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High Road Traffic Noise in Residential Buildings, High Annoyance and Self-perceived Health Problems in a Sample from Santiago, Chile

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Abstract The purpose of this study was to examine the association between exposure to high traffic noise levels in housing and the proportion of high annoyance and self-perceived health problems, through a survey applied to comparable groups of individuals with and without exposure, selected in residential buildings from urban Santiago, Chile. It was an observational, cross-sectional study. Buildings with sides exposed and unexposed to high traffic noise levels were considered. In each building, independent samples of dwellings from each side were selected. A questionnaire consisting of three parts was applied: socio-demographic and related characteristics, self-perceived health state, and annoyance caused by different sources including traffic noise. To assess association between exposure to traffic noise and each self-perceived health response (including high annoyance), multiple logistic and log-binomial regression analyses were applied, adjusting by sociodemographic and related variables. Four residential buildings were included, achieving a total of 425 respondents, 200 living in exposed dwellings and 225 living in unexposed dwellings. Adjusted significant association was found between exposure and high annoyance, high degree of problems with concentration, sleeping and feeling rested, presence of head or neck ache, and feelings of depression, anguish or neurosis.

Keywords Traffic Noise, Noise Annoyance, Self-perceived health, Survey, Santiago-Chile

1. Introduction

Environmental noise is a pollutant associated with several health problems [1]–[3]. The most studied sources have been aircraft and road traffic, the latter with greater presence in cities. Health problems that have been associated with the exposure to environmental noise include sleep disturbance, interference with daily activities, physiological effects, increase of stress and depression symptoms, cardiovascular diseases and diabetes [3]–[6].

In Europe the estimated burden of disease associated with environmental noise exceeds 1.5 million healthy life years (DALYs) lost, more than half of which are attributed to sleep disturbance and almost 40% to annoyance [3], [7]. Estimations are similar among countries, with 80% or greater attributable to road traffic noise and almost a half of the total burden attributed to transport [8]–[10]. The specific burden in Chile of ischemic heart diseases of the Population-Attributable Fraction of road traffic noise has been estimated at 4% [11].

To estimate the specific association of environmental noise exposure with health problems, observational studies have been performed applying surveys to inhabitants of dwellings exposed to different outdoor noise levels or with different indoor noise levels [4], [12], [13]. A common issue in this type of study is achieving comparable groups in terms of possible confounding variables.

The purpose of this research was to study the association between exposure to high road traffic noise levels in dwellings and high annoyance and self-perceived health problems in their residents, by means of a survey applied to comparable exposed and unexposed groups of individuals, selected in residential buildings of apartments in urban Santiago, Chile.

2. Materials and Methods

2.1. Study Design and Target Population

This was an observational, cross-sectional study, performed by the Regional Health Ministerial Secretariat

of the Metropolitan Region, a regional health authority that depends on the Ministry of Health of Chile. The study was performed from October to December, 2011, in Santiago, Chile. Santiago is the capital city of the country and it is the main urban center, containing approximately 40% of the national urban population [14]. The target population of the study was the inhabitants of residential urban buildings who were aged 15 or older near high traffic roads of Santiago.

The main assumption we made is that in a residential building, individuals living in its apartments share a set of socio-demographic characteristics. Thus if there is a building with a group of apartments exposed to a high noise level and another group of unexposed apartments, a response variable may be compared between residents of these groups, with the possible confounding variables (mainly socio-demographic) equally distributed. Accordingly, it is assumed that the groups are comparable and only differ with respect to the exposure condition, approaching to the effect of randomization in an experimental design.

Therefore, it was decided to choose buildings with one side exposed to high road traffic noise levels and an unexposed side, select a sample of residents from exposed apartments and a sample from unexposed apartments, and apply a survey to compare proportions of individuals who report annoyance and self-perceived health problems between the groups.

