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# Is exposure to night-time traffic noise a risk factor for purchase of anxiolytic–hypnotic medication? A cohort study

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**Background:** Studies suggest that road traffic noise increases risks of sleep disturbances, anxiety and depressive symptoms, but few have focused on psychotropic drug use. We examined whether exposure to night-time road traffic noise in Marseilles (France) is associated with an increased risk of purchasing anxiolytic or hypnotic medications. **Methods:** Cohort of 190 617 inhabitants of Marseilles (aged 18–64 years) covered by the National Health Insurance Fund. We used the CadnaA noise propagation prediction model to calculate a potential road noise exposure indicator at dwellings for the night-period: Ln. Association between the number of purchases of anxiolytics–hypnotics in 2008–9 and the Ln was analysed with a zero-inflated negative binomial (ZINB) model adjusted for characteristics of individuals (sociodemographic, consultations with general practitioners, presence of chronic psychiatric disorder), prescribers (demographic, specialty, workload) and neighbourhoods (medical density, complaints filed for environmental noise). Analyses were stratified by the deprivation level of the census block of residence to control for the confounding effects of neighbourhood socio-economic status. **Results:** The ZINB model showed a small but significant increase in the risk of purchasing higher numbers of anxiolytics–hypnotics for Ln greater than 55 dB(A) only in the low deprivation stratum. **Conclusion:** We found some evidence that potential exposure to night-time road traffic noise might affect individual use of anxiolytics–hypnotics. Further research based on strictly individual approaches is warranted to assess exposure to road traffic noise more precisely and reliably than allowed by noise propagation prediction models.

## Introduction

Environmental noise is, with air pollution, one of the principal environmental risk factors in terms of disability-adjusted life years lost.[1] Besides the auditory and cardiovascular effects,[2] neither of which are studied here, the published studies suggest that chronic exposure to environmental aircraft noise increases the risks of sleep disorders, stress, anxiety, irritability, psychological distress and consumption of psychotropic drugs;[3–6] the results for the risks of psychiatric disorders, especially generalized anxiety, are contradictory.[7–9] Chronic exposure to traffic noise concerns a much higher proportion of the population than exposure to aircraft noise.[10] The former is associated with symptoms of anxiety and depression,[11,12] risk of depression [starting at 70 dB(A)],[13] and the onset of sleep disturbances for nocturnal exposures.[14,15] Nonetheless, the results about consumption of psychotropic medication are contradictory.[16–18]

The aim of this article is to study whether chronic exposure to night-time traffic noise in Marseilles (the second largest city in France) is associated with the purchase of anxiolytic or hypnotic medications (as a proxy for their consumption). Anxiolytics–hypnotics are the drugs most often prescribed in France for complaints of anxiety or depressive symptoms and/or sleep disturbances.[19] A high number of purchases is a good indicator of marked and lasting non-specific mental health symptoms or sleep disorders leading to health-care utilization.[20]

## Methods

### *Study design, population and period*

We conducted a retro-prospective cohort study in 2008–9 among individuals residing in Marseilles, aged between 18 and 64 years, and insured by the French National Health Insurance Fund (NHIF) on 1 January 2009. The Fund covers most health-care expenses, including consultations with general practitioners (GPs), medication and hospitalization. Its beneficiaries (mainly salaried workers, including those unemployed) represent 83% of the general population aged 18–64 years in Marseilles; the two populations have similar gender and age profiles. We excluded from the cohort beneficiaries who left the NHIF (for example, because of a change in their professional status), those who died during the follow-up and individuals whose residential address could not be geo-located with acceptable reliability (see below).

### *Data sources and variables*

#### Individual characteristics and anxiolytic–hypnotic purchases

We obtained anonymous individual data from the databases of the NHIF in south-eastern France, after approval from the

National Data Protection Authority (*Commission Nationale de l'Informatique et des Libertés*). The NHIF records all prescribed drugs purchased by beneficiaries in community pharmacies. For each anxiolytic or hypnotic (N05B, N05CD and N05CF according to the anatomical therapeutic chemical classification) purchased between 1 January 2008, and 31 December 2009, we retrieved the dates it was prescribed and purchased as well as the prescriber's anonymous identifier.

