Noise sensitivity and subjective health: Questionnaire study conducted along trunk roads in Kusatsu, Japan

Hiroki Kishikawa, Toshihito Matsui¹, Iwao Uchiyama¹, Masamitsu Miyakawa², Kozo Hiramatsu³, Stephen A Stansfeld⁴

Graduate School of Policy and Management, Doshisha University, Japan, ¹Department of Urban and Environmental Engineering, Kyoto University, Japan, ²Department of Environmental Risk Management, Kibi International University, Japan, ³Graduate School of Asian and African Area Studies, Kyoto University, Japan, ⁴Centre for Psychiatry, Queen Mary, University of London, UK

Abstract

A questionnaire study was conducted in a residential area along trunk roads in Kusatsu, Japan, in order to investigate the association between noise exposure, noise sensitivity, and subjective health. Subjective health of the respondents was measured by the General Health Questionnaire (GHQ-28) which yields the total score as an index of psychiatric disorder and four subscales. Noise sensitivity was measured by the improved version of the Weinstein’s noise sensitivity scale named WNS-6B. The original WNS and a single question directly asking respondents’ noise sensitivity were also applied to confirm the validity of the WNS-6B for investigating the effects of road traffic noise on subjective health. Respondents were also asked about disturbances of daily life due to noise exposure to find the cause of the health effects. Three hundred and twenty three answers were entered into the analysis. Applying the WNS-6B as the noise sensitivity measurement scale, a significant correlation was found between subjective health and noise exposure in the noise-sensitive group, while no significant correlation was observed in the insensitive group. These results suggest that the adverse health effects may exist especially in the sensitive group. Application of the other two noise sensitivity measurement scales showed no significant relationship either in the sensitive group or in the insensitive group. The WNS-6B would have greater advantage for detecting adverse health effects than the other scales. Furthermore, the primary cause of the adverse health effect was investigated. The results of the analysis indicated that the adverse health effects were mainly caused by the sleep disturbance and were not caused by hearing interference.

Keywords: GHQ-28, noise sensitivity, psychiatric disorder, subjective health

DOI: 10.4103/1463-1741.50696

Introduction

Some field studies have suggested associations between exposure to environmental noise and a variety of mental health indicators such as consumption of tranquilizers, psychiatric hospital admission rates, and psychosomatic disorders.¹⁻⁴ However, in other studies, environmental noise exposure has not been demonstrated to be a significant cause of psychiatric disorder.⁷⁻¹⁰ The findings on environmental noise and mental health are inconclusive.¹¹,¹²

Results from Caerphilly Collaborative Study in the UK¹⁰ showed a significant relationship between noise sensitivity and psychiatric disorder, but no association between noise exposure level and psychiatric disorder except for a nonlinear association between noise exposure level and anxiety symptoms.¹³ In the Caerphilly study, noise sensitivity was measured by the Weinstein’s 10-item self-reported noise sensitivity scale (WNS),¹⁴,¹⁵ which had been often used as an index of noise sensitivity. However, some problems were found in WNS, and the improved scale named WNS-6B was developed by the authors.¹⁶

In this paper, the relationships between noise exposure, noise sensitivity, and effects of noise on subjective health were investigated by means of a questionnaire study conducted along trunk roads. Noise sensitivity was measured by three indices – the improved scale (WNS-6B), the original WNS, and the direct question on noise sensitivity – to confirm the validity of WNS-6B for detecting individual differences of adverse health effects. Subjective health was measured by the General Health Questionnaire (GHQ-28). The total score of GHQ-28 was used as an index of psychiatric disorder and four subscales of GHQ-28 were also applied as indices of subjective health.
Materials and Methods

Study area and subjects
A questionnaire study and noise measurements were carried out in a residential area (300 × 300 m²) along trunk roads in Kusatsu, Japan. Two trunk roads with heavy vehicles pass through the newly developed residential area where all the houses are detached. Sound levels were measured at 44 points in the area for 24 hours and day–night average sound levels (Ldn) were calculated. The primary noise source was the traffic on the trunk roads. All adult residents living in the area (N = 468) were asked to complete the questionnaire.

