



## ARTICLE

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## Effect of low frequency noise on the echocardiographic parameter E/A ratio

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## Abstract

The hearing condition of the Taiwanese aerospace maintenance workers affected by the low frequency noise had not been reported. The purpose of this research is to clarify the maintenance workers' health effect when exposed to low frequency and/or general noises and to understand the relationship between the variations of the worker's echocardiographic E/A ratio and the low frequency noise. The low frequency noise monitoring and echocardiographic E/A ratio results obtained for 213 aerospace maintenance workers indicated that the workers' hearing loss was more serious at high frequency 4k and 6k when exposed to the low frequency noise and could be more than 40 dB. The abnormality of echocardiographic E/A ratio was also higher than that of control group.

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## Full Text

### Introduction

Industrial noise has various effects on human psychological as well as physical health, and the frequency of the noise plays a vital role. [1] Taiwan's Environmental Protection Agency defines low frequency noise in the range from 20 Hz to 200 Hz. In general, a noise with the frequency less than 20 Hz is called infrasound. It may not be easy to detect, but it does exist in our living environment and may impose adverse effects on our health. Low frequency noise is not as "allergic" to human ears as high frequency noise. [2] In Taiwan, the effect of noise on the human hearing condition (such as hearing loss) has been investigated extensively. However, the studies on the effect of low frequency noise on human non-hearing conditions such as cardiac status were not found. Echocardiography has been used in clinical medicines since 1960. [3] Castelo Branco applied echocardiography to assess vibroacoustic disease (VAD). [4] Currently, echocardiography is the best choice to assess the diastolic function of the left ventricle (LV), and many parameters of this method have been developed to assess the LV function. One of the parameters is the transmitral flow velocity, which is fairly easy to obtain and can detect the thicken conditions of LV and pericardium. Echocardiography is a cardiac non-invasive inspection method. [5]

Foreign researchers indicated that long term exposure (10 years) to low frequency noise (LFN) (<500 Hz) resulted in VAD, 1 and it was found in 140 aeronautical technicians. [6] Literature showed that the pericardia of VAD patients were thickened. However, VAD patients did not display any inflammatory process. Marciniak et al. [7] used echocardiography to detect VAD among workers exposed to LFN and mentioned a remarkable difference in the E/A ratio between the group exposed to LFN and the control group. However, the E/A ratio fell within the normal range. Currently, echocardiography is effectively used to detect LV diastolic function. [8] For example, information on LV filling speed E wave during early diastole and the A wave blood in later diastole allows an accurate calculation of the E/A ratio, [9] which contributes to the evaluation of pericardium-related problems.

Moller classified abnormal LV diastolic function into three grades of E/A ratio: 1) first grade - abnormality of "impaired relaxation," E/A ratio < 0.75 with the characteristics of a descending E wave and an ascending A wave; 2) second grade - abnormality of "impaired relaxation," LV pressure increases with the characteristics of a falsely normal E/A ratio; 3) third grade - restrictive abnormal, with E wave rapidly ascending and E/A ratio < 1.5. [5] In general, in the early stage of abnormal LV function, mitral valve (MV) blood speed reveals an E wave smaller than the A wave (E/A reverse). When the diastolic function continues to deteriorate, the E/A ratio will again return to its normal value (1 ~ 1.5). This is called pseudo-normalization and can ultimately become a restrictive transmitral filling pattern with E/A ratio > 2. Other authors, Leong et al. classified abnormal LV diastolic function into four categories: First grade with E/A ratio < 1 ; second grade with E/A ratio between 1 and 1.5 2 ; third grade with E/A ratio > 2 3 ; and fourth grade with E/A ratio greater than 2.5. [10]

This research assesses the effects of exposure to aerospace low frequency noise and general noise on workers' cardiac and hearing functions by using environmental and biological monitoring methods. Environmental monitoring methods were used to assess the low frequency noise in the aerospace work environments; biological monitoring methods were used to check workers' health condition and included the evaluation of hearing function and echocardiography check-ups.

## Methods

### Study groups

213 male aerospace maintenance personnel were chosen to receive the evaluations and were divided into three groups depending on noise exposure: The first group consisted of workers exposed to LFN (n = 64); the second group consisted of workers exposed to general noise (GN) group (n = 89); the third group was the control group (n = 60).

