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Long-term exposure to residential traffic noise and changes in body weight and waist circumference: A cohort study

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ABSTRACT

Background: Traffic noise can act as a stressor and disturb sleep, and has been associated with cardiovascular disease. Recent studies suggest a possible association to metabolic outcomes and adiposity through biological mechanisms related to physiological stress and sleep disturbance.
Objectives: We aimed to investigate the association between long-term residential traffic noise and changes in adiposity.
Materials and methods: The study was based on 39,720 middle-aged Danish men and women from a cohort, with information on weight and waist circumference at two points in time. Residential exposure to traffic noise was calculated for all participants' present and historical addresses using the Nordic prediction method. The associations between traffic noise and changes in adiposity measures after a mean follow-up of 5.3 years were analyzed by linear and logistic regression with adjustments for age, sex, socioeconomic position and lifestyle factors in three models with increasing adjustment.
Results: In linear models adjusted for sex, age, socioeconomic position and competing noise sources we found road traffic noise to be significantly associated with small gains in both weight and waist circumference. For example, time-weighted mean exposure 5-years preceding follow-up was associated with a yearly weight gain of 15.4 g (95% confidence interval (CI): 2.14; 28.7) and a yearly increase in waist circumference of 0.22 mm (95% CI: 0.018; 0.43) per 10 dB. Similarly, in Poisson regression models we found an 10% increased risk for gaining more than 5 kg body weight during follow-up (95% CI: 1.04; 1.15) per 10 dB higher 5 years exposure preceding follow-up. Exposure to railway noise above 55 dB was associated with weight gain (39.9 g/year (95% CI: 10.2; 69.6)), but not with a significant change in waist circumference. We found baseline BMI ($p<0.001$) and waist circumference ($p=0.001$) to be significant effect modifiers for the association between road traffic noise and waist circumference, with gain in waist circumference only among the obese (BMI $\geq$ 30) participants (1.20 mm/year (95% CI: 0.68; 1.72)) and participants with a large waist circumference (0.83 mm/year (95% CI: 0.42; 1.23)).
Conclusion: The findings supports previous studies suggesting that traffic noise may be associated with development of adiposity. However, the potential effects are small and suggest an effect mainly among obese participants.

1. Background/introduction

Traffic noise has been consistently associated with cardiovascular disease (Babisch, 2014) as well as non-clinical outcomes such as stress, annoyance and sleep disturbance (Basner et al., 2014; Miedema and Oudshoorn, 2001; Miedema and Vos, 2007). Recently, also metabolic outcomes have become a focus of noise research., Road traffic noise has been positively associated with higher risk of diabetes (Sorensen et al., 2013) as well as higher BMI and waist circumference, though not consitently (Oftedal et al., 2015; Pyko et al., 2015). Furthermore, aircraft noise has been associated with increase in waist circumference (Eriksson et al.,

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Traffic noise is hypothesized to affect metabolism through sleep disturbance and stress. Traffic noise is associated with self-reported sleep disturbances (Miedema and Vos, 2007) and in experimental studies traffic noise has been associated with higher body motility during sleep, sleep state changes, sleep onset latency and early awakenings (Pirrera et al., 2010). Sleep deprivation may lead to dysregulation of the hormones leptin and ghrelin, which are involved in the metabolism (Chaput et al., 2007; Spiegel et al., 2004; Taheri et al., 2004; Van Cauter et al., 2008). Furthermore, sleep deprivation may also lead to reduced energy expenditure through altered thermoregulation and increased fatigue (Patel and Hu, 2008). Also, epidemiologic studies consistently find that short sleep duration is associated with development of obesity in children and young adults (Nielsen et al., 2011). Although the epidemiologic evidence with regard to adults is less clear, self-reported reduction in sleep quality and duration has been associated with larger waist circumference, higher BMI and percentage of body fat as well as risk of metabolic syndrome and diabetes in adults (Cappuccio et al., 2010; Knutson, 2012; Xi et al., 2013).

A second possible mode of action is through a stress response with activation the hypothalamus–pituitary–adrenal (HPA) axis which leads to increased levels of noradrenaline, adrenaline and corticosteroids (Babisch, 2003; Maschke et al., 2000). Some observational studies have indicated that exposure to traffic noise is associated with higher levels of cortisol and adrenalin (Schmidt et al., 2013; Selander et al., 2009a) which are supported by experimental findings (Babisch et al., 2001; Griefahn and Robens, 2010; Ising and Braun, 2000; Waye et al., 2003). Cortisol levels have been associated with higher BMI, waist–hip ratio and upper body obesity (Pasquali et al., 1993; Rosmond et al., 1998) and some studies suggest that stress induced alterations in cortisol levels is related to metabolic changes including weight gain (Rosmond et al., 1998; Vicennati et al., 2009). However, other studies find no associations between cortisol and weight gain and the overall role of cortisol in adiposity is not clear (Abraham et al., 2013).

