Living close to the railway: associations between rail traffic vibration, noise and non-fatal ischemic heart disease

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ABSTRACT

Rail traffic is increasing in Europe following policy recommendations for a more sustainable transportation model. Still, little is known about the health effects of rail traffic vibration for people living close to the railways. This study aims to investigate the associations between rail traffic vibration, noise and non-fatal ischemic heart disease (IHD). The study population (N=6629) was randomly selected from adult residents living within 1km of a trafficked railway in Southwest, Sweden. Survey data collected in 2017 was combined with modeled exposures and health register data (ICD10 codes: i.e., I20-25). A participant was considered a case (n= 332) if any of the ICD codes were registered at least once from 2007 to 2017 and was residing in the study area. The study uses a cross sectional approach and logistic regression analysis. Preliminary results suggest an association between exposure to maximum vibration levels and the period prevalence of non-fatal IHD, accounting for sociodemographic and life-style factors (OR=1.05 per 0.1mm/s V_{max}; 95% CI 0.999-1.100) whereas evidence is unsupportive for maximum rail traffic noise (OR=1.08 per 10dB L_{max}; 95% CI 0.908-1.292). Yet, findings suggest an interaction between noise and vibration in a way that in higher noise levels, as vibration increases the predicted probability of non-fatal IHD increases. The same was not observed in lower levels of noise. These findings have implications for researchers and decision-makers in the areas of environmental health, public health, infrastructure, housing, and transportation planning.

Keywords: Vibration, noise, non-fatal ischemic heart disease, effect modification

INTRODUCTION

Rail traffic is expected to keep increasing in Sweden as well as in other European countries following policy recommendations for a more sustainable transportation model. However, individuals living near railways are often exposed to unwanted vibration and noise from the rail traffic, with potential effects on several health outcomes including annoyance, sleep disturbance and diabetes[1, 2].

Yet, research on rail traffic noise is still scarce when compared to road traffic noise. Studies show conflicting results with cardiovascular outcomes, including ischemic health disease (IHD) incidence or mortality and subgroups of IHD like angina or myocardial infarction[3-6]. A recent study in Denmark reported no associations between rail traffic noise and subgroups of IHD[4] while a pooled analysis of 9 cohorts from Denmark and Sweden show a HR of 1.05 (95% CI: 1.01, 1.08) per 10 dB L_{den} for rail traffic noise during 5yr prior a IHD event after excluding angina pectoris[6].

Research on the health effects of rail traffic vibration is even more scarce, with studies focusing on the effects of vibration on annoyance and sleep disturbance[7-16]. These studies support an association between rail traffic vibration and annoyance with greatest annoyance for freight trains and during evenings and at nights[13, 15, 16]. Exposure during the night can also lead to sleep disturbance[14]. Experimental studies show vibration to change the macrostructure of sleep and to induce heart rate accelerations[7, 17, 18]. Yet, to the best of the authors knowledge there are currently no publications on the effects of vibration on IHD or other cardiovascular outcomes.

This study aims to investigate the associations between rail traffic vibration, noise and non-fatal ischemic heart disease and the potential interactions between rail traffic noise and vibration regarding this outcome.

MATERIALS AND METHODS

Study population

We selected a random sample of individuals living close to the railway in the Swedish regions Hallands, Västra Götaland, Värmland and Örebro in 2017. Populated areas within these regions were targeted following the criteria: (i) within 1 km of a railway in use, (ii) trafficked by a minimum of ten passing freight trains per day and night, (iii) in which vibration measurements had been taken in several dwellings, and (iv) with no major motorways or airports nearby. We invited up to two residents per household, aged 18–80 years old and living in one of the selected areas to participate in the study. Questionnaires were sent to 35,011 individuals and two reminders were used. The response rate of individuals completing and returning the questionnaire and giving consent to access their registry health data was 19.4% (6,808 individuals). Of these, 179 had missing exposure data, with a final sample of 6629 observations included in the present analysis. The study was conducted in accordance with the Helsinki Declaration and approved by ethical committee.

Measurements

Postal questionnaire was used for the socio-acoustic survey, providing information on residence time, sociodemographic and lifestyle factors. Questionnaire data was linked to the dwellings of the participants using Geographic Information Systems (GIS). This allowed for the addition of modelled vibration and noise estimates to the dataset. Health register data was retrieved retrospectively from national and regional patient registries, for the period between 2007-2017.

<u>Outcome: Non-fatal IHD period prevalence</u>

A participant was considered a case if any of the ICD-10 codes for IHD (I-20-25) were registered at least once from 2007 to 2017 while the person was residing in the study area. Information on previous IHD status before 2007 was not available.

