

Comparison between Pure-tone Audiometry and Otoacoustic Emissions Methods in Workers' Hearing Loss

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Abstract

Background: Noise-induced hearing loss (NIHL) is the most important physiological effect of noise that is the mechanical deterioration of outer hair cells in the organ of Corti. The study aim was to a comparison between pure-tone audiometry (PTA) and distortion product otoacoustic emissions (DPOAEs) methods in workers' hearing loss. **Materials and Methods:** A total of 120 workers were enrolled in the study, who worked in two production units of a company. Workers exposed to high levels of noise were divided into two groups of with NIHL and without NIHL. Then, their hearing status was evaluated using PTA and DPOAEs tests. **Results:** The results revealed a tangible difference between data obtained from PTA and DPOAEs methods between two groups and workers with normal hearing threshold experienced a high reduction in their DPOAEs range. This indicates a reduction in the number of outer hair cells of cochlea which is not detectable by PTA test. **Conclusion:** This study represents that DPOAEs can detect NIHL at earlier steps compared to PTA test. Therefore, it is recommended to use DPOAEs test in industrial environments for hearing screening test and early diagnosis of NIHL, instead of PTA.

Key words: Distortion product otoacoustic emissions, noise exposure, pure-tone audiometry, workers

INTRODUCTION

Numerous studies have been reported the side effects caused by noise during last two decades. The most important of these side effects include hearing loss, noise nuisance and annoyance, sleep disturbance, and fatigue. Among other effects of noise, one can refer to physiological effects such as cardiovascular complications and psychological effects include anxiety, anger, and depression.^[1-8] It has been estimated that more than 500 million people all worldwide may be at risk of hearing loss caused by noise (NIHL).^[3,9,10] NIHL as the most serious health effects, which is caused by noise, is a permanent and irreversible damage in the inner ear which is completely preventable.^[5,11,12]

Early diagnosis of NIHL can prevent from hearing loss and its spread in the frequency of conversation.^[6,13] Lab methods and modern equipment have provided significant help for recognition and further studies on the pathology

of the ear and hearing loss.^[7,14,15] Hearing damage or hearing loss is usually specified using pure-tone audiometry (PTA) test or audiometry which its normal amount is between 0 and 25 dB, and gentle damages begin from up to 26 dB.^[8,16] Since the tests suffer from limitations such as needing to the cooperation of under test person, being non-objectivity, low sensitivity in detecting lesions, and unable to provide precise details about changes caused by exposing to the noise, therefore more precise test are needed for this purpose.^[9,17,18]

Distortion production otoacoustic emissions test (DPOAEs) was introduced in 1980, as a medical diagnostic tool to assess

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cochlear.^[10,19,20] This valid test which reflects the function of ear outer hair cell is very useful in assessing the changes in inner-cochlear after exposing to noise.^[11,12,21] OAE is an objective test which can be more affordable compared to PTA due to its being cheap, act quickly and save time, not to need acoustic room, and sensitivity to hear losing.^[13,22-25] The study was conducted using PTA and OAE tests in two groups, i.e. control group including people exposed to industrial noise and without NIHL and experimental group including people with NIHL.

