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The relationship between traffic noise and insomnia among adult Japanese women

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Abstract

To clarify the relationship between traffic noise and insomnia, the authors conducted a survey and measured the actual sound level of noise in an urban area. Questionnaires were distributed to adult women who lived within 150 m from two major roads and were completed by 648 of the 1286 subjects (50.4%). The area was divided into three zones according to distance from the road (more than 50, 20–50 and 0–19.9 m). Fifty-seven subjects (8.8%) were classified as having insomnia. Average values of sound level at distances of 20, 50, and 100 m from the major road were L_{eq} 64.7, 57.1, and 51.8 dBA, respectively. Overall, there were no significant differences among the three zones in the prevalence of insomnia and no association between distance from the road and insomnia. However, the result from a sub-data set of the subjects who lived in the areas that showed decreasing noise level as the distance from the main road increased showed that distance from the road was associated with insomnia. This study suggests that researchers should consider the actual traffic situation and its sound level in epidemiological studies about the effects of traffic noise on insomnia.

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1. Introduction

Insomnia is the most commonly reported sleep problem in industrialized nations worldwide [1]. Many epidemiological studies about insomnia have been reported, but the definition of insomnia has varied, resulting in widely varying estimates of the prevalence rate of insomnia in the general population [2]. In Japan, Doi et al., conducted the first nationwide population-based survey to estimate the prevalence rate of insomnia in the general adult population and reported that the prevalence rates were 17.3% in males and 21.5% in females [3].

There is a consensus that there are many factors, such as gender, age, various medical conditions, and psychosocial stress, the cause sleep disruption or disorders which include insomnia [4,5]. Moreover, environmental noises, particularly, road traffic noise also cause sleep problems [6–8]. The present study was undertaken to investigate the effect of traffic noise on insomnia and identify other risk factors for insomnia in an area exposed to road traffic noise. In view of previous suggestions that the reaction among males and females differ [9], the study comprised females only.

The sound level of noise in the target area was measured and the relationship between environmental noise and insomnia was evaluated.

2. Methods

2.1. Survey area and subjects

A self-administered questionnaire concerning sleep, demographic information, and possible risk factors for sleep disruption was distributed to adult women living in Maebashi City (population approximately 280,000). The target area included two major roads named National Road 17 and Eastern Bypass Road and located within 150 m from the roadside. The night-time (2200–0600) traffic volume was 900 motor vehicles/h. The residential area was divided into three zones according to distance from the major road: Zone A, more than 50 m; Zone B, 20–50 m; Zone C, 0–19.9 m. Zone A was used as the reference zone. The speed limit on the major road is 50 km/h. No sound-insulating barrier is present between the houses and the road.

Subjects were selected based on a large-scale map of Maebashi City, containing the name of each household. Trained staff visited the subjects who were adult women aged 20 years or more to request their participation in this study and revisited them within 48 h to collect the replies. Questionnaires were completed by 648 of the 1286 subjects (response rate: 50.4%). The subjects ranged in age from 20s to 80s.

Subjects who had a serious problem of hearing and were using a hypnotic prescribed by a physician were excluded.

2.2. Epidemiological diagnosis insomnia

The prevalence of insomnia determined by a community survey depends on the definition of insomnia, which is related to the questions about sleep disruption. The authors referred to the criteria of International Statistical Classification of Diseases and Related Health Problems, 10th

version (ICD-10) [10], and the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) [11] for the diagnosis of insomnia because of their simplicity and comprehensiveness. The first criterion is the presence of a subjective sleep-related problem. The second criterion is the presence of any combination of the following four symptoms: difficulty in falling asleep, intermittent waking, premature morning waking, and a feeling of light overnight sleep. These symptoms must have been occurred one or more times per week and must have persisted for at least 1 month. The third criterion is the presence of one or more of the following after-effects of sleep disruption: "lethargy", "dozing or napping", "inefficiency in work", "tardiness", "error prone, particularly in work", or "overly sleepy".

The reproducibility of diagnoses based on these criteria has been confirmed by the results of a test–retest study at a 1 month interval: 56 of the 79 insomniacs (71%) were re-diagnosed as insomniacs, and 85 of the 90 non-insomniacs (94%) were re-diagnosed as non-insomniacs [12].