### Evaluation of working environment

The procedure of evaluating the work environment included:

Determination of the source noise: Sampling the noise in the aircraft maintenance work sites with a sampling height of 1.2 ~ 1.5 m, and all the noise data were taken every 3-5 meters, at least 3 times. A sound level meter, Type SVAN-945A, with Real time 1/1 octave band analyzer and statistical analysis was used to monitor the noise. The frequency ranged between 16 Hz to 20 kHz. Both A and C weightings were simultaneously used to detect the dosage of the low frequency noise in the aerospace maintenance work environment.

### Biological monitoring

Hearing evaluation: Pure-tone audiometry was used to detect the dosage of noise at frequencies 500, 1k, 2k, 3k, 4k, and 6k Hz. Hearing evaluation was performed in a closed room, and the background noise was lower than 40 dBA. Echocardiography inspection An echocardiography unit, Type SONOS-5500 PHILIPS, was used to evaluate the heart condition of the study groups. Statistical Analysis SPSS statistical software was used to analyze the data. The methods employed in this research include general descriptive statistics, ANOVA, and chi-square test.

## Results

## Basic information

4 LFN personnel were younger than the other two groups while the average ages between the GN and control groups were not statistically different. Regarding the years of work, the GN group had the longest working years (18 years) while the LFN and control groups had about 12-13 working years.

## Working environment noise

After conducting the walk-through survey, the noise sources for the LFN group were determined to be associated with generator maintenance and power inspections. The peak, maximum, minimum SPL and Leq value of the LFN, GN, and control groups are shown in [Table 1]. The average noise dosage in the LFN area was (Leq) 98 dBA, with maximum noise dosage at 109 dBA and minimum noise dosage at 41.9 dBA. The SPL within the frequency range 20 Hz and 500 Hz was 96.0 dBLin 5. However, in the GN area, the average noise dosage was 92 dBA, with maximum noise dosage at 100.6 dBA and minimum noise dosage at 84 dBA, and the SPL within the frequency range 20 Hz and 500 Hz was 82.1 dBLin 6, much less than that in LFN area. For the GN group, the noise level for each frequency measured between 20 Hz and 500 Hz was less than 80 dBLin 6 [Figure 1]. {Figure 1}{Table 1}

## Echocardiography

This is the first time in Taiwan that echocardiography was used to perform the health evaluation of personnel working in an LFN area of the aerospace maintenance work environment. Results showed that the averaged E/A ratio for the LFN group was 1.6 (maximum value: 4.0). This was higher than the value categorized 6 into the third grade - severe dysfunction, as defined by Leong et al., [10] while the averaged E/A ratios for the GN group and control group were 1.3 and 1.4, respectively. It was found that all individuals who exhibited E/A ratio greater than 3.0 (fourth grade - severe dysfunction) belonged to the LFN group [Table 2]. For the LFN group, there were 10 subjects (15.6%) who exhibited an E/A ratio < 1, 34 individuals (53.1%) exhibited an E/A ratio between 1 and 2, which was normal, and 20 subjects (31.3%) exhibited an E/A ratio > 2. The total abnormality rate within the LFN group was close to 47%. For the GN group, 65 individuals (73.0%) had normal E/A ratios, between 1 and 2, only 7 subjects (7.9%) exhibited E/A ratios greater than 2, and the total abnormality rate within the GN group was 27.0%. As far as control group was concerned, 39 individuals (65.0%) showed normal E/A ratios and only 8 (13.3%) had E/A ratios > 2. The LFN group showed a statistically significantly ( $P < 0.05$ ) higher E/A > 2 rate than the other two groups. In particular, the rate of personnel exhibiting an E/A ratio > 2 within the LFN group reached 31%, which was far higher than the other two groups (7-8%) [Table 3].{Table 2}{Table 3}

## Pure-tone audiometry 7

Based on the regulations regarding labor health examinations, a hearing test is a mandatory item to be performed during health checks. The result can be used to calculate the hearing loss index. It was found that, except for 0.5k, the hearing loss of all the personnel in the three groups (measured at 1k, 2k, 3k, 4k, and 6k) exhibited statistical differences (scheffe test  $P < 0.05$ ). As far as (0.5k + 1k + 2k)/3 methods (3-divided) was concerned, the hearing loss of LFN group and GN group did not disclose significant differences. However, it was close to a statistically significant difference when the (0.5k + 2\*1k + 2k)/4 method (4-divided) was used ( $P = 0.059$ ). In general, hearing loss for the LFN and GN groups became serious at higher frequencies, especially at 4k and 6k where the hearing loss of the LFN group reached 40 dB, and was 10 dB higher than that of GN group [Table 4].{Table 4}

