Characterization of Road Traffic Noise Exposure and Risk of Hypertension in Central Taiwan

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Abstract

Epidemiological studies have demonstrated that road traffic noise exposure is associated with hypertension in European, but the associations related to traffic sources and in other population are unclear. This study investigated the association between road traffic noise exposure and the prevalence of diagnosed hypertension among 321 male and 499 female resided near main roads in Taichung, Taiwan. Road traffic noise levels and traffic flow rates were measured simultaneously during 0900-1700 on weekdays in 2008. Multivariate logistic regressions were applied to estimate the risk of hypertension by adjusting for potential confounders. Road traffic noise levels were significantly associated with traffic flow rates of motorcycles but not with heavy-duty diesel trucks, light-duty diesel trucks or light-duty gasoline vehicles. Per one vehicle/hr increase in the traffic density of motorcycles was significantly related to the increment of 1.06±1.09 A-weighted decibels (dBA) in the road traffic noise exposure. The high-exposure group (82.2±1.7 dBA, n = 358) had a significantly higher risk of hypertension (adjusted odds ratio = 2.15, 95% CI = 1.08-4.26) than the low-exposure group (77.2±1.6 dBA, n = 462). There was an increasing trend (p = 0.023) between the risk of hypertension and residents exposed to < 77 dBA, 77-80 dBA, 80-83 dBA and ≥ 83 dBA, respectively. Such an association was pronounced after adjusting for the traffic density. The study findings suggest that exposure to road traffic noise may be associated with hypertension and motorcycles are the dominant source of road traffic noise in central Taiwan.

Keywords: Hypertension, prevalence, road traffic noise, traffic density.

Abbreviations:

BMI, body mass index; 95% CI, 95% confidence interval; dBA, A-weighted decibel; HDDT, heavy-duty diesel trucks; LA_{eq}, A-weighted equivalent sound level; LDGV, light-duty gasoline vehicles; LDDT, light-duty diesel trucks; MC, motorcycles; OR, odds ratio.

1. Introduction

Environmental epidemiological studies have reported that road traffic noise exposure is associated with the risk of hypertension in the European populations. Three community-based studies have demonstrated that residents exposed to road traffic noise of 24-h-average equivalent sound level above 55 A-weighted decibels (dBA) may have a higher risk of hypertension ranged 1.5-fold to 3.5-fold that of those exposed to less than 45 dBA in Sweden (Barregard et al., 2009; Bodin et al., 2009; Leon Bluhm et al., 2007). One study conducted in both cross-sectional and retrospective-cohort designs in the Netherlands has suggested that exposure to road traffic noise > 55 dBA may be associated with hypertension in subjects aged 45-55 years after adjusting for effects of the particulate matter (de Kluizenaar et al., 2007). The other cross-sectional study performed in Serbia has reported that male inhabitants exposed to nighttime road-traffic noise above 45 dBA may be related to the occurrence of arterial hypertension (Belojevic et al., 2008). In a cross-national study including United Kingdom, Germany, the Netherlands, Sweden, Italy and Greece, a significant exposure-response relationship between 24-h-average road traffic noise exposure and the risk of hypertension has been found for men (Jarup et al., 2008).

However, the association related to traffic sources of noise exposure is unclear.

Different types of traffic vehicles may produce the different contribution of inhabitants' noise exposure. Residents riding motorcycles from workplaces to home are found to have the higher levels of traffic noise exposure than those taking other vehicles in a past study (Orlando et al., 1994). Exposure to different kinds of noise may have different influences on the effects. One previous study has reported that residents living within 5 km of a helicopter airbase have a significantly higher prevalence risk of hypertension than the control group but such a significantly elevated risk is not observed among those living near a fight-jet airbase within the same distance (Rhee et al., 2008).

