Noise Induced Hearing Loss and the Individual Susceptibility to the Noise

Kyong-Myong Chon, M.D., Hwan-Jung Roh, M.D., Eui-Kyung Goh, M.D., Soo-Geun Wang, M.D.

Department of Otolaryngology, College of Medicine, Pusan National University, Pusan, Korea

Abstract: Although there is no specific treatment for modality of occupational noise-induced hearing loss (NIHL), the best way to manage this problem is the prevention. The fundamental prevention of NIHL is to find the persons who are more susceptible to the noise and to avoid work in the noisy environment prior to or during employment. The purpose of this study is to investigate the actual status of NIHL in the industrial complex of Pusan and Kyongnam area in Korea and to evaluate the individual susceptibility to the noise and to set-up the preventive indices of NIHL, using temporary threshold shift (TTS) and its recovery time after noise stimulation.

INTRODUCTION

The problems of occupational hearing impairment present both a challenge and an opportunity to otolaryngologists, since NIHL produced by chronic exposure to excessive sound in the work place is the second most common cause of acquired hearing impairment in adults.[1] South Korea has been trying to develop its industry in a nation-wide base since the 1960's and NIHL as an occupational disease was considered to be seriously underestimated due to the shortage of occupational medical specialists, even though there was a legal hearing conservation program designed to protect workers exposed to high levels of noise.[2] However, starting from the late 1980's, the consideration and prophylactic management about noise exposure have been increasing. It is important that the otolaryngologists should be familiar with a government hearing conservation program and medicolegal aspects of NIHL.

NIHL, although not medically or surgically treatable, is preventable and the test treatment of NIHL is the prevention. Although there is a legal obligatory hearing conservation program, the desirable and ideal preventive method is to check the individual susceptibility to the noise and to avoid work in the noisy environment. However, everyone is not equally susceptible to the noise. Until now, it is clear that the static and dynamic characteristics of the middle and inner ear, such as the stiffness of the cochlear partition, thickness of the basilar and tectorial membrane, blood supply of the cochlea, rate of oxygen metabolism and density of afferent and efferent innervation would be expected to determine how much exposure to noise can be enough to cause NIHL. Unfortunately one cannot measure these directly in the intact organism, so indirect measurement could be used to identify the more noise-susceptible individuals before NIHL is incurred. The validity grounds, the most likely overall predictor of susceptibility to NIHL could be auditory fatigue. However, the use of fatigue tests as susceptibility predictor has not been successful and practicable until now.[3,4] The temporary threshold shift (TTS) is a temporary sensorineural hearing loss that recovers almost completely within 24 hours after exposure to loud noise for seconds-to-hours. Although the correlation between TTS and noise-induced permanent threshold shift (NIPTS) remains uncertain, a daily exposure of noise does not cause TTS, and will not result in NIPTS over a working lifetime.[5] The repeated TTS and its incomplete recovery have been known as a kind of essential process to cause NIPTS.[6,7]

The authors investigated the actual condition of NIHL in the industrial complex in Pusan and Kyongnam area, one of the largest industrial complex in Korea and examined the TTS and its recovery process after noise stimulation in both normal control and NIHL groups to establish the criteria of individual susceptibility to noise and to set-up the preventive indices of NIHL using TTS and its recovery time.

Reprint requests: Kyong-Myong Chon, M.D., Department of Otolaryngology, Pusan National University Hospital, 1-10 Ami-Dong, Seo-gu, Pusan 602-739, Korea.

MATERIALS AND METHODS

Hearing tests of workers in the noisy industry

Approximately 2,258 workers of the noisy industrial complex in Pusan and Kyongnam area of Korea, who did not have any history of ear disease and noise exposure of pre-employment, were examined at a mass screening for audiometric test at 1 and 4 kHz with mobile audiometry unit by an otolaryngologist. In addition to audiometric data, a brief review of the otologic system, such as local finding of ear drum, tuning fork test and nystagmus examination were carried out. The workers who had over 40 dB pure tone threshold of air condition without masking at any of these two frequencies were referred to the Audiology Clinic of Pusan National University Hospital and were checked for the hearing level using Nagashima 51A-T72 type audiometer by ascending method at least three times. The average hearing level was divided into two ranges, speech range (SR), 500 Hz + 2 x 1000 Hz + 2000 Hz / 4 and high frequency range (HFR), 4000 Hz + 8000 Hz / 2.

The hearing loss was classified according to hearing level and frequencies as follows:

1) Mild deafness (M), 15-20 dB in SR and HFR.
2) Speech range deafness (S), over 20 dB in SR.
3) High tone deafness (H), over 20 dB in HFR.
4) Both range deafness (B), over 20 dB in SR and HFR.