MATERIALS AND METHODS

The present study was a cross-sectional study one which has been conducted on 120 workers occupied in two production units of Iran Carbon Company. Workers exposed to high levels of noise were divided in two groups of with NIHL and without NIHL. Otoscopy was used to check the normal status of anatomy and sure that no waste material exists in the ear. Evaluation of hearing loss was carried out using acoustic room and audiometer of amplivox DA260 with ear-phone model Telephonic TDH-39P in low frequencies (250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 hertz).^[14,26-30] The audiometry test was carried out on all of the participants. Pure-tone air conduction threshold was conducted using Hughson–Westlake method. The PTA test was first carried out at frequency of 10 dB, and then 5 dB was added to the frequency as a principle, and the hearing threshold was defined as two responds of three carried out tests in each frequency. OAEs test was carried out in a quiet and without noise room. First, the right ear and then the left ear was tested. OAEs were carried out using stimulus from two pure tones of f_1 and f_2 were adjusted at the rate of 1.22. In each test, two sound intensities of $L_1 = 65$ dB and $L_2 = 55$ dB in NPS and frequencies of 1.5, 2, 3, 4, 5, 6, and 8 KHz were done. The OAEs analysis was performed in different frequencies as follow: DP standard range was considered higher than 5 dB NPS, and the ratio of signal to noise (s/n) was considered higher than 6 dB NPS. According to the pass/fail criterion, the normal pattern of the present study was in the form of range changes up to -5 dB NPS and s/n ratio lower than 6 dB NPS. If one of these standards was incorrect, it means unmoral result and defects in hail cells.^[15,31-34] The gathered data were analyzed using version 16 of SPSS Software. First, Kolmogorov–Smirnov method was used to test the normality of data and continuity and paired *t*-tests such as Tokay significant difference test were used to find mean with significant difference compare to other means, as well as compare the averages and means of PTA and DPOAEs of right and left ears in two control and experimental groups. The significantly level was considered 0.05 for all of the tests. People voluntarily participated in this study, and they can leave the study in any part of the study if it was needed. In addition, ethical issues were observed based on Finland's Helsingborg Compliance.

RESULTS

The profile of understudy people has been represented in Table 1 based on their age, job experience, and exposure levels. As it can be seen, most of the participants (41%) are at the age range of 31–40 years old.

Most of the participants in both of the groups are exposed to noise levels of 85–90 dB. In addition, most of the participants in both of the groups have more than 16 years of job background. Figure 1 shows the diagram of PTA test's results for two groups. The results of correlation test and paired *t*-test of the right ear of people with and without NIHL have been represented in Tables 2 and 3, respectively.

The mean of measured values of DPOAEs related to the hearing threshold of different frequencies in the right and left ears of two groups have been represented in the graph of Figure 2.

According to the correlation test, there is a strong significant relationship between the means of DPOAEs range of left ear of people with NIHL and without NIHL at significance level of 0.000 and $r = 0.90$ [Table 2]. In the other side, the results of paired *t*-test confirm this significant difference with confidence level of 95% and $P \leq 0.05$. Table 3 indicates that there is a strong significant relationship between the means of DPOAEs range of right ear of people with NIHL and without NIHL at significance level of 0.001 and $r = 0.95$. The results of paired *t*-test confirm the significant difference between right ear of people with NIHL and people without NIHL with confidence level of 95% and $P \leq 0.001$ [Table 3]. Diagrams 1–4 represent the mean of results related to PTA and DPOAEs in both of the control and experimental groups. The results of correlation test and paired *t*-test confirm the significant difference between means of PTA and DPOAEs in both of the control and experimental groups have been provided in Tables 4 and 5 and Figures 3-6.

DISCUSSION

Occupational hearing loss can occur due to the noise, toxins, or sound impacts. Occupational hearing loss caused by noise is one of the most common occupational diseases. Assessing the hearing of labors exposing to noise is simple and economic. Nowadays, PTA is the basis of hearing conservation programs to detect NIHL. PTA test is a time-consuming mental and sensitive to environmental noises. Therefore, special and more sensitive test are required to early diagnosis of NIHL. Recently, OAE has been introduced as a better predictor method of occupational hearing loss especially in labors with NIHL.

Kolmogorov–Smirnov method was used to test the normality of data. Since the significantly level for all of the components were higher than error value ($P \leq 0.05$), the frequently distribution of under study variables is normal. The age factor

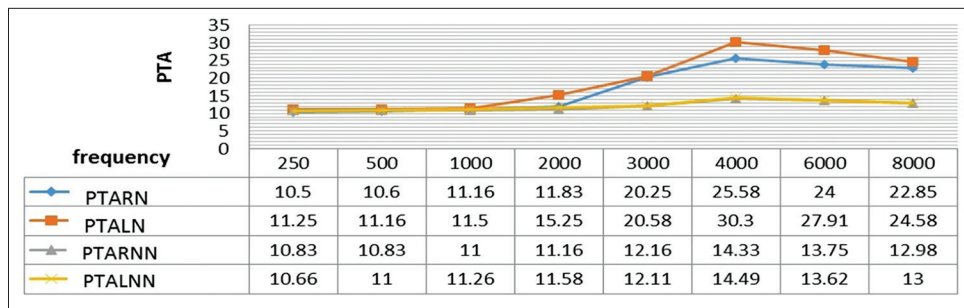


Figure 1: Comparisons of averaged PTA response the stimulus frequency both two group