## Discussion

In this research, the age and working years of the LFN group personnel were less than those of the GN group members. However, results showed that the abnormality rate of the echocardiography parameter E/A ratio within the LFN group was greater than both the GN and control group members, and the abnormality rate of E/A ratio between the latter two groups did not show any difference. Castelo Branco and coworkers pointed out that long term exposure to excessive amounts of LFN resulted in the thickening of pericardia and cardiac valves. [11] The results obtained in this research agree with the conclusions drawn by their research. Moreover, this research found that severe dysfunction cases (E/A ratio > 3) only occurred in LFN group members. Previous researchers had pointed out that one of the characteristics of VAD patients was pericardial thickening. [7] This could be verified by measuring pericardial thickness using echocardiography. However, this is not easily performed because it requires a very skillful professionalism. On the other hand, obtaining the E/A ratio is very quick. Therefore, this research provided a means for checking the health condition of people exposed to LFN. The E/A ratio could be used to screen out patients who exhibit early stage VAD symptoms, thus ensuring increased the safety and hygiene in the workplace.

Another finding in this research was that the hearing loss caused by LFN exposure was more severe at higher frequencies, 4k and 6k, and the loss of hearing could reach above 40 dB, which was in agreement with the results shown in the literature. [12] Personnel exposed to LFN resulted in a difference of at least 20 dB hearing loss at 4k and 6k when compared with the control group. However, the difference in hearing loss between the LFN and control groups at 1k, 2k, 3k were found to be within 7-9 dB. Comparing the LFN and GN groups, the hearing loss of LFN group was 3-4 dB; higher than that of the GN group at 1k, 2k, and 3k, and was 11-14 dB, higher at 4k and 6k. Although the age of workers and working years of the GN group members were longer than those of LFN group members, the hearing loss of LFN group members was more serious than that of the GN group members. 9

## Conclusions and Recommendations

Low frequency noise has a tremendous effect on human health, both psychologically and physically. This research was conducted within the Taiwanese aerospace maintenance environment and analyzes the associated environmental exposure. It was found that the SPL value for the low frequency noise (20 Hz to 500 Hz) reaches 96 dBLin. 6 After assessing the hearing condition and performing the heart evaluations of the workers, the following findings were disclosed:

For the LFN group, the averaged value of the E/A ratio echocardiography parameter was found to be greater than 1.5, which is the standard for grade of the JACC classification. The abnormality rate of the E/A ratio ( $E/A > 2$ ) was found to be close to 31% in LFN group members, which was much higher than that of the GN and control groups. The abnormality rate of the E/A ratio between the GN group and the control group did not show a significant difference. This research provides a feasible and fast biological marker for screening the effects of LFN on the heart condition and potential patients with VAD symptoms. Exposure to LFN resulted in a 40 dB hearing loss at the higher frequencies of 4k and 6k. Also, there was a 20 dB higher hearing loss in the LFN group when compared with the control group. Currently, the hearing loss index assessed in Taiwan area is limited by using 3-divided, 4-divided, and  $(0.5k + 2*1k + 2*2k + 4k)/6$  (6-divided) methods, which might result in incomplete evaluations of the hearing loss among workers, leading to an underestimation of the actual hearing loss.

## Research Limitation

There is still room for improvement between the normality and pseudo-normalization LV filling of the E/A ratio echocardiography parameter.

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## End Notes

Since vibroacoustic disease was already defined as (VAD) above, all locations should read VAD. It seems there is a gap here in the values for the E/A ratio. Second grade: 1-1.5. Third grade  $> 2$ . What about in between 1.5-2? Could Third grade be  $> 1.5$  instead of  $> 2$ ? It is necessary, here, to explain a bit more on how these workers were chosen. Did they volunteer to receive the evaluations, or were they picked in accordance to some specific criteria? The first sentence was deleted since it was a repetition of information previously provided. Is it assumed that when "dB" is used, it is meant dB without weighting? Equivalent to dBLin? Or is the SPL being measured in dBA? Or dBC? Please see footnote 3. Third grade is described as E/A ratio  $> 2$ , not 1.5. Sub-titles in bold. Reference number is missing. I recommend removing this sentence because it has long been known that (with equal exposure times) the magnitude of the sound pressure level is directly proportional to hearing loss. However, what I believe this research brings as a novelty is that the larger magnitude of hearing loss at the higher 4k and 6k frequencies seems to be specifically associated with LFN exposure.

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