In addition, effects of road traffic noise exposure on hypertension in other populations are still unknown. One field study has reported the elevations of ambulatory blood pressure after exposure to 24-hr average noise levels above 55 dBA among Taiwan adults, but their results were limited to effects of environmental noise exposure in college students aged 18-32 years and the association between traffic density and noise exposure was not considered (Chang et al., 2009). The purpose of this study was to investigate the association between road traffic noise exposure and the prevalence of hypertension and to determine the dominant sources of noise levels in central Taiwan.

2. Materials and methods

2.1. Study population

This cross-sectional study was performed in Taichung City with 1070000 inhabitants located in the middle of Taiwan. In order to determine road traffic noise and traffic density simultaneously, residents living near the four main roads crossed over Taichung City were selected as the potential study subjects. We recruited 820 volunteers resided here at least three years by interviewing along the four roads during June-September 2008. Participants included 321 men (36.5±13.9 years) and 499 women (35.6±12.1 years). The present study was reviewed and approved by the Institutional Review Board of the College of Public Health, China Medical University before the study commenced, and written informed consent was obtained from each participant.

2.2. Questionnaire and definition of hypertension

We used a standardized questionnaire to interview each subject by four well-trained investigators for collecting information related to potential confounders of hypertension during the study periods. These factors included individuals' age, height, body weight, cigarette smoking, alcohol drinking, tea consumption, coffee consumption, daily salt intake, regular exercise, and family history of hypertension. Cigarette smokers were defined as those who had smoked cigarettes on more than 3 days per week for at least 6 months; alcohol, tea, and coffee drinkers were defined by the same criterion. High salt-intake subjects were defined as those who reported to ingest the more dietary salt than others. Regular exercisers were defined as those who had participated in a sporting activity at least three times per week for six months or more. In addition, body mass index (BMI) was calculated as body weight (kg) divided by the square of the height (m^2) for all participants.

A subject was defined as having hypertension if a positive answer was given to the question: "Have you been diagnosed with hypertension by a physician in the past?". The same criterion was used to define the family history of hypertension for parents and grandparents.

2.3. Noise exposure assessment and traffic density

Road traffic noise levels were measured by using a sound-level meter (TES-1358, TES Electronic Corp., Taipei, Taiwan), which can report 1-second to 24-hour continuous equivalent sound levels (Leq) in the range of 30-130 A-weighted decibels (dBA) and time-weighted-average (TWA) noise levels. Before the performance of noise measurements, a sound-level calibrator (TES-1356, TES Electronic Corp., Taipei, Taiwan) was used to calculate the sound-level meter. The sampling sites of road traffic noise levels were set up per 1 kilometer along each of the four main roads and located away from buildings 1 meter in the distance with a height of 1.5 meter.

The 15-min TWA Leq was collected at one of total 42 locations along the four roads during 0900-1700 by industrial hygienists. Because it is impossible to measure residents' individual noise levels every day, all subjects were divided into one of similar exposure groups that have the closest locations to the sampling sites. Each subject was assigned a specific value of noise exposure that corresponded with the 8-h TWA Leq measured in his residence.

During the monitoring of road traffic noise exposure, traffic flow rates at 42 sites were calculated and classified into four types: heavy-duty diesel trucks (HDDTs), light-duty diesel trucks (LDDTs), light-duty gasoline vehicles (LDGVs), and motorcycles.

In order to examine the association between road traffic noise exposure and the prevalence rate of self-reported hypertension, we used environmental noise exposure to classify the subjects into high-exposure and low-exposure groups. We chose 80 dBA as the cut-off value between different noise-exposure groups because it was close to the median (79.3 dBA) in the distribution of road traffic noise measurements among all participants. The 820 residents were subdivided into a high-exposure group (n = 358; road traffic noise exposure ≥ 80 dBA) and a low-exposure group (n = 462; road traffic noise exposure < 80 dBA).