Tests for susceptibility to the noise:
Subjects with normal hearing

The normal hearing sujects who did not have any audiologic symptoms and abnormal finding at otologic examination were composed of two groups. One group of 69 cases (137 ears) who were within 15 dB from 250 to 4000 Hz and within 10 dB at 4000 Hz and this group was checked for the susceptibility to the noise by the change of pure tone threshold after noise stimulation. Another group of 87 cases who had within 15 dB of speech reception threshold (SRT) and got 100% discrimination score (DS) at 40 dB above SRT. This group was evaluated for the susceptibility to the noise by the change of DS after noise stimulation.

For checking the change of pure tone threshold, continuous pure tone (CPT), continuous band noise (CBN), continuous white noise (CWN) stimulation of 90 dB above threshold at 4 kHz were given for 10 minutes, and intermittent while noise (IWN) stimulation was given for 30 seconds and then rest for 30 seconds, repeating 20 times. Immediately after each mode of noise stimulation, pure tone threshold was checked at 30 second intervals and the TTS and its recovery time were obtained.

For measuring the change of DS, CBN and CWN stimulation of 90 dB above threshold at 4 kHz were given for 10 minutes. After each noise stimulation, DS at 40 dB above SRT was checked and its recovery time was obtained.

Tests for susceptibility to the noise:
Subject with NIHL

The materials were derived from 64 cases (78 ears) out of 612 workers confirmed as NIHL at Audiology Clinic of Pusan National University Hospital. After CWN stimulation with 70 dB suprathreshold at 4 kHz for 10 minutes, pure tone threshold was checked at 30 second intervals for 10 minutes. The pure tone audiometer was specially equipped with NAB-01 audiobooster (Nagashima Co., Japan) to amplify to 130 dB.

RESULTS

Hearing tests of workers in the noisy industry

1. The incidence of NIHL

After mass screening audiometric test of 2,258 workers (4,516 ears) and secondary otologic evaluation by the board certified otolaryngologist, 612 workers (1,224 ears) were confirmed as NIHL (27.1%). According to the

Table 1. The incidence of NIHL related to the duration of noise exposure and age

Duration (yrs)	-4			5-9			10-14			15-19			20-			total		
Age (yrs)	Exam Ear	NIHL	%	Exam Ear	NIHL	%	Exam Ear	NIHL	%	Exam Ear	NIHL	%	Exam Ear	NIHL	%	Exam Ear	NIHL	%
-19	1,436	202	14.1	12	2	16.7										1,448	204	14.1
20-29	1,172	356	30.4	238	70	29 4	58	14	24.1							1,468	440	30.0
30-39	398	172	43.2	530	164	30.9	206	66	32.0	50	16	32.0				1,184	418	35.3
40-49	98	42	42.9	112	44	39.3	108	40	37.0	40	14	35.0	12	4	33.3	370	144	38.9
50-	14	6	42.9	6	2	33.3	6	2	33.3	10	4	40.0	10	4	40.0	46	18	39.1
Total	3,118	778	25.0	898	282	31.4	378	122	32.3	100	34	34.0	22	8	36 4	4,516	1,224	27.1

duration of noise exposure and age, the incidence of NIHL was rapidly increased within 10 years of noise exposure and within 30 years of age. So the NIHL was mostly established within nine years after noise exposure and below 30 years-of-age (Table 1).

2. The incidence of NIHL: relation of each hearing type

Among the 1,224 ears of NIHL, type B was the most prevalent and then type H, type S and type M in order. In general, each noise exposure group and age group showed the order of prevalent types. However, type S was more common than type H in below four years of exposure group and in below 19 years of age group (Tables 2, 3).

3. The hearing threshold in each frequency: relation to the duration of noise exposure

Between 250 to 2 kHz, the hearing threshold was not proportional to the duration below 14 years of noise exposure and there was a tendency to increase hearing threshold in proportion to the duration above 15 years of noise exposure. Between 4-8 kHz, the hearing loss was proportional to the duration of noise exposure. The hearing level at 4 kHz was higher than other frequency and this is the characteristic of NIHL, C_5 dip phenomenon (Table 4).

4. Audiogram types of NIHL: relation to the duration of noise exposure

In classifying NIHL according to audiogram types, dip type was the most prevalent and then abrupt drop, descending, flat, irregular and ascending types in order. Descending type was more common than abrupt drop type in below four-years group, and abrupt drop type was the most prevalent in the 10-14 years group and in the 15-19 years group (Table 5.)