2.3. Other variables

Perceived health was classified into three categories: good and fairly good, moderate, and not so good and not good, as in a survey conducted by the Ministry of Health, Labor and Welfare [13]. Depressive state was rated on the basis of the Todai Health Index (THI), which consists of 10 questions, with higher score reflecting a more depressed state [14]. There are no questions about sleep disruption in the THI depression state scale.

Age was categorized as 20s, 30s, 40s, 50s, 60s, 70s, or 80s. Marital status was categorized as married or not married. Employment status was evaluated on the basis of whether or not the subject worked three or more days per week. Smoking was classified into three categories: never, quit, or current. Alcohol intake was classified into three categories: every day, 1–4 days/week, and less than 2 or 3 days/month or never. Other variables included whether the subject: had a regular physical activity; had a breakfast regularly; lived with a child aged six or younger; or received medical treatment. Caffeine intake was classified as frequent, sometimes, or hardly ever or never. Residential period was classified as less than 3, 3–9.9, or 10 years or more. House material was classified as reinforced, mortared, or wooded. Houses were classified as detached or apartment.

Concerning major life events, six choices were presented in the questionnaire: "moving away from home", "getting married or giving birth", "obtaining or losing a job, or changing jobs", "serious disease or injury", "death in the family", and "other stressful events". If the subject or her family member had experienced one of these life events within the last 6 months, this was counted as having experienced a major life event.

2.4. Measurement of noise

Two types of sound level measurements, L_{eq} (dBA) and L_{max} (dBA), were made using a sound level meter (NL-06; Rion Co. Ltd., Tokyo). The points of measurement were located 20, 50, and 100 m from the major roads (National Road 17 and Eastern Bypass Road) at 17 locations (total 51 points). Fig. 1 shows the L_{Aeq} levels measured at the three distance points for 11 of the 17 locations.

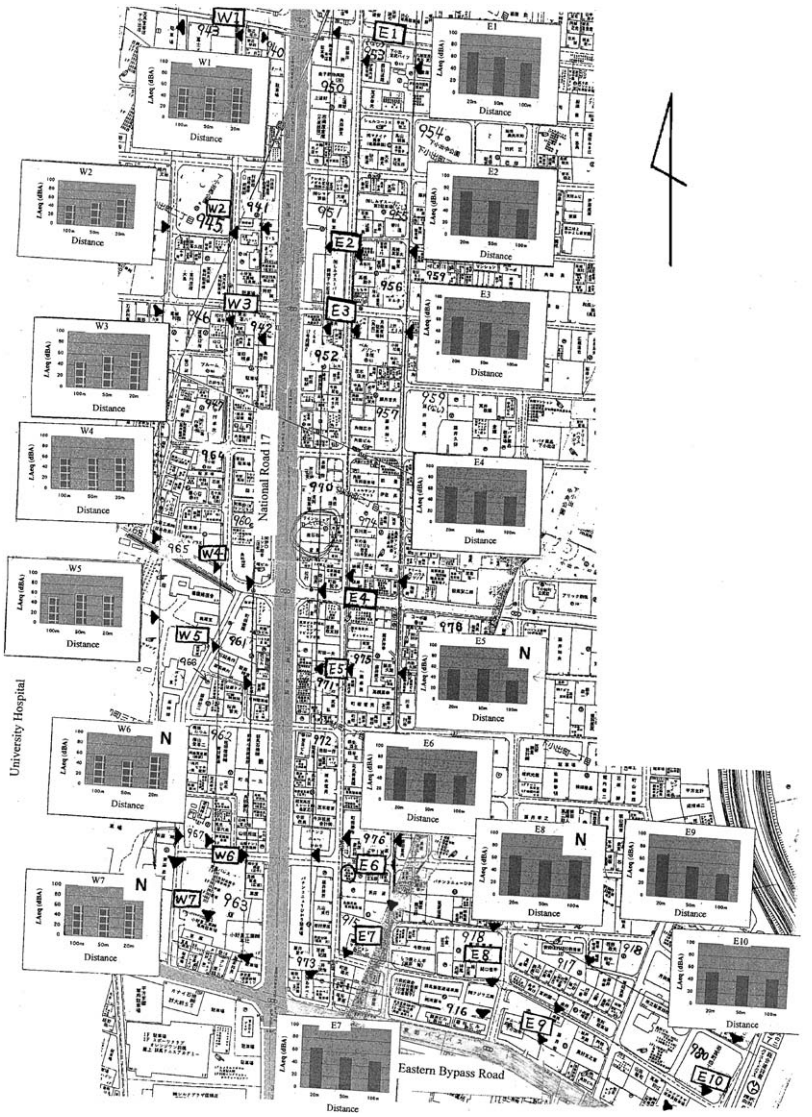

Fig. 1. Mapping of environmental noise. Black triangles mean measuring points for sound level of noise (L_{eq} (dBA)). "N" means that four spots (E5, E8, W6 and W7) did not have a linear relationship in which noise level decline as the distance from the main road increases.