We used beneficiaries' participation (obtained from the NHIF) in the public CMUC (Couverture maladie universelle complémentaire, that is, Complementary Universal Health Insurance) as an indicator of very low income: this programme exempts individuals younger than 65 years with annual incomes below 9000 € from any out-of-pocket costs.[21] Gender, age and number of consultations with GPs (including house calls) in 2008–9 were also available for all NHIF beneficiaries. We also obtained their chronic disease [Affection de longue durée (ALD)] status, recorded by expert physicians according to the International Classification of Diseases (ICD-10). It is attributed to persons with specific and expensive chronic diseases (defined by NHIF) that make them eligible for 100% reimbursement for treatment, and we used it as a proxy for severe chronic somatic or psychiatric illness.[22]

## Potential night-time road noise exposure

The estimation of annual road traffic noise levels across Marseilles has been presented in details elsewhere.[23] Briefly, we estimated it for 2006 according to the Environmental Noise Directive (END) 2002/49/EC, using the CadnaA environmental noise prediction model (Datakustik, Munich, Germany, version 4.0) to calculate acoustic propagation and noise levels in 3D. In particular, the model applied information on annual average daily traffic, traffic intensity, composition and type, available from the various transport authorities in Marseilles. To produce exposure estimations closer to real noise levels than the END approach, we used statistical data on operating speeds rather than speed limits. All the necessary attributes used by CadnaA are described in the European WG-AEN guidelines (Work Group for the END) and in the French guidelines edited by the CERTU.[24]

We estimated potential night-time road noise exposure at each cohort member's residence building using the European standard indicator for sleep disturbance assessment Ln (night level). Ln is defined as the A-weighted equivalent continuous noise level (LAeq) over the 22:00-6:00 period. 'A-weighted' means that the sound pressure levels are adjusted to take into account the physical sensitivity of human hearing at different sound frequencies. The Ln may provide a more reliable estimation of personal noise exposure than other indicators based on daytime exposure ($L_{Aeq,24h}$ or $L_{day\text{-}evening\text{-}night}$), as most individuals sleep at home and are thus exposed to road traffic noise at their home at night when they may be exposed to road traffic noise elsewhere during the day.[18]

For all individuals correctly geo-located (see below paragraph 'Location and characteristics of dwellings'), we calculated the Ln as the energetic mean of noise exposure estimated for spatial points located at a 4-m height at a 10-m resolution on each building façade (calculations for regulatory purposes are done at the most exposed façade). Ln was further categorized into discrete intervals of 5 dB(A).

## Location and characteristics of dwellings

We obtained the individual residence address of each cohort member from the NHIF. We used three different geocoding tools to match these addresses with the geographical Lambert 93 coordinates of the buildings in Marseilles. We considered each address match was acceptably reliable when the coordinates obtained with the three tools fell within a 30-m distance for buildings in central Marseilles (high building density) and within 100 m in the outer area (where most large housing estates and projects buildings are located). These coordinates were then matched with those of the buildings in the BD Topo database (Institut Géographique national, http://professionnels.ign.fr/bdtopo), which includes information on all buildings in Marseilles (coordinates, characteristics, classification into individual or multiple dwelling units and residential or commercial buildings).

## Neighbourhood-level characteristics

We matched each beneficiary's home address with his or her census block, the smallest geographic subdivision of the national census. We assumed that the blocks were representative of their inhabitants' neighbourhood environment[25,26] and extracted for each of them 17 socio-economic variables that reflect various dimensions of socio-economic status (SES) (2006 national population census, Supplementary Appendix 1).

We used an INSEE database of medical equipment and services (*Base permanente des équipements*, INSEE, 2009) to document the density of private GPs and private psychiatrists at the census block level. Finally, we counted the complaints filed from 2000 to 2010 for environmental noise due to various facilities and activities (discotheques, bars, night road repair and maintenance work, air-conditioning devices, etc.) and their locations (Direction de la santé publique de la ville de Marseille).

## Physician characteristics

We linked to each cohort member the physician consulted most frequently during the follow-up period and obtained from the NHIF the characteristics of these physicians [age in 2008, gender, specialty (GP/psychiatrist/other), and number of consultations in 2008–9] and that of their active patients (proportions of patients 60 years old or more, with a chronic disease and with CMUC coverage).

## *Statistical analysis*

A principal component analysis of the 17 socio-economic variables mentioned above allowed us to construct a deprivation index at the census block level as the linear combination of these variables on the first axis of the analysis.[23,27] This combination explained 57% of the total variance. We further categorized this variable into three categories according to the first and third quartiles. We constructed variables of the densities of private GPs and private psychiatrists per 100 000 inhabitants at the census block level according to the floating catchment method,[28] estimating them as the total number of private GPs and psychiatrists in a radius of 500 m around the census block centroid divided by the population of the census block.