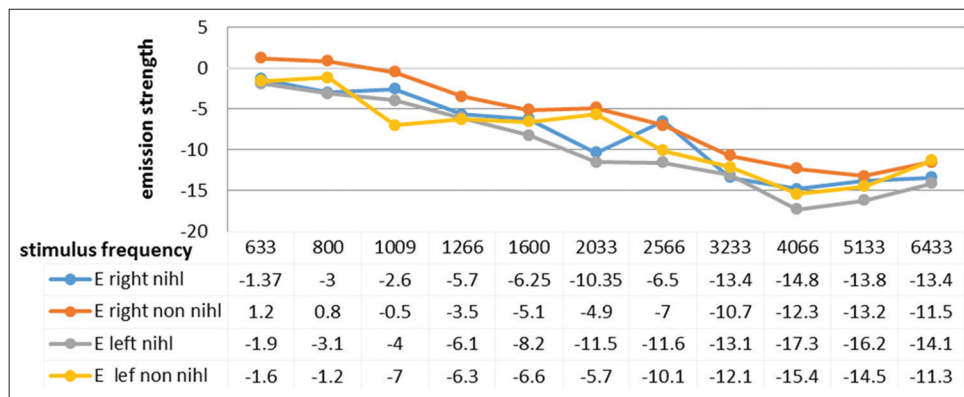


Figure 2: Comparisons of mean DPOAE responses in stimulus frequency in the groups

Table 1: demographic characteristics and NIHL in two groups

Groups	Age (yr)				Job experience (yr)				Noise exposure level (dB-A)		
	20-25	26-30	31-40	41-45	≤ 5	6-10	11-15	≥ 16	≤ 85	85-90	≥ 91
NIHL (N)	8	14	24	14	3	18	19	20	14	27	19
non NIHL (N)	7	11	26	16	6	19	16	19	19	24	17

Table 2: Correlation mean DPOAEs and PTA responses in the groups

Statistical Pairs	variables	N	correlation	Sig.
Pair 1	PTARN & PTARNN	8	0.984	0.000
Pair 2	PTALN & PTALNN	8	0.982	0.000
Pair 3	DPOAELN & DPOAELNN	11	0.97	0.000
Pair 4	DPOAERN & DPOAERNN	11	0.956	0.000

has no effect on the study, and hence, the people at age range of 20–40 years old were selected. Most of the participants (41%) were at age range of 31–40 years old. According to the distribution of understudy sample based on the job background, it is clear that there is a direct and ascending relationship between increasing procedure of NIHL, and job background and the matter indicates that long expose to noise leads to hear losing in long-term.

According to Figure 1^[35,36] and the results of PTA related to the hearing threshold of different frequencies for both of the groups, the hearing drop is significant in high frequencies which indicates hear loss caused by noise (NIHL). Another point in means of hearing threshold is related to the people with NIHL, and it seems that hear losing of these people is more severe in left ear.

According to Table 3,^[37-39] there is a significant difference between PTA means of right ear of people with NIHL and without NIHL at confidence level of 95% and $P \leq 0.05$. The results of correlation test [Table 2] indicates a significant relationship between hearing threshold of right ear of people with NIHL and NIHL (Significance = 0.000 and $r = 0.98$). In addition, there is a significant relationship between hearing threshold of left ear of people with NIHL and without NIHL (Significance = 0.000 and $r = 0.98$). In the other words, threshold dropping in left ear of people with NIHL is more severe compare to the people without NIHL. The results of paired t -test also indicate the significant difference PTA of left ear of people with NIHL and left ear of people without NIHL at confidence level of 95% and $P \leq 0.05$ [Tables 2 and 3].

