Exposure to source-specific transportation noise levels and temporal noise characteristics in association with arterial stiffness

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ABSTRACT

Transportation noise levels and their temporal characteristics may impact arterial stiffness, a predictor of cardiovascular disease. We evaluated the association of residential outdoor road, railway, and aircraft noise levels (Lden), total noise intermittency (IR), and total number of noise events (NE) with brachial-ankle pulse wave velocity (baPWV) using a cross-sectional design.

We assessed 2775 adults who underwent baPWV measurements in a Swiss cohort in 2010/2011. We assigned $Lden_{source}$, and total day- and night-time NE_{time} and IR_{time} (IR: 0%: constant, 100%: highly intermittent noise) at the most exposed dwelling façade, using 2011 source-specific models for Switzerland. Associations were analyzed with multivariable linear mixed regression.

Medians (interquartile ranges) were baPWV: 13.4 (3.1) m/s, $Lden_{road}$: 54.2 (10.6) dB, $Lden_{rail}$: 30.0 (8.1) dB, and $Lden_{air}$: 32.8 (8.0) dB. Both $Lden_{rail}$ and NE_{night} were associated with baPWV, independently of other noise sources and air pollution. The association with $Lden_{rail}$ was greater with IR_{night}>80% and with reported daytime sleepiness.

Long-term exposure to railway noise, particularly in intermittent night-time noise environments, and night-time noise events, mainly related to road noise, may impair arterial stiffness more than other noise characteristics.

INTRODUCTION

Long-term exposure to transportation noise may impact cardiovascular disease, as reported in recent meta-analyses [1,2]. While there is increasing evidence for the association between road traffic noise levels and hypertension [3], very little is known about the long-term impact of transportation noise on other major cardiovascular risk factors. One of these endpoints could be arterial stiffness, an independent strong predictor of future CVD and mortality [4]. This is suggested by one recent experimental study, which observed acute night-time aircraft noise effects on endothelial dysfunction [5]. Two recent epidemiological studies also observed associations between annual average road noise levels and isolated high systolic blood pressure [6,7], which is related to high pulse pressure, an indirect marker of arterial stiffness [4]. To our knowledge, no study to date has addressed direct markers of arterial stiffness such as brachial-ankle pulse wave velocity (baPWV) [8].

Literature has mainly focused on studying the cardiovascular effects of either road and/or aircraft noise, but less on railway noise and rarely on the three combined sources. Studies have also mainly evaluated average noise levels, however, field studies suggest that night-time noise events correlate better with awakening reactions and cardiac arousals, than average levels [11,12]. Moreover, little is known about the importance of environments with low and high noise fluctuation (i.e. constant noise versus isolated events that stand out from a quiet background, respectively).

We aimed to evaluate the association between long-term exposure to transportation noise (average levels and temporal structure) with baPWV in an adult population-based cohort, assessing home-outdoor annual average levels of road, railway and aircraft noise, total noise intermittency ratio, and total number of noise events. We also evaluated whether the studied associations were modified by different noise exposure situations and participant characteristics.

METHODOLOGY

We assessed a total of 2775 adults from the third examination of the SAPALDIA Swiss cohort (years 2010/2011), who lived in environmentally diverse areas in Switzerland. Personal interview-administered questionnaires were performed to collect information on age, sex, socio-economic status, and lifestyles.

BaPWV was measured in participants aged 50 years or older by means of a non-invasive VaSera VS-1500N vascular screening system (Fukuda Denshi, Tokyo, Japan). Measurements were performed in supine position after at least 10 minutes of rest.

We geocoded participants' addresses, assigned A-weighted day-, evening-, and night-time noise levels at the most exposed dwelling façade and used them to calculate the day-evening-night noise indicator ($Lden_{source}$, in dB) for this study. Noise estimates were derived from current source-specific Swiss noise models for the year 2011 [13], improved for the SiRENE (Short and Long Term Effects of Transportation Noise Exposure) project. We also assigned total (all-source) day- and night-time number of noise events (NE_{ime}), as those events exceeding a certain noise threshold [14] and total noise intermittency ratio (IR_{time}), which represented the fraction of acoustical energy created by noise events to the total noise level (IR: 0%: constant, 100%: highly intermittent noise) [14]. Nitrogen dioxide levels ($\mu g/m^3$) for the years 2010/2011 were derived by land-use regression models and also assigned at residential level.

Associations were analyzed with multivariable linear mixed regression and adjusted for several covariates including age, sex, diet, smoking, exercise, alcohol intake, body mass index, mean arterial pressure, nitrogen dioxide, and a random intercept by study area.

RESULTS

The study sample comprised 2775 participants after exclusions. Participants were 63 years old on average, with a range between 49 to 81 years, and 51% were women. The median (IQR: interquartile range) baPWV was 13.4 (3.1) m/s. The medians (IQR) for the noise indicators were: $Lden_{road}$: 54.2 (10.6) dB, $Lden_{rail}$: 30.0 (8.1) dB, $Lden_{air}$: 32.8 (8.0) dB, IR_{night}: 73.1 (27.2) %, IR_{day}: 63.8 (40.3) %, NE_{day}: 433 (870), and NE_{night}: 123 (179).

