function, social factors, life course and health is the method of estimation of cortisol secretion patterns. Cortisol levels in biological samples such as plasma and especially, saliva, have commonly been used as markers of daily HPA axis function and, also, of the HPA response to experimental stressors. However, in the life course context, even multi-time-point, multi-day sampling of saliva or plasma cannot provide a full picture of long-term HPA axis function and cortisol secretion.

In recent years, methods to assay cortisol in hair have been developed that provide an integrated index of cumulative cortisol exposure over an extended period of time. Raul et al. (2004), in the context of tracking illegal use of performance-enhancing steroids by athletes, demonstrated that physiological concentrations of cortisol and cortisone could be detected in human hair. Further studies demonstrated that hair cortisol levels correlate significantly with cortisol in a 24-hr urine sample (Sauvé et al., 2007) and with contemporaneously collected salivary cortisol (D'Anna-Hernandez et al., 2011). Moreover, hair cortisol was shown to correlate positively with waist-to-hip ratio, suggesting that hair cortisol reflects cortisol exposure over the long term at tissue levels (Manenschijn et al., 2011). Subsequent data have supported the use of hair cortisol as an integrated measure of long-term HPA activity. To cite just a few examples, adults with severe chronic non-malignant pain syndromes were found to have increased subjectively perceived stress, as measured by the *Perceived Stress Scale* questionnaire, and concomitantly, had elevated hair cortisol levels compared to control subjects, suggesting that hair cortisol levels could be a novel biomarker for long-term stress