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THE HEARING-IMPAIRED STUDENTS' RESPONDING MECHANISM TO LOW FREQUENCY NOISE–BUILDING UP A MODEL

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ABSTRACT

The purpose of this study was to build up a model of the responding mechanism to low frequency noise(LFN) in a reverberation room by means of comparission with the responding patterns between the hearing-impaired with and without residual hearing students aged 17 to 22. The results were as follows: (1)The hearing-impaired students responded to LFN by auditory perception mostly. And there were more feeling vibration in chest during exposure to LFN in the non-residual hearing than that in the residual hearing group. (2)There was an increasing tendency of heart rate during stimulation of LFN, except at 250 Hz and 125 Hz in the non-residual hearing group. (3) There was a tendency that the more perceived dose of stimulating noise, the more vaso-constricting response was found on the finger arteries. (4)A responding model to LFN was builded up from the above mentioned data.

Key words: the hearing-impaired, responding model
to low frequency noise.

According to Broner's review of literatures, there were some studies concerning the effects of low frequency noise(LFN) on human. such as Mohr et al.(1965),Alford et al.(1966),Edge et al.(1966),Tempest and Bryan(1972),Slarve and Johnson(1975), von Gierke et al.(1976), and Broner(1976,1978) etc.,but no any investigation regarding the effects of LFN on the hearing-impaired persons before 1978. In 1982, Fujikata et al. reported that fifteen profoundly deafened adults aged 20 to 40, responded to sounds which ranged 12.5 Hz to

160 Hz with feeling vibration in the chest, and to sounds of 250 Hz and higher frequencies with fullness in the ears. Yamada et al. (1983) also measured their minimal sensation threshold among 13 profoundly deafened adults, and reported that the minimal sensation thresholds at 31.5 Hz, 63 Hz, 125 Hz, and 250 Hz revealed 110 dB, 90 dB, 95 dB, and 100 dB,respectively.

In 1986 the author designed an experimental study on human body response to LFN in a reverberation room, and found that the changes of breathing rate, heart rate and finger pulse amplitude during exposure to LFN at 90 dB SPL revealed a significant difference between the normal hearing and the hearing-impaired young adults. From above mentioned study, the author wondered if there were different responding patterns between hearing impaired young adults with and without residual hearing. Therefore, this project was designed to search the responding mechanism from three points of view: the first from feeling sites of vibration, the second from changes of heart rate, and the third from changes of finger pulse amplitude during exposure to 90 dB SPL LFN in reverberation room.

SUBJECTS

The subjects of this study were 44 students of hard-of-hearing with residual hearing at one or more frequencies(residual hearing group), and 16 so-called totally deafened students without residual hearing at any frequency from 125 Hz through 8 KHz(nonresidual hearing group). They were senior vocational students aged 17 to 22, in Taipei Municipal School for the Deaf.

Hearing level of each subject was measured with an audiometer (Rion AA 39A) at the testing room in that school. The maximal output of this audiometer was 100 dB (ISO, 1975),except 90 dB at 250 Hz and 70 dB at 125 Hz. Analysis of their pure-tone average of 500 Hz, 1 KHz, 2 KHz of the better ear revealed that there were (1)84-89 dB in 6 persons, (2) 90 dB and/or more in 38 persons, and (3)scale-out hearing level at all frequencies in 16 persons.

METHODS

Seventy dB SPL octave band noise centered at 250 Hz, 125 Hz, 63 Hz, and 90 dB SPL centered at 250 Hz, 125 Hz, 63 Hz, 31.5 Hz were used as stimulating tones in this study.

During exposure to each stimulating noise the subjects were asked and recorded their feeling sites of vibration. Heart rate and finger pulse amplitude were recorded before and during exposure to the stimulation by means of Datagraph system(Lafayette, USA). These data were compared statistically between the residual hearing and the non-residual hearing groups.

RESULTS

1. Feeling Sites of Vibration

Six out of 44 subjects in residual hearing group felt vibration on head/or in ears during exposure to 70 dB SPL octave band noise, i.e. 5 out of 6 to centered at 125 Hz, 4 out of 6 to centered at 63 Hz and 3 out of 6 to centered at 250 Hz. Only one out of 16 subjects in non-residual hearing group felt vibration on head/or in ears during exposure to 70 dB SPL noise centered at 125 Hz. These 7 subjects may be considered as particularly sensitive to LFN because the minimal sensation level to low frequency tones was 87 dB SPL at 125 Hz and 85 dB SPL at 63 Hz among the profoundly deafened persons aged 20 to 40. (Fuji-Kata, 1982)

With the exception of 3 subjects 43 out of 44 subjects in residual hearing group and 14 out of 16 subjects in non-residual group felt vibration during exposure to 90 dB SPL octave band noise were shown in Table 1. and Figure 1. Although there was no significant inter-group difference for the feeling sites of vibration, more than 50 % of the subjects felt vibration on head and/or fullness in the ears during exposure to 90 dB SPL stimulating tones; and higher percentage of non-residual hearing group felt vibration in chest than that of residual hearing group.

