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Can area-level socioeconomic conditions and segregation explain differences in exposure to rail traffic noise and vibration?

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ABSTRACT

Previous studies suggest that environmental exposures are unequally distributed across socioeconomic groups although evidence is still conflicting. Unequal exposure, differential susceptibility, and differential ability to cope are potential mechanisms linking rail traffic exposures to health inequalities, i.e., the systematic, avoidable, and unfair differences in health between different socioeconomic groups. Rail traffic noise and vibration have an intrinsic geospatial distribution that is surely determined by the location of the rail tracks. Still, other factors like socioeconomic conditions and segregation might also contribute to this geospatial distribution of exposures. Area-level conditions and segregation relate to individual-level socioeconomic position, residential choice, residential mobility, social efficacy, urban/rural planning, transport planning among other interconnected and relevant aspects for environmental justice. Thus, we have tested three different models (i.e., linear regression, multilevel and spatial autoregressive models) to investigate whether and how area-level socioeconomic conditions and segregation influence the distribution of noise and vibration. Our analysis includes a random sample of individuals living up to 1 km of a trafficked railway (N=7280) within small areas (N=119) in the urban-rural spectrum in 4 regions in Southwest Sweden. Investigating whether there is an unequal distribution in rail traffic exposures accounting for area-level clustering and spatial autocorrelation is the first step in the research project Epivib-equality that investigates the potential cardiometabolic health inequalities due to social vulnerability in connection to rail traffic noise and vibration.

Keywords: railway noise, rail traffic vibration, unequal exposure, health inequalities

INTRODUCTION

Rail traffic is expected to increase worldwide following policy recommendations for a more sustainable transportation model. This raises valid concerns regarding the potential health effects of these environmental hazards for people living close to the railways. Studies suggest rail traffic noise and vibration to have detrimental effects on several health outcomes including annoyance, sleep disturbance and diabetes[1-4]. Despite estimates suggesting 22 million people in Europe exposed to levels of rail traffic noise that are deemed high (>55 dB L_{den})[5], most of these estimates are conservative and have not considered the possibilities of social inequalities in health.

Differential exposure, susceptibility and ability to respond capture three dimensions of social vulnerability[6] and are potential explanations linking rail traffic exposures to health inequalities: the systematic, unfair, and avoidable differences in health between different socioeconomic groups. Previous studies have focused mainly in demonstrating the unequal distribution of environmental exposures across socioeconomic groups[7]. In some studies, more deprived groups are exposed to higher levels of noise while others show that in some contexts people in higher socioeconomic position tend to live in the city centres where they are often more exposed to noise[8]. The reasons for these conflicting results relate to contextual differences between settings but also to methodological approaches, including for instance the choice of SEP indicator, level of analysis and statistical model. Also, previous studies do not consider the syndemic dimension where exposure and effects might be exacerbated due to unequal distribution of pre-existing medical conditions and other noxious living conditions.

In this paper we focus on the first dimension of social vulnerability, i.e., differential exposure. Demonstrating whether we observe an unequal distribution in rail traffic exposures accounting for area-level clustering and spatial autocorrelation is the first step in our research project Epivib-equality that investigates the potential inequalities in cardiometabolic health in connection to rail traffic noise and vibration. Importantly, rail traffic noise and vibration have an intrinsic geospatial distribution that is determined by the location of the rail tracks. This distribution is often marked by clusters of observations. Other factors might also contribute to this geospatial clustered distribution of rail traffic exposures, for instance socioeconomic conditions. In this paper, we aim to test three different models (i.e., simple linear regression, multilevel and spatial autoregressive models) to investigate whether and how area-level socioeconomic conditions influence the distribution of noise and vibration. A similar step will be performed in future analysis regarding area-level segregation (e.g., homogenous versus heterogenous socioeconomic conditions in area-level).

