

Traffic noise, insomnia and sleep medication use

Jorunn Evandt

Division of Environmental Medicine, Norwegian Institute of Public Health, Oslo, Norway.

Bente Oftedal

Division of Environmental Medicine, Norwegian Institute of Public Health, Oslo, Norway.

Norun Hjertager Krog

Division of Environmental Medicine, Norwegian Institute of Public Health, Oslo, Norway.

Svetlana Skurtveit

Division of Epidemiology, Norwegian Institute of Public Health, Oslo, Norway.

Eva Skovlund

Division of Epidemiology, Norwegian Institute of Public Health, Oslo, Norway.

Per Nafstad

Institute of Health and Society, University of Oslo, Oslo, Norway

Division of Epidemiology, Norwegian Institute of Public Health, Oslo, Norway.

Per Schwarze

Division of Environmental Medicine, Norwegian Institute of Public Health, Oslo, Norway

Gunn Marit Aasvang

Division of Environmental Medicine, Norwegian Institute of Public Health, Oslo, Norway

Summary

Background: Population-based studies on the association between road traffic noise and sleep disturbances have mainly focused on outcomes where noise is suggested as the cause of the sleep disturbances rather than outcomes such as symptoms of insomnia. Studies of the association between road traffic noise and sleep medication use are scarce.

Aims: The aims were to study the associations between night-time road traffic noise and 1) self-reported symptoms of insomnia (*difficulties falling asleep, awakenings during the night, and waking up too early*) and 2) use of sleep medications, both self-reported and register-based. We also assessed the agreement between self-reported and register-based use of sleep medication.

Methods: The study population was from the Health and Environment in Oslo study (HELMILO) (2009-10) (N=13,019). We defined insomnia symptoms as sleep problems occurring ≥ 3 -5 times per week. We obtained data on register-based sleep medication use from the Norwegian Prescription Database (NorPD). Modeled noise levels (L_{night}) were assigned to each participant's home address. Logistic regression models were used to analyze the associations. To assess the agreement between self-reported and register-based use of sleep medications we calculated sensitivity and specificity.

Results: After adjustment for potential confounders, statistically significant associations were found between noise exposure and all three symptoms of insomnia. A smoothed spline indicated a linear relationship between traffic noise and register-based sleep medication use. Compared with register-based medication use, self-reported medication use showed specificity of 95 % and sensitivity of 73 %.

Conclusions: Our results suggest that individuals living in noise exposed areas have an increased risk of insomnia symptoms. There may be a qualitative difference between self-reported and register-based medication use.

PACS no. 43.50.+y

1. Introduction

Growing traffic volumes and urbanization make traffic noise an increasing cause of concern for public health. Along with annoyance, sleep disturbances are considered the main health burden related to environmental noise. Estimates from the World Health Organization (WHO) show that environmental noise, whereof mainly road traffic noise, is responsible for nearly a million healthy life years lost annually due to sleep disturbances in Western Europe [1].

Findings both from field and laboratory studies have shown that nocturnal noise can have effects on sleep such as delayed sleep onset, awakenings, arousals and self-reported sleep disturbances [2-6]. Besides the direct impact on sleep, night-time traffic noise has also been associated with day after effects such as mood changes [7], decreased cognitive performance [8], and fatigue [9]. However, few population-based studies have examined associations between traffic noise and general symptoms of insomnia. In large scale epidemiologic studies, a common way to assess sleep disturbances is to have participants subjectively evaluate their sleep in questionnaires. The focus has mainly been on self-reported sleep disturbances where noise is given as the cause of the sleep disturbances in the wording of the questionnaire [2]. When using outcomes where traffic noise is suggested as the cause of the sleep disturbances there is a chance that sleep disturbances are over-attributed to traffic noise [10]. This problem is avoided by asking participants to report general sleep disturbances, unrelated to any particular source.

By using register-data on sleep medication use, we obtained an objective measure of sleep medication use feasible for use as an outcome in a large population based study. This could possibly reflect sleep disturbances in the study population. To our knowledge, only two previous studies have investigated register-data on sleep medications in relation with road traffic noise. One of these studies revealed some evidence that road traffic noise is associated with use of sleep medications [11], whereas the other found no association [12].

