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NIGHTTIME TRAFFIC AND SLEEP IN JAPAN

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ABSTRACT

Risk for insomnia by nighttime road traffic noise invading into dwellings was investigated for 19 pairs of case and control women in 2 areas with major road passing in Tokyo. A good correlation was observed between simultaneously measured indoor and outdoor sound levels in L_{Aeq} (1 min) during sleeping time (n=14645: 7,241 for cases and 7,404 for controls: r=0.863; $p<0.001$), whose difference was about 25 dB on the average. The ORs by quartiles of indoor L_{Aeq}(1 min) levels were 1.0 for <20 dB, 3.2 (95% CI: 2.9-3.6) for 29-34 dB, 3.6 (3.2-4.1) for 34-38 dB and 6.1 (5.5-6.8) for 38 dB or above ($p<0.001$ for trends), suggesting the minimum effective level for insomnia is around 30 dB in terms of L_{Aeq} (1 min) during sleep.

1 - INTRODUCTION

Since 1970s, there has been a continuous trend of rapid increase of motor vehicles in Japan, causing many complaints among roadside residents regarding various daily life disturbances including sleep problems during nighttime [1]. Although many community studies on the sleep disturbing effects of road traffic noise have been conducted using a combination of questions such as "there are any annoying sounds in your neighborhood?" and "if yes, your sleep is affected by the noise?", for example, neither personal exposures to invading noise during sleep nor characteristics of sleep disturbances have been investigated well in those studies. On the other hand, dose(level)-effect or -response relationships in the effects of road traffic noise on sleep have been studied under experimental settings rather than actual situations [2].

Thus, the authors purposed to examine epidemiologically the risk for chronic sleep disturbances or insomnia in association with nighttime road traffic noise invading into bedroom with considering possible confounders and effect modifiers as much as possible. There have been several preceding epidemiological studies on insomnia among the Western countries with demonstrating good quality [3], and also complete physiological adaptation to noise during sleep has not been observed, suggesting that long lasting repeated sleep disturbances are likely [4]. As demonstrated in our previous cross-sectional study on 8 different areas where one major traffic road is passing through each of them, state of insomnia could be identified satisfactorily with a questionnaire developed according to the ICD-10 [5] and APA Criteria [6] with slight modifications. Its prevalence rates among the roadside residents, especially those in the zones within 20 m from the road edge are shown to increase in proportion to the traffic volume during nighttime even after adjustment for significant confounders such as age, job, medical care and so on (Kageyama et al., 1997) [7].

In the present study, a case-control study was conducted further to clarify the possible quantitative relationships between the risk for insomnia and invading road traffic noise into bedroom, for which subjects were recruited among the previously identified insomniac cases and other women in 2 areas in Tokyo out of the 8 areas.

2 - SUBJECTS AND METHODS

Nineteen insomniac case (age in years: 30 s-60 s) and 19 their control women randomly selected with matching age and job but not distance from the major road concerned were studied, from whom agreement for participation was obtained after explanations about the present study. Each of the 2 subject area consisted of Area I and Area II was classified into 3 zones according to the distance from the edge of each major road or 0-20 m (Zone I), 20-50 m (Zone II) and 50 m < (Zone III) as defined in the previous study [7]. The mean nighttime road traffic volumes, when one heavy duty vehicle was counted as 10 small cars, were 6,000 and 2,100 per hour for Area I and Area II, respectively, according to a road traffic survey in 1994 [8].

Insomnia was defined as previously described according to one or more of the 4 complaints of "difficulty to fall asleep", "wake up during sleep", "earlier wake up in the morning" or "sleeplessness feeling after wake up", which have been lasting for one month or longer, as well as existence of difficulty in daily activities on the next day. Among the cases, the most frequent complaint was "wake up during sleep"(14 (74%)), while "earlier wake up" was the least (6 (32%)).

Among 19 cases, 5 (26 %) and 1 (5 %) were living in Zone I, 3 (16 %) and 3 (16 %) in Zone II and 5 (26 %) and 2 (11 %) in Zone III for Area I and Area II, respectively. Hypertension (26 vs. 6 %), hypnotic use (58 vs. 28 %) and menopause (84 vs. 69 %) were significantly more prevalent among cases compared to controls. On the other hand, as for those cases, material of house was wood in 74 %, bedroom was on the 2nd floor in 64 %, type of residence was solitary in 84 %, type of window was sound-proof in 32 %, bedroom was faced to the road in 79 %, current drinker was 58 %, current smoker was 11%, daily physical exercise was in 0 %, living length was longer than 10 years in 89 %, current medical care was in 42 %, life event during last 6 months was experienced once in 42 % and 2 times or more in 37 %, currently married was 95 %, and working (job) was 37 %, for each of which no significant difference was found when compared to controls. No significant difference was found in mean sleeping time, mean bedtime or mean rising time, either. No "short sleeper" with daily sleeping time of 5 hours or less or no "long sleeper" with daily sleeping time of 10 hours or more was included in the present subjects.