Table 2. The incidence of M, H, S, and B types of NIHL related to the duration of noise exposure

Duration (yrs)	-4		5-9		10-14		15-19		20-		Total	
Type	Ear	%	Ear	%	Ear	%	Ear	%	Ear	%	Ear	%
M	24	3.1	6	2.1	5	4.1					35	2,9
H	36	4.6	33	11.7	12	9.8	2	5.9			83	6,8
S	39	5.0	4	1.4	2	1.6	1	2.9			46	3.8
B	679	87.3	239	84.8	103	84.4	31	91.2	8	100	1,060	86.6
Total	778	100	282	100	122	100	34	100	8	100	1,224	100

Table 3. The incidence of M, H, S, and B types of NIHL related to the age

Age (yrs)	-19		20-29		30-39		40-49		50-		Total	
Type	Ear	%	Ear	%	Ear	%	Ear	%	Ear	%	Ear	%
M	5	2.5	18	4.1	9	2.2	3	2.1			35	2.9
H	8	3.9	18	4.1	45	10.8	9	6.3	3	16.7	83	6.8
S	20	9.8	19	4.3	6	1.4	1	0.7			46	3.8
B	171	83.8	385	87.5	358	85.6	131	91.0	15	83.3	1,060	86.6
Total	204	100	440	100	418	100	144	100	18	100	1,224	100

Table 4. The hearing thresholds in each frequency related to the duration

Hz / Duration (yrs)		250	500	1K	2K	4K	8K
- 4	Rt.	41.0	39.9	35.1	32.1	41.4	38.3
	Lt.	38.4	36.3	32.4	30.2	41.7	38.4
5- 9	Rt.	35 9	38.2	34.6	31.7	50.6	45.1
	Lt	40.8	35.7	27.5	31.4	49.2	44.7
10-14	Rt.	37.2	36.5	33.9	31.2	52.5	48.0
	Lt	35.8	32.8	30.2	32.4	49.3	34.2
15-19	Rt.	37.6	37.1	34.1	37.1	49.4	45.3
	Lt.	35.3	33.5	32.9	45.3	50.9	44.1
20-	Rt.	40.0	41.3	37.5	51.3	50.0	51.3
	Lt.	42.5	38.8	38.8	52.5	53.8	51.3

Tests for susceptibility to the noise: subjects with normal hearing

1. TTS and its recovery time by the change of pure tone threshold

The average TTS and its recovery time after CPT, CBN, CWN and IWN stimulation were shown in Table 6. There were statistical significance between CWN versus IWN in TTS, and CPT versus CBN and CPT versus CWN in its recovery time. The amount of TTS was 11-30 dB in most ears (66-75%) and the ears which had over 41 dB TTS occupied 3.8% (Table 7).

Most ears recovered within six minutes, especially within two minutes in case of CPT stimulation (Table 8). The ears which recovered above 10 minutes were shown in Table 9. Generally 50% of TTS was recovered within 30 seconds after each noise stimulation and thereafter the recovery amount of TTS was smaller and smaller as time progressed (Table 10).

Table 5. The incidence of the audiogram types related to the duration of noise exposure[7]

Types / Duration (yrs)	Dip	Abrupt drop	Descend.	Flat	Ascend.	Irregular	Total
- 4	197(25.3)	152(19.5)	170(21.9)	141(18.1)	43(5.5)	75(9.6)	778
5- 9	86(30.5)	82(29.1)	48(17.0)	18(6.4)	24(8.5)	24(8.5)	282
10-14	33(27.0)	47(38.5)	15(12.3)	16(13.1)	5(4.1)	6(4.9)	122
15-19	7(20.6)	9(26.5)	8(23.5)	6(17.7)	1(2.9)	3(8.8)	34
20-		6(75.0)		2(25.0)			8
Total	323(26.4)	296(24.2)	241(19.7)	183(15.0)	73(6.0)	108(8.8)	1,224

Table 6. The average TTS and its recovery time of normal hearing subjects in each mode of stimulated sound (n=ears)

Stimulated sound	CPT (n=136)	CBN (n=130)	CWN (n=134)	IWN (n=133)
TTS (dB)	21.54	24.42	22.46**	20.26**
Recovery time (min.)	2.70*+	4.21*	4.01+	3.43

*,** + p<0.01

Table 7. The number of the ears according to the TTS in each mode of stimulated sound Total 137 ears: (%)

Stimulated sound / TTS (dB)	CPT	CBN	CWN	IWN
No TTS	0(0)	1(0.7)	1(0.7)	1(0.7)
≤10	21(15.3)	13(9.5)	14(10.2)	32(23.4)
11-20	67(48.9)	48(35.0)	64(46,7)	53(38.7)
21-30	26(19,0)	42(30.7)	39(28.5)	37(27.0)
31-40	16(11.7)	28(20.4)	13(9.5)	11(8.0)
41-50	6(4.4)	3(2.2)	6(4.4)	2(1.5)
51≤	1(0.7)	2(1.5)	0(0)	1(0.7)

Table 8. The number of the ear according to full recovery time in each mode of stimulated sound Total 137 ears: (%)

Stimulated Sound / Recovery time (min.)	CPT	CBN	CWN	IWN
≤ 2	78 (56.9)	40 (29.2)	40 (29.2)	65 (47.4)
-4	32 (23.4)	34 (24.8)	44 (32.1)	22 (16.1)
-6	17 (12.4)	25 (18.2)	20 (14.6)	20 (14.6)
-8	7 (5.1)	17 (12.4)	17 (12.4)	15 (10.9)
-10	2 (1.5)	14 (10.2)	13 (9.5)	11 (8.0)
10 <	1 (0.7)	7 (5.1)	3 (2.2)	4 (2.9)