In most epidemiologic studies of traffic noise and sleep, noise is modeled for the most exposed facade of the building. Previous research has pointed out that by not taking location of bedroom into account, the true effect of traffic noise exposure on sleep is likely to be underestimated, because people might have their bedroom facing a less exposed side of the building [2, 13-15].

In the present study we investigated the association between night-time road traffic noise and symptoms of insomnia and also the association between night-time road traffic noise and register-based use of sleep medications. As a secondary aim, we assessed the agreement between self-reported and register-based sleep medication use.

2. Methods

2.1 Study Population

The study population was from the Health and Environment in Oslo study (HELMILO), conducted in 2009-10. A questionnaire was sent out to 27,097 Oslo inhabitants born in 1924-25, 1940-41, 1955, 1960 and 1970, whereof 13,019 responded. The response rate was 48 %. Written informed consent was obtained and the study was approved by the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate. The study was funded by The Research Council of Norway (Project no.: 204535).

2.2 Noise Exposure Assessment

Night-time road traffic noise levels (L_{night} , A-weighted night-time equivalent noise level, 2300-0700 hours) were modeled for Oslo in 2011 [16] in accordance with the European Environmental Noise Directive [17]. The noise levels were calculated according to The Nordic Prediction Method for road traffic noise [18] using the software package CadnaA. Grid points for the calculations were 5 x 5 meters and calculation height was 4 meters above terrain. Road traffic data included in the model (traffic counts, % heavy vehicles, speed limits, diurnal distribution) were obtained from the Norwegian Public Roads Administration and the City of Oslo. Residential noise levels modelled for the most exposed facade

of the building were assigned to each participant's home address using geographic coordinates.

2.3 Outcome variables

As indicators of symptoms of insomnia we used *difficulties falling asleep, awakenings during the night, and waking up too early*. The participants reported how frequently they had experienced these problems during the past twelve months on a five-point scale with the alternatives "never/rarely", "less than once per week", "1-2 times per week", "3-5 times per week", and "always/almost every night". We dichotomized this scale and considered a frequency of three to five times per week or more as presence of insomnia symptoms.

Information on register-based sleep medication use was obtained from The Norwegian prescription database (NorPD) at the Norwegian Institute of Public Health, which includes individual data on all prescription drugs dispensed at Norwegian pharmacies since 2004. The unique personal identification number assigned to all Norwegian citizens, makes it possible to store information on dispensed drugs at an individual level [19, 20]. We considered it a proxy for current use of sleep medications if an individual had dispensed a prescription on hypnotics (N05C according to the Anatomical Therapeutic Chemical (ATC) classification system [21]) at a pharmacy during a period of 100 days prior to participation in HELMILO. Self-reported sleep medication use was obtained in the questionnaire, where the participants indicated whether they currently used sleep medications, previously had used it, or never had used it. We dichotomized this information into current use versus previous or never use.

2.4 Statistical analysis

We used logistic regression for analyzing the associations between road traffic noise and symptoms of insomnia and sleep medication use, respectively. We were able to assign noise exposure (L_{night}) to 12,138 participants. Noise exposure was included as a categorical variable with the four levels $L_{\text{night}} < 45$ dB ($n=4,302$), 45-50 dB ($n=3,628$), 50-55 dB ($n=2,283$), and ≥ 55 dB ($n=1,925$). For the association between register-based sleep medication use, we performed a trend test across the four categories of noise levels. In

