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Analysis of occupational noise for the healthy life according to the job characteristics

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ABSTRACT

Noise is known that the physical risk factors defined as any unwanted sound. It can induce the health problems such as hearing loss or annoyance. The objective of this study was to assess the occupational noise exposure of nine groups for twenty peoples according to job characteristics and to compare the noise level by different variables. Personal noise levels were measured for three times using by dosimeters for each participant in Korea. The mean time weighted average noise level (TWA) of total was 73.2 ± 11.5 dBA by American conference of governmental industrial hygienists (ACGIH) standard. Especially, Korean classical music students were highly exposed to 93.2 ± 6.2 dBA but, office workers were 63.2 ± 6.6 dBA. In case of peak sound pressure level (L_{peak}), Korean classical music students and firefighters were exposed to the highest level of 151.8 dBC and 145.8 dBC during playing and dispatching, respectively. The analysis of noise level showed that L_{eq} had positive correlations between TWA by ministry of employment and labour (MOEL) (r = 0.98, $p < 0.01$) and TWA by ACGIH (r = 0.98, $p < 0.01$). Unlikely other groups, the noise exposure level of the Korean classical music students were exceeded the ACGIH standard. These results suggest that Korean classical music students were exposed high noise level and some solutions are need to reduce the noise exposure level such as using hearing protect device.

Keywords: Occupational Noise Exposure; Job Characteristics; Dosimeters; Noise Level

1. INTRODUCTION

Noise is a physical risk factor defined as any unwanted sound in the environment. It induces health problems such as stress and annoyance. Previous studies reported that noise exposure causes morphological and physiological that twisting and swelling of the hair cells, disarray of the stereocilia, and reduction of enzymes in cochlear fluids in the auditory system resulting in hearing impairment and psychological stress. Also, the long term noise exposure over 85 dBA causes not only irreversible hearing loss, but also hypertension [1-4]. On the contrary, noise exposure below 85 dBA may lead to mental symptoms such as sleep disturbance, annoyance, displeasure, and anxiety if one is consistently exposed [5-8]. Diverse occupational standards are set to protect the worker's health worldwide. For example, American conference of governmental industrial hygienists (ACGIH) and the national institute for occupational safety and health (NIOSH) set the standard level of noise exposure as 85 dBA applying 3 dB exchange rates for 8 hours. According to the noise standard by ministry of employment and labour (MOEL) in Korea, the noise exposure level is 90 dBA applying 5 dBA exchange rates in workplace. It equals to the standard set by the occupational safety and health administration (OSHA) in the state. However, health and safety executive (HSE) has the different standard with three levels of action values each at 80 dBA, 85 dBA and 87 dBA [9-13]. Human performs a variety of activities at work places, thus exposed to diverse noises. Most of the noise exposure occurs from the work and daily activities including shopping, driving, etc. Most studies are progressed for occupations such as firefighter, railroad operator, call center worker, construction worker and manufacture worker in Korea. These workers are exposed to high levels of noise exceeding the exposure standard (90 dBA) [14-19]. However, these studies were only focused on the workers exposed by high noise level and for short durations. So, studies for public group such as students and housewives have rarely been performed. We assess the cumulative noise level of nine groups for many times using dosimeters. This study is the first empirical research that compared the occupational noise exposure of diverse groups

according to their activity patterns in Korea. The objective of this study was to evaluate the occupational noise exposure of nine different groups according to their time-dependent activity patterns.

2. MATERIALS & METHODS

2.1. Noise Measurement

We assessed the level of noise exposure for nine groups, each time with three voluntary people for three times. To confirm the noise level of diverse groups for their activity pattern, we select to nine groups who expected to expose from high to low noise level. We asked nine groups people to distribute an information letter and consent forms. The letter described the aims of study and general requirements. People interested in participating in the study was instructed to have the consent forms signed by oneself and then to return the forms. Study staff visited workplace of the participants to collect the consent forms, and observed their environment and situation of workplace at the same time. In conclusion, the study was carried out for 55 days with twenty people. The levels of noise exposure were sampled between May, 2010 to May, 2011 for each group. The noise measurement was performed by dosimeters (Spark 706, Larson Davis, US.). We instructed the subjects to record their activities in each environment using time activity diary and matched the data with the noise records. The dosimeters were used to measure the personal noise exposure level of twenty peoples between 09:00 am to 06:00 pm according to occupational pattern. Noise dosimeters were put into a small cross bag for the participant's convenience and microphone with wind screen was located near the ear at a distance of 15 cm. All of the noise data was calibrated to be 94 dB and 114 dB at 1 KHz by using Calibrator (CAL150, Larson Davis, US) prior to each measurement and confirmed to be within 0.5 dB post-sampling. The instrument options are listed below.