Table 1. Feeling Sites of Vibration during Exposure to Low Frequency Noise at 90 dB SPL

Octave noise	Feeling sites	Residual hearing(43) n	%	Nonresidual hearing(14) n	%	z
250 Hz	Head/Ears	32	.74	8	.57	1.20
	Chest	14	.33	6	.43	-0.67
	Hands	20	.47	4	.29	0.87
	Abdomen	5	.12	1	.07	0.02
125 Hz	Head/Ears	27	.63	9	.64	-0.06
	Chest	19	.44	7	.50	-0.37
	Hands	25	.58	6	.43	0.97
	Abdomen	8	.19	1	.07	0.64
63 Hz	Head/Ears	27	.63	11	.78	-1.36
	Chest	26	.60	10	.71	-1.05
	Hands	20	.47	6	.43	0.26
	Abdomen	9	.21	3	.21	-1.37
31.5 Hz	Head/Ears	24	.56	7	.50	0.39
	Chest	15	.35	7	.50	-1.00
	Hands	16	.37	5	.36	0.06
	Abdomen	10	.23	1	.07	0.93

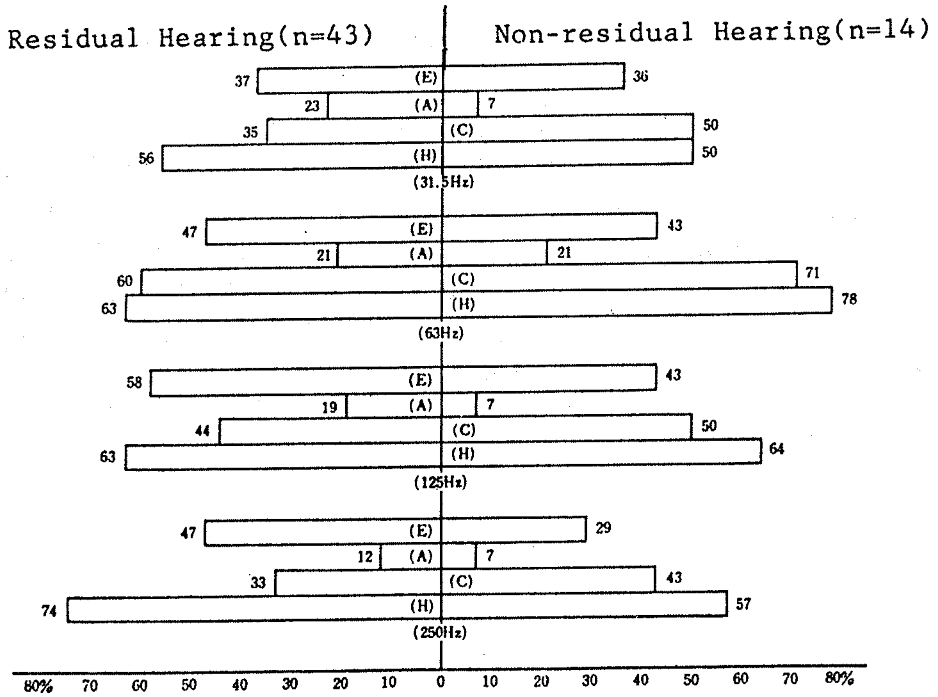

Figure 1. Feeling Sites of Vibration during Exposure to Low Frequency Noise at 90 dB SPL

(E:hands, A:abdomen, C:chest, H:head/ears)

2. Changes of Heart Rate

Although the changes of heart rate during exposure to 90 dB SPL of LFN revealed a little difference between groups, as shown in Table 2. and Figure 2., there was no significant difference, except response to octave noise centered at 250 Hz (x^2=7.7, p<.01).