2.5. Analysis

Chi-square test was used for cross table between the prevalence of insomnia and sub-type of insomnia and other factors. Two logistic regression procedures were used to investigation the association of possible risk factors for insomnia. One model was adjusted for only age class. The other model was adjusted for age class, marital status, job, living with a child aged 0–6 year, perceived health, medical treatment, smoking, alcohol intake, physical activity, regular breakfast,

caffeine intake, residential period, distance from a major road, house material, house situation, depressive state, and major life events.

After observation of the results for sound level on the points measured, the authors made the sub-data set, consisting of the subjects who live in areas that showed decreasing noise level as the distance from the main road increases, to investigate the association of the risk of road traffic noise for insomnia, further. Four of the 17 areas did not conform to this criterion and were therefore not included in the sub-set.

To avoid the errors of omission for analysis of Table 4 using the sub-data set, p values of 0.06 or less were regarded as significant for the logistic regression procedures, because the sample size was fairly small.

All analyses were performed using SPSS version 10.0J for Windows.

3. Results

3.1. General sleep behavior

The mean bed time, rising time, and time in bed on nights before weekdays were 23:11, 06:35, and 7 h, 25 min, respectively, and on the nights before weekend days and holidays, those were 23:34, 07:41, and 8 h, 6 min, respectively. Of 621 respondents, 169 (27.2%) had a habit of taking nap once or more per week, and 109 (17.5%) of 623 respondents complained of sleep-related problems.

3.2. Characteristics of prevalence of insomnia

Fifty-seven subjects (8.8%) were classified as suffering from insomnia, and the most common type of insomnia was characterized by difficulty in falling asleep (17.4%) (Table 1). The prevalence of insomnia was lowest among the subjects in their 80s (6.3%), followed by subjects in their 40s (6.5%), although none of the differences among the seven age groups were significant. Groups with a significantly higher prevalence of insomnia consist of those living with a child aged six or younger ($p<0.05$), those undergoing medical treatment ($p<0.01$), those who did not eat breakfast regularly ($p<0.05$), and those who had experienced a major life event within the last 6 months ($p<0.001$). There were significant relationships between perceived health and insomnia ($p<0.001$) and alcohol intake and insomnia ($p<0.05$), respectively.

The prevalence of insomnia among the three zones was compared, but no significant differences were found.

3.3. Risk factors for insomnia

Logistic regression analysis adjusted for age revealed that insomnia was associated with perceived health, having medical treatment, alcohol intake, regular breakfast, depressive state and a major life event within the last 6 months (Table 2). Multiple logistic regression analysis revealed that insomnia was associated with perceived health, depressive state and a major life event within

Table 1
Basic information on the prevalence of insomnia among the 648 participants in the study