Table 9. The characteristics of the ears which had above 10 minutes recovery time

Stimulated sound	CPT	CBN	CWN	IWN
No. of ear	1	7	3	4
Ratio to 137 ears(%)	0.73	5.11	2.19	2.92
TTS (dB)	20.0	31.42	28.33	23.75
Recovery time (min.)	11.0	13.93	18.25	13.25

Table 10. The recovery amount of the TTS in each Stimulated sound in the ears within 10 minutes recovery time dB

Stimulated sound Time(min.)	CPT (n=136)	CBN (n=130)	CWN (n=134)	IWN (n=133)
TTS	21.54	24.42	22.46	20.26
0.5	9.93	12.73	11.68	10.26
1	6.18	8.84	8.17	7.49
2	3.13	6.23	5.97	5.19
3	2.02	4.62	4.29	3.50
4	1,29	3.35	2.76	2.67
5	0.74	2.31	2.10	1.92
6	0.52	1.54	1.46	1.50
7	0.40	0.96	1.01	1.17
8	0.11	0.58	0.63	0.94
9	0.09	0.39	0.54	0.65

Table 11. The average recovery time between below 40 dB and over 41 dB TTS group in each mode of Stimulated sound

Stimulated sound TTS (dB)	CPT (n=136)	CBN (n=130)	CWN (n=134)	IWN (n=133)
≤ 40	2.65*	4.12**	3.97+	3.35++
≥ 41	4.10*	6.30**	5.83+	7.00++

*,**,+,++ $P < 0.01$

Table 12. Speech DS immediately after CWN and CBN stimulation

	CWN		CBN	
Age (yrs)	Male	Female	Male	Female
11-20	86.0	85.2	86.0	83.6
21-30	88.7	86.6	84.8	85.8
31-40	90.0	86.4	88.0	85.6
Average	88.3	86.2	85.9	85.3
Total	87.3*		85.6*	

* $P < 0.05$

These phenomenon could be drawn as parabolic curve ($y=8.865e^{-0.234x}$) in case of CBN stimulation (Fig. 1). Also the linear curve ($y=2.182-0.234x$, $r=0.99$) could be obtained if the recovery time substituted to logarithm (Fig. 2).