Questionnaire
Basic attributes of the residents (e.g., gender, age, socioeconomic status) were asked. Frequencies of disturbances of daily life due to noise exposure (sleep disturbance, speech interference, disturbance of watching TV) were measured with five categories – 1) never, 2) rarely, 3) sometimes, 4) often, and 5) always. Subjective health and noise sensitivity of the residents were also measured.

Subjective health
Subjective health was measured by the Goldberg’s GHQ-28.[17,18] The GHQ is a self-administered screening questionnaire designed for use in consulting settings aimed at detecting those with a diagnosable psychiatric disorder. In the Japanese-language version of the GHQ-28, respondents who score 6 points or over are judged as psychiatric cases with a sensitivity of 90% and a specificity of 86%.[19] The GHQ-28 yields four subscales – ‘somatic symptoms,’ ‘anxiety and insomnia,’ ‘social dysfunction,’ and ‘severe depression.’

Noise sensitivity
Subjective noise sensitivity was measured with three indices – the original WNS,[14,15] the improved version of the WNS named WNS-6B,[16] and a single question directly asking respondents’ own noise sensitivity. The validity of the WNS-6B was investigated in this study by comparison with the other indices.

The WNS consists of 10 questions asking attitudes toward noise in a variety of situations encountered in everyday life. The degrees of agreement on the statements are asked with six response options ranging from 0–5 (from ‘agree strongly’ to ‘disagree strongly’). The WNS-6B was developed excluding four questions from the original WNS, because the questions were regarded as inappropriate to assess noise sensitivity.[16] Binary-coding was applied to the six response options in the original WNS to reduce the effect of response bias, where 0 or 1 point was given to each answer in the WNS-6B according to the respondents’ agreement/disagreement with the questions.[16] The question “I am sensitive to noise” in the original WNS was used as a single question asking noise sensitivity.

Statistical analysis
Dose-response relationship between Ldn and possible psychiatric cases, identified by the GHQ-28, were obtained for both the sensitive group and the insensitive group with adjustment for gender, age, and socioeconomic status using multiple logistic regression analysis. The interaction between noise sensitivity and Ldn was examined by the analysis. Dose-response relationships between Ldn and the four subscales obtained from GHQ-28 were also obtained. Furthermore, association between psychiatric cases and disturbances of daily life by road traffic was examined to find the cause of the health effects. The fitness of the logistic regression model was confirmed by Hosmer-Lemeshow test. SPSS version 12.0 was used for the analysis.

Results

Study population
Four hundred and thirteen responses (88.2%) were collected. In the analysis, respondents aged over 70 years were excluded, because the number of the respondents was small (n = 28). The 323 questionnaires with complete responses to the WNS and the GHQ-28 were entered to the analysis. Sound levels were divided into three groups – <55, 55–65, and >65 dB in Ldn. The demographic attributes of the respondents for each Ldn group are shown in Table 1.

Respondents’ noise sensitivity was divided into two groups – ‘a sensitive group’ and ‘an insensitive group.’ The cut-off points of the scores of the original WNS, the WNS-6B, and the single question were 28/29, 4/5, and 2/3 (slightly agree/slightly disagree), respectively. The distributions of the noise sensitivity for each Ldn group are presented in Table 2. No significant correlation was observed between noise sensitivity and noise exposure level.

Subjective health, noise sensitivity, and noise exposure
The associations between noise exposure, noise sensitivity, and psychiatric disorder were investigated by multiple

| Table 1: Demographic attributes of the residents stratified by day–night average sound levels |
|---------------------------------|---------|---------|--------|-------|
|                                 | Ldn (dB) |         |        |       |
|                                 | <55      | 55–65   | >65    | Total |
| Gender (%)                      |          |          |        |       |
| Males                           | 73 (44.8)| 40 (46.5)| 34 (45.9)| 147 (45.5)|
| Females                         | 90 (55.2)| 46 (53.5)| 40 (54.1)| 176 (54.5)|
| Age (%)                         |          |          |        |       |
| 20–39                           | 49 (30.1)| 20 (23.2)| 23 (31.1)| 92 (28.5)|
| 40–59                           | 86 (52.8)| 33 (38.4)| 34 (45.9)| 153 (47.4)|
| 60–69                           | 28 (17.1)| 33 (38.4)| 17 (23.0)| 78 (24.1)|
| Socioeconomic status (%)        |          |          |        |       |
| Blue-collar                     | 46 (28.2)| 14 (16.3)| 10 (13.5)| 70 (21.7)|
| White-collar                    | 103 (63.2)| 58 (67.4)| 57 (77.0)| 218 (67.5)|
| Unknown                         | 14 (8.6)| 14 (16.3)| 7 (9.5) | 35 (10.8)|
| Total                           | 163      | 86       | 74     | 323    |
logistic regression analysis with adjustment for gender, age, and socioeconomic status. The number of valid answers was reduced to 288 because of missing answers to the question on socioeconomic status. The population-weighted mean between the insensitive group and the sensitive group in the area under 55 dB was set to the reference in the calculation of the odds ratio for the noise exposure and the noise sensitivity. The odds ratios of the psychiatric cases, identified by the GHQ-28, were obtained for the sensitive group and the insensitive group, respectively. The same analysis was done based on the three indices of noise sensitivity to confirm the validity of WNS-6B for detecting adverse health effects. The results are shown in Figure 1 and Table 3.