2.4. Statistical analysis

We performed univariate comparisons between the 2 groups by using the Wilcoxon test for continuous variables and the Chi-square test for dichotomous variables. We also used the Shapiro-Wilk tests to assess the normality for traffic noise levels and traffic flow rates and then transformed these data with the base-10 logarithm to fit the normal distribution. The Pearson correlation coefficients were used to correlate log-transformed noise levels with log-transformed traffic flow rates and multiple regression models were applied to determine the association. We used multivariate logistic regressions and calculated odds ratios (ORs) and 95% confidence intervals (CIs) to compare the between-group difference in hypertension by controlling for potential confounders. The SAS standard package for Windows version 9.1 (SAS Institute Incorporation, Cary, North Carolina, USA) was used for statistical analyses. The significance level was set at 0.05 for all tests.

3. Results

Table 1 summarizes the demographic characteristics and potential risk factors by the two groups for 820 subjects. Significant differences were identified in the mean value of noise exposure and the proportion of participants who took regular exercise between the high-exposure and low-exposure groups. Workers in the high-exposure group had a significantly higher mean value of Leq ($p < 0.001$) and a higher proportion of taking regular exercise ($p = 0.003$) than those in the low-exposure group. In addition, the high-exposure workers had a higher prevalence of diagnosed hypertension (7.3%) compared with the low-exposure workers (4.3%, $p = 0.070$). There were no significant differences between the two groups in terms of age, BMI, male gender, smoking status, alcohol drinking, tea consumption, coffee consumption, daily salt intake, and a family history of hypertension ($p > 0.050$).

Table 2 presents the correlations and associations between different types of traffic flow rates and road traffic noise levels. The log-transformed mean levels of road traffic noise exposure were significantly correlated with the log-transformed mean traffic flow rates of HDDT, LDDT, LDGV, and motorcycles, respectively (all p values < 0.005). However, only the log-transformed mean traffic density of motorcycles was significantly associated with the log-transformed mean level of noise exposure in a multiple regression ($p < 0.050$). An increase of 1 vehicle/hr in the traffic density of motorcycles was associated with an elevated mean level of 1.06±1.09 dBA in the road traffic noise exposure.

Table 3 summarizes the associations between road traffic noise exposure and the risk of hypertension. By using the logistic regression models, the univariate analyses showed that the risk of hypertension was higher in the high-exposure workers compared with the low-exposure workers ($p = 0.073$). In addition, the male gender, age ≥ 40 years, BMI ≥ 23 kg/m^2, and family history of hypertension were significant factors associated with the prevalence of hypertension ($p < 0.050$).

The multivariate logistic regression analysis showed that the risk of hypertension was significantly higher in the high-exposure workers than that in the low-exposure workers after controlling for the gender, age, BMI, cigarette smoking, alcohol drinking, tea and coffee consumption, daily salt intake, regular exercise, and family history of hypertension. Residents with the 8-hr TWA L_{eq} of 82.2±1.7 dBA had a 2.15-fold higher risk of hypertension than those with the 8-hr TWA L_{eq} of 77.2±1.6 dBA. We also found that subjects aged ≥ 40 years, those with BMI ≥ 23 kg/m^2, and those having a family history of hypertension were at significantly higher risk of hypertension.

By using the continuous noise levels instead of a dichotomous exposure variable (high vs. low) in a multivariate logistic regression, we found that per 3-dBA increase in the 8-hr TWA Leq exposure was associated with an elevated risk of hypertension (adjusted OR = 1.62, 95% CI = 1.11-2.36; $p = 0.013$) after adjusting for potential confounders.

In order to investigate the exposure-response association, the prevalence of hypertension was stratified by four categories of road traffic noise levels (i.e. < 77 dBA, 77-80 dBA, 80-83 dBA, and ≥ 83 dBA) in male and female subjects. As shown in Figure 1, there was a significantly increasing trend between road traffic noise exposure and the prevalence of hypertension in men ($p = 0.014$), but no apparent pattern was found in women ($p = 0.288$).