The configuration of the dosimeter is as follows:

- Range: 33 - 123 dB.
- Time weighting: slow.
- Frequency weighting: A.
- Exchange rate: 3 dB and 5 dB.
- Threshold: 80 dB.
- Criteria level: 85 dB 90 dB.
- Logging: 1 minute interval.

And then, logging data in the noise dosimeters was downloaded into a notebook using Blaze program (PCE piezotronics Inc, US.). The criterion used to assess the exposure characteristic were equivalent noise level (L_{eq}), maximum noise level (L_{max}), minimum noise level (L_{min}), and peak sound pressure level (L_{peak}): L_{eq} is frequency weighted equivalent-continuous sound pressure level in a given time period, L_{max} is the maximum value of the frequency and exponential-time weighted sound level in a given time interval, L_{min} is the minimum value of the frequency and exponential-time weighted sound level in a given time interval, L_{peak} is the maximum value of the instantaneous frequency weighted sound pressure in a given time interval.

2.2. Statistical Analysis

All downloaded data was converted to the L_{eq} by Equation (1).

$$L_{eq} = 10\log\left(\frac{1}{T}\int_{T_1}^{T_2}\frac{P^2(t)}{P_0^2}\right)\text{dB} \quad (1)$$

L_{eq}: Equivalent continuous sound pressure level (dBA); P_0: Reference pressure level = 20 μPa; P_A: Acquired sound pressure in Pa; T_1: Start time for measurement; T_2: End time for measurement.

Sigma-Plot 8.0 (Systat Software Inc., US), Excel 2007 (Microsoft, US), and SPSS 18.0 (SPSS Inc, US) were used for the statistical analysis. A Shapiro-Wilk test was applied to confirm the normality of each noise level with the normal distributions. And then, one-way ANOVA was performed to compare the mean level and to confirm the significance for each group. As well, correlation analysis was carried out to identify correlations among the noise criterions by Spearman's rho test.

3. RESULTS

3.1. Characteristics of the Noise Exposure Level

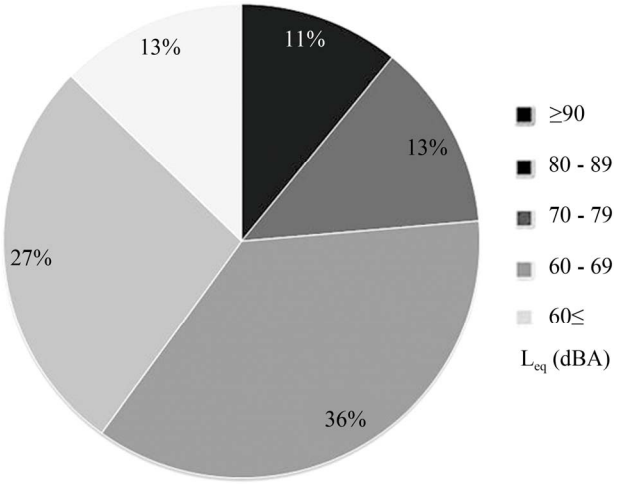
In this study, twenty subjects were participated belonging to nine groups. The total sample size was 55. **Table 1** summarized the general characteristics of the participants. The mean age of the participants was 34.3 ± 11.2 and equivalent noise level (L_{eq}) was 75.4 ± 9.8 dBA. Among the total participants, the noise levels in males were significantly higher than females (77.2 ± 10.6 dBA vs. 69.3 ± 3.2 dBA, $p < 0.001$). However, they were not exposed to significantly different levels of noises by their age (77.7

Table 1. General exposure characteristics by variables.

