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Traffic noise and determinants of saliva cortisol levels in adolescents

Alva Wallas[1], Charlotta Eriksson[2], Olena Gruzieva[1], Tomas Lind[2], Andrei Pyko[1], Mikael Ögren[3], Mattias Sjöström[2], Göran Pershagen[1,2]

[1] Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden (corresponding author)
[2] Centre for Occupational and Environmental Medicine, Stockholm County Council, Stockholm, Sweden
[3] Department of Occupational and Environmental Medicine, Sahlgrenska Academy, The University of Gothenburg, Gothenburg, Sweden

Corresponding author's e-mail address: alva.wallas@ki.se

ABSTRACT

The understanding of determinants for saliva cortisol levels in adolescents is limited. We investigated the role of road traffic noise exposure, annoyance and other factors for saliva cortisol levels. Saliva from 1751 adolescents based in Stockholm County was sampled. Residential façade noise levels from road traffic were estimated and information on various exposures and conditions were provided for each individual. Associations between determinants and saliva cortisol levels were analysed using linear regression. Saliva cortisol levels were significantly higher in females than in males, as well as in subjects with allergy related diseases. Road traffic noise exposure was not associated with saliva cortisol, however, there were statistically significant trends in saliva cortisol levels in relation to annoyance by road traffic noise at the residence and by noise from other people at school/work. Saliva cortisol levels appeared particularly high among those who were highly annoyed and exposed to road traffic noise levels ≥55 dB. Our findings indicate that individual perception of noise affects saliva cortisol levels but also point to the complexity of using this as a marker of noise exposure in adolescents.

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 and follows a diurnal pattern, commonly with the highest levels after awakening [1, 2]. Various determinants of cortisol levels have been studied such as age, sex, pubertal stage, physical activity and different diseases, including allergy and depression, as well as the psychosocial environment. Regarding childhood and adolescence, data on age effects are limited, but suggest that pubertal stage is of importance for cortisol levels [3-5]. Some studies have shown an association between asthma and saliva cortisol levels, but the data are not consistent [6, 7]. 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 [8, 9]. However, the effects of environmental noise on stress hormone levels in children and adolescents are not clear [10]. Studies investigating the effects of aircraft noise on cortisol levels in children show inconsistent results [11-14]. The current subject aimed to investigate determinants of saliva cortisol levels in adolescents. In particular, the role of noise exposure and annoyance in relation to saliva cortisol levels was examined.

METHODS

Study Population

This study was conducted within the birth cohort BAMSE, which has been described in detail elsewhere [15]. 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 followed by new questionnaires at 1, 2, 4, 8, 12 and 16 years. Three medical examinations were conducted at 4, 8 and 16 years and saliva sampling kits where handed out at 16 years. 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 and were selected for analysis after excluding of those with insufficient information on all relevant covariates.

Noise exposure assessment

To assess individual road traffic noise exposure we have constructed a noise database for Stockholm County to represent the period from 1990 and onwards. The database contains information from several national, regional and local authorities and includes 3D terrain data as well as information on ground surface, road net, daily traffic flows, speed limits and percentage of heavy vehicles. To calculate noise levels we developed and used a modification of the Nordic prediction method for road traffic [16], where possible reflection and shielding are taken into account by a Ground Space Index based on building density [17]. Our method has been validated against the full Nordic prediction method modelled with SoundPlan and showed coherent estimates [18]. For each participant, the time-weighted average noise exposure during follow-up is calculated, taking into account all addresses in Stockholm County where the subject has lived, and considering the duration of residence at each address.

Assessment of the outcome

At the 16-year follow-up morning and evening saliva samples were obtained. The morning sample was collected 15 minutes after wake-up and the evening sample at bedtime. The samples were analysed with an immune-assay procedure, which is described in detail elsewhere [19].