Figure 2 reveals the odds ratio estimates and 95% confidence intervals for the risk of hypertension in the different categories of road traffic noise exposure. There was an exposure-response association ($p = 0.023$) between road traffic noise exposure and the risk of hypertension. Subjects exposed to road traffic noise ≥ 83 dBA had a significantly higher risk of hypertension (OR = 3.41, 95% CI = 1.03-11.29; $p = 0.045$) compared with those exposed to less than 77 dBA after controlling for the gender, age, BMI, smoking status, alcohol drinking, tea and coffee consumption, daily salt intake, regular exercise, and family history of hypertension in Figure 2 (a). Such exposure-response trend was more pronounced while the traffic density was included in the multivariate logistic regression model.

Residents exposed to road traffic noise ≥ 83 dBA and those exposed to 80-83 dBA had 7.62-fold (95% CI = 1.63-35.69; p = 0.010) and 4.14-fold (95% CI = 1.10-15.47; p = 0.034) risks of hypertension than those exposed to < 77 dBA in Figure 2 (b).

4. Discussion

In the present study, we found that exposure to road traffic noise was associated with the prevalence of hypertension. Residents exposed to 82.2±1.7 dBA had a 2.15-fold higher risk of hypertension compared with those exposed to 77.2±1.6 dBA that was higher than results in most of past studies ranging 1.31-1.90 (Barregard et al., 2009; Belojevic et al., 2008; Bodin et al., 2009; de Kluizenaar et al., 2007; Jarup et al., 2008). One of the possible reasons might be that most of past studies used the predicted models of road traffic noise exposure to combine with the geographic information systems for replacing the actual measurements. The other might be that residents being assessed included those living in the lane (far away the main streets) or in a district with lower traffic flow rates. In contrast, all of our study subjects lived near the main roads to have the higher levels of road traffic noise exposure. For example, one study used the manual noise assessment also reported a 3.47-fold risk of hypertension (Leon Bluhm et al., 2007). The results of this study showed that the association between road traffic noise exposure and the risk of hypertension was also found in other non-Caucasian populations.

Our findings demonstrated that the intensity of road traffic noise exposure was correlated with the traffic density, primarily coming from the effect of motorcycles in Taiwan. By comparing with the results of previous studies that reported the levels of noise exposure ranged 45-70 dBA, there were 90% of road traffic noise levels above 75 dBA in the present study indicating that road traffic noise exposure was more serious in Taiwan than in the European. One possible reason might be that few past studies used the actual measurements of noise exposure to investigate the association between hypertension. The other might be that the present study measured road traffic noise exposure only during the daytime (0900-1700) to have the higher noise levels compared with those measured during 24 hours. One study conducted in Italy to monitor noise levels in an urban environment showed the mean value of noise exposure during the day (0700-2200) was 73.7 dBA that was higher than one of 72.0 dBA during 24 hours (Orlando et al., 1994). In addition, residents transferred from home to the workplace by using motorcycles had the highest levels of noise exposure (77.1 dBA) during 24 hours than those using other vehicles (Orlando et al., 1994). Such comparisons indicated that our measurements during the day might be little higher than those during 24 hours and motorcycles might be the dominant source of road traffic noise exposure in both Taiwan and Italy.

We also found that the threshold of road traffic noise exposure on the prevalence of hypertension decreased from 83 dBA to 80 dBA after adjusting for the traffic density, as well as an increasing risk from 1.95 (95% CI = 0.75-5.07) to 4.14 (95% CI = 1.10-15.47) for 80 dBA, suggesting the possible effects of other traffic-related pollutants on hypertension. One previous study reported that the risk of hypertension related to road traffic noise exposure increased from 1.21 (95% CI = 1.05-1.38) to 1.31 (95% CI = 1.08-1.59) after controlling for exposure to particulate matter less than 10 μm in diameter (de Kluizenaar et al., 2007). Future studies should investigate the independent and combined effects of road traffic noise exposure and traffic-related pollutants on the risk of hypertension.

