Environmental Research 138 (2015) 144–153

Contents lists available at ScienceDirect

Environmental Research

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

Road traffic noise and markers of obesity – A population-based study

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ARTICLE INFO

Article history:
Received 1 September 2014
Received in revised form
19 December 2014
Accepted 12 January 2015
Available online 21 February 2015

Keywords:
Noise
Obesity
Overweight
Body mass index
Traffic

ABSTRACT

Background: Noise has been found to be associated with endocrine changes and cardiovascular disease. Increased cortisol levels and chronic sleep problems due to noise may increase the risk of obesity.
Objectives: We investigated the relationship between road traffic noise and obesity markers. Furthermore, we explored the modifying role of noise sensitivity, noise annoyance, and sleep disturbances.
Methods: We used data from a population-based study, HUBRO ($N=15{,}085$), and its follow-up study HELMILO ($N=8410$) conducted in Oslo, Norway. Measurements were used to define body mass index (BMI), waist circumference (WC), waist–hip ratio (WHR), and these binary outcomes: BMI ≥ 30 kg/m^2, WC ≥ 102 cm (men)/88 cm (women), and WHR ≥ 0.90 (men)/0.85 (women). Modelled levels of road traffic noise (L_{den}) were assigned to each participant's home address. Linear and logistic regression models were used to examine the associations.
Results: The results indicated no significant associations between road traffic noise and obesity markers in the total populations. However, in highly noise sensitive women ($n=1106$) a 10 dB increase in noise level was associated with a slope (=beta) of 1.02 (95% confidence interval (CI): 1.01, 1.03) for BMI, 1.01 (CI: 1.00, 1.02) for WC, and an odds ratio (OR) of 1.24 (CI: 1.01, 1.53) for WHR ≥ 0.85. The associations appeared weaker in highly noise sensitive men. We found no effect modification of noise annoyance or sleep disturbances. In a sub-population with bedroom facing a road, the associations increased in men (e.g. an OR of 1.25 (CI: 0.88, 1.78) for BMI ≥ 30 kg/m^2), but not in women. Among long-term residents the associations increased for BMI ≥ 30 kg/m^2 (OR of 1.07 (CI: 0.93, 1.24) in men and 1.10 (CI: 0.97, 1.26) in women), but not for the other outcomes.
Conclusion: In an adult urban Scandinavian population, road traffic noise was positively associated with obesity markers among highly noise sensitive women. The associations appeared stronger among men with bedroom facing a street, representing a population with more accurately assigned exposure.

1. Introduction

Obesity is a global challenge to health, and one of the main risk factors for several important diseases like diabetes, cardiovascular disease (CVD) and cancer (WHO, 2013). According to WHO, nearly 3 million adults die each year as a result of overweight or obesity. In a large sample of the European population, both general adiposity, measured by body mass index (BMI), and abdominal adiposity, expressed by waist circumference (WC) and waist–hip ratio (WHR), were found to be associated with increased death rate (Pischon et al., 2008). As in other countries, there has been a marked increase in mean BMI in the Norwegian population over the last decades (Jenum et al., 2007).

Urbanisation is another global trend that influences health through its impact on the environment. One of the major problems is traffic noise. In the EU, it is estimated that 53% of the population in the largest cities are exposed to road traffic noise above the recommended level of 55 dB L_{den} (EEA, 2010). Whereas several studies have investigated the association between environmental noise and CVD and positive associations are found (Babisch et al., 2005; Selander et al., 2009b; Sørensen et al., 2012), only a few have investigated noise and metabolic outcomes (Eriksson et al., 2014; Sørensen et al., 2013).

The association between traffic noise and CVD is hypothesised

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http://dx.doi.org/10.1016/j.envres.2015.01.011
0013-9351/

to be mediated by stress-related increase in hypothalamic–pituitary–adrenocortical (HPA) and sympathetic adrenal medullary (SAM) activity (Babisch, 2003). Temporary elevations in hormone levels, heart rate and blood pressure after acute exposure to moderate noise levels are reported (Babisch, 2003; Croy et al., 2013). There is also some support for an association between long-term exposure to noise and endocrine effects (Babisch et al., 2001; Ising and Braun, 2000; Selander et al., 2009a). Nocturnal noise exposure has been given special attention, since cardiovascular responses to noise during sleep have shown poor habituation (Carter et al., 2002; Griefahn et al., 2008). Furthermore, inadequate sleep has been found to be associated with elevated cortisol levels (Rodenbeck et al., 2002), obesity (Bjorvatn et al., 2007), diabetes type 2 (Vgontzas et al., 2009), and CVD (Meisinger et al., 2007). Increased levels of cortisol contribute to increased fat accumulation in visceral depots (Anagnostis et al., 2009). The association between sleep deprivation and obesity has further been supported by studies showing changes in the levels of neuropeptides involved in the regulation of appetite, after sleep restriction (Patel and Hu, 2008). A recent experimental study found that partial sleep deprivation by moderate levels of environmental noise increased food intake and body weight in obesity-resistant rats (Mavanji et al., 2013).