Variables	Sub-group	Insomnia	Subtype of insomnia			
			Difficulty in falling asleep	Intermittent waking	Premature morning waking	Light overnight sleep
Total		8.8 (57/648)	17.4	9.9	6.2	7.7
Age	20s	10.8 (10/93)	18.5	3.2	4.3	7.5
	30s	9.4 (12/127)	10.4	5.5	1.6	7.9
	40s	6.5 (8/124)	15.3	6.5	3.3	5.7
	50s	8.3 (10/121)	18.5	9.1	7.6	9.2
	60s	9.6 (11/115)	21.1	16.8	12.3	7.1
	70s	9.5 (4/42)	31.0	19.0	4.9	7.3
	80s	6.3 (1/16)	13.3	26.7***	20.0**	14.3
Marital status	Married	8.4 (41/490)	17.1	10.5**	6.8	7.6
	Not married	8.3 (11/133)	17.4	3.0	3.0	6.1
Job ($\geqslant$3day/week)	Employed	8.6 (26/302)	15.1	6.3	5.0	7.4
	Other	8.8 (28/317)	20.1	12.7**	6.7	8.0
Live with a child	Yes	14.0 (18/129)*	16.7	11.7	5.5	11.6
($\leqslant$6 year)	No	7.2 (33/457)	17.6	8.8	6.0	6.9
Perceived health	"Good, fairly good"	2.7 (7/258)	9.8	5.8	3.9	2.4
	Moderate	10.5 (31/296)	20.2	8.5	5.2	9.9
	"Not so good, not good"	22.7 (15/66)***	33.8***	30.8***	17.2***	19.7***
Medical treatment	Yes	13.6 (27/199)**	25.9***	11.2	8.6	9.6
	No	6.8 (28/412)	13.8	8.5	4.7	7.1
Smoking	Never	8.1 (38/471)	15.3	8.5	6.0	7.3
	Quit	11.4 (5/44)	27.3*	15.9	7.0	9.1
	Current	10.2 (11/108)	22.4	9.3	6.5	9.3
Alcohol intake	Every day	17.2 (11/64)*	18.8	14.1*	10.9	9.4
	1–4/week	5.6 (4/72)	15.5	1.4	1.4	2.8
	"Less 2,3/month or never"	8.0 (39/486)	17.7	9.9	6.3	8.3
Physical activity	Yes	6.4 (9/140)	18.0	10.7	6.5	7.9
	No	9.3 (45/485)	17.3	9.1	6.1	7.3
Regular breakfast	Yes	7.2 (35/488)	15.1	9.5	5.8	6.2
	No	13.0 (19/146)*	25.5**	10.3	6.2	11.0
Caffeine intake	Constantly	10.4 (35/336)	17.8	9.5	5.4	9.9
	Sometimes	6.2 (12/195)	17.5	7.2	5.7	4.6
	Hardly ever or never	8.1 (8/99)	17.5	14.4	10.4	6.3
Residential period	$-$2.9 year	10.8 (12/111)	19.3	9.9	8.2	6.3
	3–9.9 year	10.9 (14/129)	15.0	6.2	2.3	9.3
	10 year	7.3 (29/398)	17.5	10.1	6.6	7.4
Distance from a major road	$>$50 m (Zone A)	8.8 (35/400)	16.7	8.3	5.3	7.4
	20–50 m (Zone B)	6.9 (10/144)	20.1	12.0	7.7	9.1
	0–19.9 m (Zone C)	11.5 (12/104)	17.6	13.5	8.7	7.8
House material	Reinforced	11.4 (21/184)	16.6	10.9	5.5	9.3
	Mortared	7.1 (11/154)	16.9	7.2	7.3	6.6
	Wooded	7.7 (21/274)	18.9	10.6	5.5	7.8

Table 1 (*continued*)

Variables	Sub-group	Insomnia	Subtype of insomnia			
			Difficulty in falling asleep	Intermittent waking	Premature morning waking	Light overnight sleep
House situation	Detached	8.2 (40/490)	17.1	10.2	6.0	7.2
	Apartment	11.4 (17/149)	18.9	8.7	6.1	9.4
Major life events	Yes	14.5 (36/249)***	24.1***	10.4	7.7	10.9*
	No	5.3 (21/399)	13.6	9.6	5.4	5.9

* $p<0.05$, ** $p<0.01$ and *** $p<0.001$ (Chi-square test).

the last 6 months (Table 2). Distance from a major road was not associated with insomnia in the analysis.

3.4. Sound level of noise and the risk of insomnia

The average values (standard deviations) of environmental sound level by L_{Aeq} at distance of 20, 50, and 100 m from the major road among 17 spots were L_{eq} 64.7 (4.83) dBA, L_{eq} 57.1 (4.17) dBA, and L_{eq} 51.8 (6.36) dBA, respectively. Moreover, the average values (standard deviations) of environmental sound levels by L_{Amax} at distances of 20, 50, and 100 m from the major road among 17 spots were L_{max} 79.7 (6.24) dBA, L_{eq} 70.6 (6.32) dBA, and L_{eq} 67.7 (8.38) dBA, respectively. Spearman's rank correlation coefficients between the sound level and the distance from a major road were -0.74 ($p<0.01$) for L_{Aeq} and -0.57 ($p<0.01$) for L_{Amax}. Four of 17 spots did not have relative relationship between the distance from the major road and the sound level of noise by L_{Aeq} (Fig. 1).

