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A SURVEY ON HEALTH EFFECTS DUE TO AIRCRAFT NOISE ON RESIDENTS LIVING AROUND KADENA AIR BASE IN THE RYUKYUS

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Results are reported of a questionnaire survey relating to a scale for general health, the Todai Health Index, in a town, bordering on a large U.S. airbase in the Ryukyus. The level of aircraft noise exposure, in the town, expressed by WECPNL, ranges from 75 to 95 or more. The sample size was 1200, including a 200 person "control" group. Results of the analysis of the responses in terms of the noise exposure suggest that the exposed residents suffer psychosomatic effects, especially perceived psychological disorders, due to the noise exposure to military aircraft, and that such responses increase with the level of noise exposure.

1. INTRODUCTION

In the years after World War II, U.S. forces have used a large portion of Okinawa Island for military purposes, over 20% as of the summer of 1996. Accordingly, many Okinawans have been compelled to live in the vicinity of military bases and suffer from different, innumerable fallouts from the base. One of the fallouts is the intense noise from the aircraft operating at all hours of the day and night.

Having landed on the west coast of Okinawa Island on April 1, 1945, U.S. forces started using Kadena airfield, which the Japanese army had constructed in the middle of Okinawa Island, as an air base, first to attack Japanese cities by air during World War II. Through the periods of the Korean and Vietnam wars, it was expanded and enhanced to make the largest U.S. air base in the West Pacific and Far East. One can easily imagine how serious the noise exposure around the airport has been and that it may cause potential health effects on the inhabitants in its vicinity.

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This is the report of a questionnaire survey relating to general health in a town neighbouring the air base.

2. NOISE EXPOSURE

Occasional measurements of noise exposure by the local authority were undertaken during the American occupation of the Ryukyus which terminated on May 15, 1972. A reliable record [1] of measurement of the noise exposure is that conducted by the Defence Facilities Administration Agency (DFAA) from November 1972, just after the retrocession of Okinawa, the Ryukyus, to Japan, when Vietnam war was at its fiercest stage. Table 1 shows the disclosed records of measurements from Yara in Kadena Village and at Sunabe in Chatan Village in the vicinity of the airport during the period from November 1972 to March 1973. Note that the measurement sites were not directly under the paths for landing and taking-off but at the sides of runways and that the noise sources were engine testing without a silencer, warming up and taxiing operated at the distance of 150 m from the local residences. The flyover noises, they say, were comparatively less intense. In the table are shown the average time in seconds exceeding 90 dB(A) per day and the monthly maximum sound level observed during the five months. One can see from the table the tremendous level of noise exposure. The Yara measurements show the maximum level of 127 dB(A) and the average time exceeding 90 dB(A) of 2869 seconds a day over five months including Sundays, holidays and Christmas. Local newspapers used to call the noise "murderous."

Yara is not forest or rice fields but a residential area with a town office, a school, a kindergarten, a church, restaurants and so forth. The villages became townships in 1976 and 1980. Residents of a town such as Kadena Township, over 85% of whose area had been acquired against their will, had no other choice than to stay in Yara, however unacceptable the environmental conditions may have been. The case is basically the same in Sunabe, which is near the southwest edge of a runway, opposite to Yara with respect to runways. This is the acoustic environment the residents around the air base have more or less suffered from in the last half century.

TABLE 1

Record of noise measurement at (A) *Yara, Kadena Village, and* (B) *Sunabe, Chatan Village, conducted by the Defence Facilities Administration Agency*

		1972		1973			
(A)Yara, Kadena Village		Nov.	Dec.	Jan.	Feb.	March	Average
Maximum sound level,	dB(A)	118	123	127	126	118	–
Average time in	> 100 dB(A)	465	575	560	320	475	479
seconds observed	95–99 dB(A)	775	950	765	795	770	811
in a day	90–94 dB(A)	1465	1575	1405	1565	1885	1579
Monthly average time in seconds a day exceeding	90 dB(A)	2705	3100	2730	2680	3130	2869
(B) Sunabe, Chatan Village							
Maximum sound level,	dB(A)	124	120	120	120	122	–
Average time in	> 100 dB(A)	345	300	325	410	450	365
seconds observed	95–99 dB(A)	595	585	595	455	525	550
in a day	90–94 dB(A)	990	1190	990	830	850	970
Monthly average time in seconds a day exceeding	90 dB(A)	1930	2075	1910	1695	1825	1885

