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# A questionnaire survey on health effects of aircraft noise for residents living in the vicinity of Narita International Airport: The results of physical and mental health effects.

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**ABSTRACT**

A questionnaire survey on health effects of aircraft noise was performed by the Narita International Airport Corporation (NAA) for residents living in the vicinity of Narita International Airport. The survey was implemented to investigate psychological effects like noise annoyance, night-time insomnia, mental effects like emotional instability and depressive tendency, and physical effects like high-blood pressure. In this paper, we particularly focused on the results of physical and mental effect of aircraft noise. The questionnaire was consisted of both Total Health Index (THI) questionnaire constructed from about 130 self-rating questions asking perceived health and a general questionnaire asking about systolic/diastolic blood pressure and noise sensitivity. The survey was carried by postal mail and the total of valid responses collected from the mail survey was 3,659. In order to analyze health effects of aircraft noise, we applied logistic regression model to the responses of this questionnaire survey. From these results, we concluded that some of mental effects might be suspected to associate with aircraft noise exposure however the associations between physical effects and aircraft noise exposure were not found.

## INTRODUCTION

Narita International Airport, this large-scale inland airport has attempted to improve noise environment of the surrounding areas. Especially in night-time, the government and NAA impose night-time curfew to bans operations between 23:00 and 6:00 except for emergency and to limit the flight operations after 22:00 within a maximum of 10 movements for each runway. However, in preparation for current Open Skies Agreements, the remarkable increase of LCC’s flight movements and the hosting of Tokyo Olympic and Paralympic Games in 2020 [1], it is necessary to enhance operational performance with ensuring safety by partially relaxing restrictions of aircraft operation. Currently, NAA is planning to strengthen the function of airport and expanding the capacity of airport to enhance international competitiveness of airport among neighboring countries in East Asia through active cooperation with Tokyo-Haneda Airport.

The government and NAA have implemented conditional relaxation of night-time curfew since 2013 both to enhance competitiveness in air transport in East Asia and to improve convenience for customers. At the beginning of conditional relaxation on night-time curfew, NAA promised to perform a survey on health effect of aircraft noise, because residents who lived in areas around airport had a strong demand from surrounding community for investigating health effect due to night-time aircraft noise corresponding to the conditional relaxation of curfew.

We carried out a questionnaire survey on health effects, which are noise annoyance, disturbances of daily life, insomnia, and physical / mental impact, of aircraft noise for residents living in the vicinity of Narita International Airport [1, 2]. In this paper, at first, we reported a procedure of this survey and analysis method. Secondly, we showed the results of physical and mental effect of aircraft noise. Finally, we discussed in greater detail these results.

## SURVEY PROCEDURE AND ANALYSIS METHOD

### Respondents and noise assessment

The detail procedure of a questionnaire survey on health effect of aircraft noise around Narita International Airport is shown in Figure 1, and survey areas are shown in Figure 2.