2.2. Selection of Buildings, Dwellings and Subjects

Eligible buildings had to satisfy the following criteria: a) being located in front of a high traffic road (urban highway, high use road or a street with public transport), with high day and night noise levels (>70 dBA) according to a noise map of Santiago produced close to the sampling time [15]; b) have a complete side facing the high traffic road and exposed to the noise generated by its vehicle flow (20 meters or less from the road edge); c) have one or more sides where dwellings were not exposed to traffic noise from the main road and whose acoustic condition corresponded to noise levels considerably lower than those of the exposed side (qualitative assessment); d) absence of relevant noise sources other than road traffic (e.g. constructions, industries, workshops, transport terminals, schools, nightclubs, etc.); e) being inhabited for at least one year.

Access to four buildings that satisfied the above criteria was achieved. By means of a systematic procedure with a random seed and steps by 2 or 3 units, depending on the number of eligible units, in each building two independent samples of dwellings (apartments) were selected, one in each side (exposed and unexposed). In each selected dwelling, one of its residents, 15 years or older and chosen by the residents themselves, answered a self-responding questionnaire.

2.3. Exposure

Traffic noise levels for exposed sides were estimated from the noise map of Santiago [15]. To estimate differences between the exposure conditions in each building, 20 minutes daytime outdoor measurements of continuous equivalent level LAeq were made: on the sidewalk to assess the exposed side and in a rear zone for the unexposed side. In all measurements the microphone was located at a height between 1.2 and 1.5 meters and at a distance of 3.5 meters or more from reflective surfaces. The measurement equipment was a sound level meter Larson Davis model LxT2.

2.4. Data Collection Procedure and Questionnaire

Once the sample of buildings was determined, meetings were held to obtain permission from persons in charge of administration, given that this kind of property has restricted access. A presentation letter from the Health Authority was provided in which the scope and methodology of the study were briefly described, and confidentiality was assured.

Collection of data from individuals was made with a semi-postal technique. The questionnaire was provided inside closed envelopes, including a letter from the Health Authority explaining the objectives of the study and inviting the residents to participate voluntarily and self-respond to it anonymously. To avoid possible bias in responses, the study was presented as a general research about health and wellbeing, without a focus on environmental noise.

The questionnaire had 3 sections. The first section included 6 questions about socio-demographic information of the respondents and their homes. The second section included 11 items about the self-perceived state of health, extracted from the Spanish adaptation of the Health State module of the World Health Survey (WHS) of the World Health Organization (WHO) [16], using dimensions Overall Health, Pain and Discomfort, Cognition, Sleep and Energy and Affect, all of them with 5-point scale Likert responses. In the final question a list of 6 symptoms was given, where the respondent should indicate if she/he had some of these in the last two weeks.

Third section contained 8 items related to annoyance due to the noise generated by road traffic and other sources. Internationally standardized questions were used [17] with a 5-point response scale, which was previously validated for the Chilean population according to recommendations from The International Commission on the Biological Effects of Noise (ICBEN) [18]–[20]. Questions were added about the time of day of annoyance, type of sources different from road traffic and the audibility degree of outdoor noise.

2.5. Statistical Analysis

For both groups (exposed and unexposed), socio-demographic information is described through medians, minima and maxima for quantitative variables, and frequencies and percentages for qualitative variables. The groups are compared to evaluate if differences in the variables are statistically significant, using the Mann-Whitney test for age and time of residence, and the Chi-square test for sex, education, activity and income [21].

Five-point scale responses about road traffic noise annoyance and self-perceived health were dichotomized, grouping the lowest three categories and the highest two. Thus, the analyzed response variables correspond to indicators of high annoyance from road traffic noise, bad overall health state, high difficulty with concentrating, high degree of problems with sleeping, high degree of problems due to not feeling rested, presence of head or neck ache, and feelings of depression, anguish or neurosis. Only these response variables were selected from all items of the questionnaire, because they were theoretically and more plausibly related to environmental noise.

To assess association between exposure to road traffic noise and each response, a logistic regression model was applied to estimate the adjusted Odds Ratios (OR), and a log-binomial model to estimate adjusted Prevalence Ratios (PR) [22]. Adjusting variables in both models were sex, age, education and time of residence in the dwelling. All statistical analyses were performed using software STATA version 12.0 and R version 3.1.2 [23], [24].

