ARTICLE IN PRESS

International Journal of Hygiene and Environmental Health xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

Road traffic noise and determinants of saliva cortisol levels among adolescents

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ARTICLE INFO

Keywords:
Saliva cortisol
Adolescents
Traffic noise
Annoyance

ABSTRACT

Objectives: The understanding of determinants for saliva cortisol levels in adolescents is limited. This study investigated the role of road traffic noise exposure, noise annoyance and various other factors for saliva cortisol levels.

Methods: We collected morning and evening saliva samples from 1751 adolescents from the BAMSE birth cohort based in Stockholm County. Façade noise levels from road traffic were estimated at the residences of the study subjects and repeated questionnaires and medical examinations provided extensive information on various exposures and conditions, including annoyance to noise from different sources. Cortisol was measured using radioimmunoassay. Associations between determinants and saliva cortisol levels were analysed using linear regression.

Results: Morning saliva cortisol levels were significantly higher in females than in males (geometric mean 42.4 and 35.0 nmol/l, respectively) as well as in subjects with allergy related diseases. Height and age were related to saliva cortisol levels as well as sampling season. Road traffic noise exposure was not associated with saliva cortisol, however, annoyance to noise tended to increase the levels. Saliva cortisol levels appeared particularly high among those who were highly annoyed and exposed to road traffic noise levels ≥55 dB L_{den} (50.5 nmol/l, $p = 0.02$).

Conclusion: Our findings suggest that individual perception of noise may be of importance for saliva cortisol levels. The results also point to the complexity of using saliva cortisol as a marker of noise exposure in adolescents.

1. Introduction

Stress activates the hypothalamic-pituitary-adrenal (HPA) axis leading to release of stress hormones such as cortisol. Cortisol can be measured in serum, saliva, urine and hair (Smith et al., 1996; Hellhammer et al., 2009). Levels show a diurnal pattern and are usually highest after awakening. The levels vary between individuals but hereditary factors appear to play a minor role. Various determinants of cortisol levels have been studied such as age, sex, pubertal stage, physical activity and various diseases, including allergy and depression, as well as the psychosocial environment. Studies have shown diverging results for age in adults where high levels were found in younger and adult males as well as in older females, but other studies report a general increase of saliva cortisol levels with age in both sexes (Nicolson et al., 1997; Seeman et al., 2001; Kudielka et al., 2009; Nater et al., 2013; Hidalgo et al., 2015). Regarding childhood and adolescence, data on age effects are limited, but suggest that pubertal stage is of importance for cortisol levels (Allen et al., 2009; Tsai et al., 2013; King et al., 2016). Some studies have shown an association between asthma and saliva cortisol levels, but the data are not consistent (Stenius et al., 2011; Kamps et al., 2014). Depressive disorders have been associated with an activation of the HPA-axis in young individuals, however, lower cortisol levels were observed in subjects who experienced parental divorce during childhood (Bloch et al., 2007; Lopez-Duran et al., 2015).

The effects of traffic related noise on cortisol levels in adults have been investigated with some evidence for elevated morning saliva cortisol levels in relation to aircraft noise (Babisch 2003; Selander et al., 2009). However, the effects of environmental noise on stress hormone levels in children and adolescents are not clear (Hohmann et al., 2013).

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https://doi.org/10.1016/j.ijheh.2017.11.003
Received 3 March 2017; Received in revised form 4 November 2017; Accepted 20 November 2017
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Please cite this article as: Wallas, A., International Journal of Hygiene and Environmental Health (2017), https://doi.org/10.1016/j.ijheh.2017.11.003

Studies investigating the effects of aircraft noise on cortisol levels in children show inconsistent results (Hygge et al., 1996; Evans et al., 1998; Haines et al., 2001; Bigert et al., 2005). Raised levels of adrenaline and noradrenaline were found in the Munich airport study in relation to aircraft noise, whereas, no association was observed in a study on children exposed to aircraft noise from Heathrow airport (Hygge et al., 1996; Evans et al., 1998; Haines et al., 2001). One study on noise from road traffic and railways found higher overnight urinary cortisol levels in children in noisier areas. (Lercher et al., 2013) Classroom noise has been found to be related to headache, symptoms of fatigue and reduced diurnal cortisol variability (Walinder et al., 2007).

The aim of our study was to investigate determinants of saliva cortisol levels in adolescents from a birth cohort in Stockholm. In particular, we examined the role of noise exposure and annoyance in relation to saliva cortisol levels.