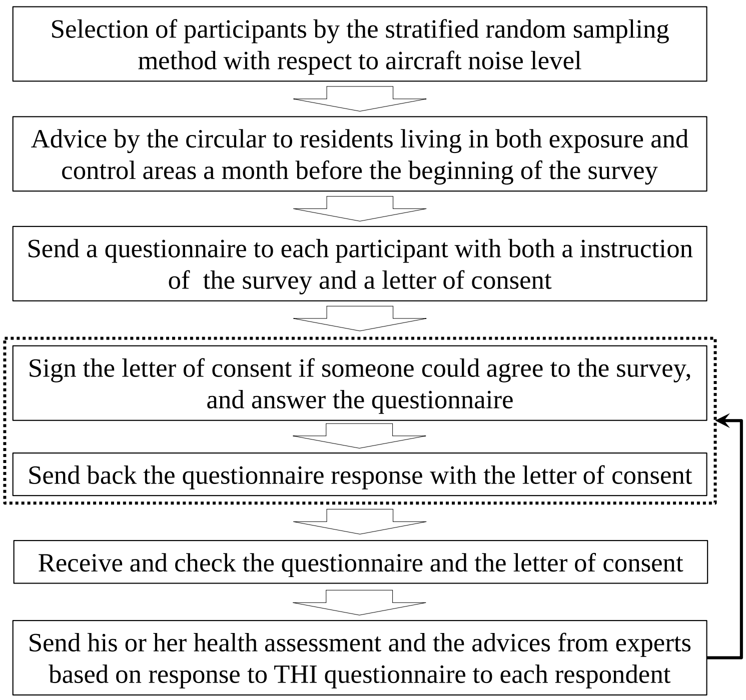



**Figure 1:** A detail flow chart of the questionnaire survey

The survey areas consisted of “exposure areas” surrounding the airport and “control area” where are adjacent to the airport but have not affected by aircraft noise exposure. 8,000 of participants aged from 20 to 79 years old were sampled from residents’ ledger by means of the stratified random sampling method with respect to aircraft noise in exposure areas. However all residents of target age group were selected in exposure areas of high level, because of small population of appropriate residents in the area. Two thousands of participants of target age group were sampled by the same method in control areas. In exposure areas 3,035 residents (Response Rate: 39.2 %) agreed, and 624 (RR: 31.7 %) did in control area. 1,496 adults (49.3 %) in exposure area and 293 (47.0 %) in control area were males out of 3,659 respondents. In both areas, around 60 % of them were aged in their fifties or above and average ages of male and female were 50's. About 70 % and over in exposure area and around 80 % in control area had been living for more than 10 years at the same place. About 30 % and over of them was employee in both areas. No significant difference between exposure and control areas was observed for the above variables ($p$=0.05).

Annual averaged outdoor noise exposures of residents' houses in exposure area, $L_{den}$ and $L_{Aeq,night(22-07)}$, were determined at an interval of 5 dB from the measured results of aircraft noise at 89 unattended monitoring stations surrounding Narita International Airport. On the other hand, exposure levels were estimated from the measured result during two weeks in control area at the same period that the survey on health effect was performed. Exposure levels at all respondent's houses in control area were below 40 dB in $L_{den}$ and 30 dB in $L_{Aeq,night(22-07)}$, and they were negligibly small [3, 4]. The number of respondents is shown in Table 1 stratified by the rank of $L_{den}$ and $L_{Aeq,night(22-07)}$. Because of a small sample in the highest exposure group, the following results were derived from analyzed response of the questionnaire, except in the data of the highest exposure one.