In 1978 the local authority of Okinawa Prefecture conducted measurements of sound levels at Sunabe and counted the average number of events of over 70 dB(A) a day to be 592 [2]. Another measurement was undertaken during that year by a consultant [3] for the Defence Facilities Administration Agency, who counted the number of daily flyovers to be 378 on average and 546 at maximum. The agency estimates the total number of landings and taking-offs undertaken in Kadena Base to be 98 505 in 1991 and the average daily events to be 270.

Operation at night and early morning is also a hazard to the vicinity. The maximum number of events observed from 00:00 to 07:00 at Sunabe was 123 and the average was ten during the fiscal years from 1987 to 1991 [4]. Needless to say, the military flights are irregular with a variety of operations, such as touch-and-go operations and flight-pass operations, which cause the residents fear, anxiety and annoyance.

3. WECPNL

The Japanese EPA sets the environmental standard for aircraft noise around commercial airports using the rating scale of a simplified version of WECPNL (Weighted Equivalent Continuous Perceived Noise Level). It is 70 or 75 according to the type of area: $\text{WECPNL} = L_A + 10 \log N - 27$, where L_A(dB(A)) denotes the energy mean of all peak levels of any one day, and N is the value obtained from the equation $N = N_2 + 3N_3 + 10(N_1 + N_4)$, where N_1 is the number of aircraft between 00:00 and 07:00, N_2 the number between 10:00 and 12:00, N_3 the number between 19:00 and 22:00, and N_4 the number between 22:00 and 24:00.

For the noise exposure around the military airport—where the number of events changes a great deal from day to day—the DFAA notes that the number of aircraft should be represented by the number of flyovers per day equaled or exceeded by the number of flyovers 10% of the day in a year [5]. The representation is based on research reported by Kimura *et al*. [6] in which they compared community responses around commercial airports with those around military airports and found that the responses were equivalent when the number of flyovers around military airports are represented as above.

The Defence Force Administration Agency [7] notifies areas in which compensation is made to the inhabitants for soundproofing the houses around the airport. Since the location of the area is determined according to the level of noise exposure on the basis of the measurement of aircraft noise [3], the value of WECPNL of a particular place can be estimated in the area. In Chatan, WECPNL, as notified by the DFAA, ranges from 75 to 95 or more over the entire area, which exceeds the environmental standards for aircraft noise set by the Japanese EPA.

4. MATERIALS AND METHODS

4.1. METHOD AND QUESTIONNAIRE

The survey was undertaken by means of a leave-and-pick-up questionnaire method in Chatan. The questionnaire used in the present investigation is the Todai Health Index (THI) developed by workers of the University of Tokyo (“Todai” in Japanese) in 1974 [8] for the purpose of supplementing the Cornell Medical Index–Health Questionnaire. It consists of 130 questions regarding subjective symptoms, mental health, habits, and so forth. The THI has 12 scale scores constructed on the basis of the results of factor analysis of 191 items, and it has three discriminant function values for estimating tendencies toward neurosis, psychosomatic disease [9] and schizophrenia [10]. In this paper, 12 scale scores and two discriminant function values, PSD and NEURO, are calculated in the way indicated by the developers of the THI. These are tabulated in Table 2.

The questionnaire used by the present authors includes four additional questions, besides the original 130 ones, concerned with hearing loss, health perceptions, occasion of physical exercise and death of a family member.

4.2. SUBJECTS

Inhabitants of Chatan were stratified into five groups according to the level of noise exposure expressed in WECPNL from 75–79, 80–84, 85–89, 90–94 and over 95. One hundred males and 100 females aged over 20 years were sampled from the pollbook of each group by stratified random sampling. As a non-noise-exposed "control" group, another 200 male and female subjects were sampled from Kitanakagusuku Village neighbouring Chatan Town, located in the opposite direction from the airport. The total sample size was thus 1200. The present authors name the groups stratified according to the value of WECPNL as Group 75 and the like in the following paragraphs.