2. Material and methods

2.1. Study population

This study used a cross-sectional design and was conducted within the birth cohort BAMSE, which has been described in detail elsewhere (Ekstrom et al., 2015). The original cohort consisted of 4089 children born between 1994 and 1996 in predefined areas in Stockholm County. Shortly after birth baseline data were obtained through parental questionnaires aiming at environmental and other risk factors for allergies as well as socioeconomic characteristics. The baseline questionnaire was followed by new questionnaires at 1, 2, 4, 8, 12 and 16 years of age which also focused on different allergic symptoms and diseases as well as on medications in relation to allergic and asthmatic outcomes (Lannero et al., 2002). At the 12- and 16-year follow-ups the children and adolescents also filled in questionnaires themselves. Medical examinations were conducted at 4, 8 and 16 years of age. At the 16-year follow-up 3155 individuals (77% of the original cohort) completed the questionnaire and 2593 (63%) took part in the medical examination where saliva cortisol sampling kits were handed out (Fig. S1). Saliva sampling was initiated two months after the medical examination started, implying that not all participants in the medical examination were offered saliva cortisol analysis. A total of 1794 subjects sent in morning and evening saliva cortisol samples, however, 22 morning and 20 evening saliva samples contained too little material for analysis. Finally, 1751 individuals remained after exclusion also of those without information on relevant covariates and these were selected for analysis.

2.2. Noise exposure assessment

The traffic noise exposure assessment was performed using data from several national, regional and local authorities. Briefly, the noise exposure levels were estimated at the most exposed façade of the residential buildings of the study subjects at the time of saliva sampling. Noise level calculations are based on the Nordic prediction method for road traffic noise (Nielsen, 1997). This method utilizes information on different terrain and road traffic characteristics. To account for shielding and reflections of buildings, a Ground Space Index was used to measure building density. This implies that the denser the building structure and the longer the distance from the source to the receiver, the higher the probability becomes of both reflections and screening by buildings (Salomons and Berghauser Pont, 2012). A-weighted sound pressure level was calculated and assuming a 24h distribution of road traffic as 75% /20% /5% for day, evening and night, respectively, we expressed noise levels as Lden, which corresponds to the equivalent level weighted with a penalty of 3.4 dB considering noise during evening (+5 dB) and night (+10 dB) (Murphy and King, 2010). A more detailed description of the methodology for estimating noise levels from road traffic is provided elsewhere (Ögren and Barregard, 2016).

Maternal exposure to occupational noise during pregnancy was estimated based on questionnaire responses from the mothers on their occupation combined with a job-exposure-matrix. The job-exposure-matrix listed more than 300 different occupations and groups of occupations. Occupations were classified according to the Nordic occupation code and each occupation and/or occupation-group was assigned a noise level based on multiple measurements over time. Noise was assessed in five-year intervals from 1970 to 2014 and categorised in five levels. A detailed description of the job-exposure-matrix for noise can be found elsewhere, and this matrix was further developed for the present study.

2.3. Definition of outcome

2.3.1. Saliva cortisol

At the 16-year follow-up morning and evening saliva samples were obtained. The morning sample was collected 15 min after wake-up and the evening sample at bedtime. Both samples had to be taken before dental cleaning. The saliva samples were collected by sterile rolls (Salivette®, SARSTEDT AG & Co., D-51582 Nümbrecht), which the study participants were instructed to keep in the mouth for some minutes until soaked with saliva. The cotton rolls were placed in labelled tubes and sent to the laboratory via mail. The samples were centrifuged and stored at −80 °C until analysed, using the CORT-CT2 Cortisol RIA (125_I) kit from CISBIOassays, Sollentuna, Sweden. (Hansen et al., 2003) Samples from the same individual were analysed in the same assay. Outlying/extreme values were examined twice to secure their accuracy.

2.3.2. Annoyance

To assess annoyance due to different sources of environmental noise a supplementary questionnaire was sent in 2015 to all participants of the BAMSE birth cohort who had taken part in the 16-year follow-up. Questions on hearing disorders and tinnitus were also included as well as on listening behaviours in relation to headphones and the usage of ear-plugs. The questions and assessment of noise annoyance were based on the ISO standard (ISO 2003). Individuals were asked to assess the level of annoyance within the past 12 months related to several potential noise sources at the residence, work and/or school. Some examples include people/ neighbours, motor vehicles, trains, airplanes and wind turbines. The degree of annoyance was evaluated by a verbal rating scale with five alternatives (not at all, slightly, moderately, very, and extremely).

A total of 1782 of the participants at the 16-year-follow-up filled in the supplementary questionnaire and 1096 of them had data from the saliva cortisol analysis (Fig. S1). Only 737 of these subjects were living at the same address as at the 16-year follow-up and were included in the sub-analysis. After excluding 30 individuals who lived in homes with insulated windows and 2 individuals with insufficient data on selected covariates 705 individuals remained.

2.3.3. Allergy related diseases

Asthma was defined as more than 3 episodes of wheeze in the last 12 months prior to the date of the 16-year questionnaire and/or at least 1 episode of wheeze in the last 12 months, in combination with prescribed inhaled steroids occasionally or regularly (Ekstrom et al., 2015). Eczema was present if the individual had a rash located near hand/foot joint, elbow/knee or throat/neck and had dry skin during the last 12 months. To be defined as allergic rhinitis an individual showed symptoms of sneezing, a runny or blocked nose, or itchy, red and watery eyes after exposure to furred pets and/or pollen in the last 12 months prior to date of the questionnaire.

2.4. Statistical analysis

Geometric means of morning saliva cortisol levels were calculated according to selected background characteristics and one-way ANOVA

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