Correlations between noise indicators were small (i.e. < 0.14), except for NE_{day} and NE_{night} which were mainly correlated to $Lden_{road}$ (Spearman's rank r = 0.77 and 0.67, respectively). The correlation between $Lden_{road}$ and nitrogen dioxide was low to moderate (r=0.42).

$Lden_{rail}$ was significantly associated with baPWV, both in single- and multi-exposure models, and independently of other noise sources and air pollution (See Figure 1). NE_{night} was also significantly associated with baPWV, independently of other noise sources and air pollution (See Figure 2). NE_{day}, IR_{day}, $Lden_{road}$, and $Lden_{aircraft}$ were not associated with baPWV.

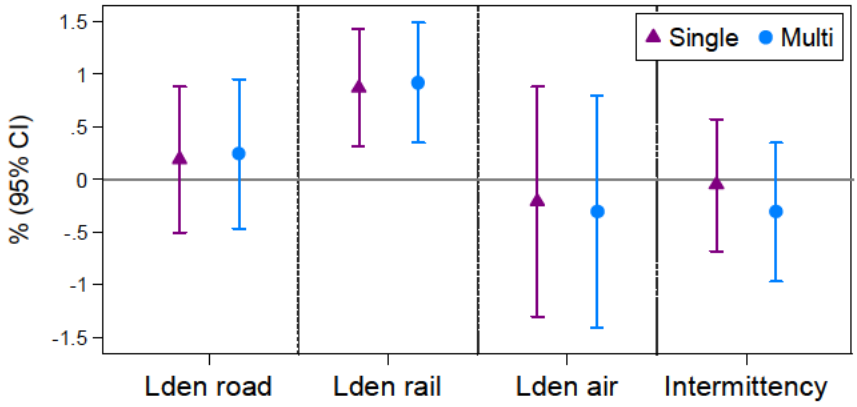

Figure 1: Adjusted percentage change (%) and 95% confidence intervals (95%CI) for the associations of annual average transportation noise levels (Lden) and total night-time noise intermittency ratio with arterial stiffness (n=2775) per IQR change in noise levels. Single-exposure models are represented with a triangle and include one noise indicator at-a-time. Multi-exposure models are represented with a circle and include all source-specific Lden levels and intermittency ratio.

Regarding effect modification, the association between $Lden_{rail}$ and baPWV was greater when participants were exposed to IR_{night} above 80% and with reported daytime sleepiness (data not shown). We also observed a borderline significant association between $Lden_{road}$ and baPWV in urban areas, coupled with a negative non-significant tendency in rural areas.

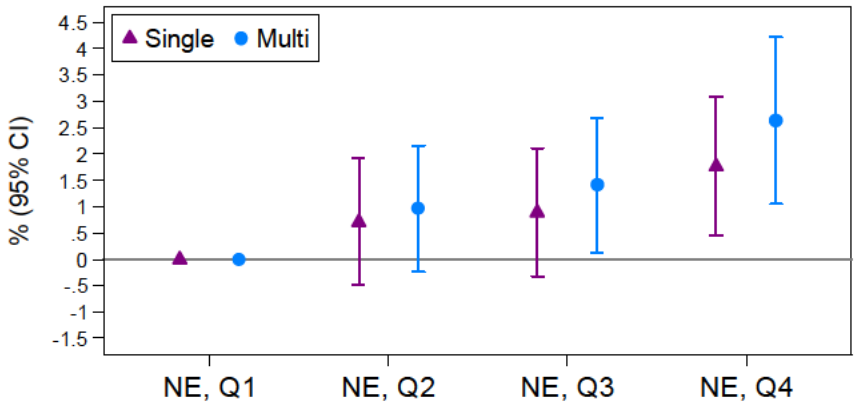

Figure 2: Adjusted percentage change and 95% confidence intervals for the association between increasing quartiles in the total number of night-time noise events and arterial stiffness (n=2775). Single-exposure models are represented with a triangle. Multi-exposure models are represented with a circle and are additionally adjusted for all source-specific Lden levels and intermittency ratio.

DISCUSSION AND CONCLUSION

To our knowledge, this is the first epidemiological study to evaluate the association between long-term exposure to transportation noise and a direct marker of arterial stiffness, exploring the relative contribution of the different noise sources and the impact of total noise events and total noise intermittency ratio.

Results indicate that railway noise levels, particularly in highly intermittent night-time noise environments, may be associated with arterial stiffness, more than other noise sources and/or characteristics. Results further suggest a potential role of the night-time period and sleep, given that the association between railway noise levels and arterial stiffness was greater in participants reporting daytime sleepiness and that associations were only observed with night-time, not day-time noise events.

The night-time noise events seemed to predict arterial stiffness better than $Lden_{road}$ alone. The latter seemed to be more representative in urban than in rural areas, where participants lived closer to traffic and were exposure to noise events was greater.

In conclusion, long-term exposure to railway noise, particularly in an intermittent environment, and to the total number of noise events, mainly related to road traffic noise, may impair arterial stiffness, more than other noise characteristics. The impact might be more relevant at night-time and potentially relate to sleep impairment. These initial findings should be replicated in future longitudinal studies.

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