The original WNS and the single question did not show any significant association between psychiatric cases and noise exposure. The interactions between noise sensitivity and Ldn were not significant. With regard to the WNS-6B, the odds ratio for the sensitive group increased significantly with the noise exposure. No significant change in the odds ratio was observed in the insensitive group and the pooled data (broken line). The interaction between noise sensitivity and Ldn was significant ($P < 0.05$). The all odds ratios obtained using the WNS-6B as an index of noise sensitivity are presented in Table 4.

The GHQ-28 yields four subscales – 1) somatic symptoms, 2) anxiety and insomnia, 3) social dysfunction, and 4) severe depression. The relationship among subscale scores, noise sensitivity, and noise exposure were also investigated by multiple logistic regression analysis with the WNS-6B as a noise sensitivity measurement scale. The explanatory variables were the same as in Table 4. In the Japanese-language version of the GHQ-28, the cut-off points between minor and moderate disorder are 3/4 for ‘somatic symptoms’ and ‘anxiety and insomnia’ and 2/3 for ‘social dysfunction’ and ‘severe depression’. The odds ratio of the moderate or severe disorder was calculated with adjustment for gender, age, and socioeconomic status. The subscale ‘severe depression’ was excluded from the analysis, because there were few respondents having moderate or severe disorder on the score. The results are shown in Figure 2 and Table 5. In the sensitive group, the odds ratio for ‘somatic symptoms’ and ‘anxiety and insomnia’ increased significantly with Ldn. In the insensitive group, the odds ratio for ‘somatic symptoms’ showed a slight decrease and the odds ratio on ‘social dysfunction’ decreased significantly with Ldn. The interactions between noise sensitivity and Ldn of ‘somatic symptoms’ and ‘social dysfunction’ were significant ($P < 0.05$, $P < 0.01$, respectively), and the interaction of ‘anxiety and insomnia’ was not significant.

![Figure 1](image.png)

**Figure 1:** (a) Original WNS; (b) WNS-6B; (c) Single question. Odds ratio of the psychiatric cases, identified by the GHQ-28, and its 95% confidence interval with adjustment for gender, age, and socioeconomic status. The population-weighted mean between the insensitive sensitive groups in the area under 55 dB was set to the reference. Broken line represents the odds ratio calculated from the pooled data. *$P < 0.05$*
Factors causing adverse health effects

Relationships between disturbances of daily life and Ldn were examined. The answers: 4) often and 5) always, were regarded as frequent disturbances. Percentages of the residents who revealed the frequent disturbances of daily life were calculated for each Ldn group [Table 6]. In the highest noise-exposed group, 30–40% residents revealed frequent disturbances.

Multiple logistic regression analysis was applied to the residents living in the highest noise-exposed area to investigate the effects of disturbances of daily life on psychiatric disorders. The odds ratios of the psychiatric cases in the respondents who revealed frequent disturbances were calculated with adjustment for age [Table 7]. Gender and socioeconomic status were excluded from the explanatory variables, because the odds ratios of these factors were insignificant [Table 4]. The result showed that sleep disturbance was significantly related to the psychiatric disorder.