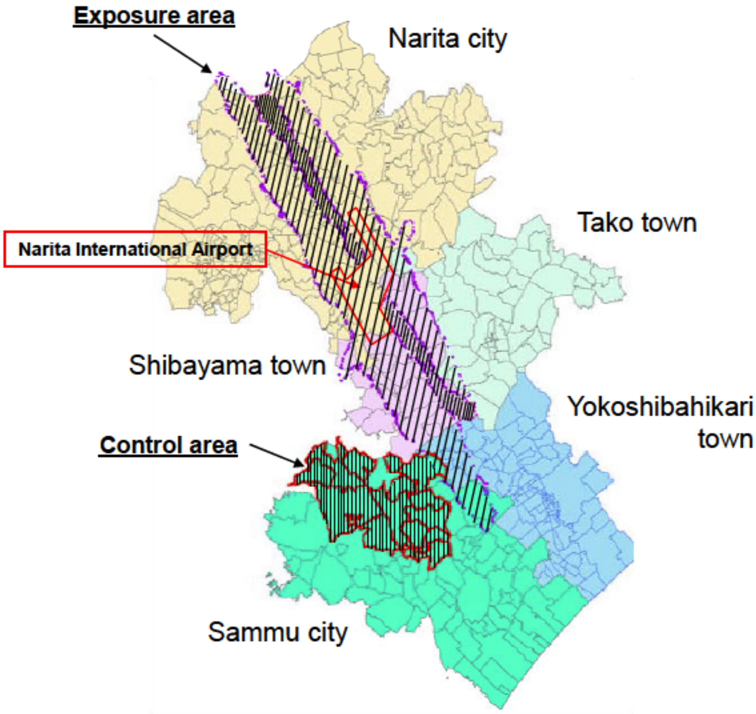



**Figure 2:** Cities and towns of questionnaire survey on health effect of aircraft noise

**Table 1:** The number of respondents in both exposure groups and control one

| $L_{den}$ | | $L_{Aeq,night(22-07)}$ | |
|---|---|---|---|
| Ctrl. | 624 | Ctrl. | 624 |
| 52-57 dB | 1,260 | 40-45 dB | 755 |
| 57-62 dB | 1,404 | 45-50 dB | 1,909 |
| 62-67 dB | 352 | 50-55 dB | 352 |
| 67- dB | 19 | 55- dB | 19 |

### Questionnaire and analysis method

The survey on health effects of aircraft noise for residents living around the airport was carried out by a postal questionnaire within two-and-a-half months. The questionnaire consisted of the Total Health Index (THI) questionnaire [5], a general questionnaire asking about living environment developed by INCE/Japan [6], questionnaire dedicated to sleep effects [7], important questions asking about noise sensitivity (WNS-6B) [8], information on individuals (sex, age, BMI (height and weight), systolic/diastolic blood pressure et al.) and house environment. Especially, THI questionnaire were used for investigating health effects of aircraft noise exposure in several surveys [9, 10].

Using THI questionnaire, physical and mental health was assessed in terms of 130 subjective symptoms summing-up to the following 12 scales: many Subjective symptoms (SUSY), Respiratory (RESP), Eye and skin (EYSK), Mouth and anal (MOUT), Digestive organ (DIGE) symptoms, Irritability (IMPU), Lie scale (LISC), Mental instability (MENT), Depression (DEPR), Aggression (AGGR), Nervousness (NERV) and Irregularity of life (LIFE). A response to each symptom was scored into 1, 2 or 3 points, and summed up by the above item groups for calculating scores of the above 12 scales. Moreover, the following 5 secondary scales were derived from these primary ones: psychosomatics (PSD), neurotics (NEURO), and schizophrenics (SCHZO) making use of 50 patients of the three diseases, and two additional scales, named T1 and T2. Where, the higher T1 score means the more physical and mental symptoms, and the higher and the lower T2 score indicates the more physical symptoms and the more mental distress, respectively. And then for the standardization we converted the score to a cumulated percentile of each scale based on the distribution of scores of middle-aged ca. ten thousand adult population supported by the authors of THI plus [11].

As for the questionnaire developed by INCE/J, we calculate the percentage of highly annoyed, disturbances of listening, conversation and sleep for aircraft noise in each exposure group and control one. Insomnia was estimated from response of several questions based on the International Classification of Sleep Disorder (ICSD), Diagnostic and Statistical Manual of Mental Disorders (DSM-5) and International Statistical Classification of Diseases and Related Health Problems (ICD-10). The respondents with the WNS-6B score of over 5 inclusive were determined as noise-sensitive.

In this study, in order to statistically analyze association between the above-mentioned items of health effect and aircraft noise, we used bivariate analysis, logistic regression analysis and Student’s t-test. In the first method, to examine the significant association between health impact and noise exposure, we used Fisher’s exact test and Mantel-Haensel chi-square test, and the second one is a general method to estimate health impact by means of odds ratio (OR) of high-risk group (i.e. high-risk approach). The last one is method to evaluate health impact of the entire group by using mean values (i.e. population approach). Because environmental stressor such as noise exposure might cause a variety of symptoms due to inter-individual difference, we applied the different statistical approaches to analyze physical and mental effect. In the high-risk approach, as to 12 primary and 2 secondary (T1 and T2) scales, we converted percentile scores to dichotomous variables, that is high score group and otherwise, based on 10 percentile values in each exposure group and the control one. As to other three secondary scales (PSD, NEURO and SCHIZO), we converted scale scores to dichotomous variables based on the criteria proposed by the authors of THI [5].