Annoyance and sleep disturbances due to traffic noise are well documented (WHO, European Commission, 2011). Some studies indicate that health outcomes may be more closely related to the subjective reaction to noise than to the noise exposure itself, and variability in sensitivity towards noise may play an important role (Fyhri and Klaeboe, 2009; Heinonen-Guzejev et al., 2007). Traffic noise may pose its effect both during day and night-time. Thus, increased cortisol levels and chronic sleep problems due to noise may contribute to weight gain.

In this study we aimed to examine the association between residential road traffic noise outside the most exposed façade and markers of general and abdominal obesity such as BMI, WC and WHR. This was done using the population-based HUBRO study of adults living in Oslo, Norway, including long-term residents. Furthermore, we assessed the modifying role of noise sensitivity, noise annoyance, and sleep disturbances.

2. Methods

2.1. Study population

The HUBRO study was conducted in 2000-2001 in Oslo, Norway. All adults born in 1924, 1925, 1940, 1941, 1955, 1960, and 1970 who resided in Oslo on December 31, 1999 were invited to participate by postal invitation and a questionnaire. The participants were given an additional self-administered questionnaire at the physical examination. The participation rate was 45.9% ($N=18{,}770$) (Søgaard et al., 2004). A total of 17,594 accepted to link their information to registries. Using the national identification number, Statistics Norway provided the residential addresses at inclusion. The addresses were geocoded by the Municipality of Oslo, giving the corresponding geographical coordinates for each participant ($N=17{,}183$). Thereby traffic noise was linked to each participant's home address ($N=16{,}752$). Only participants of western origin were included in this study (Europe, USA, Canada, or Australia as birth country) ($N=15{,}203$). The women reporting to be pregnant were excluded ($n=118$). The long-term residents at enrolment are the participants who have lived at the same address for at least 10 years prior to the physical examination (2913 men and 3972 women).

In 2009–2010 a follow-up questionnaire survey (HELMILO) was conducted, where 8410 subjects (3686 men and 4724 women) participated in both studies. The long-term residents at follow-up (2082 men and 2699 women), those who lived at the same address at follow-up as at enrolment, are sub-populations.

The study was approved by the Regional Committee for Medical and Health Research Ethics in Norway. Written informed consent was obtained from the study participants.

2.2. Assessment of obesity

All participants underwent a physical examination at enrolment, including measurement of anthropometric variables according to a standard protocol (Søgaard et al., 2004). As marker of general obesity we used BMI, calculated as weight (kg) divided by height (m^2). Furthermore, we used WC and WHR as markers of abdominal obesity. WHR was calculated by WC (cm) / hip circumference (cm). We applied the commonly used cut-off value to define general obesity: BMI ≥ 30 kg/m^2, and abdominal obesity: WC ≥ 102 cm (men) / ≥ 88 cm (women), WHR ≥ 0.90 (men)/ ≥ 0.85 (women) (WHO, 2000, 2008).

2.3. Noise exposure assessment

Noise exposure from road traffic was calculated according to the European Environmental Noise Directive (European Commission, 2002) for 2006 (Municipality of Oslo, 2007). We used the Nordic Prediction method for road traffic noise (Bendtsen, 1999; Jonasson and Lyse–Nielsen, 1996) in the acoustical software CadnaA, version 3.6 (DataKustik, 2004). Geographic information system was used to calculate the noise levels on 5×5 m^2 grids at 4 m height at a resolution of 0.1 dB. The grid levels were interpolated at points along the façade of each residential building, with 3 m distance between each point. Input data were road traffic data (traffic counts, percentages of heavy vehicles, speed limits, and diurnal distributions) from the Norwegian Public Roads Administration and the City of Oslo. Other input data were digitalised terrain data, ground type, buildings, and noise screens in 3D. All terrain areas were given hard ground type and completed with soft ground in areas where this was likely.

After evaluating changes in road infrastructure, location of buildings, and traffic density backwards in time, traffic noise was recalculated for the year 2000. Noise exposure was assessed for all study participants as L_{den} outside the most exposed façade of the residential buildings within 500 m from national roads (roads with high traffic counts) and within 300 m from local roads (roads with medium traffic counts). L_{den} is the annual average A-weighted noise level weighted with 5 dB extra in the evening (19.00–23.00) and with 10 dB extra at night (23.00–07.00). Due to very strong correlation with L_{night} (Spearman correlation $R_s=0.999$), we only used L_{den} in the analyses. Since modelled road traffic noise levels are considered less accurate at lower levels and/or at increasing distance from the noise source (Alberola et al., 2005), L_{den} levels less than 40 were set to 40 dB.

2.4. Covariates

The covariates used as confounders were based on literature searches to develop a Directed Acyclic Graph (DAG) (Shrier and Platt, 2008), separately for men and women (Figs. S1a and b). Using Dagitty.net this minimal set of confounders was suggested to assess the direct effect of road traffic noise on obesity: age, employment status, physical activity, smoking status, sleep disturbances, mental health, diet, alcohol and education for men, with use of hormonal replacement therapy (HRT) and marital status in addition for women.

Most of the covariates were extracted from the questionnaires; age (30, 40, 45, 59/60, 75/76 years of age), employment status