To avoid the possible bias introduced by the tendency of the answers toward showing the effect of noise in the case that the respondents had been aware of the purpose of the survey, neither the respondents nor the deliverers were given any additional information than that the survey was undertaken for the purpose of obtaining information for controlling the general health of the community.

5. RESULTS AND DISCUSSION

One thousand and fifty three persons answered the survey, which was 87·8% of the subjects. The number fell to 830, 415 males and 415 females, since respondents who did not answer one or more items used to calculate the scale scores are omitted in the following analysis.

5.1. SCALE SCORES AND DISCRIMINANT FUNCTION VALUES

Significant differences were found between the noise-exposed groups and the control group in the mean values of some scale scores and discriminant function values. These are related to mental complaints, MENT, DEPR, NERV, LIFE, PSD, NEURO, as shown in Table 3. One or more noise-exposed groups showed significantly higher mean values in the scale scores and discriminant function values. In the table are tabulated as examples the Group 75–95, the noise-exposed group, and Group 95, the highest noise-exposed group with the level of significance.

The scales and functions listed in Table 3 are the aspects of noise effects on human beings generally pointed out by many workers. In that sense the list is reasonable. However, in the report [11] of the survey conducted by Higashitani around the Osaka International Airport, Japan, she found that scale scores for vague complaints, impulsiveness, and mental instability increased as WECPNL increased and that discriminant function values of PSD and NEURO showed little difference among the groups of different levels of noise exposure. In the survey, she delivered the THI questionnaire to 2030 housewives, who were classified into three groups according to the level of noise exposure expressed in WECPNL, 70, 80 and 90. Taniguchi [12] compared the scale scores and discriminant function values obtained from 100 pairs, a pair consisting of one from the exposed group and one from the control, who were male, and 80 pairs of females under 60 years of age living around Komatsu Airport, which is used for both commercial and military purposes. He found significant differences in the scale score of SUSY and discriminant function values of PSD for males, and in the scale scores of SUSY and MENT and discriminant function

TABLE 2

Scales and discriminants to be calculated

SUSY: Many subjective symptoms	MENT: Mental instability	RESP: Complaints reg. respiratory organs
DEPR: Depressiveness	EYSK: Complaints reg. eyes and skin	AGGR: Aggressiveness
MOUT: Complaints reg. mouth and evacuation	NERV: Nervousness	DIGE: Complaints reg. digestive organs
LIFE: Irregularity of daily life	IMPU: Impulsiveness	PSD: Psychosomatic disease
LISC: Lie scale	NEURO: Neurosis	

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TABLE 3

Scales and discriminants for which significant difference is detected

Scale and Discriminant	Stratified group	Significance level
IMPU	Control *vs*. Group 95	0·10
DEPR	Control *vs*. Group 75–95†	0·05
	Control *vs*. Group 95	0·10
NERV	Control *vs*. Group 75–95	0·05
	Control *vs*. Group 95	0·10
LIFE	Control *vs*. Group 75–95	0·10
PSD	Control *vs*. Group 75–95	0·10
	Control *vs*. Group 95	0·10
NEURO	Control *vs*. Group 75–95	0·05
	Control *vs*. Group 95	0·05

† Pooled Groups of WECPNL = 75, 80, 85, 90 and 95.

values of PSD and NEURO for females between the noise-exposed group and the control. Ogawa *et al*. [13] carried out a THI Questionnaire survey in Maebashi, Japan, and reported that the percentage of highly annoyed decreased as the sound level of road traffic noise decreased and that annoyance responses were closely related to all the 12 scale scores in the THI.

The results of the previous studies on noise and THI reported by workers are not the same as each other nor the study presented here.

5.2. RESPONSE ON HEARING LOSS AND HEALTH

Among 89 females in Group 95, 24 persons answered "yes" to the question "Are you hard of hearing?" The rate of "yes" responses was significantly higher than that among the controls, in which five among 87 females answered "yes" to the question. Although further investigation on hearing loss, including an actual hearing test is needed before a definite conclusion, females who spend most of their time in the household and the neighbourhood could have suffered from the noise exposure most and, as a result, have noise-induced hearing loss.