The relationship among psychiatric disorder, sleep disturbance, and noise sensitivity in the highest noise-exposed area was also investigated by multiple logistic regression analysis. Including the interaction between sleep disturbance and noise sensitivity (WNS-6B) in the logistic regression model, the odds ratios of psychiatric cases were obtained with adjustment for age [Figure 3]. The population-weighted mean between the insensitive and the sensitive groups in the residents who were not disturbed in their sleep infrequently was set to the reference. The odds ratio of the psychiatric cases in the sensitive

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### Table 4: Odds ratios of psychiatric cases

|                         | n   | OR  | 95% CI          | P-value |
|-------------------------|-----|-----|-----------------|---------|
| Noise sensitivity and   |     |     |                 |         |
| noise exposure*         |     |     |                 |         |
| Insensitive group       |     |     |                 |         |
| <55 dB                  | 89  | 0.88| 0.67–1.16       | 0.371   |
| 55–65 dB                | 34  | 0.59| 0.25–1.39       | 0.230   |
| >65 dB                  | 37  | 0.62| 0.28–1.39       | 0.242   |
| Sensitive group         |     |     |                 |         |
| <55 dB                  | 60  | 1.20| 0.80–1.83       | 0.371   |
| 55–65 dB                | 38  | 1.60| 0.73–3.49       | 0.237   |
| >65 dB                  | 30  | 3.15| 1.30–7.60       | 0.011   |

Gender and age

|          |     |     |                 |         |
|----------|-----|-----|-----------------|---------|
| Males    |     |     |                 |         |
| 60–69    | 43  | 1   |                 |         |
| 40–59    | 66  | 2.73| 1.07–6.97       | 0.035   |
| 20–30    | 30  | 4.41| 1.51–12.91      | 0.007   |
| Females  |     |     |                 |         |
| 60–69    | 29  | 2.21| 0.74–6.55       | 0.154   |
| 40–59    | 72  | 2.85| 1.15–7.06       | 0.024   |
| 20–30    | 48  | 5.66| 2.14–14.99      | <0.001  |

Socioeconomic status

|          |     |     |                 |         |
|----------|-----|-----|-----------------|---------|
| Blue-collar | 70 | 1   |                 |         |
| White-collar | 218| 1.09| 0.59–2.01       | 0.773   |

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### Table 5: Odds ratio of psychiatric cases and its 95% confidence intervals stratified by noise sensitivity

| Subscales                  | <55   | 55-65 | >65   |
|----------------------------|-------|-------|-------|
| Somatic symptoms           |       |       |       |
| Sensitive                  | 1.09  | 1.58  | 2.46  |
| Insensitive                | 0.94  | 0.56  | 0.37  |
| Anxiety and insomnia       |       |       |       |
| Sensitive                  | 1.13  | 2.96  | 3.28  |
| Insensitive                | 0.92  | 1.09  | 0.75  |
| Social dysfunction         |       |       |       |
| Sensitive                  | 1.16  | 1.25  | 2.41  |
| Insensitive                | 0.90  | 0.54  | 0.10  |

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### Table 6: Percentages of the residents who revealed frequent disturbances of daily life

|                         | <55 | 55-65 | >65 |
|-------------------------|-----|-------|-----|
| Sleep disturbance (%)   | 6.8 | 22.1  | 30.6|
| Speech interference (%) | 3.7 | 5.8   | 28.4|
| Disturbance of watching TV (%) | 8.6 | 14.0  | 43.2|

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Figure 2: (a) Somatic symptoms; (b) Anxiety and insomnia; (c) Social dysfunction. Odds ratio of the moderate or severe disorder, identified by the GHQ-28 subscales, and its 95% confidence interval with adjustment for gender, age, and socioeconomic status. The population-weighted mean between the insensitive and the sensitive groups in the area under 55 dB was set to the reference. Broken line represents the odds ratio calculated from the pooled data. *P < 0.05, **P < 0.01
group increased significantly with the sleep disturbance (OR = 17.48, \( P = 0.001 \)), while the odds ratio in the insensitive group did not change (OR = 0.45, \( P = 0.430 \)).