The widespread exposure to traffic noise combined with global increase in the prevalence of obesity makes research into the association between traffic noise and development of adiposity important. The aim of this study was to investigate the association between exposure to road traffic and railway noise and changes in weight and waist circumference.

2. Methods

2.1. Study population

The present study was based on the Danish Diet, Cancer and Health cohort, which has been described in detail previously (Tjonneland et al., 2007). Briefly, between 1993 and 1997, 160,725 persons aged 50–64 years with no history of cancer and living in either Aarhus or the greater Copenhagen area were invited to participate. In total, 57,053 accepted the invitation, representing 7% of the Danish population in this age group. Participants filled in questionnaires and height and trained laboratory technicians at two centers (Copenhagen and Aarhus) measured weight and waist circumference. Questionnaires were scanned at the study centers and immediately checked for reading errors and missing information. All unclear information was then clarified with the participant during a computer-guided interview performed by a lab technician. In 1999–2002, participants received a follow-up questionnaire, and provided self-reported body weight and self-measured waist circumference. In total, 45,271 persons filled in the follow-up questionnaire, yielding a response rate of 79%. All participants gave informed consent for participation and the study was conducted in accordance with the Helsinki Declaration II and approved by local ethics committees.

2.2. Outcome

Height was measured standing without shoes at baseline and rounded to the nearest half centimeter. Baseline body weight was measured on a digital scale in light clothing and rounded to the nearest 100 g, and baseline waist circumference was measured at the narrowest part between the lower rib and the iliac crest and rounded to the nearest centimeter. At follow-up, waist circumference was self-measured at the level of the umbilicus using a measuring tape mailed to all participants together with a questionnaire. Also included was a description of how to self-measure the waist circumference. Body weight at follow-up was self-reported. Misreporting of anthropological measures is related to adiposity measures in the DCH cohort and may introduce bias (Bigaard et al., 2005). However, the self-reported measurements at follow-up have been shown to be useful in analysis of changes in weight and waist circumference (Bigaard et al., 2005).

Follow-up time was $\sim$5 years but varied between individual participants. Therefore, yearly changes in bodyweight and waist circumference were calculated by dividing change in body weight and waist circumference from baseline to follow-up with the individual follow-up time in years. Changes in weight were calculated as g/year and change in waist circumference was calculated as mm/year. Furthermore, a binary outcome variable for weight gain above and below 5 kg during follow-up was generated.

2.3. Exposure assessment-road traffic noise

Residential address history was collected for all cohort members for the period of five years preceding enrollment until date of follow-up by linkage with the Danish Civil Registration System (CRS) using the unique personal identification number. The CRS contains full address history in Denmark from 1977 and onwards, it is maintained continuously by the administrative system, is subject to ongoing validation and registration is required by law (Pedersen, 2011). Of the present and historical addresses we were able to assign a geographical coordinate to more than 95% of the addresses using data obtained from the National Danish Address Register which has a positional accuracy of $+/-$ 5 m for 98% of the address points (UPU, 2012). Additional validation of the data was carried out during exposure assessment where only 0.02% of the geographical coordinates could not be linked to an address. Road traffic noise exposure was calculated using SoundPLAN (http://www.soundplan.dk/), which implements the joint Nordic prediction method for road traffic noise (Bendtsen, 1999). Equivalent noise levels were calculated for each address at the most exposed facade of the building using the following input variables: point for noise estimation (geographical coordinate and height (floor) for each residential address), road links (information on annual average daily traffic, vehicle distribution, travel speed, and road type) and building polygons for all Danish buildings. Data for building polygons were provided by the Danish Geodata Agency (www.gst.dk) and we obtained traffic counts from a national road and traffic database (Jensen et al., 2009), with collection of traffic data on municipal roads from 140 Danish municipalities, covering 97.5% of the addresses included in the present study. No data on noise barriers were available. The included municipal roads typically have more than 1000 vehicles per day based on traffic counts as well as estimated/modeled numbers. Traffic data represents the period from 1995 to 1998; (2) Traffic data from a central database covering all the major state and county roads; (3) Traffic data for 1995–2000 for all major roads in the Greater Copenhagen Area; (4) Smoothed traffic data for 1995 for all roads based on a simple