Annoyance to various environmental noise sources was assessed with a supplementary questionnaire sent in 2015 to all participants of the BAMSE birth cohort who had taken part in the 16-year follow-up. All questions and the assessment of noise annoyance were based on the ISO standard [20]. This implies that questions related to annoyance within the past 12 months and levels of annoyance were assessed by a verbal rating scale with five alternatives (Not at all, slightly, moderately, very, and extremely). Only those 705 individuals who sampled saliva cortisol, still lived at the same address as at 16 years of age, and had sufficient data on selected covariates, were included in the sub-analysis on annoyance.

Statistical analysis

Geometric means of morning saliva cortisol levels were calculated according to selected background characteristics and one-way ANOVA tests were used to assess whether levels differed between categories.

Linear regression models were used to analyse the association between residential noise exposure and saliva cortisol levels. We used a forward selection stepwise regression model to identify covariates with a high impact on saliva cortisol levels ($p \leq 0.05$). Most data on covariates were extracted from the questionnaire at the 16-year follow-up, however, data on parental occupation and municipality were obtained from the baseline questionnaire. All statistical analyses were performed with Stata (release 14; Stata Corp., College Station, TX, USA).

RESULTS

At 16 years of age females had reached higher pubertal stages compared to males. Females were mostly late-pubertal (75 %) and 24 % were post-pubertal compared to 53 and 2 %, respectively, in males (data not shown). Approximately 10 % of all individuals had asthma and/ or eczema and more than twice as many were diagnosed with rhinitis. About half of the participants were exposed to road-traffic noise levels <45 dB Lden but only 15 % had levels ≥55 dB Lden at the façade of the residence.

Morning saliva cortisol levels ranged from 1.1 to 318.8 nmol/l, with a geometric mean of 38.8 (95 % CI 37.8 to 39.8), and were close to normally distributed on a logarithmic scale.

Table 1 shows covariates which were related to morning saliva cortisol levels. Females had higher levels as well as those with allergic disease (asthma, rhinitis or eczema). Age, height, physical activity and season also affected the saliva cortisol levels.

Table 1: Morning saliva cortisol levels in relation to selected characteristics of the study subjects

Morning saliva cortisol		
	nmol/l*	**p-value**
Female/ Males	42.4 / 35.0	<0.001
Age ≤16.5/ >16.5 yrs	40.9 / 37.4	0.01
Height ≤1.73/ >1.73 m	41.4 / 36.0	<0.001
Asthma yes/no	42.4 / 38.6	0.02
Eczema yes/no	42.3 / 38.3	<0.001
Rhinitis yes/no	40.9 / 37.9	0.01
Physical activity ≥5/ <5 (h/week)	39.9 / 37.3	0.01
Season Oct- Dec/ Jan- Sep**	42.5 / 38.3	<0.001

* Geometric mean
** mean geom.mean from Jan-Mar, Apr-Jun, Jul-Sept

Table 2 shows the association of road traffic noise exposure at the individual's residence and morning saliva cortisol levels adjusted for sex, age, rhinitis, eczema and sampling season which were the covariates that remained statistically significant when all significant variables shown in table 1 were included in a regression model. We did not observe any clear relation between estimated noise exposure and saliva cortisol levels, neither using noise as a categorical nor as continuous variable.

Table 2: Morning saliva cortisol levels in relation to categorical and continuous road traffic noise at the residence among 16-year olds from Stockholm (N= 1612)*

Residential road traffic, l_{den}	**N (%)**	**β**	**(95% CI)**
<45 dB	837 (52)	Ref.	-
45-54 dB	538 (33)	-1.05	(-3.63 - 1.52)
≥55 dB	237 (15)	-3.09	(-6.52 - 0.34)
Change per 10 dB	1612	-0.79	(-1.87 - 0.30)

* Adjusted for age, sex, rhinitis, eczema and sampling season

Table 3 shows increasing prevalence rates of annoyance to road traffic noise with estimated noise levels at the façade. For example, at ≥55 dB Lden 25 % were very annoyed compared to 15 % at levels below 45 dB Lden. Geometric mean cortisol levels in saliva was particularly high in those very annoyed and exposed to road traffic noise ≥55 dB Lden (50.5 nmol/l, p=0.02).