Table 3 shows prevalence of insomnia in the three zones among 261 residents who live in areas that showed decreasing noise level as the distance from the main road increases. Although none of the differences among the three zone groups were significant, the prevalence of insomnia for Zone A, Zone B, and Zone C were 6.4%, 8.5%, and 15.6%, respectively.

Table 4 shows odds ratio (OR) and 95% confidential interval (95% CI) of insomnia according to distance from the major road among 261 residents in the selected area. Logistic regression analysis adjusted for age revealed that insomnia was associated with Zone C (OR = 2.8, 95% CI = 1.0–8.1, $p = 0.06$) and intermittent waking and premature morning waking were also associated with Zone C (OR = 3.8, 95% CI = 1.0–14.5, $p = 0.05$ and OR = 6.6, 95% CI = 1.0–44.5, $p = 0.05$, respectively). Multiple logistic regression analysis also revealed that insomnia was associated with Zone C (OR = 13.7, 95% CI = 0.9–217.4, $p = 0.06$).

4. Discussion

Insomnia was not associated with distance from the major road in the analysis that used all data from the survey area. However, the authors measured the actual sound level of noise in the target area made. The results from the sub-data set of the subjects who lived in areas that showed

Table 2
Odds ratio of insomnia according to several related factors

Factor	Age adjusted		Full adjusted	
	OR	95% CI	OR	95% CI
Not get married	0.8	0.3, 1.9	1.4	0.4, 5.8
Not having a job	1.1	0.5, 2.0	2.0	0.7, 5.9
Living with a child aged 0–6 year	2.0	0.9, 4.4	1.0	0.3, 3.7
Perceived health (good, fairy good)				
Moderate	4.1***	1.7, 9.6	3.7*	1.2, 11.2
Not so good, not good''	8.8***	2.7, 28.0	11.9**	2.4, 58.0
Having medical treatment	2.0*	1.0, 3.9	1.1	0.4, 3.0
Smoking (never)				
Quit	1.4	0.4, 4.2	0.8	0.2, 3.8
Current	1.3	0.6, 2.8	0.3	0.1, 1.2
Alcohol intake ($\leqslant 2, 3$/month or never)''				
Every day	2.6*	1.2, 6.0	2.2	0.4, 12.4
1–4/week	0.8	0.3, 2.3	0.5	0.1, 2.0
No physical activity	2.7	0.9, 7.8	4.1	0.8, 20.0
No regular breakfast	2.0*	1.0, 4.0	1.3	0.4, 4.1
Caffeine intake (hardly ever or never)				
Constantly	1.1	0.4, 2.6	2.0	0.5, 7.1
Sometimes	0.5	0.2, 1.4	0.5	0.1, 2.2
Residence period (within 3 year)				
3–9.9 year	2.2	0.8, 6.1	4.4	1.0, 20.3
10 year	1.6	0.6, 4.5	1.4	0.3, 7.3
Distance from a major road (>50 m; Zone A)				
20–50 m; Zone B	0.7	0.3, 1.7	0.9	0.3, 3.1
0–19.9 m; Zone C	1.7	0.8, 3.6	1.4	0.4, 5.3
House material (reinforced)				
Mortared house	0.6	0.2, 1.4	0.8	0.2, 3.1
Wooded house	0.8	0.4, 1.7	1.0	0.3, 3.6
Apartment house (vs. detached)	1.3	0.6, 2.8	1.3	0.4, 5.2
Depressive state (THI)	1.2***	1.1, 1.3	1.2**	1.1, 1.3
Major life events	3.7***	1.9, 7.3	4.7**	1.7, 13.2

Parenthesis is the reference. Age adjusted; logistic regression analysis with adjustment for age.
Full adjusted; adjusted for age and all variables in the table.
*** $p<0.001$, ** $p<0.01$ and * $p<0.05$.

decreasing noise level as the distance from the main road increased clearly showed that distance from the major road was associated with insomnia, intermittent waking and premature morning waking. Laboratory studies using sleep EEG also showed that shallow sleep including intermittent wakefulness increased with exposure to road traffic noise [15].