## RESULTS OF HEALTH EFFECTS

### Physical and mental effects

Between 311 respondents (8.5 %) and 434 ones (11.9 %) were classified as high score group in 12 primary and 2 secondary scales (T1 and T2). Each respondent of high score group in the other three scales (PSD, NEURO and SCHIZO) was 976 (26.7 %), 726 (19.8 %) and 1,300 (35.5%). The prevalence rates of high score group for SUSY (11.6 %) and RESP (10.8 %) in exposure area have statistically significant difference from those rates (9.3 % for SUSY and 8.3 % for RESP) in control one ($p<0.05$).

Table 2 shows the prevalence rate of high score group by noise exposure category for each physical and mental effect estimated by THI. This result indicated that aircraft noise exposure did not correlate with health effect ($p$=0.05), while the prevalence rates of high score group for SUSY and RESP seemed to increase with a raise in noise exposure level.

Table 3 shows significance probabilities of 12 primary and 5 secondary scales for physical and mental impact for independent variables, that is, noise exposure, sex, age-group and noise sensitivity. From these results, dose-response relationships between aircraft noise and THI scales were not found with the exception of EYSK, however, EYSK scale seemed to decrease with a rise of noise exposure level. Moreover, some of THI scales were related to sex and/or age-group.

**Table 2:** Prevalence rate of high score group by THI for physical and mental effect

| | THI scales | Noise exposure $L_{den}$ | | | | $Chi^{2}_{MH}$ | probability |
|---|---|---|---|---|---|---|---|
| | | Ctrl. | 52-57 dB | 57-62 dB | 62-67 dB | | |
| Physical effect | SUSY | 9.3 | 12.1 | 12.1 | 12.8 | 4.297 | 0.231 |
| | RESP | 8.3 | 11.3 | 10.9 | 13.6 | 7.218 | 0.065 |
| | EYSK | 9.0 | 9.9 | 8.7 | 8.2 | 1.625 | 0.654 |
| | MOUT | 9.8 | 10.1 | 9.9 | 9.4 | 0.165 | 0.983 |
| | DIGE | 8.5 | 9.9 | 9.8 | 9.4 | 1.092 | 0.779 |
| | PSD | 24.5 | 26.7 | 28.2 | 23.9 | 4.634 | 0.201 |
| Mental effect | LIFE | 9.9 | 11.6 | 13.0 | 12.2 | 3.986 | 0.263 |
| | MENT | 9.6 | 11.0 | 12.8 | 12.5 | 4.909 | 0.179 |
| | DEPR | 9.6 | 11.8 | 12.7 | 9.4 | 5.789 | 0.122 |
| | NEURO | 17.9 | 19.1 | 21.5 | 18.8 | 4.578 | 0.205 |
| | T1 | 9.1 | 10.3 | 10.6 | 10.8 | 1.167 | 0.761 |
| | IMPU | 9.3 | 9.7 | 10.3 | 7.7 | 3.353 | 0.740 |
| | NERV | 9.8 | 10.9 | 10.1 | 8.5 | 1.837 | 0.607 |
| | AGGR | 9.6 | 8.4 | 7.6 | 9.9 | 3.336 | 0.343 |
| | T2 | 9.6 | 9.2 | 8.3 | 10.8 | 2.423 | 0.489 |
| | LISC | 9.5 | 9.8 | 8.1 | 7.7 | 3.091 | 0.378 |
| | SCHIZO | 36.4 | 36.0 | 35.2 | 33.0 | 1.367 | 0.713 |