In this study, we found an increasing trend between road traffic noise exposure and the risk of hypertension in men that was consistent with previous studies (Barregard et al., 2009; Jarup et al., 2008). By contrast, one community-based study reported that the adjusted OR for hypertension was 1.71 (95% CI = 1.17-2.50) per 5-dBA increase only among women (Leon Bluhm et al., 2007). One panel study showed that the higher levels of 1.65 (95% CI = 1.36-1.94) mmHg systolic blood pressure (SBP) and 1.51 (95% CI = 1.27-1.75) diastolic blood pressure (DBP) in females compared with 1.15 (95% CI = 0.76-1.54) mmHg SBP and 1.27 (95% CI = 0.96-1.58) mmHg DBP in males induced by per 5-dBA noise exposure (Chang et al., 2009). The possible reason might be that men had the higher mean values of resting blood pressure than women to be easily defined as hypertensive subjects by using the criteria of World Health Organization for hypertension (i.e., SBP ≥ 140 mmHg or DBP ≥ 90 mmHg).

We also found the effects of age, BMI and family history of hypertension on the risk of hypertension. Residents aged above 40 years and those with a family history of hypertension had 8.17-fold and 9.12-fold risk compared with those aged less than 40 years and those without a family history of hypertension that indicated the stronger effects of these two factors on hypertension than the road traffic noise exposure. The increased risk of hypertension with age was consistent with three previous studies (Belojevic et al., 2008; Jarup et al., 2008; Leon Bluhm et al., 2007), however, two past studies reported the association broken down with age (Bodin et al., 2009; de Kluizenaar et al., 2007). This inconsistency might be due to the differences in age grouping between these studies. The higher risk of hypertension in residents with a family history of hypertension might be from the specific genetic predisposition including angiotensinogen gene M235T and angiotensin-converting enzyme gene I/D (Chiang et al., 1997; Jeng et al., 1997; Ji et al., 2010) or exposure to the same intensity of road traffic noise over a longer time (Barregard et al., 2009) compared with the study subjects. In addition, the higher BMI was associated with the increased risk of hypertension that jibed with findings reported in a previous study (Jarup et al., 2008).

The present study was strengthened by using the results of environmental sampling to classify subjects for preventing the non-differential misclassification of exposure that might bias the risk estimate towards the null value (Checkoway et al., 2004). The sufficient number of participants might obtain the acceptable power (85%) for the precision of this study. In addition, monitoring road traffic noise levels and counting traffic flow rates simultaneously could be more accurate to evaluate their correlations and to identify the main source of road traffic noise exposure.

However, some limitations in this study should be taken into account. Our definition of hypertension might cause the information bias, which was also found in previous studies (Barregard et al., 2009; Bodin et al., 2009; de Kluizenaar et al., 2007; Leon Bluhm et al., 2007) adopting the same approach. Using self-reported doctor diagnosis of hypertension instead of blood pressure measurements might have the various degree of sensitivity from 33.3% to 71% but have the higher degree of specificity ranged 91%-96% (Molenaar et al., 2007; Vargas et al., 1997). However, the sensitivity might vary between different social groups and ages.

Second, a cross-sectional design of a temporal problem might restrict the causal inference between exposure to road traffic noise and risk of hypertension. Although all of the study subjects had inhabited here over 3 years, the health status of participants prior to reside the concurrent address was unknown, which limited the ability to elaborate upon the between-group differences in the prevalence of hypertension due to road traffic noise exposure.

Third, some potential confounders were not considered as covariates in our analyses. Important but uncontrolled risk factors of hypertension include low-density lipoprotein cholesterol, serum uric acid, and dietary sodium and potassium intake (Beilin et al., 1999a; Beilin et al., 1999b; Lemne et al., 1994; Viazzi et al., 2005). These unmeasured factors might contribute to the sustained difference between the high-exposure and low-exposure groups.

5. Conclusions

Our data showed an association between exposure to road traffic noise and the prevalence of hypertension in central Taiwan. The intensity of road noise exposure was correlated with the traffic density and motorcycles were the significantly main source. There were increasing trends between noise exposure and the risk of hypertension in men. Such associations were pronounced after adjusting for traffic flow rates. Road traffic noise exposure was more serious in the present study compared with those reported in European populations. Related regulations should be considered to reduce the noise levels in Taiwan.