Among the 80 males in Group 95, 17 persons answered "no" to the question "Do you think you are healthy?" In the control group, eight among 83 answered "no" to this question.

5.3. DOSE–RESPONSE RELATIONSHIP

Clear dose–response relationships were not found between scale scores and noise exposure nor between discriminant function and noise exposure in the range of WECPNL from 75–94. Figure 1 shows as an example the discriminant values as a function of noise exposure in the form of box and whisker plots. The whiskers and boxes indicate the range and the quartiles of the distribution, respectively. The bar in the middle indicates the median. The upper parts of the figure plot the values against WECPNL in five-unit steps. In the lower part, Group 75, Group 80, Group 85 and Group 90 are pooled into one group, Group 75–90, and plotted as such, where a steady increase of the value is found.

It is not clear why a steady dose–response relationship is not found for the scale scores and WECPNL in five-unit steps. Some possible factors are the sample size not being large enough to reveal the difference, uncertainty of noise exposure the subjects had and errors in the survey. The possibility cannot be rejected, of course, that the response is in reality unproportional to the noise exposure. The present authors, however, consider this

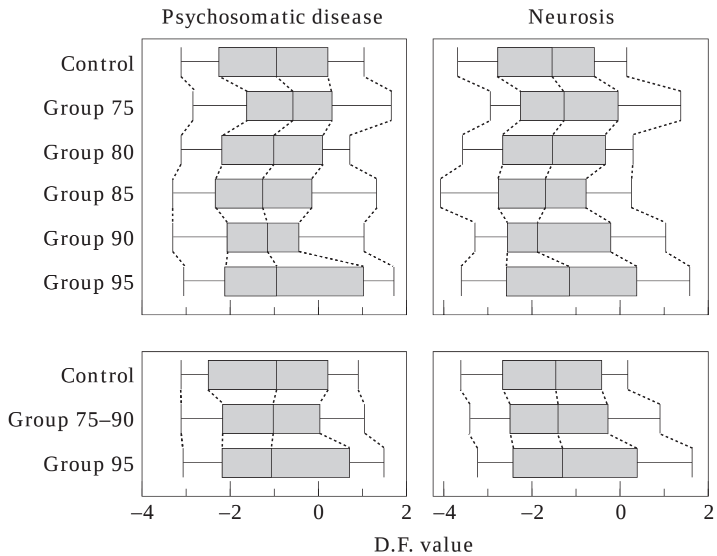

Figure 1. Discriminant function (D.F.) values of male subjects as a function of noise exposure. The whiskers and boxes indicate the range and the quartiles of the distribution of values, respectively. The vertical bar in the middle indicates the median. Groups 75, 80, 85, 90 and 95 indicate the groups of subjects with a WECPNL noise exposure from 75–79, 80–84, 85–89, 90–94 and over 95 inclusive, respectively. In the lower part of the figure the former four groups are pooled into one group, Group 75–90.

possibility to be low as the difference between the noise-exposed groups and the control group is highly significant.

In Figure 2, the cumulative percents of the respondents are illustrated as functions of the scale scores, MENT and DEPR, and a discriminant function value NEURO for different female and male groups of Group 95, Group 75–90 and the control. From the figure one can see that the response increases as dose expressed by WECPNL becomes higher.

5.4. FACTOR ANALYSIS

Factor analysis, principal factor method with varimax rotation, was carried out using the 12 scale scores given to all the respondents, and two factors were extracted. The first factor consists of the scales of SUSY, RESP, EYSK, MOUT, DIGE and LIFE, and the second the scales of IMPU, MENT, DEPR and NERV. The first factor is interpreted as the factor of perceived somatic diseases related to the autonomic nervous system derived from the old cerebral cortex. The second factor is interpreted as the factor of perceived mental diseases related to the higher nervous system derived from the new cerebral cortex.