Table 3: The results of pair sample T- test of mean DPOAEs and PTA responses in the groups

Statistical Pairs	variables	Paired differences				t	df	Sig.	
		Mean	Standard deviation	Standard error mean	95% Confidence Interval of the difference				
					Lower				Upper
Pair 1	PTARN - PTARNN	5.34	5.89	2.08	0.41	10.27	2.56	7	0.037
Pair 2	PTALN - PTALNN	6.85	6.52	2.30	1.39	12.30	2.96	7	0.021
Pair 3	DPOAELN - DPOAELNN	-1.590	2.291	0.690	-3.10	-0.051	-2.303	12	0.047
Pair 4	DPOAERN - DPOAERNN	-2.209	1.561	0.470	-3.258	-1.159	-4.692	10	0.001

Table 4: The results of correlation of mean DPOAEs and PTA responses in the groups

Statistical Pairs	variables	N	Correlation	Sig.
Pair 1	PTALN & DPOAELN	8	0.944	0.000
Pair 2	PTALNN & DPOAELNN	6	-0.598	0.118
Pair 3	PTARN & DPOAERN	8	-0.810	0.150
Pair 4	PTARNN & DPOAERNN	8	-0.745	-0.034

According to the measured mean values of DPOAEs related to the hearing threshold of different frequencies in left ear of both of the groups which have been represented in Figure 2, the values of ranges in have more dropping in high frequencies. In the other words, the received signals become weaker than ear hair cells. According to the results, signals being weaker in the right ear of people with NIHL are more clear compare to the people without NIHL. The relationship is also true for the left ear of people with NIHL and without NIHL. The results of correlation test also confirm the matter, in a way that there is a strong and significant relationship between DPOAEs levels of the left ear of people with NIHL and without NIHL at significance level of 0.000 and $r = 0.90$ [Table 2]. In the other side, the results of paired *t*-test clearly indicate the matter at confidence level of 95% and $P \leq 0.05$ [Table 3].

To compare the means of PTA and DPOAEs results, seven central frequencies of DPOAEs were selected and comprised with the frequencies of PTA. In Figure 1 (means of PTA and DPOAEs results related to the right ear of people with NIHL), hearing loss is more severe in high frequencies for both of the tests, especially at frequency of 4000 hertz. Another important point about PTA test is that hearing threshold is normal at frequency of 2000 hertz; however, emitted signals of outer hair cells are weak in this frequency, and the matter itself indicates damage in hair cells. The analysis of inferential statistics also proofs this matter. The comparison of paired *t*-test results obtained from means of PTA and DPOAEs related to the right ear of people with NIHL indicates significantly of means at significance level of 0.001 and confidence level of 95%



Figure 3: The results of mean DPOAEs and PTA responses for right ear in NIHL workers

[Table 4]. According to the results of correlation test [Table 5], there is a strong and significant relationship between these two variables. It means that whatever mean PTA of hearing threshold is weaker or whatever hearing loss is higher, the value of DPOAEs range is decreased (Significance = 0.000, $r = 0.98$). According to Figure 6, there is a significant relationship between means of PTA and DPOAEs related to the left ear of people with NIHL, in a way that hearing loss and signals being weaker become clearer with frequency increasing. Therefore, it can be said that the means of DPOAEs results indicate hear losing caused by noise as like PTA results. The relationship is properly confirmed by comprising PTA and DPOAEs tests' result related to the left ear of people with NIHL using Pearson's coefficient (Sig. = 0.000 and $r = 0.94$). In addition, a significant difference between averages of these variables is confirmed with confidence level of 95% and significantly level of 0.001, and its means that the means of DPOAEs ranges decreased with decrease in hearing threshold, and the relationship is very strong and significant with $r = 0.94$ [Tables 4 and 5].

In Figure 5, although hearing threshold measured by PTA is normal; however, the results related to DPOAEs ranges indicate damages in hair cells, in a way that signals emitted from signals in frequencies up to 3000 hertz are weak. The results obtained from paired *t*-test indicated a significant difference between these two variables at Significance = 0.002 and confidence level of 95% [Table 5]. In the other

Table 5: The results of pair samples T- test of mean DPOAEs and PTA responses in the groups.