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Table 1. Demographic characteristics and risk factors of hypertension in two different study groups.

Characteristics	High-exposure groups (n = 358)	Low-exposure groups (n = 462)	*P*-value
Gender			
Male (%)	144 (40.2)	177 (38.3)	0.578[a]
Age (years)			
Mean ± SD	36.1 ± 12.6	35.9 ± 13.0	0.758[b]
Body mass index (kg/m^2)			
Mean ± SD	22.4 ± 3.4	22.5 ± 3.8	0.919[b]
LA_{eq} 8 hr (dBA)			
Mean ± SD	82.2 ± 1.7	77.2 ± 1.6	<0.001[b]
Current smoking			
Yes (%)	84 (23.5)	103 (22.3)	0.692[a]
Alcohol drinking			
Yes (%)	37 (10.3)	55 (11.9)	0.480[a]
Tea consumption			
Yes (%)	226 (63.1)	312 (67.5)	0.188[a]
Coffee consumption			
Yes (%)	132 (36.9)	178 (38.5)	0.628[a]
Salt intake			
High (%)	87 (24.3)	123 (26.6)	0.450[a]
Regular exercise			
Yes (%)	199 (55.6)	209 (45.2)	0.003[a]
Family history of hypertension			
Yes (%)	119 (33.2)	157 (34.0)	0.823[a]
Diagnosed hypertension			
Yes (%)	26 (7.3)	20 (4.3)	0.070[a]

SD, standard deviation; LA_{eq} 8 hr, A-weighted equivalent sound level at 09:00—17:00; dBA, A-weighted decibel.

[a] Wilcoxon signed rank sum test of the difference between the two groups.

[b] Chi-square test of the difference between the two groups.

Table 2. Correlation and association between traffic flow rate and road noise levels.

Traffic density	Number	Mean ± SD (vehicles/hr)	Log_{10}-transformed Correlation		Log_{10}-transformed Multiple regression		
			Coefficient	*P*-value	β	Seβ	*P*-value
MC	42	578 ± 358	0.634	<0.001	0.024	0.009	0.016
LDGV	42	749 ± 518	0.624	<0.001	0.012	0.010	0.235
LDDT	42	166 ± 107	0.469	0.002	-0.001	0.009	0.917
HDDT	42	55 ± 43	0.712	<0.001	0.010	0.008	0.256

MC, motorcycles; LDGV, light-duty gasoline vehicles, LDDT, light-duty diesel trucks; HDDT, heavy-duty diesel trucks.

Table 3. Association between traffic road noise exposure and prevalence of hypertension.

Variables		Number	Hypertension cases (%)	Univariate OR (95% CI)	P-value	Multivariate OR[a] (95% CI)	P-value
Groups	Low-exposure	462	20 (4.3)	1.00		1.00	
	High-exposure	358	26 (7.3)	1.73 (0.95-3.15)	0.073	2.15 (1.08-4.26)	0.029
Gender	Female	499	21 (4.2)	1.00		1.00	
	Male	321	25 (7.8)	1.92 (1.06-3.50)	0.032	1.37 (0.63-2.98)	0.428
Age (years)	<40	560	10 (1.8)	1.00		1.00	
	>=40	260	36 (13.9)	8.84 (4.31-18.12)	<0.001	8.17 (3.68-18.12)	<0.001
Body mass index (kg/m^2)	<23	505	14 (2.8)	1.00		1.00	
	>=23	315	32 (10.2)	3.97 (2.08-7.56)	<0.001	2.14 (1.01-4.54)	0.048
Alcohol drinking	No	728	37 (5.1)	1.00		1.00	
	Yes	92	9 (9.8)	2.03 (0.94-4.34)	0.070	1.21 (0.44-3.30)	0.709
Family history of hypertension	No	544	10 (1.8)	1.00		1.00	
	Yes	276	36 (13.0)	8.01 (3.91-16.41)	<0.001	9.12 (4.21-19.77)	<0.001

OR = odds ratio; 95% CI = 95% confidence interval.