3. Results

Following the criteria and steps described above, the sample consisted of four buildings located in the Santiago municipality, including a total of 425 dwellings, 200 exposed and 225 unexposed. The main characteristics of the selected buildings are shown in Table 1, and the study area with the streets where those buildings are located is shown in Figure 1.

Table 2 shows the characteristics of respondents. Median age was similar between exposed and unexposed subjects. Most of respondents were female and had more than 12 years of education. The main activity was working outside home, followed by student. The most frequent income group was >$670,000 Chilean pesos (about Intl$1,900) [25]. None of the above variables showed a statistically significant difference between the two exposure groups. Median residence time was significantly greater in unexposed group (3.4 years [Min-Max: 0.1-12.16]) than in the unexposed group (2.4 years [Min-Max: 0.1-11.3]).

Table 3 shows the results of association between exposure condition and annoyance and self-perceived health responses. Association was statistically significant for all responses, except for bad overall health state. The strongest association was with high difficulty in concentrating, followed by high annoyance, high degree of problems due to not feeling rested, and high degree of problems with sleeping. The weakest associations, though statistically significant, were with symptoms of head or neck ache, and feelings of depression, anguish or neurosis.

Table 1. Main characteristics of selected buildings

Building	Years inhabited	Number of floors	Exposed dwellings			Unexposed dwellings			Estimated difference Exposed-Unexposed (dBA)
			Nº	Type of road faced	LAeq (dBA)	Nº	Type of road faced	LAeq[f] (dBA)	
1	Less than 5	17	139	Urban highway[a]	70-75 (Lday) 60-65 (Lnight)	120	Local[d]	59	11-16
2	More than 5	11	91	Main avenue[b]	70-75 (Lday) 60-65 (Lnight)	143	None[e]	54	16-21
3	Less than 5	21	131	Main avenue[c]	70-75 (Lday) 60-65 (Lnight)	223	None[e]	68	2-7
4	More than 5	7	84	Urban highway[a]	70-75 (Lday) 65-70 (Lnight)	205	None[e]	60	10-15

a) 3 express lanes and 3 local lanes in each direction; b) 4 total lanes; c) 3 lanes in each direction; d) 2 lanes; e) courtyard, f) daytime