Variable	People (n)	Days (n)	L_{eq} (dBA)	*p*-value
Total	20	55	75.4 ± 9.8	
Sex				
Male	15	42	77.2 ± 10.6	<0.001
Female	5	13	69.3 ± 3.2	
Age				
30<	9	25	77.7 ± 13.2	0.107
≥30	11	30	77.3 ± 5.6	

Data were expressed as the means ± standard errors (SE) of the means. L_{eq}: equivalent noise level; dBA: A-weighted decibel.

± 13.2 dBA vs. 77.3 ± 5.6 dBA, p = 0.107). **Figure 1** shows the distribution of time weighted average noise level (TWA) for total 55 days. Among the 55 samples, 6 samples (11%) exceeded 90 dBA, 13 samples (24%) were over 80 dBA, and 36 samples (65%) were under 80 dBA. All of the 6 samples were from the Korean classical music students. Noise exposure levels of the nine groups are expressed in **Table 2**. The equivalent noise level was commonly used to assess the level of noise exposure. Additionally, we applied the criterion both TWA and dose that confirmed the level of risk. The TWA was analyzed with ACGIH and MOEL at the same time. The average TWA of the total subjects was 73.2 ± 11.5 dBA by ACGIH and 61.7 ± 15.8 by MOEL. Especially, Korean classical music students were highly exposed to the noise (93.2 ± 6.2 dBA, ACGIH). Next was the livestock farmers exposed to 78.4 ± 1.5 dBA, the hypermarket workers to 77.1 ± 3.9 dBA, the firefighters to 77.1 ± 4.1 dBA, the industrial hygienists to 75.9 ± 1.6 dBA, the high school students to 71.2 dBA, the housewives to 66.0 ± 5.4 dBA, the graduate students to 63.6 ± 5.4 dBA, and the office workers to 63.2 ± 6.6 dBA. In case of the Korean classical music student, the dose was 1339.2 ± 1403.7 by ACGIH, and 106.6 ± 85.2 by MOEL. It highly exceeded the standard (dose = 100), which has a high risk of hearing loss. However, other groups were not exposed to the noise over the standard (**Figure 2**). **Figure 1** shows the distribution of TWA for total 55 days. Among the 55 samples, 6 samples (11%) exceeded 90 dBA, 13 samples (24%) were over 80 dBA, and 36 samples (65%) were under 80 dBA. All of the 6 samples were from the Korean classical music students.



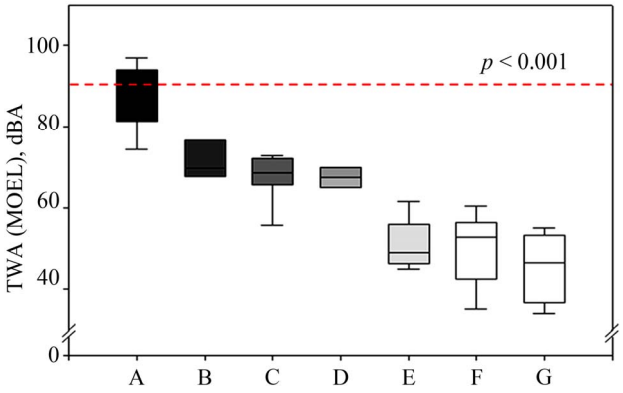
The total number of the subjects is 55. MOEL, ministry of employment and labour; L_{eq}: equivalent noise level; dBA: A-weighted decibel.

Figure 1. Percentage of time weighted average noise level (MOEL) for each group.

Table 2. Summary of noise exposure level.