Bivariate analyses used the Kruskal–Wallis test when the variables were not normal (number of anxiolytics–hypnotics purchased; Ln) and chi-square tests for categorical variables.

We studied whether the total number of purchases of anxiolytics–hypnotics during the follow-up period was associated with the Ln. We stratified the analyses according to the deprivation index at the census block level (three strata) to control for the confounding effect of neighbourhood SES, as anxiolytic–hypnotic purchases may be associated with neighbourhood SES[26,29,30] as well as with chronic exposure to traffic noise.[23]

We used the zero-inflated negative binomial (ZINB) model, which is particularly adapted for modelling count variables with excessive zeros, especially with over-dispersion. It consists of a negative binomial (NB) count model and a logit model predicting excess zeros.[31,32] We tested the significance of the dispersion parameter of the NB model to verify whether it would better fit the data than a Poisson model[33] and calculated the Vuong test to verify whether the ZINB model would fit the data better than a standard NB model.[34] We adjusted the NB count model for characteristics of the cohort members: age at inclusion; gender; chronic somatic disease (yes/no); severe psychiatric disorder (yes/no); CMUC coverage as a proxy for low income (yes/no); number of consultations in 2008–9 with GPs; characteristics of the linked physicians and their clientele; density of GPs and of psychiatrists; and number of complaints filed for noise problems other than traffic noise in each individual's census block. We adjusted the logit model for the number of consultations with GPs in 2008–9, for it was the main predictor of anxiolytic–hypnotic prescriptions. To take into account potential effects due to chronic or psychiatric diseases, we ran the model again after excluding individuals with such illnesses (ALD).

All analyses were based on two-sided *P*-values at a $P < 0.05$ level of statistical significance. Analyses were performed with SAS version 9.2 (SAS Institute, Cary, NC) and the GENMOD/NLMIXED procedures for ZINB modelling.

## Results

Of the 427 256 NHIF beneficiaries aged 18–64 years residing in Marseilles on 1 January 2009, 2.4% were excluded because they left the NHIF or died during the follow-up, and 53.0% because they could not be geo-located with acceptable reliability.

The cohort included 190 617 individuals with a mean age at inclusion of 41.5 years (SD: 12.5, table 1). Cohort members were significantly older than the Marseilles inhabitants. The mean Ln for the entire cohort was 49.0 [±5.5 dB(A)]. The percentages of cohort members with an Ln greater than 55 dB(A) increased significantly with the deprivation level of the census blocks ($P < 10^{-4}$, table 2). The percentage of individuals exposed to Ln greater than 55 dB(A) was higher than in the general population of Marseilles (11.8 vs. 8.7%): people excluded due to unreliable geo-located data were more likely to reside in the city's outskirts, where noise levels are lower than in the rest of the city.

In the entire cohort, the mean number of anxiolytics–hypnotics purchased increased significantly with the deprivation level of the census block, from 2.1 ± 5.8 in 2008–9 in the low deprivation stratum to 2.6 ± 8.5 in the high ($P < 10^{-4}$). Among those who purchased at least one anxiolytic–hypnotic in 2008–9, the corresponding figures were 6.4 ± 8.7 and 7.7 ± 13.2 ($P < 10^{-4}$).

### Bivariate analyses

The mean numbers of anxiolytics–hypnotics purchased in 2008–9 varied significantly according to the Ln in all deprivation strata although the direction of these variations varied with the deprivation

**Table 2** Potential night-time road noise exposure Ln (dB(A)) calculated at the dwelling level in three areas according to their deprivation level (Marseilles, France, $n = 190\,617$)

| Deprivation level | Mean Ln (SD)* | Ln (% of cohort members) | | | |
|---|---|---|---|---|---|
| | | <45 | [45–50[ | [50–55[ | ≥55 |
| **All (*n* = 190 617)** | 49.0 (5.5) | 21.4 | 31.6 | 35.2 | 11.8 |
| **Low deprivation (*n* = 41 054)** | 45.9 (5.7) | 39.7 | 37.2 | 19.7 | 3.5 |
| **Intermediate deprivation (*n* = 102 284)** | 49.7 (4.9) | 16.7 | 31.1 | 39.1 | 13.1 |
| **High deprivation (*n* = 47 279)** | 50.2 (5.5) | 15.5 | 27.9 | 40.2 | 16.4 |

*Kruskal–Wallis test between the three deprivation levels: $P < 0.0001$.