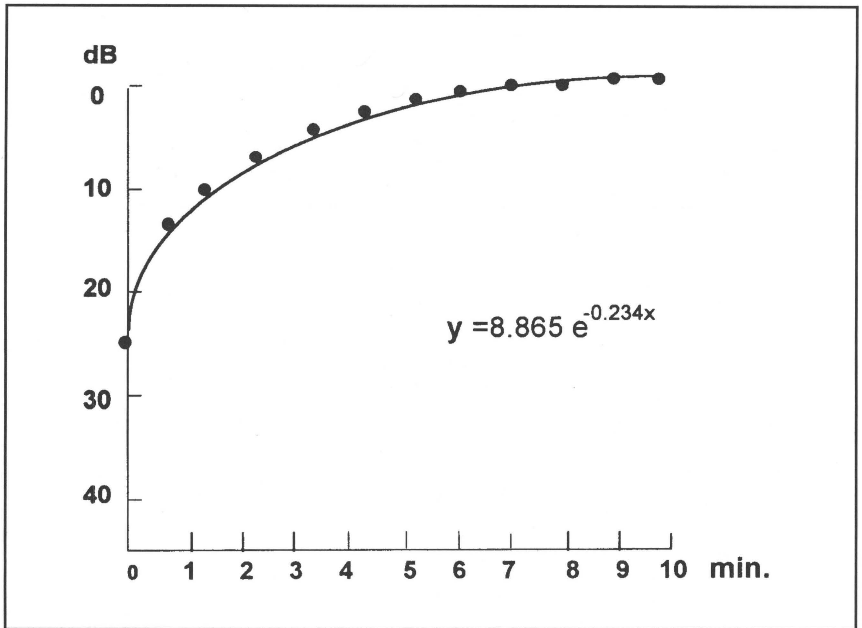

Fig. 1. The TTS against the recovery time after CBN stimulation

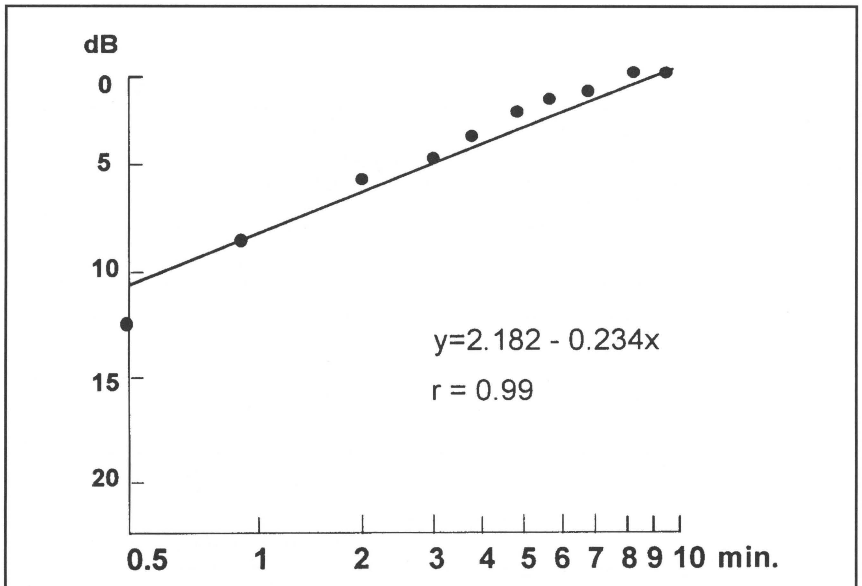

Fig. 2. The TTS against the logarithm of the recovery time after CBN stimulation

It showed that the more TTS, the longer recovery time because the correlation coefficient (r) between TTS and its recovery time was 0.99. However, it was difficult to compare between below and above 50 dB TTS groups because the number of ears above 50 dB TTS group was not sufficient (Table 7). The over 41 dB TTS group had 1.5-3.6 minutes longer recovery time than below 40 dB TTS group in each mode of stimulation and there were statistical significance in each stimulation ($P<0.01$) (Table 11).

2. TTS and its recovery time by the change of DS
Immediately after CWN and CBN stimulation, the average DS at 40 dB above SRT were 87.3% and 85.6% respectively and there was significance between them ($P<0.05$) (Table 12). Among 87 cases, the cases which belonged to the lower 5% critical region in a normal distribution curve, according to DS were five cases (5.7%) after CWN stimulation and three cases (3.4%) after CBN stimulation and their DS were 76.0% and 74.0% respectively (Fig. 3).

Also the cases which belong to lower 5% critical region in normal distribution curve according to the recovery time were three out of 87 cases (3.4%) after CWN stimulation and two out of 87 cases (2.3%) after CBN stimulation and their recovery time was above six minutes in both groups (Fig. 4). There was no statistical significance of DS and recovery time among age groups and between sex groups.