MATERIALS AND METHODS

Study population

We selected a random sample of individuals living close to the railway in the Swedish regions Halland, 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. 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, and it included information on sociodemographic and lifestyle factors. We linked the questionnaire data 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 as well as area-level socioeconomic factors that were used to capture the area-level socioeconomic conditions. Area-level was defined using Statistics Sweden's small-area division. These small areas are referred to as DeSO (n=5984 in Sweden) with varying areas and population ranging from 700 to 2700 inhabitants.

Area level socioeconomic conditions

Area level socioeconomic conditions was calculated using a SES index for the included DeSO areas (n=119). This index was calculated based on the average of the proportion of individuals with low economic standard (i.e., disposable income lower than 60 percent of the median income), low education level (i.e., compulsory education – 9 years education) and unemployment greater than 6 months or under financial welfare support for at least 10 months. This index was then used to classify areas into 4 groups as follows:

- areas facing socioeconomic challenges: ≥ mean SES index + 1 SD
- areas with fair socioeconomic conditions: ≥ mean SES index + 0 SD and < mean SES index + 1 SD
- areas with good socioeconomic conditions: ≥ mean SES index –1 SD and < mean SES index + 0 SD
- areas with very good socioeconomic conditions: < mean SES index - 1SD

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[9]. 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 (LAeq) for the most exposed facade using the Nordic prediction method revised in 1996[10]. Noise level was expressed as L_{den}, and used as a continuous variable. L_{den} was constructed from LAeq levels during the day, evening, and night, with a penalty of 5 dB added for the evening period 19:00 to 22:00 and a penalty of 10 dB added for the night period 22:00 to 07:00).

Statistical analysis

Associations between area-level socioeconomic conditions and participants' exposure to rail traffic noise and vibration respectively were estimated using three different regression models. In model 1 we used standard linear regression. This model ignores that observations are nested within DeSOs and that observations might be spatially distributed. Model 2 is a multilevel linear regression model that accounts for the potential non-independence of observations due to clustering. With this model, we estimate the level of clustering. We used a Moran's I statistic test to assess spatial autocorrelation in exposure levels. Based on the Moran's I test we move to model 3, a spatial autoregressive model that uses spatial lags (contiguity) for controlling for spatial autocorrelation in noise and vibration levels, area-level socioeconomic conditions and in the errors.

RESULTS

Table 1 provides descriptive statistics of participants' exposure to rail traffic noise and vibration according to the area-level socioeconomic conditions classification. Mean exposures levels vary between different areas. For both rail traffic noise and vibration, better-off areas have lower exposure levels. For vibration we don't see a clear trend while for noise we do. The reasons for higher levels of vibration in areas with fair socioeconomic conditions are unclear. Different from noise, vibration levels are dependent on soil characteristics which could be related to housing practices and thus to socioeconomic factors. Full models including individual level socioeconomic characteristics that could be related to housing practices and other aspects of residential choice might assist in explaining these findings.

Table 1. Descriptive statistics of the distribution of study participants' exposure levels to rail traffic noise and vibration according to area-level socioeconomic conditions (n=7280)

	N	**Noise – L_{den}** Mean(SD)	**Vibration - V_{max}** Mean(SD)
Area-level socioeconomic conditions			
Socioeconomic challenges	422	59.2 (5.3)	0.07 (0.18)
Fair socioeconomic conditions	1497	59.0 (5.6)	0.11 (0.24)
Good socioeconomic conditions	4829	58.6 (6.0)	0.08 (0.22)
Very good socioeconomic conditions	532	56.7 (6.5)	0.01 (0.07)

Regression analysis findings (tables 2 and 3) confirmed to some extent the descriptive findings. Model 1 based on the standard linear regression model suggests that in areas with better socioeconomic conditions, the noise and vibration levels are lower. For noise we also observe a trend with decreasing exposure levels following improving socioeconomic conditions. Model 2 shows a slightly different pattern especially for vibration for which there is now a gradient of decreasing exposure over increasing socioeconomic conditions. The larger confidence intervals in model 2 are expected as a consequence of correcting for the non-independence of observations. Clustering at DeSO-level explains 14,5% and 25,9% of the within DeSO area variation in vibration and noise, respectively. However, area-level socioeconomic conditions do not explain the area-level effects observed.