addition, we assessed this relationship by estimating a spline where we included noise exposure as a continuous variable with a cut-off at $L_{\text{night}} 35$ dB. We ran two models for the association between traffic noise and symptoms of insomnia and sleep medication use, respectively. Model 1 was adjusted for age and sex, and model 2 was in addition adjusted for body mass index (BMI), education level (low, medium, high), marital status (married/cohabiting, unmarried, divorced/separated, widowed), employment status (unemployed, working 1-29 hours/week, working ≥ 30 hours/week, old age-retired), household income (low, medium, high), physical activity (sedentary, moderately active, very active), alcohol consumption during the last year (abstainer/not been drinking the last year, ≤ 3 times/month, 1-3 times/week, 4-7 times/week), smoking status (current, previous, never), mental distress (high vs. low degree), chronic respiratory diseases (yes vs. no), and railway noise ($L_{\text{night}} \geq 45$ dB vs. < 45 dB). Railway noise exposure was modelled according to the Nordic prediction method for rail traffic noise [22] using the software package CadnaA. Participants who had lived at their current address less than one year at the time of inclusion in the study were excluded from the analyses ($n=367$). For the analyses of traffic noise and insomnia, we excluded participants who reported to currently use sleep medications ($n=1,294$) because this could affect the participants' perception of how they sleep. In the analyses of noise and sleep medication use, we excluded the participants in the oldest age group ($n=1,341$). This was done because medications dispensed at institutions are not registered in NorPD at an individual level. Taking into consideration that the participants in the oldest age group were 84-85 years old when they were included in the study, we considered it likely that some of them were living in nursing homes.

In addition to the main models, we performed separate analyses for the individuals who had their bedroom facing a road. Information on bedroom location in the building was collected in the questionnaire.

We evaluated the agreement between self-reported and register-based sleep medication use by computing sensitivity and specificity, commonly used measures for assessing the validity

of diagnostic tests. We considered register-based sleep medication use as the reference standard.

The level of statistical significance was set at 5 %. Statistical analyses were carried out in STATA version 12 (StataCorp, College Station, Texas, USA). The spline was estimated in R statistical software 2.15.1 (R-project, library mgcv, function gam, Vienna, Austria).

3. Results

In the total study population 6.4 % (n=685) reported difficulties falling asleep 3-5 times per week or more, 9.7 % (n=1,019) reported awakenings during the night 3-5 times per week or more, and 8.5 % (n=896) woke up too early 3-5 times per week or more. Regarding sleep medication use 6.0 % (n=583) had filled at least one prescription on hypnotics during 100 days prior to participation in HELMILO and 8.7 % (n=844) reported use of sleep medications in the questionnaire. Table 1 shows the distribution of age and sex along with the distribution of symptoms of insomnia and sleep medication use in the total study population.

Regarding the insomnia symptom *difficulties falling asleep*, we found statistically significant associations with noise. Compared with $L_{\text{night}} < 45$ dB, exposure to noise levels of $L_{\text{night}} 50-55$ dB, gave an odds ratio (OR) of 1.43 [95 % confidence interval (CI): 1.11, 1.84] and exposure to $L_{\text{night}} \geq 55$ dB gave an OR of 1.47 (95 % CI: 1.12, 1.92). The analysis of the association between noise exposure and *awakenings during the night* yielded an OR of 1.32 (95 % CI: 1.06, 1.65) for $L_{\text{night}} \geq 55$ dB. *Waking up too early* was statistically significantly associated with $L_{\text{night}} 45-50$ dB vs. $L_{\text{night}} < 45$ dB (OR = 1.25; 95 % CI: 1.02, 1.52) and $L_{\text{night}} \geq 55$ vs. < 45 dB (OR = 1.58; 95 % CI: 1.25, 1.98).

Compared with the total study population, the effect estimates of the association between traffic noise and *difficulties falling asleep* were higher among individuals with their bedroom facing a road. Regarding *awakenings during the night*, we did not find any significant results among individuals with bedroom facing a road, but compared with the total study population the effect estimates were higher for the noise categories 45-55 dB and ≥ 55 dB. The results of the analyses for *waking up too early* among individuals with bedroom facing a road indicated a stronger

relationship with noise than in the total study population.

Regarding register-based sleep medication use, we observed positive, however, non-significant, effect estimates in the two highest noise categories, $L_{\text{night}} 50-55$ dB and $L_{\text{night}} \geq 55$ dB in the total study population, after adjusting for potential confounders. Among individuals with bedroom facing a road we observed positive effect estimates for the noise category $L_{\text{night}} 45-50$ dB and higher levels, although non-significant. A statistically significant trend across the four noise categories was observed for the total study population ($p=0.02$). Among the individuals with a bedroom facing a road the trend test was non-significant ($p=0.1$). The spline was assessed visually and we found a linear relationship between road traffic noise and sleep medication use. We did not find any significant association between self-reported sleep medication use and noise.