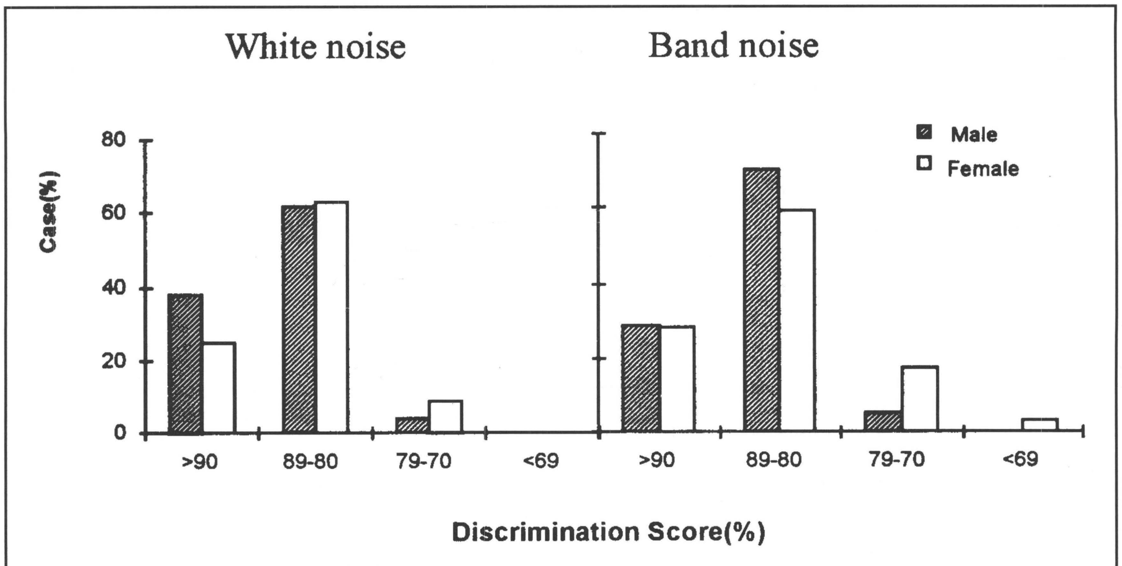

Fig. 3. Case distribution according to speech discrimination score

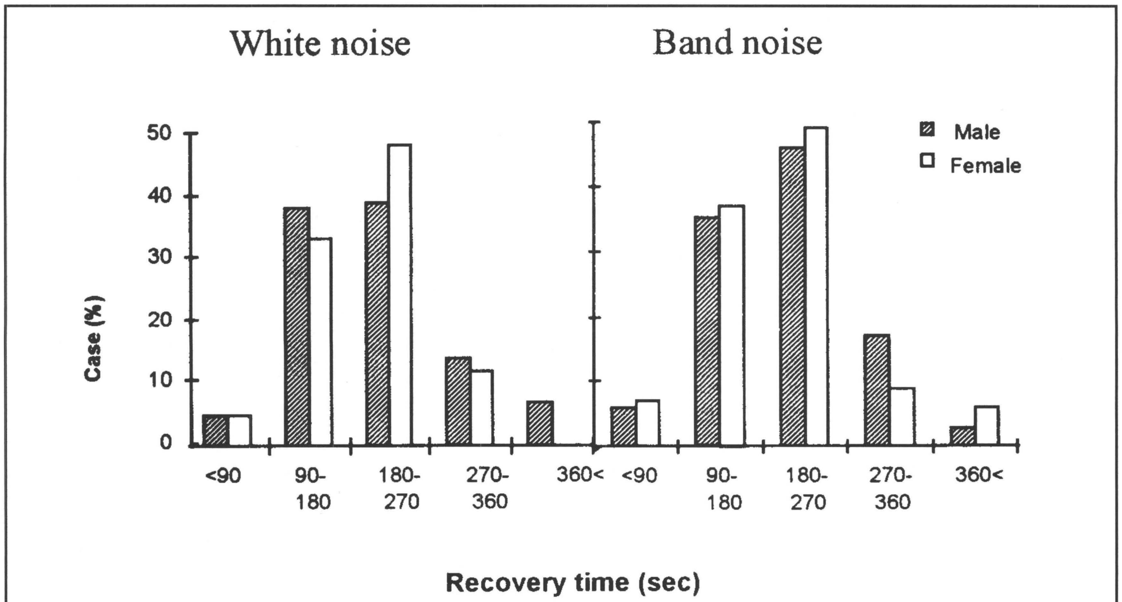

Fig. 4. Case distribution according to recovery time

Tests for susceptibility to the noise: subjects with NIHL

The average TTS after CWN stimulated at 70 dB suprathreshold of 4 kHz for 10 minutes was 14.29 dB and its average recovery time was 11.65 minutes. The amount of TTS were 10-20 dB in most ears (73%) and the ears which had over 25 dB TTS occupied eight out of 78 ears (10.2%) (Table 13).

In the aspect of the recovery time at two minute intervals scale until the full recovery of TTS, 73.1% recovered within six minutes and 15.4% had above 10 minutes recovery time (Table 14).

Table 13. The number of the ears according to TTS: In cases of NIHL

TTS(dB)	No. of ear (%)
No TTS	2(2.6)
5	11(14.1)
10	20(25.6)
15	21(26.9)
20	16(20.5)
25	3(3.8)
30	5(6.4)

Table 14. The number of the ear according to the full recovery time of the TTS: In cases of NIHL

Recovery time (min)	No. of ear (%)
0	2 (2.6)
-2	20 (25.6)
-4	24 (30.8)
-6	11 (14.1)
-8	5 (6.4)
-10	4 (5.1)
10<	12 (15.4)

This phenomenon could be drawn as parabolic curve ($y=12.486e^{-0.085x}$) until six minutes (Fig. 5), and also the linear curve ($y=10.936-1.703x$, $r=0.91$) could be obtained if the recovery time substituted to logarithm (Fig. 6). The correlation coefficient between TTS amount and its recovery time was 0.91, so that there was close relationship between these two parameters. The TTS and its recovery time between the groups which had within 10 minutes and above 10 minutes recovery time were shown in Table 15 and there was statistical significance of TTS and its recovery time between these two groups ($P<0.05$).

Table 15. The TTS and its recovery time between below and over 10 min. time group: In cases of NIHL

	< 10 min	> 10 min
No. Of ear	66	12
Ratio to 78 ears(%)	84.6	15.4
TTS (dB)	12.54*	22.92*
Recovery time(min)	3.71+	55.25+

*,+ P < 0.05

Over 25 dB TTS group had 28.7 minutes longer recovery time than below 20 dB TTS group and this had statistical significance ($P<0.01$) (Table 16).

In general, the more hearing loss, the less TTS and the longer recovery time. The TTS and its recovery time had statistical significance in each hearing loss group ($P<0.05$) except 56-70 dB group which had insufficient ears to compare (Table 17).

