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Relation between salivary cortisol as stress biomarker and dietary pattern in children

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Summary
Purpose: Psychological stress has been suggested to result in hormonal effects (e.g. changes in cortisol pattern) that may change food selection in unhealthy ways. This study examines whether children's dietary pattern is indeed related to salivary cortisol levels.
Methods: In 323 children (5—10 years old) participating in the Belgian ChiBS study, salivary cortisol samples, a biomarker for stress, was sampled when waking up, 30 and 60 min after wake up and in the evening on two consecutive weekdays. Data on the children's dietary pattern (frequency of sweet foods, fatty foods, snacks, fruit and vegetables) was collected with a food frequency questionnaire. Multilevel time modelling was used with adjustments for sex, age, body mass index, parental education and wake up time.
Results: Higher overall cortisol levels and a large cortisol awakening response (CAR) were associated with more frequent consumption of sweet foods. A steeper diurnal cortisol decline was associated with a higher sweet, fatty and snack food consumption frequency. No associations with fruit and vegetables consumption were found.
Conclusions: High cortisol levels were linked to an unhealthier dietary pattern (more fatty food, snacks and especially sweet food). This supports the theory of cortisol-induced comfort food preference and strengthens the stress—diet relation.

1. Introduction

Psychological stress has been suggested to change food selection into unhealthy choices and potentially trigger overweight (Bjorntorp, 2001; Dallman et al., 2003; Torres and

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Nowson, 2007). Indeed, stress has been associated with emotional eating behaviour, overall energy intake and an unhealthy dietary pattern (Dallman et al., 2003; Adam and Epel, 2007; Macht, 2008). The theory of stress-induced craving for so-called 'comfort foods' (energy-dense foods high in sugar and fat content) explains stress-related eating as a way of avoidant stress coping, eating-induced stress reduction or because of the reward feelings associated with comfort foods that change food salience (Dallman et al., 2003; Adam and Epel, 2007).

One of the major neuroendocrine systems adapting the organism to stress situations is the hypothalamus—pituitary—adrenal (HPA) axis with cortisol production as hormonal end product. Cortisol secretion has a circadian rhythm with lowest levels in the first half of the night and a peak in the early morning. Apart from this circadian rhythm, a cortisol awakening response (CAR) is elicited by a quick cortisol increase within 30 min after wake up (Fries et al., 2009). In general, the CAR is speculated to be an anticipation of the upcoming day by activation of memory representation and by orientation in time and space. Next to the single cortisol values, cortisol patterns such as this CAR and the diurnal slope (decline from morning to late evening) can serve as an index for adrenocortical activity on longer term.

The associations that have been reported between stress-exposure and cortisol levels are quite complex, giving conflicting hypotheses on the mechanism at work with both hyper- and hypo-cortisolism in response to stress. A hyper-/hypo-cortisolism hypothesis was published suggesting that recent exposure to a stressor may initially elevate cortisol levels (hypercortisolism with high morning cortisol and steep diurnal slope), while the HPA axis may develop a counter-regulatory response of cortisol lowering after extended stress exposure (Heim et al., 2000). A lower diurnal slope (mostly caused by low morning and/or high evening values) has been suggested as a less adaptive profile associated with stress, although with sometimes contradictory findings (Kristenson et al., 2012). Furthermore, a recent meta-analysis found a global positive relation of the CAR with life stress (Chida and Steptoe, 2009). Apart from the cognitive appraisal of upcoming events, the higher CAR may reflect a dysregulation of the cortisol axis resulting from previous stress exposure. In a previous analysis based on self-reports, the stress-cortisol relations found in our child sample was more in line with the stress hypercortisolism hypothesis as self-reported stress was related to higher cortisol values and a steeper diurnal decline (Michels et al., 2012b).

Interestingly, this stress biomarker cortisol has been hypothesised as an appetite-stimulating hormone leading to stress-related dietary changes. The effect of cortisol on food consumption is mainly reward based: increased food salience and reward feeding using comfort foods. Cortisol can directly influence the reward pathways (e.g. in the mesolimbic system) through increased levels of opioids (role in hedonic evaluation of food) and dopamine (role in motivational aspects of eating). Furthermore, the cortisol effect may also be indirect through its influence on other hormones (e.g. insulin, leptin and NPY) that regulate appetite and reward (Dallman et al., 2003; Adam and Epel, 2007; Torres and Nowson, 2007; Epel et al., 2012).

As suggested by Torres and Nowson (2007), studying this interesting pathway is relevant and measuring a biological marker of stress (i.e. cortisol) will increase our understanding of the physiological mechanism underlying the stress-eating relation. The relation between cortisol levels and variables related to eating remains largely unexplored as subjective stress measurements have commonly been applied in stress research. Although stress questionnaires have been related to cortisol levels, variability in cortisol stress-response exists due to the nature of the stressor (social or physical) and to the person facing it (emotional response and psychiatric sequelae) (Miller et al., 2007). Consequently, measuring an objective marker of stress to examine this stress—diet relation is recommended.

Consequently, the present study aims to unravel the hypothesised detrimental effects of high cortisol levels (as a consequence of stress) on the dietary pattern in children. More specifically, three indices of unhealthy food consumption (sweet food, fatty food and unhealthy snacks, including both high fat and sugar) and one index of healthy food consumption (fruit and vegetables) were measured in a sample of preadolescent children. We hypothesised that high cortisol values and patterns (diurnal decline and CAR) might be associated with a higher unhealthy food consumption and a lower intake of fruit and vegetables. We focus in this study on children as the foundations of dietary habits are established from the ages of 3—4 years old (Singer et al., 1995) and may track into adolescence and adulthood (Wang et al., 2002; Mikkila et al., 2005). As such, this could elucidate opportunities for prevention.

2. Methods

2.1. Participants and general procedures

The subjects were 323 Belgian children (49% boys) between 5 and 10 years old participating in the baseline 2010 survey of the ChiBS study (Children's Body composition and Stress). The ChiBS study examines stress and the relationship between stress and body composition development longitudinally. Random cluster sampling was used in inviting participants: all children in the 1st to 4th year of primary schools (that gave consent to contact their pupils and to perform measures at school) in the city of Aalter. Invitation letters were not distributed by mail but via the school to increase the response rate. Further contact for the measurements was also via the school. Detailed aims, design, methods, population and participation characteristics were described elsewhere (Michels et al., 2012c). The study was conducted according to the guidelines laid down in the Declaration of Helsinki and the project protocol was approved by the Ethics Committee of the Ghent University Hospital. Parents gave their written informed consent. As salivary cortisol sampling was an optional measurement module and some food questionnaires had missing data, only 323 of the 523 ChiBS children (=62%) were included for the current paper. The excluded sample did not differ in sex, age, socio-economic status and body composition.

Children's weight was recorded in underwear with an electronic scale (TANITA BC 420 SMA) to the nearest 0.1 kg and height was measured with a stadiometer (SECA 225) to