In the assessment of the agreement between self-reported and register-based sleep medication use, we found that 417 participants (4.4 %) used medications according to both HELMILO and NorPD, 427 (4.5 %) had medication use reported in HELMILO only, 152 (1.6 %) had medication use reported only in NorPD, and 8,563 (89.6 %) had no medication use reported in either HELMILO or NorPD. Sensitivity was computed as $417 / (417 + 152) = 0.73$. Specificity was computed as $8,563 / (8,563 + 427) = 0.95$.

4. Conclusions

In the total study population, residential exposure to outdoor road traffic noise at night-time was statistically significantly associated with the insomnia symptoms *difficulties falling asleep*, *awakenings during the night* and *waking up too early in the morning*. Of the outcomes we examined, we found that *difficulties falling asleep* and *waking up too early* showed the strongest positive associations with noise, both in the total study population and among individuals with bedroom facing a road. This indicated that shorter sleep duration may be a consequence of night-time traffic noise exposure. The effect estimates for the

association between road traffic noise and *difficulties falling asleep* were higher among individuals with bedroom facing a road than for the total study population. A likely explanation is the more accurately assigned noise exposure in this sub-population.

We did not find any statistically significant associations between road traffic noise at night-time and register-based sleep medication use. However, the magnitude of the effect estimates and assessment of the spline suggest an exposure-response relationship. Furthermore, we observed a stronger relationship between road traffic noise and sleep medication use in the sub-population of individuals with bedroom facing a road compared with the total study population. Since noise calculations are performed at the most exposed facade of the building, it is likely that noise exposure is more precisely estimated for individuals with bedroom facing a road. In order to better assess the causal mechanisms of this relationship, a study with longitudinal design should be performed.

The evaluation of the agreement between self-reported and register-based use of sleep medications indicated that there was good agreement between those who reported not using sleep medications and those who were not registered in the NorPD. However, the agreement between those who reported to use sleep medications and those who were registered in the NorPD was not as good. This indicates that there was a difference between self-reported medication use and register-based medication use, as there was a higher proportion of participants who reported using sleep medications in the questionnaire than those registered in the NorPD.

A possible explanation for this is that the participants have a wider definition of what sleep medications are than the definition according to the register. We defined register-based use as prescription required sleep medications only. When individuals report drug use in a questionnaire they may possibly also include over-the-counter drugs in their definition.

From this study we cannot conclude whether it is best to apply self-reported or register-based medication use in studies where sleep medication use is used as outcome. However, it is important that researchers are aware of the

possible differences between the two sources of information.

Table 1. Characteristics of the total study population

Variable	Population No. (%)
	Total study population (N= 10,844)
Age	
39	2,354 (21.7)
49	2,518 (23.2)
55	2,264 (20.9)
68-69	2,762 (25.5)
84-85	946 (8.7)
Sex	
Female	5,706 (52.6)
Male	5,138 (47.4)
Difficulties falling asleep	
≥ 3-5 times per week	685 (6.4)
< 3-5 times per week	9,959 (93.6)
No. of missing values	200
Awakenings during the night	
≥ 3-5 times per week	1,019 (9.7)
< 3-5 time per week	9,505 (90.3)
No. of missing values	320
Waking up too early	
≥ 3-5 times per week	896 (8.5)
< 3-5 times per week	9,582 (91.5)
No. of missing values	366
Sleep medication use*	
- Register-based	
Yes	583 (6.0)
No	9,159 (94.0)
- Self-reported	
Yes	844 (8.7)
No	8,898 (91.3)