Table 16. The average recovery time in below 20 dB and over 25 dB TTS groups: In cases of NIHL

TTS(dB)	Recovery time(min)
≤ 20	8.71*
≥ 25	37.38*

* P < 0.01

Table 17. The TTS and its recovery time according to hearing loss: In cases of NIHL

PTA (dB)	TTS(dB)	Recovery time(min)
-26	15.38*	9.36+
27-40	13.88*	8.95+
41-55	12.5*	18.13+
56-70	21.25	32.5

*,+: P < 0.05

DISCUSSION

Although there is a legal hearing conservation program in each industry, 27.1% incidence of NIHL in one of the largest industrial complex of Korea suggests that the otolaryngologist should play a role to seek another preventive method which can be applied to the hearing conservation program. Although noise reduction for individuals obviously can prevent NIHL, no single study offers convincing evidence of the efficacy of conventional occupational hearing conservation programs, primary due to methodologic flaws.[8] The fundamental preventive way of NIHL can be to find out the persons who are more susceptible to the noise and have them avoid working in the noisy environment during or prior to employment.

In relation to the duration of noise exposure, the incidence of NIHL rapidly increased until nine years of exposure. In the group below four years of exposure, type B was 87.3% and type H was just 4.6%. These results suggest that NIHL could be developed in the early period of working and could involve not only in the high frequency initially but also in the speech range simultaneously, which are not in agreement with the concept that high frequencies are more susceptible and initially involved. The loss in the high frequencies stops worsening after 10 years of exposure, but gradually the loss spreads into the low frequencies.[6,9] Although there is inconclusive evidences whether the young ear will be more easily damaged or not,[3,10,11,12] the 14.1% incidence of NIHL

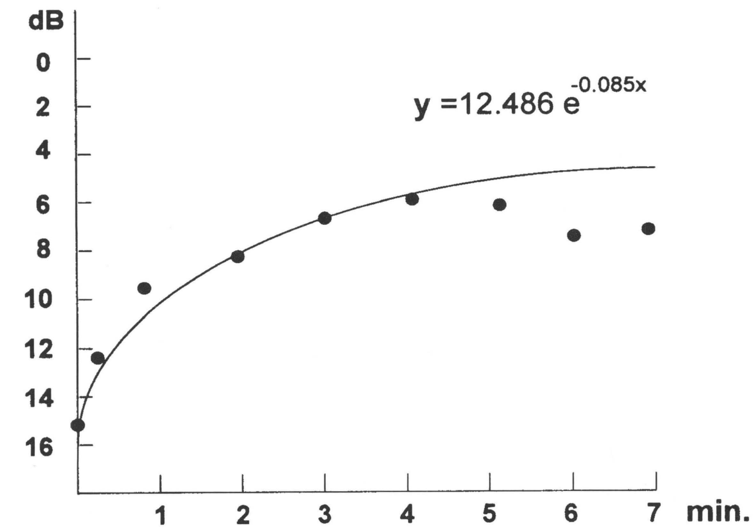

Fig. 5. The TTS against the recovery time after continuous white noise stimulation

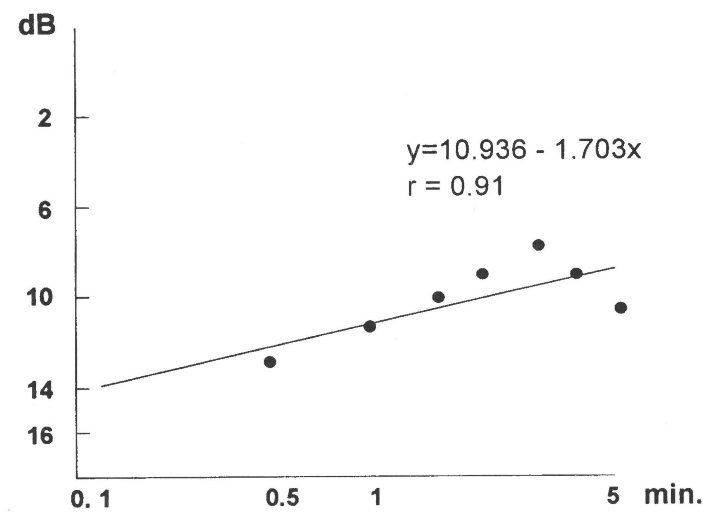

Fig. 6. TTS against the logarithm of recovery time after continuous white noise stimulation

and the prevalence of type B (83.8%) in the age group below 19-years makes a guess that NIHL could be developed in the young ear of a teen-ager. In general, most audiograms were dip, abrupt drop, descending and flat type. There was no remarkable change of audiogram types as the duration of noise exposure processed, suggesting that hearing loss had occurred in the early period of noise exposure and remained from that time on.

In normal subjects there was no statistical significance of TTS among each continuous mode of stimulation. However, there was statistical significance between CWN and IWN stimulation and this is well concordant that the interrupted noise exposures cause less TTS than continuous exposures with the same overall duration.[5] The reasons why the TTS of NIHL subjects (14.2dB) was smaller than that of normal subjects (22.4dB) after CWN stimulation was presumed that the stimulated intensity was 70dB suprathreshold in NIHL subjects and 90dB above in normal subjects and the hearing loss of NIHL subjects was more than that of normal subjects.