Exposure

Vibration

Rail traffic vibration exposure was estimated using an empirical calculation scheme based on vibration measurements and geological data. More information on the vibration calculations have been presented and discussed elsewhere[19]. Vibration exposure was expressed as the maximum weighted vibration velocity at the building foundation (V_{max}) in mm/s.

Noise

Rail traffic noise was calculated as the equivalent continuous A-weighted sound pressure level (L_{Aeq}) for the most exposed facade using the Nordic prediction method revised in 1996[20]. Model input variables included terrain and altitude data, and data on track location and noise screens from the Swedish Transport Administration. To save calculation time, reflection loss and/or shadowing of buildings were not included. This simplification was checked against values derived for the European Noise Directive and found to be comparable. We focus the present analysis on L_{max} as a suitable noise parallel to maximum vibration speed. Rail traffic noise (L_{max}) was operationalized into the analysis as a continuous variable, with odds ratio reported per 10 dB increments.

Covariates

Covariates used for the regression analysis were selected a priori: age (years), sex (male/female), education level (up to elementary school, gymnasium, university), household income (SEK/month; <15000, 15000–29999, 30000–44999, 45000–59999, >60000), residence time (continuous in years), smoking status (never, former, current), alcohol intake (classified according to recommended levels among male and females) and physical activity (yes/no; hr/week among active).

Statistical analysis

We used logistic regression models in a cross-sectional study approach to test for the associations between residential exposure to rail traffic vibration and noise and registered medical diagnosis of non-fatal IHD. Model 1 was adjusted to age and sex. Model 2 was further adjusted to other sociodemographic, life-style factors and residence time. For the interaction analysis we include an interaction term between noise and vibration in model 1. We report OR and 95% confidence intervals of main model estimates and p-value of the interaction term. All analysis were performed in Stata 17.

RESULTS

Preliminary findings suggest the 11-year period prevalence of non-fatal IHD is 5%.
Compared to the reference population in the study, IHD cases were more likely to be older, men, lower educated and had lower income. They lived longer in the present address. In addition, they smoked more and were less physically active (see table 1).

Table 1. Sample descriptive

	Total Cohort ***(N=6629)***	**IHD** ***(N=332)***
Age (years) (%)		
<45	25.7	0.3
45 to 64	37.9	19.3
>= 65	36.4	80.4
Women %	50.1	26.5
Level of education (%)		
Up to Elementary school	22.4	48.9
Gymnasium	36	21.1

University	41.6	30
Household income (SEK/month) (%)		
<15000	5.4	10.3
15000–29999	18.2	35.4
30000–44999	24.3	28.2
45000–59999	20.7	12.8
>60000	31.3	13.2
Residence years	20.16 (14.6)	27.3 (14.9)
Smoking status %		
Never	67.5	41.7
Former	26.4	50.6
Current	6.1	7.7
Alcohol use [a]		
Never	18.1	21.7
Yes, within recommended levels	75.9	74.2
Yes, > recommended levels	6	4.1
Physical activity		
No	16	20.4
<30 min per week	20.2	21.6
30-60 min per week	19.3	21.3
60-90 min per week	14.8	10.7
90-120 min per week	12.4	8.5
>120 min per week	17.2	17.4

[a] Recommended maximum alcohol consumption: up to 10 g/day for female and 20 g/day for male (National Food Administration, Nutrition and Eating habits, 2021).
[b] P50 refers to the 50th percentile or the median, P (5–95) refers to the 5th and 95th percentile.

V_{max} has a skewed distribution, with levels ranging from 0 to 2.58 mm/s and median of 0.01mm/s. 90% of the sample is exposed to levels below 0.21 mm/s. L_{max} has a normal distribution with exposure levels ranging from 47.1 to 92.6 dB and mean levels of 69.8 dB. V_{max} and L_{max} are as expected correlated (see figure 2), but not completely overlapping. Vibration levels equal or above 0.2 mm/s V_{max} (potential level of human perception of vibration) are associated with noise levels ranging between 68.5 to 92.6 dB.

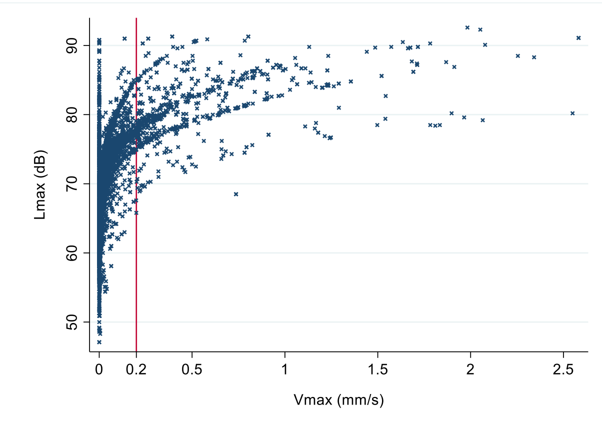

Figure 1. Pairwise scatter plot: V_{max} and L_{max}.