A substantial spatial autocorrelation in the area-level residuals evidence by the Moran's I test suggest that a spatial autoregression model should be fitted to control for this phenomenon. Model 3 address this issue using spatial lags for rail traffic noise and vibration, area-level socioeconomic conditions and residuals. Model 3 presents estimates more similar to the logistic regression analysis for both noise and vibration with indications of trend of decreasing noise exposure levels as socioeconomic conditions improve. Findings (not shown) supports significant spatial autocorrelation effects not only for the residuals but also for rail traffic noise, vibration and area-level socioeconomic conditions, as expected.

Table 2. Regression analysis for the associations between study participants' residential exposure to rail traffic *noise* and area-level socioeconomic conditions (n=7280).

	Model 1		**Model 2**		**Model 3**	
	*Coef.**	*95% CI*	*Coef.**	*95% CI*	*Coef.**	*95% CI*
Area-level socioeconomic conditions						
Socioeconomic challenges	Ref.		Ref.		Ref.	
Fair socioeconomic conditions	-0.40	-1.05; 0.25	0.09	-2.82; 3.00	-0.11	-0.75; 0.52
Good socioeconomic conditions	**-0.92**	**-1.52; -0.32**	-1.13	-3.89; 1.62	-0.50	-1.11; 0.10
Very good socioeconomic conditions	**-2.97**	**-3.74; -2.20**	-3.21	-7.35; 0.92	**-1.68**	**-2.47; -0.88**

*Coefficients for changes in 1dB (L_{den}).

Table 3. Regression analysis for the associations between study participants' residential exposure to rail traffic *vibration** and area-level socioeconomic conditions (n=7280).

	Model 1		Model 2		Model 3	
	*Coef.**	*95% CI*	*Coef.**	*95% CI*	*Coef.**	*95% CI*
Area-level socioeconomic conditions						
Socioeconomic challenges	Ref.		Ref.		Ref.	
Fair socioeconomic conditions	**0.49**	**0.03; 0.07**	-0.00	-0.10; 0.10	**0.30**	**0.01; 0.05**
Good socioeconomic conditions	0.11	-0.01; 0.03	-0.26	-0.12; 0.07	-0.01	-0.02; 0.02
Very good socioeconomic conditions	**-0.54**	**-0.08; -0.03**	-0.87	-0.18; 0.00	**-0.50**	**-0.07; -0.02**

*Coefficients for changes in 0.1mm/s V_{max}.

DISCUSSION

Preliminary analysis suggests that rail traffic noise and vibration might be unequally distributed according to area-level socioeconomic conditions in Southwest, Sweden. Areas with better socioeconomic conditions are less exposed to rail traffic noise and vibration when accounting for spatial lags. The use of different statistical modelling strategies points to the need to consider both clustering and spatial autocorrelation effects in this kind of analysis. Standard regression analysis seems to fail to deal with these assumptions, offering biased estimates.

To the best of our knowledge, this is the first study to investigate the unequal distribution of rail traffic noise and vibration, testing different models. A similar approached was used previously for the analysis of road traffic noise[8] and aircraft noise[11]. Both studies support the approach of testing models that accounts for potential cluster and/or spatial effects. Methods of model selection need to be further discussed in such an approach. Preliminary model evaluations using AIC criteria support the use of spatial regression models in our analysis, but further tests are still needed.