Analysis of variance was carried out with respect to the means of the factor scores between the three groups, Group 95, Group 75–90 and the control. The results of ANOVA indicate that a significant difference was found among the means of scores of the second factor, with the significance level of 0·05. This suggests that the effect of aircraft noise appears more clearly in the factor of perceived mental diseases.

5.5. MULTIPLE REGRESSION ANALYSIS

Multiple regression analysis was carried out with scale scores and discriminant function values as dependent variables, and marital condition, type of house, sex, length of residence, age and WECPNL as explanatory variables. Except for the scales of SUSY, EYSK and MOUT, the regressions of scale scores and discriminant function values to one or more explanatory variables were found significant. Scales and discriminant functions that are regressible to WECPNL are tabulated in Table 4, which shows the normalized value of regression coefficient and alpha (α) value which is the upper probability of t-distribution. From the table, one can see that a tendency toward neurosis is strongly influenced by noise exposure, particularly in the case of females. Mental instability, depressiveness, nervousness and psychosomatic disease are significantly influenced by the intense noise exposure. The results found in the analysis agree with what was discussed above.

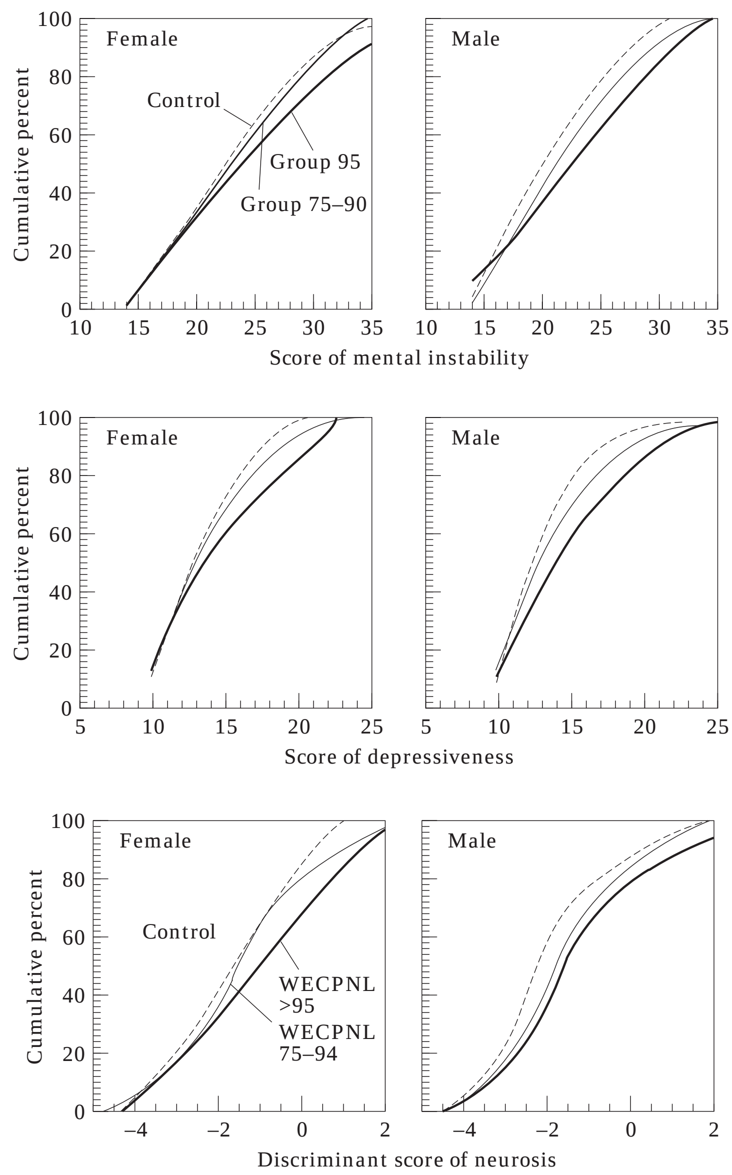

Figure 2. Cumulative frequency curves of respondents in different groups as a function of scale scores for mental instability and depressiveness, and a discriminant function (D.F.) value for neurosis.