**Table 1** Individual characteristics of the cohort members by census block deprivation level (Marseilles, France, $n = 190\,617$)

| | Deprivation level* | | | |
|---|---|---|---|---|
| | Low deprivation (*n* = 41 054) *n* (%) | Intermediate deprivation (*n* = 102 284) *n* (%) | High deprivation (*n* = 47 279) *n* (%) | All (*n* = 190 617) *n* (%) |
| **Gender** | | | | |
| Male | 18 478 (45.0) | 46 582 (45.5) | 22 915 (48.5) | 87 975 (46.1) |
| Female | 22 576 (55.0) | 55 702 (54.5) | 24 364 (51.5) | 102 642 (53.9) |
| **Age (years)** | | | | |
| 18–34 | 10 840 (26.4) | 34 571 (33.8) | 17 160 (36.3) | 62 571 (32.8) |
| 35–44 | 10 199 (24.8) | 25 862 (25.3) | 12 445 (26.3) | 48 506 (25.5) |
| 45–54 | 10 539 (25.7) | 22 471 (22.0) | 9857 (20.9) | 42 867 (22.5) |
| 55–64 | 9476 (23.1) | 19 380 (18.9) | 7817 (16.5) | 36 673 (19.2) |
| **CMUC[a]** | | | | |
| No | 39 242 (95.6) | 89 655 (87.7) | 31 330 (66.3) | 160 227 (84.1) |
| Yes | 1812 (4.4) | 12 629 (12.4) | 15 949 (33.7) | 30 390 (15.9) |
| **Severe chronic somatic illness[b]** | | | | |
| No | 36 571 (89.1) | 90 690 (88.7) | 41 473 (87.7) | 168 734 (88.5) |
| Yes | 4483 (10.9) | 11 594 (11.3) | 5806 (12.3) | 21 883 (11.5) |
| **Severe chronic psychiatric illness[b]** | | | | |
| No | 40 276 (98.1) | 99 703 (97.5) | 46 157 (97.6) | 186 136 (97.6) |
| Yes | 778 (1.9) | 2581 (2.5) | 1122 (2.4) | 4481 (2.4) |
| **Number of consultations with a GP during the study period** | | | | |
| 0 | 3677 (8.9) | 7940 (7.8) | 3240 (6.8) | 14 857 (7.8) |
| 1–5 | 16 337 (39.8) | 38 635 (37.8) | 15 204 (32.2) | 70 176 (36.8) |
| 6–12 | 12 759 (31.1) | 30 298 (29.6) | 12 280 (26.0) | 55 337 (29.0) |
| >12 | 8281 (20.2) | 25 411 (24.8) | 16 555 (35.0) | 50 247 (26.4) |
| **Number of purchases of anxiolytics and/or hypnotics during the study period** | | | | |
| 0 | 27 738 (67.6) | 67 851 (66.3) | 31 400 (66.4) | 126 989 (66.6) |
| 1–5 | 9056 (22.1) | 22 543 (22.0) | 10 531 (22.3) | 42 130 (22.1) |
| 6–11 | 1699 (4.1) | 4276 (4.2) | 1923 (4.1) | 7898 (4.2) |
| >11 | 2561 (6.2) | 7614 (7.5) | 3425 (7.2) | 13 600 (7.1) |

a: Complementary Universal Health Insurance programme: programme for persons with very low income.
b: 'Expensive chronic disease' status, for which treatment is completely free of charge (see text).
*chi-square test between the three deprivation levels: $P < 0.0001$ for all characteristics.

stratum (figure 1). Similar results were observed with the percentages of participants who purchased at least one anxiolytic–hypnotic (Supplementary Appendix 2).

### *ZINB model*

The dispersion parameter of a standard NB regression of the number of anxiolytics–hypnotics purchased was significantly different from zero [4.30; 95% confidence interval (CI) = 4.25–4.35] and thus indicated that the NB model fit better than a standard Poisson model. Similarly, the highly significant Vuong test result ($P < 10^{-3}$) indicated that the ZINB model fit better than a standard NB model.[34] The ZINB model, adjusted for individual, physicians and neighbourhood characteristics, showed a slightly significantly higher risk of purchasing higher numbers of anxiolytics–hypnotics in the low deprivation stratum only for Ln levels greater than 55 dB(A) (table 3). We obtained similar results after excluding individuals with severe chronic and/or psychiatric illness (results available on request).