**Table 3:** Results of logistic analysis on both physical and mental effects by THI percentile scores

| | THI scales | Independent variables | | | |
|---|---|---|---|---|---|
| | | Noise exposure $L_{den}$ [Ctrl.] | Sex [Male] | Age-group [50's] | Noise sensitivity [non-sensitive] |
| Physical effect | SUSY | 0.443 | 0.199 | 0.000 *** (-) | 0.000 *** (+) |
| | RESP | 0.487 | 0.000 *** (+) | 0.005 ** (-) | 0.000 *** (+) |
| | EYSK | 0.042 * (-) | 0.002 ** (+) | 0.000 *** (-) | 0.000 *** (+) |
| | MOUT | 0.660 | 0.265 | 0.090 | 0.000 *** (+) |
| | DIGE | 0.535 | 0.000 *** (+) | 0.000 *** (-) | 0.000 *** (+) |
| | PSD | 0.331 | 0.000 *** (+) | 0.675 | 0.000 *** (+) |
| Mental effect | LIFE | 0.477 | 0.000 *** (-) | 0.000 *** (-) | 0.000 *** (+) |
| | MENT | 0.558 | 0.502 | 0.000 *** (-) | 0.000 *** (+) |
| | DEPR | 0.824 | 0.993 | 0.000 *** (-) | 0.000 *** (+) |
| | NEURO | 0.451 | 0.000 *** (+) | 0.000 *** (-) | 0.000 *** (+) |
| | T1 | 0.964 | 0.236 | 0.000 *** (-) | 0.000 *** (+) |
| | IMPU | 0.547 | 0.724 | 0.000 *** (-) | 0.000 *** (+) |
| | NERV | 0.618 | 0.965 | 0.046 * (+) | 0.000 *** (+) |
| | AGGR | 0.804 | 0.702 | 0.078 | 0.000 *** (-) |
| | T2 | 0.661 | 0.021 ** (+) | 0.321 | 0.777 |
| | LISC | 0.548 | 0.143 | 0.000 *** (+) | 0.000 *** (-) |
| | SCHIZO | 0.455 | 0.240 | 0.000 *** (+) | 0.000 *** (-) |

Note: *$p$<0.05, **$p$<0.01, ***$p$<0.001, where $p$-value indicates the significance probability of logistic analysis. (+)/(-) signs show OR increase/decrease by a rise of the independent variable. The variable in square bracket mean reference category.

As for physical effect, comparisons of averaged THI percentile score among exposure groups and control one are shown in Figure 3, and similar comparisons for those of mental effect and others are shown in Figure 4. In these figure, *p*-values manifested by asterisk symbols were significance differences obtained by applying Student's t-test as statistical test. As shown in Figure 3, the averaged THI percentile scores for physical effect were not found to be associated with aircraft noise exposure same as the results of the other analysis. Only a percentile scale of SUSY in the group of 57-62 dB for female was statistically different from that of control one. On the other hand, Figure 4 shows that some of the averaged THI percentile scores for mental effect were different from those of control group, while remarkable dose-response relationships were not found.

Figure 5 demonstrates the distribution of self-reported systolic/diastolic blood pressures as function of age-group. Both systolic and diastolic blood pressure increased by age gradually and mean value of blood pressure in each age-group was different each other. On the basis of mean value of average blood pressure between systolic and diastolic ones by age-group, we converted individual value of average blood pressure to dichotomous variables in each age-group. And then, logistic regression models were used to analyze the relationships between aircraft noise exposure $L_{den}$ and relatively high blood pressure. Figure 6 shows OR of relatively high blood pressure by noise exposure and significance probabilities for independent variables, that is, noise exposure, sex, age-group, noise sensitivity and degrees of obesity classified by body mass index (BMI). The result of logistic analysis indicated that average blood pressure did not have association with noise exposure but rather increase with raising degree of obesity. Moreover, as to each one of systolic/diastolic blood pressure, OR of relatively high blood pressure classified by the same manner responded in similar way to average blood pressure as shown in Figure 6.