Job category	People (n)	Days (n)	L_{eq} (dBA)	L_{max} (dBA)	L_{min} (dBA)	TWA (dBA)		p-value	Dose		p-value
						ACGIH	MOEL		ACGIH	MOEL	
Total	**20**	**55**	**75.4 ± 9.8**	**131.5**	**46.3**	**73.2 ± 11.5**	**61.7 ± 15.8**	**<0.001**	**226.9 ± 727.2**	**19.7 ± 50.4**	**0.040**
Undergraduate students	3	9	93.4 ± 6.7	131.5	48.2	93.2 ± 6.2	87.5 ± 7.7	0.106	1339.2 ± 1403.7	106.6 ± 85.2	0.030
Livestock farmers	2	2	78.3 ± 1.3	111.6	46.3	78.4 ± 1.5	67.1 ± 0.1	0.059	22.3 ± 7.4	4.2 ± 0.1	0.179
Hypermarket workers	1	4	77.9 ± 3.3	103.3	49.3	77.1 ± 3.9	71.4 ± 5.1	0.126	22.8 ± 23.6	9.4 ± 8.0	0.342
Firefighters	3	9	77.7 ± 3.3	113.5	48.8	77.1 ± 4.1	67.8 ± 5.3	<0.001	22.0 ± 14.3	5.6 ± 2.8	0.007
Industrial hygienists	1	3	76.2 ± 1.7	110.9	47.5	75.9 ± 1.6	67.6 ± 2.5	0.016	13.6 ± 6.2	4.6 ± 1.5	0.136
High school students	1	1	73.1	95.2	47.2	71.2	63	-	4.1	2.4	-
Housewives	3	9	69.3 ± 3.2	107.1	45.2	66.0 ± 5.4	51.0 ± 5.7	<0.001	2.4 ± 2.4	0.6 ± 0.6	0.066
Graduate students	3	9	68.6 ± 3.1	98.6	48.9	63.6 ± 5.4	50.2 ± 8.5	0.001	1.3 ± 1.1	0.6 ± 0.5	0.157
Office workers	3	9	66.0 ± 4.6	102.1	46.6	63.2 ± 6.6	44.9 ± 8.3	<0.001	1.6 ± 1.9	0.3 ± 0.3	0.097

The t-tests were performed between American conference of governmental industrial hygienists (ACGIH) and ministry of employment and labour (MOEL). The noise exposure level of the high school student was analyzed only for one day. Undergraduates were Korean classical music students. L_{eq}: equivalent noise level; L_{max}: maximum noise level; L_{min}: minimum noise level; dBA: A-weighted decibel; TWA: time weighted average noise level.



A: undergraduate students (Korean classical music); B: hypermarket workers; C: firefighters; D: industrial hygienists; E: house wives; F: graduate students; G: office workers; TWA: time weighted average noise level; MOEL: ministry of employment and labour; dBA: A-weighted decibel.

Figure 2. Comparison of noise level by group; values shown are median (line within box), 25th and 75th percentiles (bottom and top of the box), 5th and 95th percentiles (lower and upper bars on whisker).

3.2. Time History Exposure Level According to the Activities

Noise levels according to the special activities are shown in **Table 3**. The activities occurred during the day time were expected to induce high levels of noised, thus we applied the criterion such as Maximum noise level (L_{max}) and peak sound pressure level (L_{peak}). The percentage of expose duration of event for undergraduate students, industrial hygienists, hypermarket workers, livestock farmers, house wives, firefighters, office workers, graduate students, and high school students were 25.8%, 15.9%, 46.9%, 44.8%, 6.2%, 22.5%, 72.9%, 12.6%, 17.1%, respectively. Especially, the Korean classical music students were exposed to the highest L_{max} level of 131.5 dBA during the practicing. As well, the noise exposure of the industrial hygienists, hypermarket workers, and livestock farmers while they were measuring, working, and feeding were 110 dBA, 113.5 dBA, 111.6 dBA, and 110.9 dBA, respectively. Other groups were exposed to low levels of noises below 110 dBA. In general, the noise levels of housewives, firefighters, office workers, graduate students, and high school students during transporting, dispatching, working, transporting, and recreation were 107 dBA, 103.3 dBA, 102 dBA, 98.6 dBA, and 95.2 dBA, respectively. **Figure 3** presents time history graph of the nine groups during the working hours (9:00 am-6:00 pm) where L_{eq} was applied. The exposure patterns were similar as shown in **Table 3**.