### Discussion

#### Subjective health, noise sensitivity, and noise exposure

The original WNS and the single question directly asking respondents’ noise sensitivity did not show any significant relationships between noise exposure and the psychiatric cases, identified by GHQ-28. Application of the WNS-6B, however, indicated a significant correlation between the psychiatric cases and the noise exposure in the sensitive group [Figure 1b]. In the highest noise-exposed area, highly significant difference of the odds ratios was obtained between the sensitive and the insensitive groups classified by WNS-6B, and small difference of the odds ratios was found in the lowest noise-exposed area. These results could be interpreted as follows – WNS-6B correlates closely with the individual differences of noise-related effects only in a noise-exposed area. Our studies conducted along Shinkansen Railway[21] and Narita International Airport[22] showed similar results. The WNS-6B seemed to be more effective in predicting the adverse effects on subjective health due to noise exposure than the other noise-sensitivity scales.

The pooled data did not show any significant relationships between the psychiatric cases, identified by GHQ-28, and the noise exposure. Moreover, the odds ratios of the moderate/severe disorder on ‘somatic symptoms’ and ‘anxiety and insomnia’ increased significantly with Ldn in the sensitive group, while the pooled data did not show any significant relationships. These results suggest that the adverse effects on subjective health due to environmental noise exposure may exist especially in a sensitive group. Analysis of a sensitive group may be more efficient than that of pooled data for detecting noise effects.

In the insensitive group, the score of ‘social dysfunction’ decreased significantly with Ldn, and the score of ‘somatic symptoms’ showed a slight decrease [Figure 2]. These results might be interpreted by the following hypothesis. In the studied area, the residents cannot take effective countermeasures against the noise pollution. Emotion-focused coping behavior[23] may occur, and the insensitive residents would not care about the noise exposure. If the coping lead similar positive behaviors in their everyday life, the score of ‘social dysfunction’ would decrease in the insensitive group.

#### Subjective health and sleep disturbance

Two questions in the GHQ-28 ask about insomnia – “Lost much sleep over worry?” and “Had difficulty in staying asleep once you are off?” If the answers to these questions were related to the noise exposure level, the relationship between the psychiatric cases, identified by the GHQ-28, and sleep disturbance could be confounded. The relationships between the answers to the two questions and the noise exposure were investigated by multiple logistic regression analysis. No significant relationship was observed either in the sensitive group.
group or in the insensitive group.

The odds ratio of the psychiatric cases increased with sleep disturbance in the sensitive group, while the odds ratio did not change in the insensitive group [Figure 3]. Similar results were obtained from our studies conducted along Shinkansen Railway[21] and around Narita International Airport.[22] The sensitive group seems to be more vulnerable to sleep disturbance than the insensitive group, and to have high risk for the adverse effects on subjective health caused by sleep disturbances although it is difficult to be certain of the direction of causal pathways in this cross-sectional data.

The limitations of this study

We ascertained the advantage of application of WNS-6B to subjective health, and indicated the difficulty to use original WNS. This result is consistent with the results of our studies of railway noise[21] and aircraft noise.[22] There is the possibility that other previous studies using the original WNS might show the relationship between subjective health and noise exposure, if the noise sensitivity would be measured by WNS-6B. However, our studies were carried out using Japanese version of GHQ-28 and WNS. Further investigation would be required to confirm the reliability of the results in other countries and other languages. This study was a cross-sectional study, and the number of the samples was limited. Further investigation of the relationship between noise sensitivity, sleep disturbance, and subjective health is also needed, although similar results were obtained from our other studies.[21,22]

Conclusions

A questionnaire study was carried out in the residential area along trunk roads to examine the association between subjective health, noise sensitivity, and noise exposure. Applying the WNS-6B as a noise sensitivity measurement scale, significant association was found between the psychiatric cases identified by the GHQ-28 and noise exposure in the sensitive group, while no significant correlation was observed in the insensitive group. The adverse effects on subjective health may exist especially in the sensitive group.

Application of the other two scales showed no significant relationship either in the sensitive group or in the insensitive group. The WNS-6B seemed to have a great advantage to detect psychiatric disorder caused by environmental noise exposure.

In the sensitive group, the odds ratios of the moderate/severe ‘somatic symptoms’ and ‘anxiety and insomnia’ were positively correlated with noise exposure. In the insensitive group, there was a decreasing trend of the odds ratio on ‘somatic symptoms’ and ‘social dysfunction’ with noise exposure. And it was found that sleep disturbance was related to the psychiatric disorder.

Address for correspondence:
Dr. Hiroki Kishikawa,
Karasuma Imadegawa, Kamigyo-ku, Kyoto,
Japan 602-8580.
E-mail: hkishika@mail.doshisha.ac.jp

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