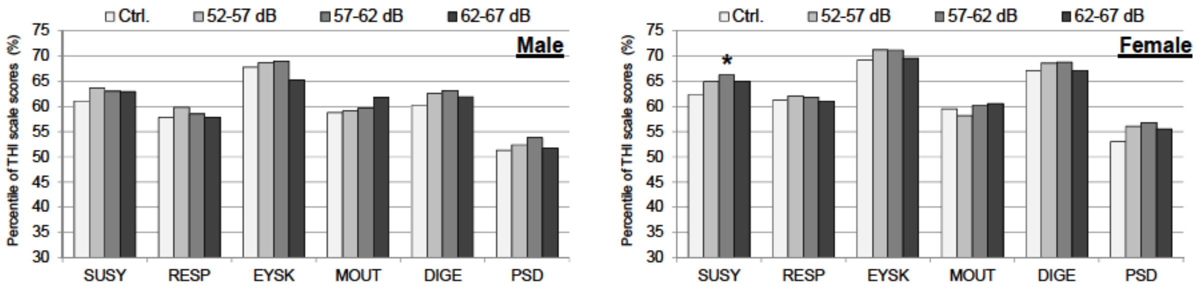



**Figure 3:** Comparisons of averaged THI percentile score on physical effect among exposure groups and control one (**p*<0.05, ***p*<0.01, ****p*<0.001)

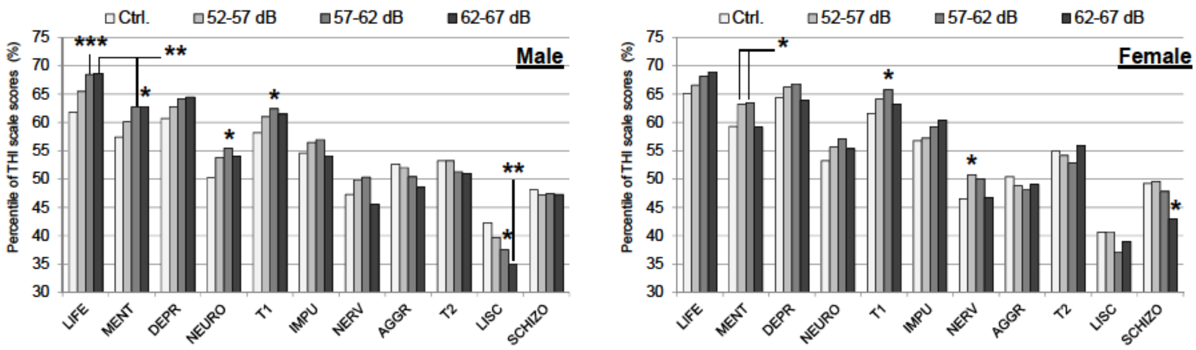
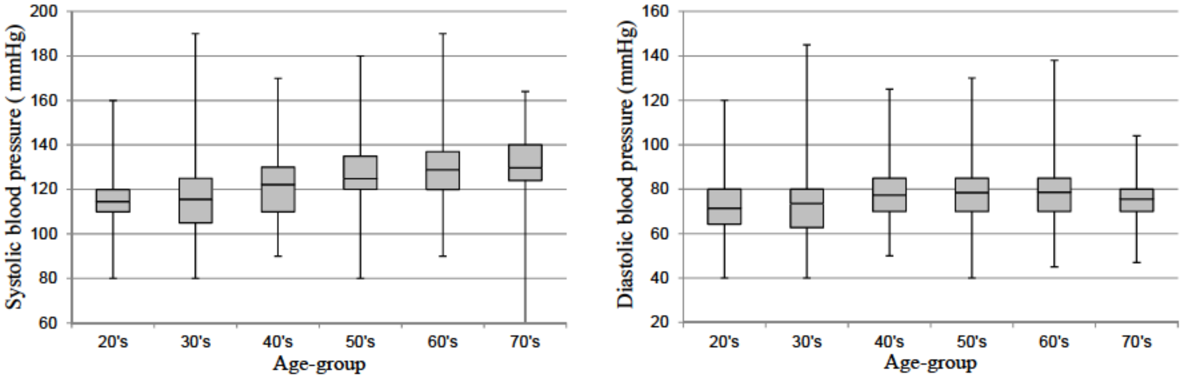
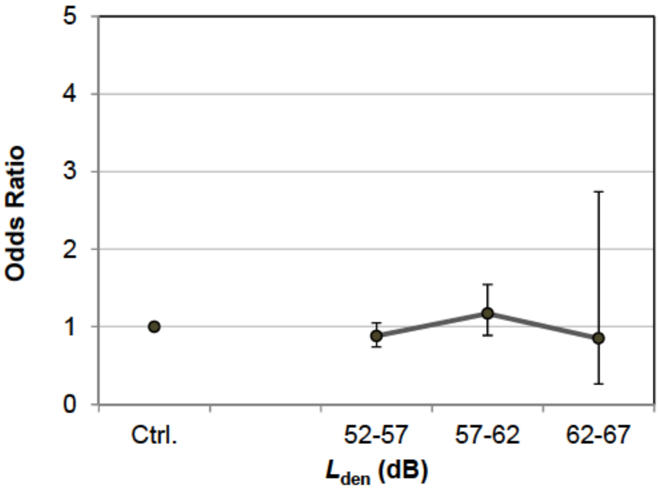