According to the study of Davis et al.(1955), the heart rate after exposure to noise revealed a minor change usually, however, in this study the residual hearing group responded an increasing tendency of heart rate in proportion to frequency of the stimulating tones, while the non-residual hearing group showed a decreasing tendency of heart rate in proportion to frequency of the stimulating tones. The latter responding pattern might be considered as an effect of the vibrotactile perception because the non-residual hearing subjects felt more vibration in chest during exposure to LFN (around 63 Hz and 31.5 Hz) than to higher frequency noises (125 Hz or more).

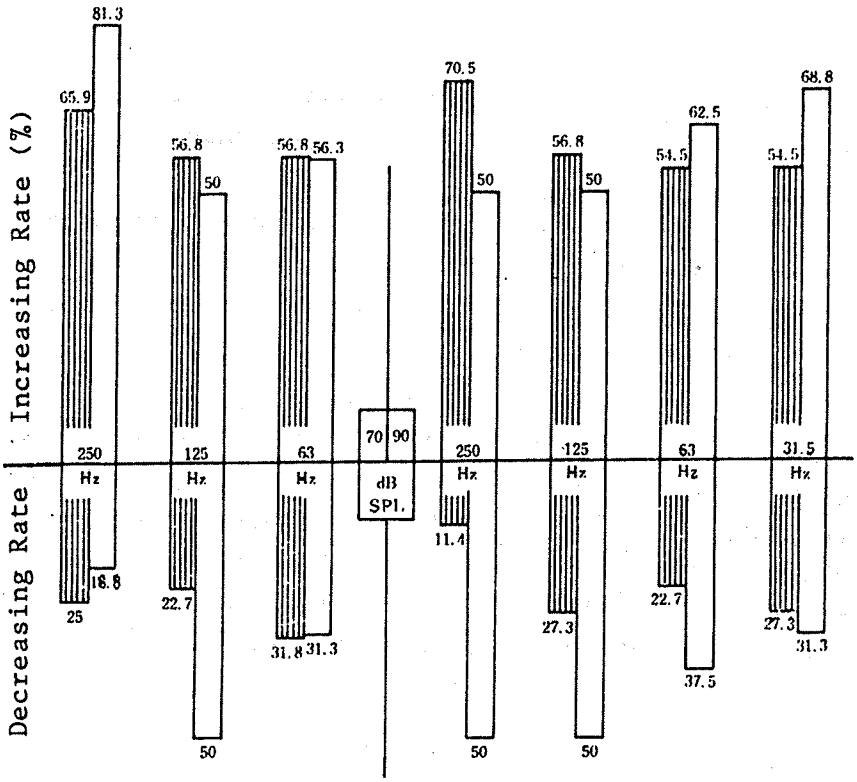

Figure 2. Heart Rate during Exposure to Low Frequency Noise at 70 dB SPL and 90 dB SPL

Table 2. Heart Rate during and/or after Exposure to LFN at 90 dB SPL

Group	Response	250 Hz	125 Hz	63 Hz	31.5 Hz
Residual Hearing (n=44)	increasing	31	25	24	24
	unchanged	8	7	10	8
	decreasing	5	12	10	12
Nonresidual Hearing (n=16)	increasing	8	8	10	11
	unchanged	0	0	0	0
	decreasing	8**	8	6	5

** : $p<.01$

3. Changes of Finger Pulse Amplitude

Post-stimulatory responses of finger pulse amplitude during exposure to LFN were showed in Table 3. and Figure 3. The residual hearing group revealed more vaso-constricting type than vaso-dilating type during exposure to 90 dB SPL octave noise centered at 250 Hz (equivalent to 82 dBA) and 125 Hz (equivalent to 75 dBA), equal percentage of both types during exposure to octave noise centered at 63 Hz (equivalent to 65 dBA), and more vaso-dilating type during exposure to octave noise centered at 31.5 Hz (equivalent to 57 dBA).

In other words, over 50 % of the residual hearing persons responded to more than 57 dBA of octave noise centered at 250 Hz, 125 Hz, 63 Hz and 31.5 Hz with vaso-constriction of finger arteries; while over 56 % of the non-residual hearing persons responded to louder than 75 dBA of octave noise with vaso-constriction of finger arteries. and over 63 % of them to softer than 57 dBA of octave noise with vaso-dilation of finger arteries.