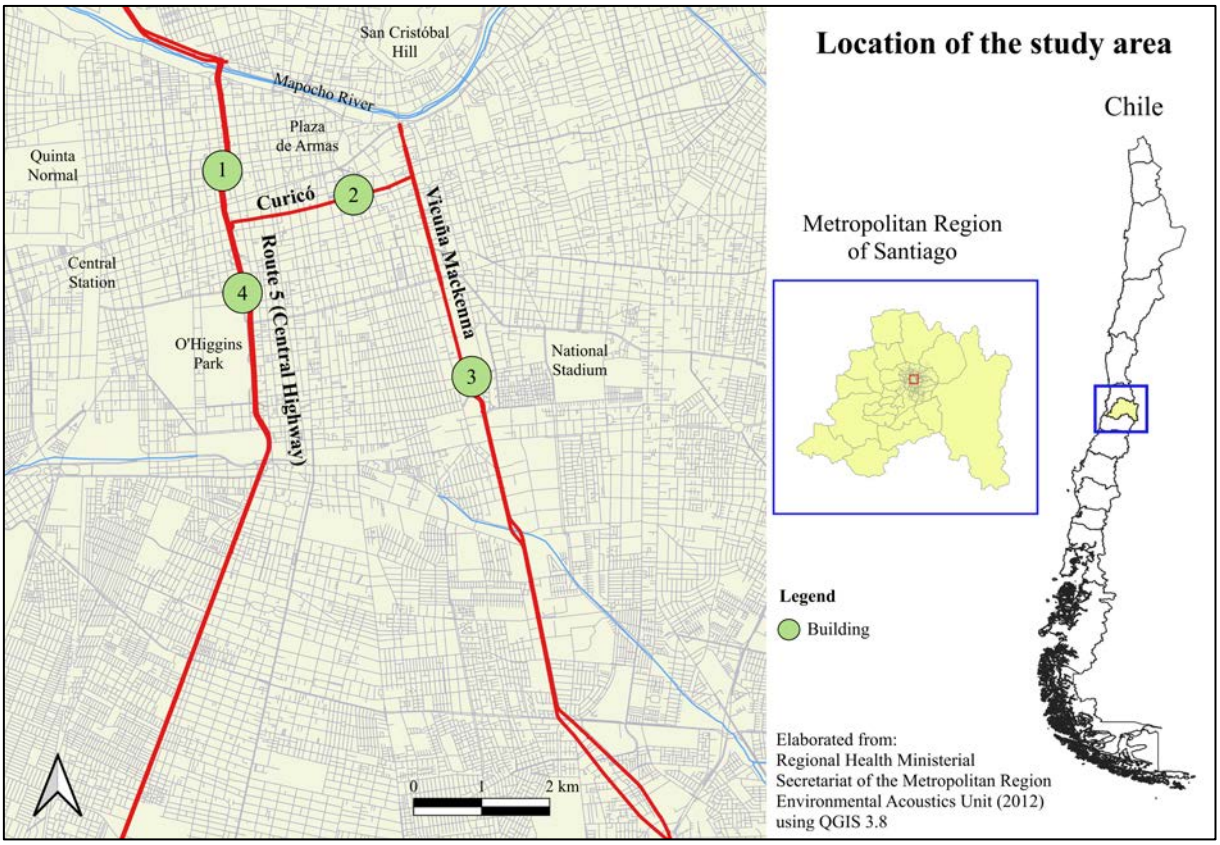

Figure 1. Study area and streets where selected buildings are located

Table 2. Characteristics of respondents by exposure condition

Variable	Exposed (n=200)	Unexposed (n=225)	*p*
Age, years			
Median (Min-Max)	36 (18-80)	35 (15-80)	0.418[a]
Sex			
Male, n (%)	83 (41.5)	93 (41.3)	0.972[b]
Years of education, n (%)			
12 years or less	74 (37.4)	78 (35.9)	0.762[b]
More than 12 years	124 (62.6)	139 (64.1)	
Main activity, n (%)			
Student	29 (14.6)	36 (16.0)	0.243[b]
Housewife	20 (10.1)	12 (5.3)	
Work out of home	130 (65.3)	146 (64.9)	
Retired	15 (7.5)	19 (8.4)	
Other	5 (2.5)	12 (5.3)	
Income (CLP[c]), n (%)			
< $440,000	54 (27.8)	64 (29.1)	0.876[b]
$440,000 - $670,000	54 (27.8)	64 (29.1)	
> $670,000	86 (44.3)	92 (41.8)	
Time of residence, years			
Median (Min-Max)	2.4 (0.1-11.3)	3.4 (0.1-12.6)	0.016[a]

a) Mann-Whitney test; b) Chi-square test; c) Chilean pesos (1 international dollar = 348.017 CLP [25])

Table 3. Results of high annoyance and self-perceived health responses and associations with exposure condition

Response	Exposed n (%)	Unexposed n (%)	OR[a*] (CI95%)	PR[b*] (CI95%)
High annoyance	144 (72.7)	62 (27.6)	7.01 (4.52-10.86)	2.67 (2.12-3.36)
Bad overall health state	11 (5.5)	6 (2.7)	1.94 (0.64-5.83)	1.60 (0.60-4.29)
High difficulty with concentrating	29 (14.5)	5 (2.2)	7.53 (2.81-20.13)	6.34 (2.51-16.0)
High degree of problems with sleeping	69 (34.5)	31 (13.8)	3.17 (1.94-5.19)	2.39 (1.63-3.51)
High degree of problems due to not feeling rested	60 (30.2)	23 (10.2)	3.94 (2.29-6.75)	3.06 (1.95-4.82)
Symptoms: Head or neck ache	149 (75.3)	145 (64.4)	1.89 (1.20-2.96)	1.20 (1.07-1.35)
Symptoms: feelings of depression, anguish or neurosis	62 (31.2)	45 (20.2)	1.66 (1.05-2.64)	1.40 (1.01-1.95)

a) Odds Ratio; b) Prevalence Ratio; *Adjusted by sex, age, education and time of residence

4. Discussion

In this study a statistically significant association was found between road traffic noise exposure and high annoyance and several self-perceived health problems, such as high difficulty in concentrating, high degree of problems due to not feeling rested and with sleeping, as well as presence of head or neck ache and symptoms related to mood disorders.