**Figure 4:** Comparisons of averaged THI percentile score on mental effect among exposure groups and control one (**p*<0.05, ***p*<0.01, ****p*<0.001)




Note: The box shows 25, 50, 75 percentiles, and whisker plots are maximum and minimum values.

**Figure 5:** Distribution of self-reported systolic/diastolic blood pressures as functions of age-group




| Independent variables | Significance probability |
|---|---|
| Noise exposure ( $L_{den}$ ) | 0.209 |
| Sex | 0.000 *** (-) |
| Age-group | 0.278 |
| Noise sensitivity | 0.110 |
| Degree of obesity ( BMI ) | 0.000 *** (+) |

***: no more than significant level of 0.1%
(+)/(-) signs mean the gradient of OR.

Note: The table shows significance probabilities analyzed by logistic regression.

**Figure 6:** Odds ratios and 95 % confidence intervals of relatively high blood pressure *vs*. aircraft noise exposure by $L_{den}$

## Discussions

Firstly, from the results of high-risk approach (bivariate analysis and logistic regression analysis), it was a finding that the relationship between physical/mental effect which was assessed by THI questionnaire and aircraft noise exposure was modified by noise sensitivity, age-group and sex. The associations between SUSY/RESP and aircraft noise exposure disappeared after statistical adjustment of noise sensitivity, age-group and sex, however there is statistically significant difference of the prevalence rates for these two THI scales in between exposure and control area.

Table 4 shows the brief results of both bivariate analysis (chi-squared test) and logistic regression analysis for highly annoyed and insomnia. As for Noise annoyance, that is the most frequent response to environmental noise, the strong relationships were found between aircraft noise exposure $L_{den}$ and noise annoyance. On the other hand, it was found that insomnia was associated with night-time noise exposure $L_{Aeq,night(22\text{-}07)}$ of aircraft, however insomnia had weak associations with noise exposure compared to those of noise annoyance. Especially, Table 4 indicates that ORs of insomnia were statistically significant not for night-time noise exposure but rather for being sensitive to noise [12].

It was reported that the amount of variance in noise-induced sleep disturbance due to inter-individual difference that could not explained by age and gender (sex) was very wide [13]. Since various symptoms caused by noise exposure of aircraft varied due to inter-individual difference more widely, it might be resulted that physical and mental impacts were not correlated with airport noise exposure but rather closely associated with noise sensitivity.

