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Years of life lost and morbidity cases attributable to transportation noise and air pollution: A comparative health risk assessment for Switzerland in 2010

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ABSTRACT

Background: There is growing evidence that chronic exposure to transportation related noise and air pollution affects human health. However, health burden to a country of these two pollutants have been rarely compared.
Aims: As an input for external cost quantification, we estimated the cardiorespiratory health burden from transportation related noise and air pollution in Switzerland, incorporating the most recent findings related to the health effects of noise.
Methods: Spatially resolved noise and air pollution models for the year 2010 were derived for road, rail and aircraft sources. Average day-evening-night sound level (Lden) and particulate matter (PM_{10}) were selected as indicators, and population-weighted exposures derived by transportation source. Cause-specific exposure–response functions were derived from a meta-analysis for noise and literature review for PM_{10}. Years of life lost (YLL) were calculated using life table methods; population attributable fraction was used for deriving attributable cases for hospitalisations, respiratory illnesses, visits to general practitioners and restricted activity days.
Results: The mean population weighted exposure above a threshold of 48 dB(A) was 8.74 dB(A), 1.89 dB(A) and 0.37 dB(A) for road, rail and aircraft noise. Corresponding mean exposure contributions were 4.4, 0.54, 0.12 $\mu g/m^3$ for PM_{10}. We estimated that in 2010 in Switzerland transportation caused 6000 and 14,000 YLL from noise and air pollution exposure, respectively. While there were a total of 8700 cardiorespiratory hospital days attributed to air pollution exposure, estimated burden due to noise alone amounted to 22,500 hospital days.
Conclusions: YLL due to transportation related pollution in Switzerland is dominated by air pollution from road traffic, whereas consequences for morbidity and indicators of quality of life are dominated by noise. In terms of total external costs the burden of noise equals that of air pollution.

Introduction

There is a large body of evidence on the health effects of air pollution, specifically fine particle matter (PM) generated by traffic sources in urban areas. There is robust evidence for a link of PM fractions with long-term mortality (Hoek et al., 2013) and infant mortality (Woodruff et al., 1997), and various morbidity outcomes, such as cardiorespiratory hospital admissions (Atkinson et al., 2014), bronchitis (Abbey et al., 1995; Schindler et al., 2009), asthma (Hoek et al., 2012; Weinmayr et al., 2010) and restricted activity days (Ostro, 1987). This evidence has been used for estimating the burden of air pollution in different settings (Lim et al., 2012; WHO, 2013a).

Less is known about the health effects of transportation related noise, although there has been substantial growth in the body of evidence in the last years. While the negative health impacts from noise were principally linked to annoyance, auditory and other

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non-auditory health effects (Basner et al., 2013), new studies are finding an association between chronic exposure to transportation related noise and cardiovascular outcomes, such as ischaemic heart disease (IHD), hypertensive diseases and stroke, independent of the effects of air pollution (Sørensen et al., 2011; van Kempen and Babisch, 2012; WHO, 2011).

In Switzerland, the political consensus is that heavy vehicles (above 3.5 tonnes) must cover the entirety of the costs they generate, including the external costs from damage to environment and health. Thus, the LSVA (performance related heavy vehicle charge) has been traditionally derived in part on calculation of external costs of noise and air pollution, revised every 5 years (ARE, 2004a,b, 2008, 2014a). So far, external costs of noise were principally driven by the effects of quality of life indicators (annoyance and sleep disturbance) and were reflected by calculating the loss of rents in noise exposed apartments (ARE, 2008). Health effects represented by mortality due to hypertension and ischaemic heart disease have also been included in past evaluations but cost contributions were minor compared to loss of rents (ARE, 2008, 2014a). The recent epidemiological literature shows that the mortality effects of noise are much higher than earlier studies suggested. The impact of noise from transportation was thus most likely only partially accounted in past burden and cost evaluations studies in Switzerland and elsewhere.

As an input for the latest external traffic cost estimates in Switzerland, this study estimates the years of life lost (YLL) and attributable burden for different cardiorespiratory outcomes due to the noise and air pollution generated from road, rail and aircraft transport in 2010 in Switzerland, incorporating the most recent findings related to the health effects of noise and air pollution.

Materials and methods

We combined population exposure to noise and air pollution with exposure–response functions and baseline cardiorespiratory morbidity and mortality data to estimate the years of life lost (YLL) and the number of morbidity cases attributable to noise and air pollution from transportation on the roads, railways and in the air.