Although the evidence of effects of environmental noise on health and wellbeing outcomes is not conclusive, the results are consistent with several studies in the field, and the highest relationship found here was with interference and disturbance of daily activities like concentrating, sleeping and feeling rested, with a higher prevalence of high annoyance in exposed dwellings [26], [27]. The prevalence ratios obtained are fairly comparable with other studies [28], [29], [30]. High annoyance could be related to and even be produced by the other effects, all of that contributing to deteriorate the quality of life [3]–[6].

Sleep disturbance is considered as one of the most harmful effects of environmental noise [3]. In this study, a high degree of problems with sleeping was reported by a proportion more than twice greater in exposed dwellings, where estimated night noise levels exceed the recommended values by 5 to 10 dBA, compared to unexposed ones. Above those recommended limits there is a risk for health, with considerable proportions of highly annoyed and sleep disturbed people, in addition to risk of increase of cardiovascular diseases [3], [31]. Poor quality of sleeping, especially an inadequate duration, may impact on the occurrence of chronic illness such as diabetes, depression and cardiovascular diseases [32].

The proportion of individuals who report a high degree of problems due to not feeling rested during the day was more than three times higher in exposed homes. In many cases it may be a consequence of poor sleeping quality, and it impacts on a poorer quality of life and has repercussions in low productivity, cognitive difficulties and risk of accidents at work or in activities like driving, for example.

Self-report of symptoms related to mood (feelings of depression, anguish or neurosis) were also associated with noise exposure. These symptoms are often related to sleeping problems [32], and therefore indirectly to sleep quality and tiredness during the day [33]. Self-reported presence of head or neck ache also had 20% greater prevalence with exposure to noise. This could be related to sleeping problems and day tiredness, and additionally to psychological effects like stress and irritability [1]–[3], [12].

Finally, although in this study the association was not statistically significant, a relationship was observed between exposure condition and overall health state reported as "bad", whose prevalence was higher in exposed dwellings. This result is consistent with those discussed above and with the literature in this field.

The selection methodology allowed balancing socio-demographic variables of respondents that could confound the differences in responses. Homogeneity of the socio-demographic variables was verified by finding no statistically significant differences for any of them. This method tried to approach random allocation in an experimental design, preserving the observational character. Similar designs and approaches have been used in other studies, but with different objectives or not exclusively in apartment buildings [4], [12], [13]. An advantage of this design is that both exposure and no exposure are expected be quite homogeneous in terms of noise level incident in each side. This allowed using PR as an adequate indicator to compare responses between the groups.

The unsupervised self-responding method for filling out the questionnaire, without a selection of respondent by researchers could have introduced some bias. There is no certainty that the respondent really complied with the age criterion (15 years old or more), and it was not possible to verify if the questionnaire was completed by a single resident of each dwelling. It was very difficult to access further control due to the doormen of the buildings.

Given that this is a cross-sectional study, it is impossible to establish neither causality nor temporality of analyzed events. However, the relationships found indicate that the existence of that causality is plausible, and future research could consider a design to study it. In further analysis of these data, direct and indirect relations could be explored between annoyance and self-perceived health, always

considering confounding socio- demographic variables [33], adding day of time of annoyance, also included in the questionnaire, and time of residence, which was lower in exposed dwellings and could be related to the exposure condition.

5. Conclusions

The results suggest the existence of a relationship between high traffic noise levels and health, with higher prevalence of people living in exposed housing declaring high annoyance and self-perceived health problems, after adjusting for sex, age, education and time of residence in the dwelling.

The study design permitted obtaining comparable groups of individuals to assess the exposure effect in non-experimental conditions. This is verified since no significant difference was found in confounding variables (except for time of residence).

It is necessary to take account traffic noise in the planning of new residential sites as well as of new transit infrastructure where residential zones already exist. In existing residential areas facing high traffic roads, it is crucial to take actions to mitigate the high noise levels incident in dwellings and houses, as their residents may be suffering severe health effects.

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