3.3. Correlation of Noise Level among Criterion

Correlation between the noise level and criterion are shown in **Table 4**. Due to the lack of sample size, we used the Spearman's rho correlation test. All criterions were significantly and positively correlated. Among the L_{eq}, TWA by MOEL, and TWA by ACGIH, the highest positive correlation was shown ($r = 0.98$, $p < 0.01$). Additionally, another positive correlation was shown between TWA by MOEL and TWA by ACGIH ($r = 0.97$, $p < 0.01$).

4. DISCUSSION

In this study, we assessed the noise exposure levels of the nine groups. Most of all, Korean classical music students were highly exposed to the noise level exceeding the standard. There are some studies performed to investtigate the noise exposure of musicians according to their instruments. Phillips *et al*. (2008) carried out an assessment of the noise exposure level for music students in practice rooms [20]. The results implied that the students were exposed to different levels of noises depending to the instrument. For example, students played brass were exposed to the level of 95.2 dBA, string to 87.0 dBA, woodwind to 90.4 dBA, and percussion to 90.1 dBA [20]. Other studies for student musicians showed that the students were usually exposed to the noise exceeding 100 of does. Our results were consistent with the previous studies. The student musicians were at risk of the hearing loss [21,22]. According to previous studies of firefighters, the firefighters were exposed to high levels of noises over 92.7 dBA, which could cause the hearing loss. However, they were exposed to the level of 77.1 dBA in our study. Different measurement time in the process of sampling could be the reason for the discrepancy. We assessed 8 hours of noise exposure, and the previous studies were 24 hour [23,24]. L_{peak} was slightly different from L_{max} in terms of the event. Different time weight was suspected to cause the difference. Also, C-weighted decibel (dBC) applied to L_{peak} and A-weighted decibel (dBA) to L_{eq} or L_{max} because of characteristics of frequency weighting. The Korean classical music students and firefighters were exposed to the highest L_{max} at 151.8 dBC and 145.8 dBC, respectively, during the practicing and dispatching. These levels exceeded the noise standard of ACGIH (140 dBC) [25]. Given that the noise exposure over 140 dBC could induce temporary hearing loss or other hearing damage, the music students and the firefighters were at a high risk of such impairments [26]. **Figure 3** presents time history graph of the nine groups during the working hours (9:00 am-6:00 pm) where L_{eq} was applied. The exposure patterns were similar as shown in **Table 3**. There are various measures to control the noise: isolation, reduction and substitution. Hearing protection device (HPD) is the most efficient way to reduce the noise exposure with its usability, and practicality [27]. A previous study proved that ear plug of noise reduction ratio (NRR) is 20 - 40 dB,

Table 3. Noise level according to the activity.

Job category	Event	Duration (%, event/total)	L_{max} (dBA)	L_{peak} (dBC)
Undergraduate students (Korean classical music)	Playing	(25.8, 1669/6480)	131.5	151.8
Industrial hygienists	Workplace measuring	(15.9, 344/2160)	113.5	132.1
Hypermarket workers	Working in market	(46.9, 1352/2880)	111.6	129.6
Livestock farmers	Feeding	(44.8, 645/1440)	110.9	134.1
House wives	Transportation	(6.2, 399/6480)	107.1	120.3
Firefighters	Dispatching	(22.5, 1456/6480)	103.3	145.8
Office workers	Working in office	(72.9, 4726/6480)	102.1	123
Graduate students	Transportation	(12.6, 817/6480)	98.6	122.1
High school student	Recreation	(17.1, 123/720)	95.2	110.5

Duration is divide event time and total time for sampling. dBA: A-weighted decibel; dBC: C-weighted decibel; L_{eq}: equivalent noise level; L_{max}: maximum noise level; L_{peak}: peak sound pressure level.

Table 4. Correlation coefficients among the noise criterion.

	L_{eq} (dBA)	TWA (MOEL)	TWA (ACGIH)
L_{eq} (dBA)	1		
TWA (MOEL)	0.98**	1	
TWA (ACGIH)	0.98**	0.97**	1

Spearman's rho correlation test was performed among the variables. ** $p < 0.01$. L_{eq}: equivalent noise level; dBA: A-weighted decibel; TWA: time weighted average noise level; MOEL: ministry of employment and labour; ACGIH: American conference of governmental industrial hygienists.