## Discussion

To the best of our knowledge, this study is the first to study the impact of chronic potential exposure to night-time road traffic noise on psychotropic drug use in a cohort of about 190 000 individuals in an urban area followed for 2 years. We found significantly higher risks of anxiolytic–hypnotic purchases for Ln greater than 55 dB(A) only in the least deprived census blocks.

Using purchases of anxiolytics–hypnotics over a 2-year period is a strength of our study; previous studies of this topic used self-report measures (see for example in refs 17,18), which may be less reliable.[35] Although purchasing drugs is a proxy for using them, a high number of purchases, indicating chronic/regular consumption, attests to its reliability.[20] Moreover, using NHIF databases enabled us to study a large sample, which increased our statistical power at a rather low cost, and a large geographical area with great variability in the environmental noise levels. Another important advantage of using the NHIF database is that we could follow anxiolytic–hypnotic purchases over a 2-year period. We could also adjust our analyses for various potential confounders at different levels: patients (in particular, chronic psychiatric disorders and a robust proxy for individual low SES), physicians (whose characteristics are known to be associated with psychotropic drug prescriptions) and neighbourhood environment (complaints filed for noise problems, medical density). Previous publications about the impact of traffic noise on health have not been able to study medication use over such a period or adjust as thoroughly. The associations found with these factors [increased risk for women, people aged 55–64 vs. 18–34 years, patients with a high number of consultations with GPs in 2008–9 or whose prescriber was a psychiatrist (vs. a GP); results available on request] are in line with previous publications.[20,36,37] We could not adjust for other potential confounders, such as indicators capturing SES gradient (e.g. educational level).[17,20] However, adjusting for number of consultations with GPs (associated with both Ln and anxiolytic–hypnotic purchases) may have partly addressed this problem because SES influences healthcare-seeking.[38] To better control for the confounding effect of socio-economic factors, we also stratified the analysis by the neighbourhood deprivation level, however. We could not take into account characteristics of the neighbourhood environment that might confound the relation between traffic noise and purchases of anxiolytics–hypnotics (e.g. housing quality and presence of and satisfaction with green spaces).[6,39]

However, this study shares with other previously published studies using environmental noise prediction models such as CadnaA several limitations in its noise exposure assessment.[17,18,40] First, such tools require large quantities of input data and parameters, each subject to some degree of uncertainty, due to data sources, estimation methods or measurement tools. Because all of these are difficult to assess and could not be taken into account in the modelling, they could have induced substantial exposure error. Secondly, the Ln was assessed at the building for

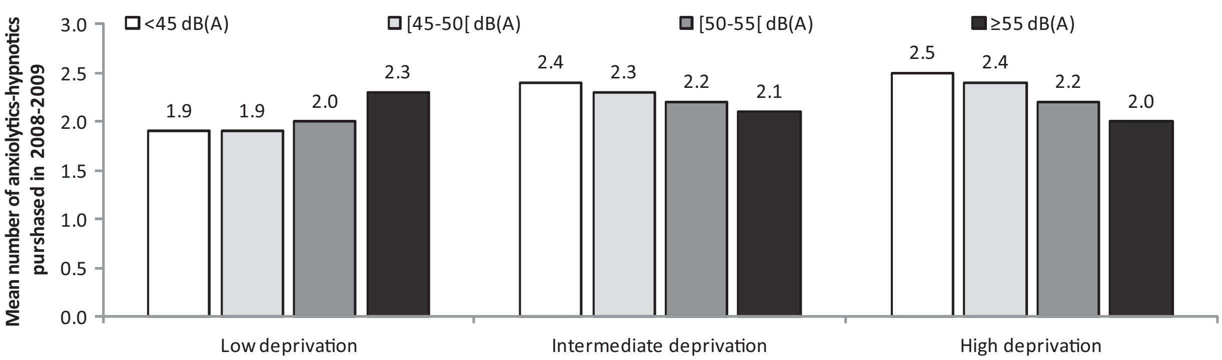


**Figure 1** Mean number of anxiolytics–hypnotics purchased in 2008–9 according to the individual potential night-time road noise exposure Ln (dB(A)) and the census block deprivation level* (Marseilles, France, $n = 190\,617$). *Kruskal–Wallis tests between the four levels of noise exposure: $P < 0.001$ for all deprivation levels