Table 3: Saliva cortisol level in relation to road-traffic noise exposure at the residence and annoyance among 705 adolescents from Stockholm

	Not annoyed		Moderately annoyed		Very annoyed		
Residential road traffic, L_{den}	**No (%)**	**Geom. mean**	**No (%)**	**Geom. mean**	**No (%)**	**Geom. mean**	**Total**
<45	208 (58)	41.0	97 (27)	38.3	55 (15)	43.1	360
45- 54	134 (52)	36.4	78 (30)	43.9	48 (18)	41.1	260
≥55	42 (49)	36.4	22 (26)	31.8	21 (25)	50.5	85
Total	384		197		124		705

DISCUSSION

Our findings show no clear association between exposure to road traffic noise at the residence and saliva cortisol levels in adolescents from Stockholm, Sweden. Morning saliva cortisol levels were affected by sex, height, weight, allergic diseases, physical activity, and season. Furthermore, annoyance to noise appeared to be related to morning saliva cortisol levels, particularly annoyance to road traffic noise in the residence and noise from other people at school or work. Associations were generally weaker in analyses based on evening saliva cortisol levels.

Road traffic noise exposure did not appear to affect saliva cortisol levels in our study. However, only 15 % of the study population lived in homes with levels of road traffic noise of ≥ 55 dB L_{den} at the façade, which might partly explain the lack of association. Studies on the association between traffic related noise and cortisol levels in childhood and adolescence are sparse and inconsistent. A study on road traffic and railway related noise exposure found elevated cortisol levels in urine in children living in noisier areas (mean 62 dB $L_{day\text{-}night}$), compared to children from more quiet neighbourhoods (mean 46 dB $L_{day\text{-}night}$)[21]. Another study on aircraft noise concluded that urinary cortisol levels were not related to exposure [12]. The association between transportation noise and saliva cortisol may be mediated or modified by annoyance [13, 22]. Our data supports this assumption showing increased cortisol levels in individuals annoyed by noise, particularly from road traffic. Saliva cortisol levels appeared especially elevated in those both annoyed and living on addresses with the highest road traffic noise levels.

In this study saliva cortisol levels in females were observed to be higher compared to males. This observation is not correspondent with findings in adults and children <8 years where males showed higher levels than females [23]. However, a recently published systematic review showed that patterns of cortisol levels changed from age 8-18 and females have higher levels in this age group [23]. In our study levels of saliva cortisol were significantly higher in individuals with asthma, eczema or rhinitis. This corresponds well with previous findings where significant associations between saliva cortisol levels and eczema, as well as, asthma in children were observed [7]. A possible explanation could be increased stress among those with allergic diseases.

This study has some limitations. Morning and evening saliva samples in this study were only sampled on one occasion, hence, a long-term variability in cortisol levels for the individuals cannot be determined. Furthermore, it is a cross-sectional study and assessments of causality are complicated by the uncertain time sequence between some determinants and saliva cortisol levels. Additionally, detailed information on individual stress factors could not be assessed. Although extensive data on many conditions and exposures known to affect cortisol levels i.e. age, sex, pubertal stage, allergic disease, smoking and noise were available for the study subjects, we lacked information on many psycho-social factors that may affect the levels, such as the living situation at home and bullying in school etc. Furthermore, no data on exposures or stress immediately preceding the saliva sampling was available. In the analysis of annoyance it must also be taken into consideration that the questions were posed several years after the saliva sampling.

The strengths of this study includes the traffic noise exposure assessment with very detailed information on noise sources, and individual assessment of noise levels, considering exposure modifiers, such as window insulation and location of the bedroom etc. Additionally, a large number of potential determinants of saliva cortisol levels were investigated. Furthermore, this study appears to be the first to assess the combined effect of traffic noise exposure and annoyance on saliva cortisol levels.

CONCLUSION

In conclusion, this study showed no clear association between residential road traffic noise exposure and saliva cortisol levels in adolescents. However, there was a significant association between annoyance to road traffic, as well as to noise from other people at school or work, and morning saliva cortisol levels, suggesting that individual perception influences the saliva cortisol levels.

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