Indoor and outdoor sound levels were determined simultaneously using two digital sound level meters (NL-04, Rion Co. Ltd.) for every 1 min based on 100 measurements with 60 msec intervals, which were expressed in terms of L_{xx} (1 min), on the same night for each pair of case and control. The sound levels only during sleeping time were extracted for each subject according their activity records.

Statistical analyses were performed with the PC-SAS, with which estimated odds ratios (ORs) were calculated based on conditional logistic regression analysis. Statistical significance of case-control differences were examined by t-test using GLM (generalized linear model).

3 - RESULTS

Indoor and outdoor sound levels in L_{Aeq} (1 min) for sleeping time of an insomniac case living in Zone I of Area I, which were the highest among all the subjects are shown in Fig. 1, as an example. Mean indoor and outdoor sound levels in L_{Aeq} (1 min) were 52 dB and 77 dB, respectively, with their difference of 25 dB. As apparent in the figure, both sound levels are behaving parallel with each other with a correlation coefficient of 0.863 ($p<0.001$), indicating indoor sounds are reflecting invading outdoor sounds. Moreover, it is also indicated by the mean indoor and outdoor L_{Aeq} (1 min) levels as shown in Fig. 2, in which mean indoor L_{Aeq}(1 min) levels were in the same order of mean outdoor L_{Aeq} (1 min) levels.

On the other hand, for both indoor and outdoor sounds, L_{max} (1 min), L_{Aeq} (1 min) and L_{50} (1 min) levels were significantly higher in cases than in controls, on the average, as shown in Table 1, although the case-controls were much smaller for indoor sounds than for outdoor sounds. Correlations between indoor and outdoor sounds were fairly good for each of the 3 parameters (Table 2) although those between L_{max} and L_{50} were slightly lower compared to others.

	Mean Indoor Sound Level			**Mean Outdoor Sound Level**		
	Case	**Control**	**Diff.**	**Case**	**Control**	**Diff.**
L_{max} (1 min)	**46.6**	**42.7**	**3.9**	**64.3**	**55.6**	**8.7**
L_{Aeq} (1 min)	**37.6**	**33.8**	**3.8**	**57.2**	**47.8**	**9.4**
L_{50} (1 min)	**35.3**	**31.4**	**3.9**	**53.9**	**45.8**	**8.1**

Table 1: Mean indoor and outdoor sound levels during sleep in cases and controls.

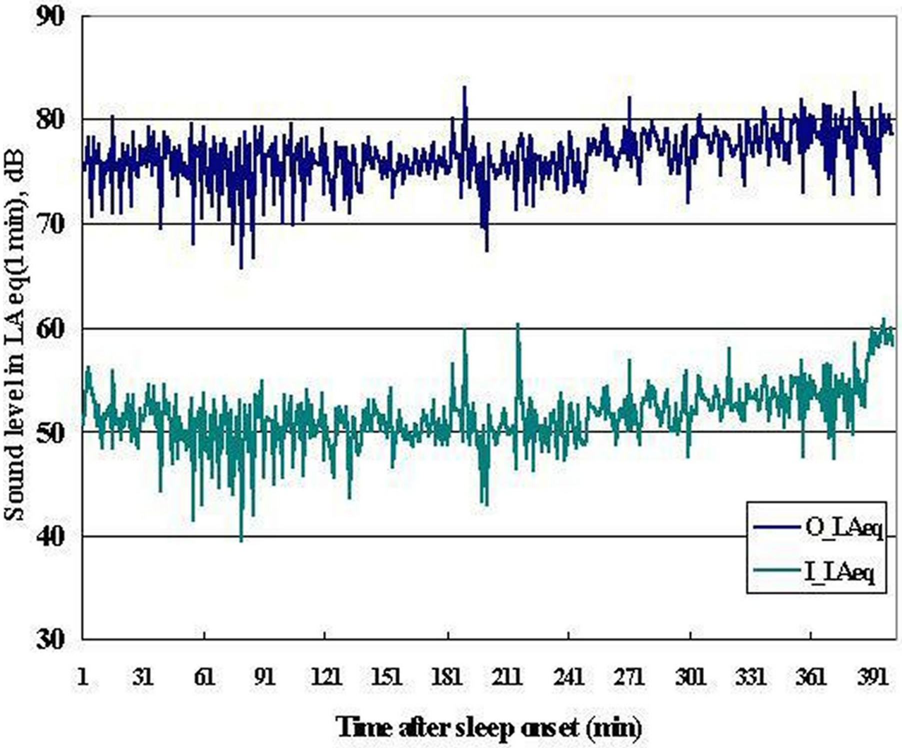

Figure 1: Indoor and outdoor sound levels in L_{Aeq} (1 min) during sleeping time in one case with the highest exposure level in Area I & Zone I.