This is a preliminary analysis. Discussions about the spatial lags are still necessary. For this preliminary analysis we used a spatial weighting matrix based on the inverse distance between observations. Other weighting approaches need to be tested for example a contiguity matrix based on nearest observations. In addition, future analysis will address indicators of socioeconomic segregation, focusing on whether areas are homogenously or heterogeneously occupied regarding socioeconomic factors. Individual level indicators are also going to be included in future analysis to refine the assessment of socioeconomic factors involved in the distribution of these rail traffic exposures. This can assist in explain the increase in vibration exposure levels in areas with fair socioeconomic conditions when compared to the areas with socioeconomic challenges.

There are multiple intersections between socioeconomic factors and environmental exposures that could explain this differential exposure according to socioeconomic groups. In the case of rail traffic exposures, these intersections can be related to for instance transport planning, habitational policies, and residential choice. Literature shows that residential choice is more restricted among individuals in lower socioeconomic positions due to financial constraints, persistent discrimination and residential segregation[12]. The restricted residential choice could then explain why lower SEP groups tend to live in highly exposed places. It is also important to mention that authorities could be less responsive to places where people in lower SEP live, considering that these groups have less power, influence, awareness, and social efficacy to demand better living conditions.

CONCLUSION

Preliminary results suggest a need for exploring different models in the investigation of socioeconomic inequalities in rail traffic noise and vibration exposure distribution. Spatial autoregressive models are potentially a better model in our analysis. Future analysis will focus on the refinement of these models, including other socioeconomic indicators in area- and individual-levels in addition to the discussions about model selection. These findings are relevant to the discussion about socioeconomic inequalities in environmental health and the need to consider different methodologies for better assessing and understanding these inequalities.

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REFERENCES

1. Vincens N, Persson Waye K. *Railway noise and diabetes among residents living close to the railways in Västra Götaland, Sweden: Cross-sectional mediation analysis on obesity indicators.* Environmental Research 2022;212:113477.
2. Vincens N, Ögren M, Li H, van Kempen E, Edgren S, Persson Waye K. Epivib: hälsoeffekter av att bo vid en järnväg. 2021.
3. Thacher JD, Roswall N, Damm P, et al. *Transportation noise and gestational diabetes mellitus: A nationwide cohort study from Denmark.* International Journal of Hygiene and Environmental Health 2021;231:113652.
4. Waddington D, Woodcock J, Smith MG, Janssen S, Persson Waye K. *CargoVibes: human response to vibration due to freight rail traffic.* International Journal of Rail Transportation 2015;3(4):233-48.
5. EEA. Number of Europeans exposed to harmful noise pollution expected to increase. 2020; Available from: https://www.eea.europa.eu/highlights/number-of-europeans-exposed-to.
6. Diderichsen F, Hallqvist J, Whitehead M. *Differential vulnerability and susceptibility: how to make use of recent development in our understanding of mediation and interaction to tackle health inequalities.* International Journal of Epidemiology 2019;48(1):268-74.
7. Dreger S, Schule SA, Hilz LK, Bolte G. *Social Inequalities in Environmental Noise Exposure: A Review of Evidence in the WHO European Region*. International journal of environmental research and public health 2019; 20;16(6).
8. Havard S, Reich BJ, Bean K, Chaix B. *Social inequalities in residential exposure to road traffic noise: an environmental justice analysis based on the RECORD Cohort Study*. Occup Environ Med. 2011;68(5):366-74.
9. Ögren M, Ekblad A, Johansson P, Koopman A, Persson Waye K. *Ground and Building Vibration Estimation for Health Impact Research.* Noise and Vibration Mitigation for Rail Transportation Systems 2021;487-95.
10. Naturvårdsverket. Buller från spårburen trafik - Nordisk beräkningsmodell. Rapport 4935. 1999.
11. Tonne C, Milà C, Fecht D, et al. *Socioeconomic and ethnic inequalities in exposure to air and noise pollution in London.* Environ Int. 2018;115:170-9.
12. Swope CB, Hernández D. *Housing as a determinant of health equity: A conceptual model.* Social Science & Medicine 2019;243:112571.