Population exposure

Exposures to noise were obtained from existing models for year 2010. For road and rail noise population exposures were derived from SonBase, the Swiss GIS-based noise model (Karipidis et al., 2014). SonBase models the noise propagation from source to reception points, taking account of building height, first order reflections and noise barriers. Noise levels at source points are first calculated with CADNA-A and STL-86+ models using data from a detailed Swiss national traffic model for 2010 from the Federal Office for Spatial Development (ARE, 2014b). SonBase calculates equivalent continuous noise level (Leq) at the most exposed façade of each building per floor in Switzerland, with noise in steps of 1 dB(A). Estimates of aircraft noise for the national airports of Zurich and Geneva come directly from the airport operators, which annually evaluate the airport-specific noise. The data for Basel and 10 regional airports were derived from the SonBase model developed by the Federal Office of Civil Aviation (ARE, 2004a; Huss et al., 2010).

The noise metric used in our study was Lden [dB(A)], the average sound level over all 24 h periods of a year with a respective 5 and 10 dB(A) penalty for evening (18:00–22:00) and night (22:00–06:00) hours. Noise levels modelled at residential addresses were combined with population counts to determine total exposure in 1 dB(A) steps from 40 to ≥80 dB(A) (in burden calculations, population in areas with modelled road and rail noise <40 dB(A) were assigned a level of 40 dB(A)). For subsequent burden calculations, a threshold of no effect of 48 dB(A) was assumed (see section "Derivation of exposure–response relationship"). We thus calculated the population-weighted mean exposure over this threshold for each noise source.

For air pollution, PM_{10} was used as the pollutant indicator to allow for comparability with past studies. Exposure levels for 2010 were obtained from a 200 m × 200 m dispersion model for PM_{10} which accounted for primary particulates, secondary particle formation from precursor emissions (NO_x, SO_2 NH_3 and NMVOC) and transboundary large-scale PM_{10} (BAFU, 2013). The dispersion model was run for total air pollution and separately for each transport source (road, rail and air). Population counts in each grid cell were combined with PM_{10} levels to obtain population-weighted concentrations by source type.

Derivation of exposure–response relationship

We conducted a literature review to derive or obtain exposure–response relationships reflecting the most current scientific evidence in the association between noise, particulate matter and cardiorespiratory mortality or morbidity.

We had previously developed meta-analytic estimates of the effects of noise on several cardiovascular outcomes (ARE, 2014a; Vienneau et al., 2015). This included a meta-analysis to derive an exposure–response function for ischaemic heart disease (IHD) and stroke, and the pooling of two existing meta-analysis estimates to derive a summary estimate for hypertension (Table 1). The methods in brief were as follows. For IHD, we combined the results of 10 studies conducted since the mid-1990s, providing 13 relative risk estimates for morbidity or mortality. Most were conducted in Europe for road noise; four investigated exposure to aircraft noise, two of which were in North America; none were found for railway noise. Six studies were combined for stroke, contributing a total of 8 relative risk estimates for meta-analysis: 3 road, 4 aircraft and 1 rail noise. For hypertension, we combined the two recent meta-analyses, van Kempen and Babisch (2012) on road and Babisch and van Kamp (2009) for aircraft, to derive the exposure–response function. To specify the starting point for the noise exposure–response associations, we globally pooled the study specific reference values (i.e., for three outcomes) using the derived meta-analysis weights of each study. This resulted in a threshold of 48 dB(A) below which no effects were considered. We did not include annoyance, sleep disturbance and cognitive impairment as outcomes to allow for comparability with past cost evaluations in Switzerland, and to avoid potential double counting of effects.

For air pollution related health effects we applied the recommendations of the HRAPIE (Health risks of air pollution in Europe) project (WHO, 2013a,b) (Table 2). For some outcomes such as mortality, HRAPIE proposes an exposure–response function for $PM_{2.5}$. In this case the exposure–response function was converted to PM_{10} by applying the ratio of the population-weighted means for $PM_{2.5}/PM_{10}$ of 0.73 (calculated in the Swiss dispersion model).

Calculation of morbidity and mortality burden

We used mortality rates observed in Switzerland to calculate changes in YLL for a reference and the counterfactual scenario using the life table approach (Miller and Hurley, 2003; Röösli et al., 2005). In the reference scenario, 1-year age interval life tables for the Swiss population were calculated extrapolating observed survival probabilities in the year 2011, obtained from Federal Statistics Office (BfS), to 2010 population (differentiated for male and female). For the counterfactual scenario, life tables were rerun with modified survival probabilities that assumed no one in the population was exposed to source-related transportation noise (above 48 dB(A)) or PM_{10} concentrations. Thus cause-specific