Secondly, as for the results of population approach, the averaged THI percentile scores for physical effect were not found to be associated with aircraft noise exposure except as resulted in SUSY of 57-62 dB for female, while on the other hand, some of the averaged THI percentile scores for mental effect were different from those of control group. Considering the fact that environmental stressor causes various symptoms due to inter-individual difference, some of THI scales which differed from those of control group statistically regardless of sex might be regarded as a sign of mental effect. By thinking about physical impact in the same way, the associations between physical effect and aircraft noise exposure were not found in both high-risk approach and population approach.

Finally, as to self-reported blood pressure, blood pressure did not have association with aircraft noise exposure but rather increase with raising degree of obesity, regardless of difference in the classification. Moreover, blood pressures for male seemed to be higher than those for female as shown in Figure 6, and this result also agreed with a general trend on high-blood pressure in Japan [14].

**Table 4:** Results of chi-square-test and logistic analysis for highly annoyed and insomnia

Prevalence rate of highly annoyed and insomnia (chi-square-test)

| | Noise exposure | | | | $Chi^2_{MH}$ | probability |
|---|---|---|---|---|---|---|
| | Ctrl. | Zone 1 | Zone 2 | Zone 3 | | |
| highly annoyed | 3.1 | 22.6 | 34.6 | 43.1 | 270.676 | 0.000 *** (+) |
| insomnia | 13.7 | 33.8 | 40.3 | 12.1 | 11.630 | 0.009 ** (+) |

Note: **p*<0.05, ***p*<0.01, ****p*<0.001, where *p*-value indicates the significance probability of chi-square-test. Zone 1 to 3 means $L_{den}$ 52-57 dB, 57-62 dB, 62-67 dB for highly annoyed, and $L_{night(22\text{-}07)}$ 40-45 dB, 45-50 dB, 50-55 dB for insomnia. (+)/(-) signs show the gradient of OR.

Probability of each factor for highly annoyed and insomnia (logistic analysis)

| | Independent variables | | | |
|---|---|---|---|---|
| | Noise exposure | Sex | Age-group | Noise sensitivity |
| highly annoyed | 0.000 *** (+) | 0.725 | 0.003 *** (+) | 0.000 *** (+) |
| insomnia | 0.028 * (+) | 0.552 | 0.508 | 0.000 *** (+) |

Note: **p*<0.05, ***p*<0.01, ****p*<0.001, where *p*-value indicates the significance probability of logistic analysis. (+)/(-) signs show the gradient of OR. Noise exposure means $L_{den}$ for highly annoyed, and $L_{Aeq,night(22\text{-}07)}$ for insomnia.

## CONCLUSIONS

A questionnaire survey on health effects of aircraft noise, based on the agreement for conditional relaxation of curfew (23:00-6:00) at the meeting of Narita Airport and Community Council, was performed by the Narita International Airport Corporation (NAA) for residents living in the vicinity of Narita International Airport. In order to investigate various health effects, that is, noise annoyance, insomnia, and physical/mental effects, we used the questionnaire which consisted of both Total Health Index (THI) questionnaire constructed from 130 self-rating questions asking perceived health and a general questionnaire asking about living environment and sleep impact. In this paper, we particularly focused on the results of physical and mental effect of aircraft noise. In order to statistically analyze association between the above-mentioned items of health effect and aircraft noise, we used three different statistical approaches, that is, bivariate analysis, logistic regression analysis (high-risk approach) and Student’s t-test (population approach). From the results of both high-risk and population approaches, the associations between physical effect and aircraft noise exposure were not found. On the other hand, we concluded that some of THI mental scales might be regarded as a sign of mental effect, while dose-response relationships with aircraft noise exposure were not found. From a public health perspective, it must be continued to watch the situation of nighttime aircraft operations and also to carry out similar surveys on health effects of aircraft noise continuously.

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