The correlation coefficient between the TTS and its recovery time was 0.99 in normal subjects and 0.91 in NIHL subjects, suggesting the close correlation and linear relationship between these two parameters. That means the more TTS, the longer recovery time. There was statistical significance of recovery time between below 40 and over 41 dB TTS groups in normal subjects and between below 20 dB and over 25 dB TTS groups in NIHL subjects. So the persons who have over 41 dB TTS after noise stimulation of 90 dB above threshold in normal hearing subjects and have over 25 dB TTS after noise stimulation of 70 dB suprathreshold in NIHL subjects are thought to be a high risk group to have more susceptibility to the noise. The recovery time from TTS to pre-stimulation level in NIHL subjects (11.6 minutes) were longer than that in normal subjects at each mode of stimulation (2.7-4.2 minutes). There was statistical significance of TTS amount between the groups which had above and within 10 minutes of recovery time in normal and NIHL subjects, suggesting the critical point of noise susceptibility in the aspect of recovery time could be 10 minutes.

Instead of measuring the pure tone threshold shift and recovery time, authors checked the change of speech DS and its recovery time after CWN and CBN stimulation in normal subjects. In most cases, the DS and recovery time were over 80% and within six minutes respectively. The cases which belong to lower 5% critical regions in normal distribution curve had 76% (CWN stimulation) and 74% (CBN stimulation) of DS and over six minutes of recovery time, suggesting the normal individuals who have DS below 76% and recovery time above six minutes after noise stimulation could have a high risk of developing NIHL if they are exposed to noisy working environment.

CONCLUSION

The workers with NIHL occupied 27.1% in Korea and NIHL was mostly established within nine years after noise exposure and below 30 years of age. Initially, NIHL could involve not only in the high-frequency range but also in the speech range simultaneously. Among subjects with normal hearing, those who had the TTS over 41 dB and the recovery time above 10 minutes and those who had a speech DS below 76% and a recovery time above six minutes after noise stimulation had a high risk of developing NIHL. Among subjects with NIHL, those who had the TTS over 25 dB and the recovery time above 10 minutes after noise stimulation had individual susceptibility to the noise. On the basis of these results, the TTS and its recovery time after noise stimulation are useful preventive indices for evaluation of individual susceptibility to the noise.

REFERENCES

1. Sprinkle PM, Lundeen C: The Otolaryngologist and the Occupational Safety and Health Act. In Otolaryngology, Paparella MM, Shumrick DA, Gluckman JL, Meyerhoff WL (eds.). W.B. Saunders Company, Philadelphia, PA 12:1037-1052, 1991.

2. Chon KM: Audiological study on the hearing acuity of noise industrial worker. *J Pusan Med Assoc* 16:11-22, 1980.

3. Ward WD: Noise-induced hearing damage. In Otolaryngology, Paparella MM, Shumrick DA, Gluckman JL, Meyerhoff WL. W.B. Saunders Company, Philadelphia, PA 45:1639-1652, 1991.

4. Ward WD: Susceptibility to auditory fatigue. In Neff WD (ed.): Contributions to Sensory Physiology, Vol. 3, Academic Press, New York, 191-226, 1968.

5. Dobie RA: Noise-induced hearing loss. In Head and Neck Surgery-Otolaryngology, Bailey BJ; J.B. Lippincott Company, Philadelphia, PA.135:1782-1792, 1992.

6. Alberti PW. Occupational hearing loss. In Disease of the Nose, Throat, Ear, Head, and Neck, Ballenger JJ, Lea and Febiger, Philadelphia, PA 49:1053-1068, 1991.

7. Glorig A, Ward WD, Nixon J: Damage risk criteria and noise-induced hearing loss. *Arch Otolaryngol* 74:405-407, 1961.

8. Dobie RA: Prevention of noise-induced hearing loss. *Arch Otolaryngol Head Neck Surg* 121:385-391, 1995.

9. Burns W, Hinchcliffe R, Littler TS: An exploratory study: Hearing and noise exposure in textile workers. *Ann Occup Hyg* 7:323-328, 1964.

10. Coleman JW: Age dependent changes and acoustic trauma in the spiral organ of the guinea pig. *Scand. Audiol* 5:63-68, 1976.

11. Danto J, Caiazzo AJ: Auditory effects of noise on infant and adult guinea pigs. *J Am Audiol Soc* 3:99-110, 1977.

12. Kup W: Der Einfluss des Lebensalters auf Entstehung und Progredienz der Lärmschwerhörigkeit. *HNO* 14:268-272, 1966.

ACKNOWLEDGMENT

The above work was supported by grants from the Pusan National University Hospital.

The NIHL report was presented at the annual meeting of the American Academy of Otolaryngology-Head and Neck Surgery, New Orleans, LA, September 17-20, 1995.