Table 3. Post-stimulatory Responses of Finger Pulse Amplitude

dB SPL	Group	Response	250 Hz	125 Hz	63 Hz	31.5 Hz
70	Residual Hearing (n=44)	constricting	39	28	22	
		unchanged	0	2	3	
		dilating	5	14	19	
	Nonresidual Hearing (n=16)	constricting	3	4	1	
		unchanged	2	1	1	
		dilating	11**	11	14**	
90	Residual Hearing (n=44)	constricting	41	35	31	24
		unchanged	0	1	0	1
		dilating	3	8	3	19
	Nonresidual Hearing (n=16)	constricting	11	9	8	5
		unchanged	0	0	0	1
		dilating	5*	7*	8	10

** : $p<.01$, * : $p<.05$

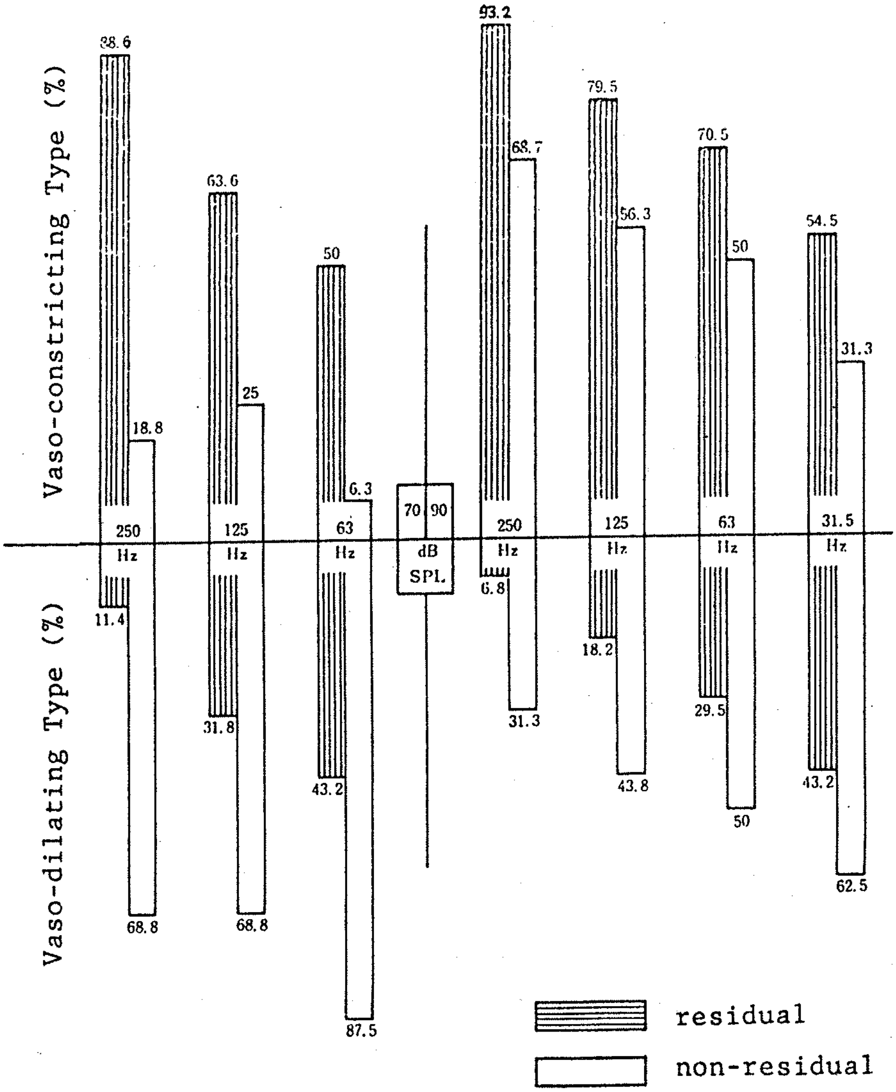

Figure 3. Finger Pulse Amplitude during Exposure to LFN

It might imply that the residual hearing persons could perceive more stimulation during exposure to LFN than the nonresidual hearing persons, and there was a significant intergroup difference in the responding patterns of finger arteries during exposure to the octave noise centered at 250 Hz and 125 Hz ($p<.05$).

4. From the above mentioned responding patterns, the author builded up a responding model to LFN as shown in Figure 4.

In this model, the sound components were transmitted through cochlea to auditory cortex by auditory perception system and were heard as sound. The vibration components were mostly transmitted by vibrotactile perception system from receptors in chest wall to the control centers of heart rate and respiratory rate in the brainstem, and partial vibration (pressure component) might inflence directly on heart and lungs.

Some vibration components might be switched to "harmonic distortion" (von Gierke, HE, 1968) by function of middle ear, then transmitted through auditory pathway to auditory cortex and were heard as sound.