*84-85 year olds excluded

References

- [1] WHO. Burden of disease from environmental noise. Quantification of healthy life years lost in Europe. WHO Regional Office for Europe: Copenhagen (2011).
- [2] H. M. Miedema, H. Vos: Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies. *Behavioral Sleep medicine* 5 (2007) 1-20.
- [3] E. Öhrström, E. Hadzibajramovic, M. Holmes, H. Svensson: Effects of road traffic noise on sleep: Studies on children and adults. *Journal of environmental psychology* 26 (2006) 116-126.
- [4] M. Basner, U. Müller, E.-M. Elmenhorst: Single and combined effects of air, road, and rail traffic noise on sleep and recuperation. *Sleep* 34 (2011) 11-23.
- [5] G. M. Aasvang, B. Øverland, R. Ursin, T. Moum: A field study of effects of road traffic and railway noise on polysomnographic sleep parameters. *The Journal of the Acoustical Society of America* 129 (2011) 3716-3726.
- [6] J. I. Halonen, J. Vahtera, S. Stansfeld, T. Yli-Tuomi, P. Salo, J. Pentti, M. Kivimäki, T. Lanki: Associations between Nighttime Traffic Noise and Sleep: The Finnish Public Sector Study. *Environmental Health Perspectives* 120 (2012) 1391-1396.
- [7] A. Skånberg, E. Öhrström: Sleep disturbances from road traffic noise: a comparison between laboratory and field settings. *Journal of sound and vibration* 290 (2006) 3-16.
- [8] E.-M. Elmenhorst, D. Elmenhorst, J. Wenzel, J. Quehl, U. Mueller, H. Maass, M. Vejvoda, M. Basner: Effects of nocturnal aircraft noise on cognitive performance in the following morning: dose-response relationships in laboratory and field. *International archives of occupational and environmental health* 83 (2010) 743-751.
- [9] B. Griefahn, A. Marks, S. Robens: Noise emitted from road, rail and air traffic and their effects on sleep. *Journal of sound and vibration* 295 (2006) 129-140.
- [10] F. Langdon, I. Buller: Road traffic noise and disturbance to sleep. *Journal of Sound and Vibration* 50 (1977) 13-28.
- [11] A. Bocquier, S. Cortaredona, C. Boutin, A. David, A. Bigot, V. Sciortino, S. Nauleau, J. Gaudart, R. Giorgi, P. Verger: Is exposure to night-time traffic noise a risk factor for purchase of anxiolytic-hypnotic medication? A cohort study. *The European Journal of Public Health* 24 (2013) 298-303.
- [12] J. I. Halonen, T. Lanki, T. Yli-Tuomi, A. W. Turunen, J. Pentti, M. Kivimäki, J. Vahtera: Associations of traffic noise with self-rated health and psychotropic medication use. *The Scandinavian Journal of Work, Environment & Health* 40 (2014) 235-243.
- [13] G. M. Aasvang, T. Moum, B. Engdahl: Self-reported sleep disturbances due to railway noise: Exposure-response relationships for nighttime equivalent and maximum noise levels. *The Journal of the Acoustical Society of America* 124 (2008) 257-268.
- [14] A. Fyhri, G. M. Aasvang: Noise, sleep and poor health: modeling the relationship between road traffic noise and cardiovascular problems. *Science of the Total Environment* 408 (2010) 4935-4942.
- [15] P. Frei, E. Mohler, M. Rössli: Effect of nocturnal road traffic noise exposure and annoyance on objective and subjective sleep quality. *International journal of hygiene and environmental health* 217 (2013) 188-195.
- [16] The Municipality of Oslo. Støykartlegging 2012. Støysituasjon for år 2011. (Strategic Noise mapping in Oslo). Forurensningsforskriftens kapittel 5 - støysituasjon for år 2011 (2012).
- [17] European Commission. European Union. Directive 2002/49/EC relating to the Assessment and Management of Environmental Noise, in *Official Journal of the European Communities* (2002)
- [18] Nordic Council of Ministers: Road traffic noise-Nordic prediction method. TemaNord, Århus, (1996:525).
- [19] K. Furu, B. Wettermark, M. Andersen, J. E. Martikainen, A. B. Almarsdóttir, H. T. Sørensen: The Nordic countries as a cohort for pharmacoepidemiological research. *Basic & clinical pharmacology & toxicology* 106 (2010) 86-94.
- [20] K. Furu: Establishment of the nationwide Norwegian Prescription Database (NorPD)—new opportunities for research in pharmacoepidemiology in Norway. *Norsk epidemiologi* 18 (2008) 129-136.
- [21] WHO. Guidelines for ATC classification and DDD assignment, in WHO Collaborating Centre for Drug Statistics Methodology. (2013).
- [22] Nordic Council of Ministers: Railway noise-the Nordic prediction method. TemaNord, Århus, (1996:524).