TABLE 4

Multiple regression analysis

Scale/D.F.	Explanatory variable	Normalized regression coefficient	α
INPU	Female	0·130	0·001
	WECPNL 95	0·114	0·018
DEPR	Wood & bricks	0·067	0·076
	WECPNL 95	0·138	0·004
NERV	WECPNL 95	0·083	0·088
PSD	Female	0·183	0·000
	Length of residence	−0·080	0·071
	WECPNL 95	0·090	0·059
NEURO	Female	0·089	0·019
	WECPNL 75–90†	0·084	0·090
	WECPNL 95	0·152	0·002

† Pooled Groups of WECPNL 75–90.

5.6. RADAR CHART

The scores described above are normalized by means of the following equation and are illustrated as radar charts in Figure 3: $Z = (X - Y)/S$, where X is the mean of scale score, discriminant function value or factor score of the noise-exposed groups, Y that of the control and S the standard deviation of the scores of the control. The inner and outer circles have radii of $Z = -0{\cdot}5$ and $0{\cdot}5$, respectively.

The zero value of the normalized score, Z, indicates that the average score for the group is equal to that for the control group. The value of 0·5 means the average score of the group deviates from that of the control at a distance of half of the standard deviation of the control group. In the figure, it can be seen that significant differences in the scores among the groups are found in the scales NEURO, PSD, DEPR, MENT and NERV and that the scores increase as the noise exposure becomes more intense. In the case of males, the Z value of the scale of aggressiveness implies extroversion and a positive attitude toward life. The decrease of the Z value of aggressiveness with the increase of the level of noise suggests, therefore, the influence of noise on mental activity. The figure also shows

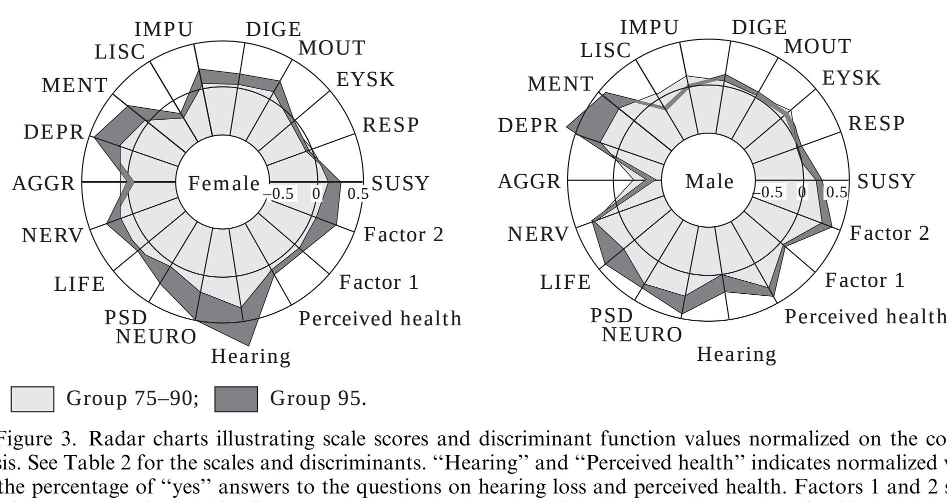

Figure 3. Radar charts illustrating scale scores and discriminant function values normalized on the control basis. See Table 2 for the scales and discriminants. ''Hearing'' and ''Perceived health'' indicates normalized value of the percentage of ''yes'' answers to the questions on hearing loss and perceived health. Factors 1 and 2 show the factor scores obtained by factor analysis. Groups 75–90 and 95 indicate the groups of subjects with noise exposure of WECPNL from 75–94 and over 95 inclusive, respectively.

values obtained by factor analysis and those given for the answers to the questions on hearing loss and perceived health.

6. CONCLUSIONS

Results of a questionnaire survey carried out on general health in a town neighbouring a large U.S. airbase in the Ryukyus, using the Todai Health Index, suggest that the residents of the town suffer from psychosomatic effects, especially perceived mental disease, due to the noise exposure to military aircraft and that such responses increase with the level of noise exposure.

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