On the other hand, a part of nerve impulses evoked by sound and vibration components seemed to be transmitted through brainstem to autonomic nervous system, then caused sympatheticotonus and influenced the peripheral arteries and endocrine glands.

DISCUSSION

Feeling sites of vibration during exposure to LFN were mostly on head and/or ears among the hearing-impaired persons. And feeling vibration in chest during exposure to LFN were more in the non-residual hearing persons than in the residual hearing persons. It might be interpreted to mean that the residual hearing persons respond to LFN by auditory perception mostly, while the non-residual hearing persons do by auditory perception and also by vibrotactile perception through Pacinian corpuscles (von Bekesy, 1967) or/and stretch receptors (Jacob, 1976) which are distributing in chest wall.

In previous study (1986) the author found that there were a significant difference in vaso-constriction of finger arteries during exposure to LFN at 90 dB SPL between the normal hearing and the hearing-impaired young adults($p<.01$ at 125 Hz, 63 Hz, 31.5 Hz; and

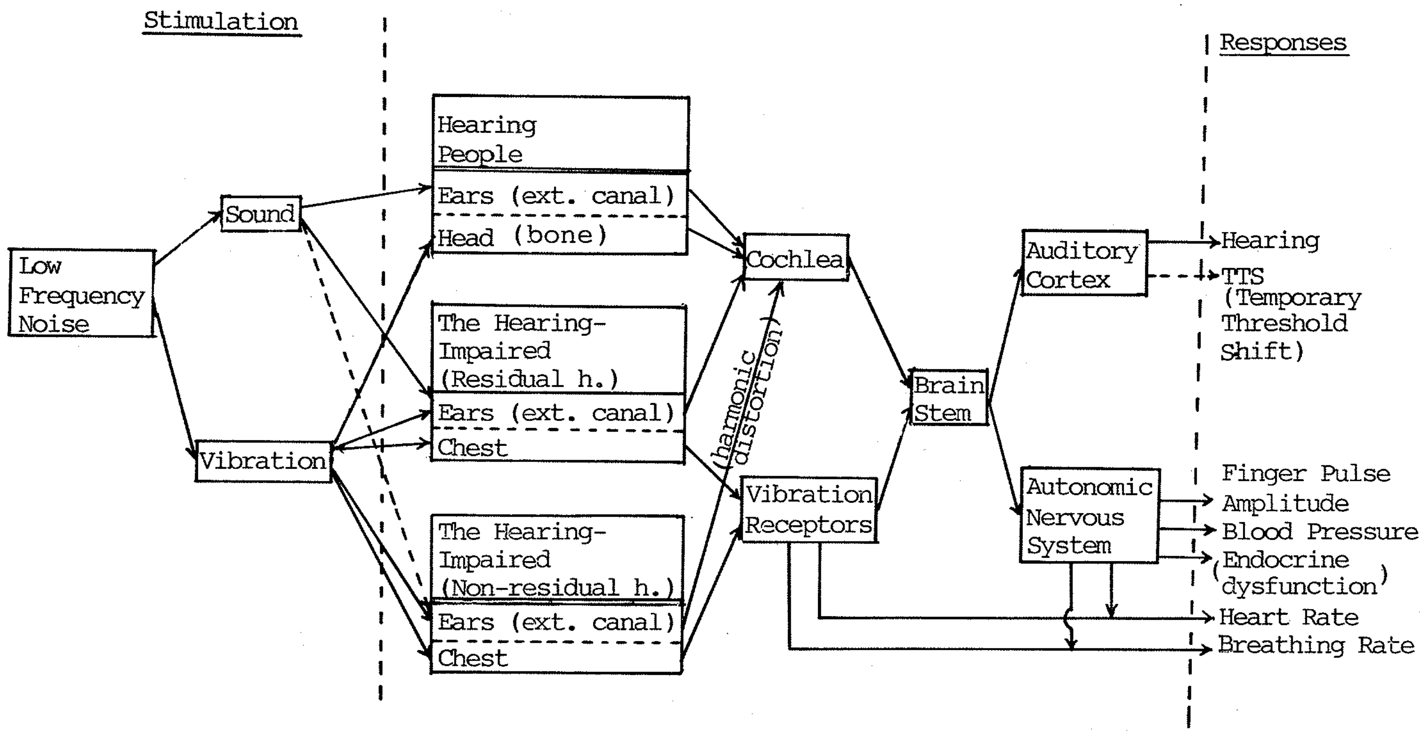

Figure 4. Responding Model to Low Frequency Noise in Reverberation Room

$p<.5$ at 250 Hz). In this study the author also found a significant difference between the residual hearing and the non-residual hearing students with vaso-constriction of finger arteries during exposure to LFN at 90 dB SPL octave noise centered at 250 Hz(equivalent to 82 dBA) and at 125 Hz(equivalent to 75 dBA) ($p<.05$).