Kageyama et al. [12] reported that the female respondents who lived in an area within 19.9 m from a high traffic density road had a significantly higher risk of insomnia than those who lived in an area 20 m or more from the road. Their target areas were 8 areas (5 cities), which had a major road in Japan, and the traffic volume of the road was comparably heavy. But only one area of

Table 3
Prevalence of insomnia among 261 residents in the selected area

Variables	Sub-group	Insomnia	Subtype of insomnia			
			Difficulty in falling asleep	Intermittent waking	Premature morning waking	Light overnight sleep
Total		8.6 (22/261)	16.7	6.9	3.5	7.4
Distance from a major road*	>50 m; Zone A	6.4 (10/157)	13.5	3.8	2.0	6.5
	20–50 m; Zone B	8.5 (5/59)	22.0	12.1	5.1	8.5
	0–19.9 m; Zone C	15.6 (7/45)	20.5	11.1	6.7	8.9

*None of the differences among three zone groups were significant using Chi-square tests.

Table 4
Odds ratio and 95% confidential interval of insomnia according to distance from the major road in selected area

	Distance from the big road			
	0–19.9 m; Zone C		20–50 m; Zone B	
Variables	OR	95% CI	OR	95% CI
Insomnia	2.8	(1.0, 8.1) $p = 0.06$	1.3	(0.4, 4.2)
Sub-type of insomnia				
Trouble falling asleep	1.7	(0.7, 4.1)	1.9	(0.8, 4.2)
Intermittent waking	3.8	(1.0, 14.5) $p = 0.05$	3.2	(0.9, 11.2)
Premature morning waking	6.6	(1.0, 44.5) $p = 0.05$	3.0	(0.4, 20.0)
Feeling of light overnight sleep	1.7	(0.5, 6.0)	1.7	(0.5, 6.0)

Statistics are logistic regression analysis with adjustment for age. The reference is >50 m (Zone A) of the distance from the major road.

Tokyo showed the effect of distance from a major road on insomnia. The target area of this study, Maebashi City, was one of the Kageyama et al. study areas that did not show such a result [12]. The authors considered that the result was caused by the traffic situation, such as using short-cuts, access to a facility used at night, etc. That is, there is not always a correlation between distance from a major road and the sound level of noise because of the use of smaller roads as bypasses or building location.

In the areas that do not have a linear relationship in which noise level decline as the distance from the main road increases, there are two representative places. One place is on the periphery of the University Hospital that is located in the west on the map (Fig. 1). The traffic density of the road along the hospital was high, even at midnight. Another place is on the periphery of the junction between National Road 17 and Eastern Bypass Road (Fig. 1). Around there, there are a lot of cars which use short-cuts. Furthermore, it may be that the noise from the fan of a large refrigerator used by a supermarket also has an effect on sleep in the residential area. At any rate, many kinds of noise are mixed in the real residential area. Therefore, this study suggests that when researchers conduct an epidemiological study about traffic noise and insomnia, they should consider the actual traffic situation and its sound level and other noises.

The prevalence rate of insomnia was 8.8% in this study. This rate is comparatively low compared to previous studies. Ohayon reviewed the prevalence rate of insomnia majored by epidemiological studies [2]. He mentioned that prevalence of insomnia can be viewed in four ways: (1) as insomnia symptoms (difficulty in initiating sleep, disrupted sleep and early morning awakenings); (2) as accompanied with daytime consequences; (3) as dissatisfaction with sleep quality or quantity and (4) as a medical diagnosis of insomnia. He identified the definition of insomnia used in this study as the third way. As the third definition represented 8–18% of the general population, the prevalence rate of insomnia in this study was in accord with those in previous studies that used same method.

Several variables were associated with insomnia such as perceived health, having a medical treatment, alcohol intake, having a breakfast regularly, depressive state and major life events. Age was not significantly associated with insomnia. Previous studies reported that risk factors of insomnia were poor perceived health [16–22], having a chronic disease [22–26], drinking alcohol every day [27], depressive state [20,28–30] and stressful life events [26,31].

This study has two limitations which are (1) the response rate was fairly low and (2) estimating distance from the major road as exposure level of road traffic noise.

Although this response rate was not satisfactory, the authors concluded that this sample was valid, because there was no difference in age between the respondents and non-respondents. Furthermore, those who were absent when the staff visited them are included in the sample. The rejection rate was similar to other four areas' in the study by Kageyama et al. [12].

Regarding exposure, measurement of the sound level at each subject's bedroom is ideal, but too much cost would be involved.

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