Note: All of the case-control differences were significant ($p<0.001$) S.E. values were not shown, since they were around 0.1 or smaller.

Indoor	L_{max} **(1 min)**	L_{50} **(1 min)**
$_{LAeq}$ **(1 min)**	**0.907**	**0.916**
L_{max} **(1 min)**	**-**	**0.736**
Outdoor	L_{max} **(1 min)**	L_{50} **(1 min)**
L_{Aeq} **(1 min)**	**0.963**	**0.962**
L_{max} **(1 min)**	**-**	**0.891**

Table 2: Correlations among 3 parameters of indoor and outdoor sound levels during sleep (all subjects).

Note: all coefficients were statistically significant ($p<0.001$).
Finally, risk for insomnia or the estimated odds ratios (ORs) in each quartile of indoor and outdoor sounds of every 1 min during sleep, using the lowest quartile as referent, was analyzed using conditional logistic regression with age and job being matched and also tow possible confounders, or "current medical care" and "life events during last 6 months", as indicated to be confounders in the previous study, being adjusted. As summarized in Table 3, in all of the 6 analyses for each of the 3 parameter for indoor sounds and outdoor sounds, statistically significant risk trends were observed, although the risk trends for indoor L_{50} (1 min) was much smaller than those for L_{Aeq} (1 min) and L_{max} (1 min).
Thus, the minimum effective sound levels on insomnia are suggested to be in the range of 28-34 dB in L_{Aeq} (1 min) and 36-41 dB in L_{max} (1 min) for indoor sounds and 45-53 dB in L_{Aeq}(1 min) and 42-49 dB in L_{50}(1 min) for outdoor sounds, since the existing reports based on experiments are suggesting the lowest level is around 29 dB in L_{Aeq}(Eberhardt et al., 1987), or the reference level in the present analysis. As far as indoor sounds are concerned, L_{Aeq} (1 min) is suggested to be more sensitive parameter compared to L_{50} (1 min).

4 - DISCUSSION

The present case-control analysis suggested that road traffic noise invading into bedroom during sleep