[a] The multivariate logistic regression models were used to adjusted for current smoking, tea consumption, coffee consumption, salt intake, and regular exercise.

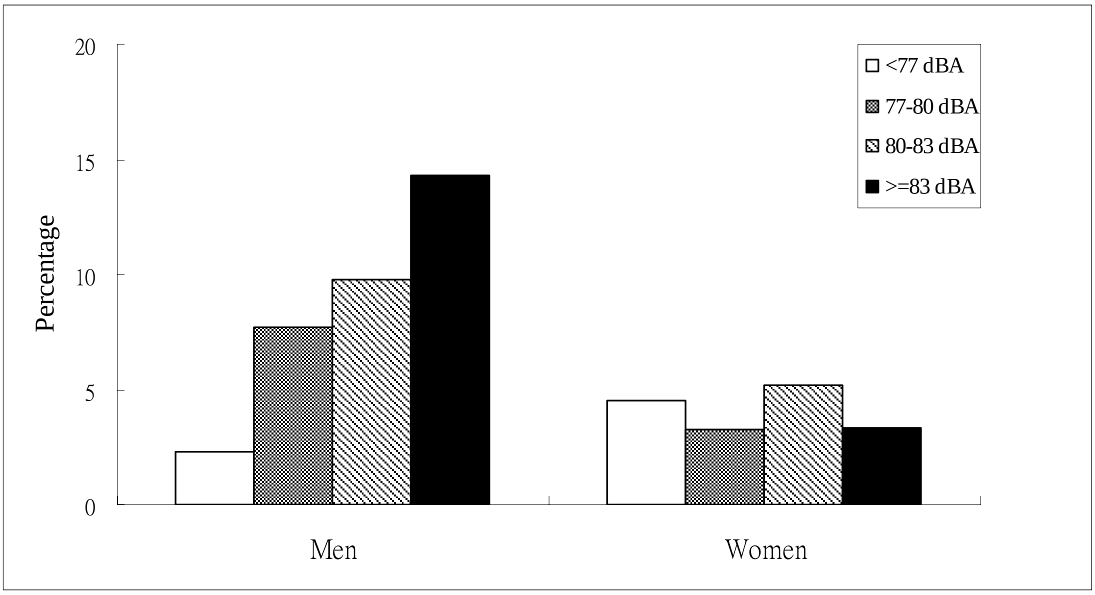
Figure legends

Figure 1

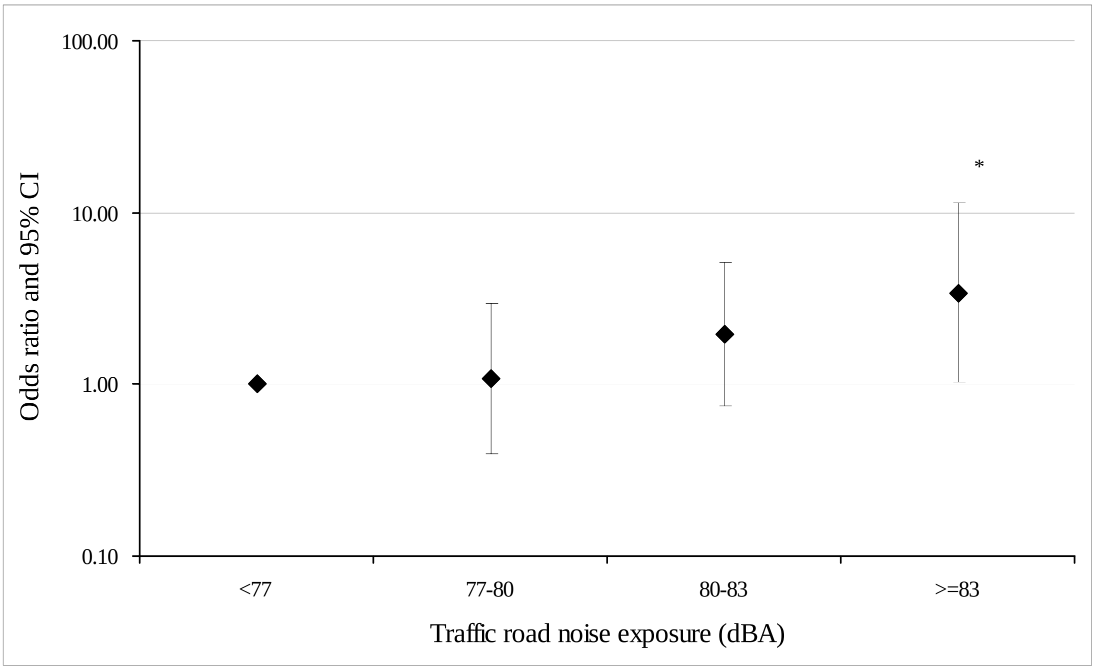
Prevalence of hypertension stratified by exposure to road traffic noise in men and women.