Jansen(1970) reported that constriction of peripheral arteries are evoked by sympatheticotonous status secondary to noise-induced response. Guyton(1974) also reported that sympathetics can either further constrict the vessels by increasing this stimulation or they can dilate the vessels by decreasing their stimulation. So the responding models to LFN in this study may imply that the more perceived dose of the stimulating noise, the more vaso-constricting responses of finger arteries can obtained. In other words, the residual hearing persons can obtain more stimulation by auditory and vibrotactile perception system than that of the non-residual hearing persons.

In order to improve the function of hearing aid for the hearing-impaired, the author recommend the Mandarin speaking hearing-impaired students wearing low frequency hearing aid, which may supply more supra-segmental features to the hearing-impaired through vibrations. However, the amplified sound level should be restricted to more than 90 dB SPL and less than their loudness discomfort level.

Concerning the measurement of loudness discomfort level, Beattie and Boyd(1986) reported that the pure-tone loudness discomfort levels are not accurate predictors of speech loudness discomfort level, so that one has to measure the upper intensity for listening to speech sound directly.

With regard to utilize the responding patterns of finger pulse amplitude during exposure to octave noise centered at 250 Hz and 125 Hz as an indicator for objective diagnosis of auditory function is worthy of further research.

REFERENCES

1. Alford BR,Jerger JF, Coates AC, Billingham J, French BO, McBrayer RO (1966). Human tolerence to low frequency sound. Transactions of the American Academy of Ophthalmology and Otolaryngology 701,40-47.
2. Beattie RC and Boyd RL (1986). Relationship between pure-tone and speech loudness discomfort levels among hearing-impaired subjects. Journal of Speech and Hearing Disorders 51;120-125.
3. Broner N (1978). The effects of low frequency noise on people -A review. Journal of Sound and Vibration 58(4);483-500.
4. Davis RC et al. (1955). Autonomic and muscular responses and their relation to simple stimuli. Psychol Monographs 69,405. cited by Kryter KD: The. effects of noise on man. NY:Academic press p.491.
5. Edge PM and Mayes WH (1966). Some initial results of low frequency noise research. Proceedings of the Conference on Langley Reseach Related to the Apollo Mission, 179-188. cited by Broner.
6. Fujikata S,Ikuji M,Nakashima H,Fukuda H,Kosaka T,Watanabe T and Yamada S (1982). Body sensation of low frequency sound of deaf and ordinary persons. Proceedings of Conference on Noise Control, Japan Noise Control Engineering Society, p.209-212.
7. Guyton AC (1974). Function of the human body (4th ed). Philadelphia: W B Saunders Co.
8. Jacob SW and Francone CA (1970).Elements of anatomy and physiology. Philadelphia:W B Saunders Co.
9. Jansen G (1970). Relation between temporary threshold shift and peripheral circulatory effects of sound. In Welch AS(ed) Physiological effects of noise. NY: Plenum Press.
10. Mohr GC,Cole JN,Guild E and von Gierke HE (1965). Effects of low frequency and infrasonic noise on man. Aerospace Medicine 36, 817-824. cited by Broner.
11. Slarve RN and Johnson DL (1975). Human whole-body exposure to infrasound. Aviation, Space and Environmental Medicine 46;428 -431. cited by Broner.
12. Tempest W and Bryan ME (1972).Low frequency sound measurements in vehicles. Applied Acoustics 5;133-139.cited by Broner.
13. von Bekesy G (1967). Sensory inhibition. Princeton NJ:Princeton University.

14.von Gierke, HE (1968). Response of the body to mechanical forces. Annals of the New York Academy of Sciences, 152;170-186.
15.von Gierke HE and Nixon CW (1976).Effects of intense infrasound on man. London:Academic Press.
16.Wang LT,Huang CC,Chen YN and Liu GY (1987).An experimental study on effects of low frequency noise upon human body in reverberation room. Journal of Environmental Protection Society (ROC) 10(1);16-34.
17.Yamada S,Watanabe T and Kosaka T (1983). Sensory organs of low frequency noise. Noise Control (Japan) 7(5);36-38.