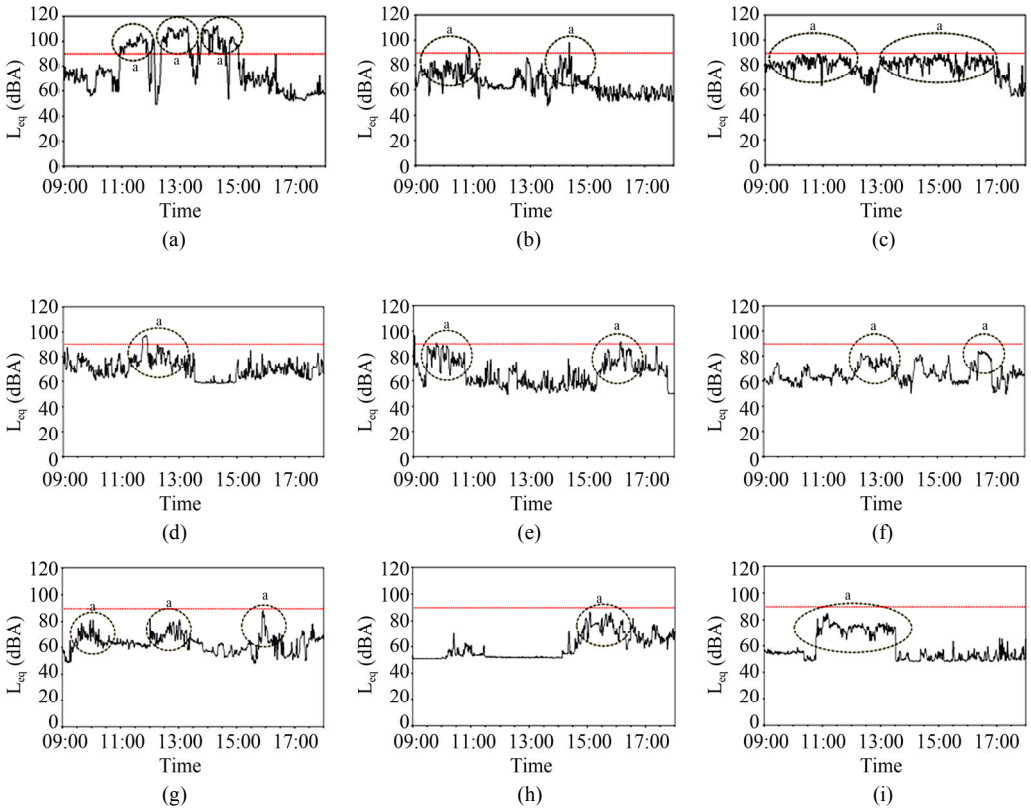


Figure 3. Time history pattern graph of each group. Circles shown are each activities (a) Undergraduate students (playing); (b) Livestock farmers (feeding); (c) Hypermarket workers (working); (d) Firefighters (dispatching); (e) Industrial hygienists (measuring); (f) High school student (recreation); (g) Housewives (transporting); (h) Graduate students (transporting); (i) Office workers (working).

which could reduce the risk of hearing loss [28,29]. Therefore, the measure such as using of hearing protection was essentially required to reduce the noise exposure during special activities. Spearman's rho analysis result among the criterions showed that were significantly correlated. Unlike TWA and dose used a threshold that estimate the risk, L_{eq} don't applied the threshold. Generally, L_{eq} is used to assess the noise level in the atmospheric environment for area sampling whereas TWA and dose is used in the workplace for personal sampling. Statistical results showed highly positive correlation among the criterions. Therefore, L_{eq} and TWA are sufficient enough for the personal sampling. We evaluated the noise levels for the nine groups in this study. Conclusively, we found that the Korean classical music students were exposed to the highest noise level at 87.5 ± 7.7 dBA by MOEL on day time. The high risk activities included instrument playing for the Korean classical music students (L_{peak} 151.8 dBC) and dispatching for the firefighters (L_{peak} 145.8 dBC). Therefore, it is necessary to make some alternatives to reduce the noise exposure, for example, by using earplug and earmuff. This study is expected to provide basic data for further studies regarding health effects of the noise for the public.

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