Preliminary logistic regression analyses suggest an association between exposure to maximum vibration levels and the 11-year period prevalence of non-fatal IHD, accounting for sociodemographic and life-style factors whereas evidence is unsupportive for L_{max} (Table 2).

Table 2. Logistic regression models for non-fatal ischemic heart diseases (IHD) and rail traffic vibration (V_{max} in mm/s) and noise (L_{max} in dB).

Vibration	Noise

	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)
V_{max} per 0.1 mm/s	1.04 (0.99-1.09)	1.05 (0.99-1.10)		
L_{max} per 10dB			1.09 (0.93-1.29)	1.08 (0.91-1.29)

Model 1: age and sex
Model 2: age, sex, education, income, residence time, smoking, alcohol use and physical activity

The interaction analysis suggests that the effects of vibration on non-fatal IHD depends on the levels of noise (p= 0.06 for the interaction term V_{max} * L_{max}). In higher L_{max} levels (approx. >80dB) increasing V_{max} is associated with increasing probability of non-fatal IHD. These findings will be further explored and presented at the ICBEN 2023 Congress.

DISCUSSION

Preliminary analysis suggests an association between residential exposure to rail traffic vibration and noise and 11-year period prevalence of non-fatal IHD in Sweden. We observed increased odds of non-fatal IHD of about 1.05 times per 0.1mm/s V_{max}, accounting for sociodemographic and life-style factors. For rail traffic noise we report unsupportive estimates of an association. Vibration exposure above 0.2 mm/s V_{max} is observed in connection with high noise levels (<70dB L_{max}). This relates to the interaction pattern where the effects of rail traffic vibration on the outcome seems to depend on the level of noise in a way that in higher levels of noise as vibration increases the probability of non-IHD increases.

To the best of our knowledge, this is the first study to report an association between rail traffic vibration and cardiovascular diseases. Previous research shows an effect on vibration on annoyance and sleep disturbance, which are often proposed as potential pathways from exposure to cardiovascular outcomes. Furthermore, laboratory studies points to effects of rail traffic vibration and noise on changes of sleep stage and arousals and induced heart rate accelerations[7, 17, 18].

On rail traffic noise, our findings do no support an association similar to previous studies[4]. Yet, our study uses a different noise indicator - L_{max} which is not directly comparable with previous studies that often use L_{den}. Although the use of L_{max} limit the comparability between studies, this indicator might reflect exposure characteristics that could be relevant and complementary to understand the effect of rail traffic noise on health. The present analysis will be complemented with estimates for L_{den} in the future.

Importantly, our outcome is also not directly comparable to previous research, considering it includes only non-fatal IHD cases. It is possible that our findings are thus underestimated if one assumes that the most severe cases were not included, and previous evidence suggests higher risk for fatal events[6]. Yet, future studies targeting rail traffic exposures are still needed, especially of prospective longitudinal design, to elucidate whether rail traffic exposures, both noise and vibration, are associated with IHD irrespective of subtypes of IHD and of fatality.

Strengths and limitations

This is a relevant cohort for the studies on rail traffic exposures and health among adults, especially as we intend to have a follow up evaluation soon. Furthermore, the area covered a significant variation between urban and rural settings. Our design focus on rail traffic exposures, avoiding sampling individuals living close to major roads hence minimizing the combined exposure to road traffic noise and air pollution. The study had a low response rate which was attributed in part to the positive perception regarding the rail traffic among the individuals invited for the study. This could mean that the sample has an over-representation of people that are displeased and maybe disturbed by the rail traffic although comparison with other similar studies do not support that possibility[2]. We are aware of the limitations regarding the cross-sectional design in relation to causality inferences. The cross-sectional nature of the analysis prevents causal statements and reverse-causality cannot be ruled out.

CONCLUSION

Preliminary results suggest an association between exposure to maximum vibration levels and the 11-year period prevalence of non-fatal IHD, accounting for sociodemographic and life-style factors. Our findings suggest an interaction between rail traffic vibration and noise in a way that in higher noise levels (approx. >80dB L_{max}) as vibration increases, we observe an increase in the prevalence of non-fatal IHD. These findings have potential implications for researchers and decision-makers in the areas of environmental health, public health, infrastructure, housing, and transportation planning.

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