Figure 2

Odds ratio estimates and 95% confidence intervals for the risk of hypertension. (a) Analysis was adjusted for gender, age, body mass index, smoking status, alcohol consumption, tea consumption, coffee consumption, high salt intake, regular exercise and family history of hypertension. (b) Analysis was adjusted for all variables in (a) and traffic density (including motorcycles, light-duty gasoline vehicles, light-duty diesel trucks and heavy-duty diesel trucks). $^{*}p < 0.050$.



20
15
10
5
0
Percentage
<77 dBA
77-80 dBA
80-83 dBA
>=83 dBA
Men
Women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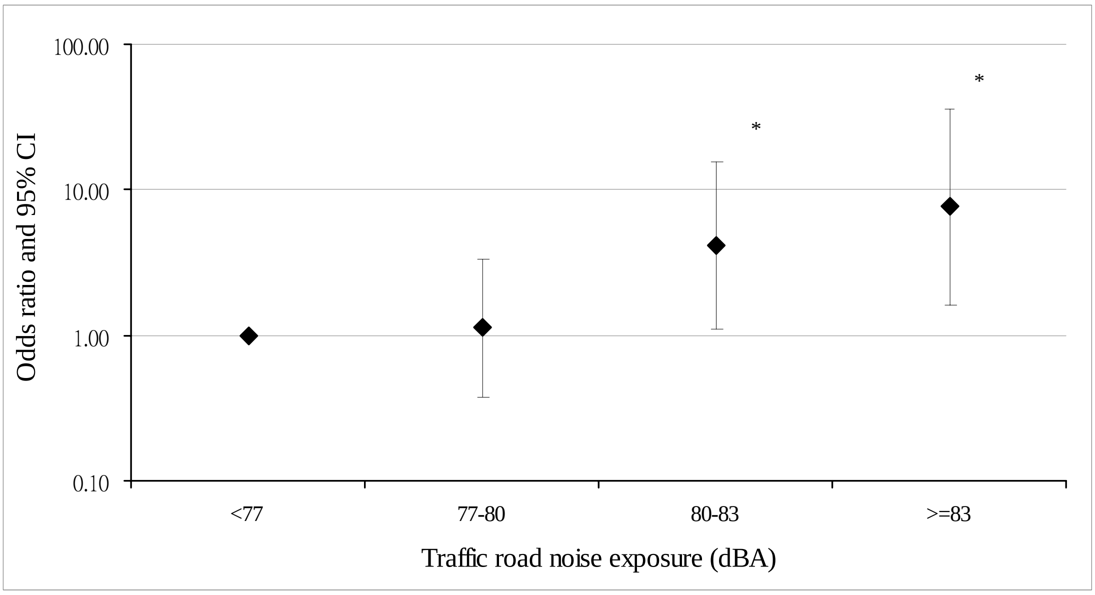
Odds ratio and 95% CI
*
<77
77-80
80-83
>=83
Traffic road noise exposure (dBA)

(a)


100.00
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Odds ratio and 95% CI
*
*
<77
77-80
80-83
>=83
Traffic road noise exposure (dBA)

(b)