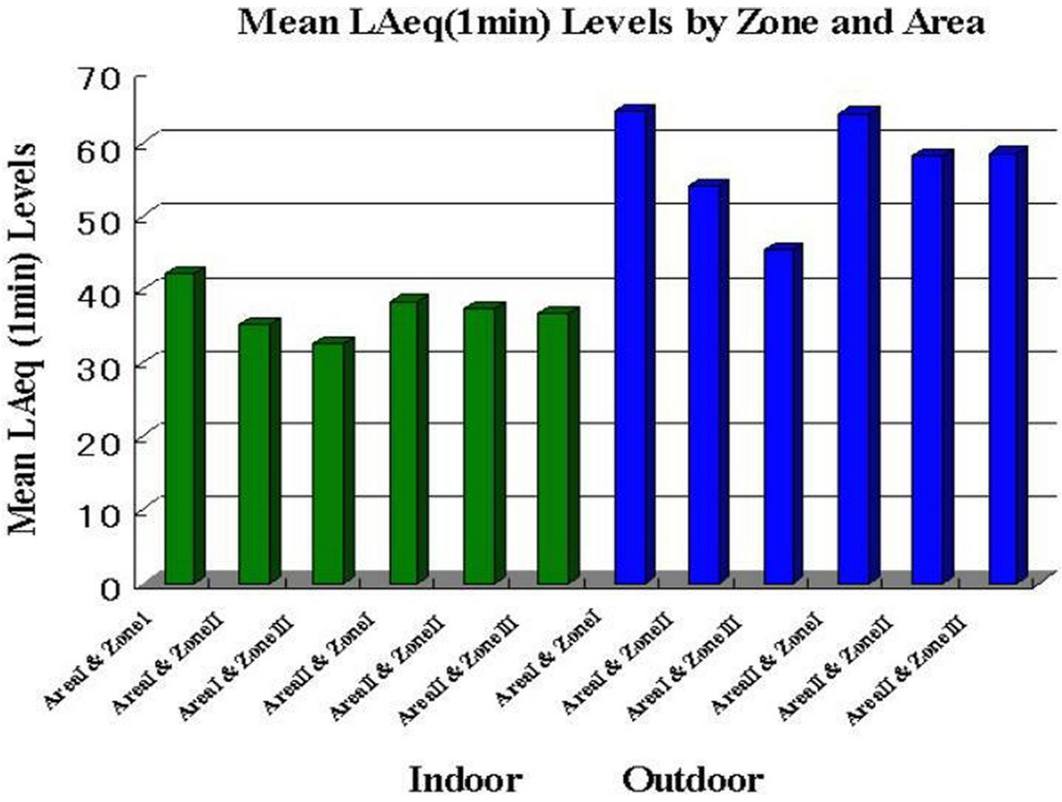

Figure 2: Mean L_{Aeq} (1 min) levels during sleeping time by Zone and Area. Number of L_{aeq} (1 min) levels were 5,174, 4,482, 6,579, 1,414, 2,263 and 2,329 for Zone I, II and III in Area I and II, respectively.

may be a risk for chronic sleep disturbances even at the level of around 30 dB in L_{Aeq} (1 min), although this result should be interpreted carefully, since the analyses were based on sound levels of every 1 min. According to another study by the authors [9] on the effects of indoor sounds, sound levels of which significantly correlated with those of outdoor sounds, on body movements during sleep measured with actimetry in subjects living in a roadside area in Tokyo, L_{Aeq}(1 min) levels were positively associated with the probability of movements. It is, thus, likely that an increase of indoor sounds exceeding the above minimum effective level may eventually increase the probability of "waking up" possibly through such noise-induced body movements. As noted in Subjects and Methods, the most frequent complaint among cases was also "wake up during sleep".

Although the estimated traffic volume was 6,000 vehicles/hour, or 100 vehicles/min on the road in Area I, actual number of vehicles must be less than this if heavy-duty vehicles, which may produce higher sounds than usual cars, are considered. It is, therefore, expected that the measured sound levels for every 1 min in the present study must have covered all of the peaks due to passing vehicles. This may also explain why L_{Aeq} (1 min) or L_{max} (1 min) were more strongly associated with the risk for insomnia than L_{50} (1 min), since L_{50} is generally less sensitive in responding to peaks of sound fluctuations compared to the former two.

Anyway, the present results may provide new epidemiological evidence that indoor sounds exceeding 30 dB in terms of L_{Aeq} (1 min) reflecting invading road traffic noise may cause chronic sleep disturbances in areas near major roads. This finding is roughly compatible with the existing experimental data showing the lowest road traffic noise level, which affected sleep physiology, was 29 dB in L_{Aeq} by Eberhardt et al. [10].

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Quartiles of sound level (dB)	No of cases and controls	ORs## (95% CI)	Quartiles of Sound level (dB)	No of cases and controls	ORs## (95% CI)
Indoor sounds L_{Aeq} (1 min) <28	666/1,662	1.0	Outdoor sounds L_{Aeq} (1 min) <41	291 / 1,683	1.0
28 – 34	1,505/1,748	3.2 (2.9 – 3.6)	41 – 45	425 / 1,709	0.9 (0.7 – 1.0)
34 – 38	1,703 / 1,691	3.6 (3.2 – 4.1)	45 – 53	1,591 / 1,699	3.3 (2.9 – 3.7)
38	3,366 / 1,723	6.1 (5.4 – 6.8)	58	4,568 / 1,727	9.9 (8.9 – 11.0)
Lmax (1 min)<36	678 / 1,696	1.0	L_{max} (1 min)<47	578 / 1,692	1.0
36 – 41	1,341 / 1,702	2.9 (2.6 – 3.2)	47 – 53	618 / 1,698	1.4 (1.2 – 1.6)
41 – 49	2,287 / 1,713	4.2 (3.8 – 4.7)	53 – 63	1,956 / 1,714	4.4 (3.9 – 4.9)
49	2,994 / 1,715	5.1 (4.6 – 5.6)	63	4,088 / 1,718	9.7 (8.7 –10.9)
L50 (1 min)<27	785 / 1,601	1.0	L_{50} (1 min)<42	409 / 1,686	1.0
27-30	740 / 1,780	1.1 (1.0 – 1.1)	42 – 49	727 / 1,694	2.3 (2.0 – 2.6)
30-36	2,348 / 1,731	1.7 (1.6 – 1.8)	49 – 57	1,535 / 1,711	4.9 (4.3 – 5.6)
36	3,367 / 1,714	1.6 (1.5 – 1.6)	57	4,568 / 1,733	14.9(13.2 –16.9)

Table 3: Odds ratios for insomnia by quartiles of indoor and outdoor sound levels (1 min) during sleep.

#: reference category; ##: adjusted for age and job; P-value for trends was statistically significant (<0.001) for ORs for each of the 3 parameters of indoor and outdoor sounds.