**Table 3** Number of anxiolytics–hypnotics purchased in 2008–9: results of the ZINB* model adjusted for individual, physician and neighbourhood characteristics after stratification by census block deprivation level (Marseilles, France, $n = 190\,617$)

| | **Low deprivation (*n* = 41 054)** | | **Intermediate deprivation (*n* = 102 284)** | | **High deprivation (*n* = 47 279)** | |
|---|---|---|---|---|---|---|
| | ***n*** | **RRa 95% CI** | ***n*** | **RRa 95% CI** | ***n*** | **RRa 95% CI** |
| **Ln (dB(A))** | | | | | | |
| <45 | 16 289 | Ref. | 17 074 | Ref. | 7342 | Ref. |
| [45–50[ | 15 267 | 0.96 (0.91–1.01) | 31 800 | 1.02 (0.97–1.07) | 13 190 | 1.00 (0.93–1.08) |
| [50–55[ | 8075 | 1.04 (0.97–1.11) | 40 013 | 0.99 (0.94–1.03) | 19 015 | 1.02 (0.94–1.10) |
| ≥55 | 1423 | 1.16 (1.01–1.32) | 13 397 | 0.96 (0.91–1.02) | 7732 | 0.95 (0.86–1.04) |

*Only the results of the count part (NB) are displayed.

each cohort member: the dimensions (e.g. number of floors or length of a building located orthogonally to a road axis) of large multiple dwellings may lead to substantial traffic noise exposure variability in the Ln that may have resulted in classification errors in the attribution of noise exposure to the cohort members. Thirdly, we could not collect individual data on living conditions (e.g. location of the rooms used for sleeping) or residential characteristics, in particular, countermeasures to protect homes against environmental noise (e.g. double glazing or air conditioning to avoid opening windows in summer) that may moderate the impact of noise.[41] Fourthly, we were not able to take the various sources of environmental noise into account, especially occupational exposure to noise; the Ln should not be influenced by such exposure, however. Moreover, we took complaints filed for certain sources of environmental noise into account, which previous studies have not done. Contrary to other publications,[42] however, we could not take individual noise annoyance and sensitivity into account.

Finally, some characteristics of our cohort (age and Ln distribution) differed from those of the general population of Marseilles. Nonetheless, this should not have biased the results regarding the link between night-time traffic noise and the purchase of anxiolytics–hypnotics.[43,44]

### *Comparison with the published literature*

As far as we known, only two previous studies examined links between road traffic noise and psychotropic drug consumption in urban areas both for 24-h and night-time periods;[17,18] neither found any significant association. They did not provide results according to the deprivation level of the area of residence however.

### *Interpretation*

The slight increased risk observed for a Ln above 55 dB(A) only in the low deprivation areas is puzzling and merits discussion. This finding might result from a lower proportion of multiple dwellings (flat blocks) and a higher proportion of single-family homes in more advantaged areas, which could reduce noise exposure misclassification. When we restricted the analysis to single-family buildings, regardless of the deprivation level, we found a similar increased risk for Ln greater than 55 dB(A) [relative risk (RR) = 1.13; CI = 1.02–1.24], but no excess risk in collective buildings (results available on request). Finally, we can hypothesize that annoyance due to exposure to traffic noise—under the same noise conditions—might be greater for people with a higher, compared with a lower, SES although evidence for this remains contradictory.[45–47] We can also assume that some non-acoustic factors associated with noise annoyance (e.g. noise sensitivity, awareness of the health effects of noise, negative opinions about road traffic noise management)[47,48] might be more frequent among high SES people; these factors could increase their perception of the negative health impact of road traffic noise and the risks of sleep disorders and psychological distress.

## Conclusion

This study was based on a large cohort of individuals, on the objective indicator of anxiolytic–hypnotic purchases, and on a well-recognized tool for urban noise mapping, the CadnaA prediction model, to estimate potential night-time exposure to road noise at home. Its results showed a small but significant increase in the risk of purchasing higher numbers of anxiolytics–hypnotics for Ln greater than 55 dB(A) only in the least deprived census blocks. Although the sample size of our study was high enough to detect slight to moderate excess risks, these risks might nonetheless have been masked or reduced by exposure misclassification at individual level, and lack of consideration of other important sources of environmental noise. Further research is warranted; it should use methods that can correct these methodological issues and take noise annoyance into account.

## Supplementary data

Supplementary data are available at *EURPUB* online.

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*Conflicts of interest*: None declared.

## Key points

- Studies suggest that road traffic noise increases risks of sleep disturbances, anxiety and depressive symptoms, but few focused on psychotropic drug use.
- This study shows slightly higher risks of anxiolytic–hypnotic purchases for potential night-time road noise exposure greater than 55 dB(A) only in the least deprived census blocks.
- Further research is warranted using design reducing exposure misclassification at individual level, and assessing noise annoyance.

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