Statistical pairs	Variables	Paired differences				t	df	Sig.	
		Mean	Standard deviation	Standard Error Mean	95% Confidence Interval of the difference				
					Upper				Lower
Pair 1	PTALN - DPOAELN	2.56	12	4.24	16.46	36.54	6.24	8	0.000
Pair 2	PTALNN - DPOAELNN	1.82	5.18	1.83	13.90	22.57	9.94	8	0.020
pair 3	PTARN - DPOAERN	2.35	10.83	3.83	14.53	32.65	6.15	8	0.000
Pair 4	PTARNN - DPOAERNN	1.58	5.23	1.84	11.64	20.21	8.56	8	0.002

side, there is a proper relationship between means of hearing threshold and DPOAEs ranges with Significance = 0.03 and $r = 0.74$ [Table 4]. Although the means of hearing threshold are in normal ranges and no loss has been observed in hearing system, but data obtained from DPOAEs indicate damages in hair cells in high frequencies. In Figures 3-6 and according to the means of PTA and DPOAEs for the left ear of people without NIHL, although hearing threshold measured by PTA is in normal range (10–15), the results related to DPOAEs ranges indicate damages in hair cells. In a way that signals emitted from hair cells are weak in high frequencies. The results obtained from paired *t*-test indicated a significant difference between these two variables at Significance = 0.020 and confidence level of 95% [Table 5]. In the other side, according to Table 4, there is an inverse relationship between PTA means of hearing threshold and DPOAEs ranges with Significance = 0.1 and $r = 0.59$.

Therefore, according to Figures 5 and 6, it can be said although hearing threshold is normal in audiogram; however, outer hair cells have been mechanically damaged caused by exposing to the noise, and the matter is clearly detectable by DPOAEs ranges. Hence, DPOAEs can detect hear loss caused by noise one phase earlier compare to PTA which indicates higher sensitivity of OAE in detecting NIHL compare to PTA as like the results of previous studies.^[16,17] According to Figures 4-6 and similar to the study of Harrel *et al.*, the clinical relationship of PTA and mean levels of DPOAEs is weak in lower frequencies; however, in intermediate and high frequencies, which are effective in NIHL, the relationship is stronger.^[18] The result of the present study as like previous studies^[19,20] confirms the matter that means levels of PTA and DPOAEs have stronger relationship in intermediate and high frequencies compare to the lower frequencies. Therefore, mean levels of DPOAEs ranges decreased when exposed to noises which indicate that the outer hair cells are damaged in these frequencies. In people exposed to the noise, although the hearing system was normal based on the PTA data, hair cells of Corti organ were mechanically damaged, and decrease in means of DPOAEs data confirms the matter. Furthermore, the results of Attias *et al.* study has been conducted on comparison the PTA and DPOAEs test for early diagnosis of NIHL in three groups (two groups exposed to the noise and one group not exposed to the noise) confirms this matter. Their results

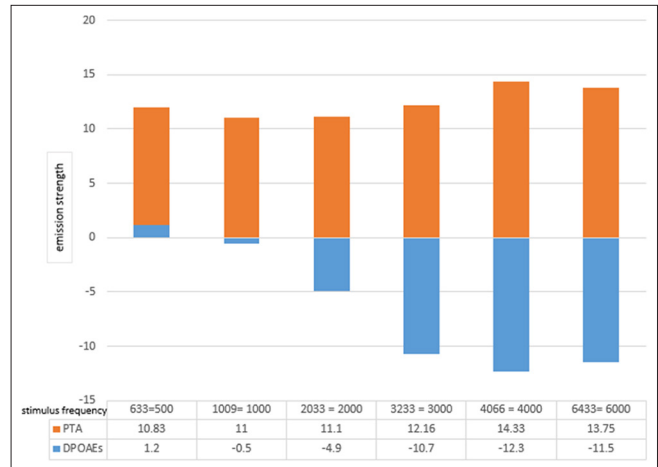


Figure 4: The results of mean DPOAEs and PTA responses for right ear in non NIHL workers

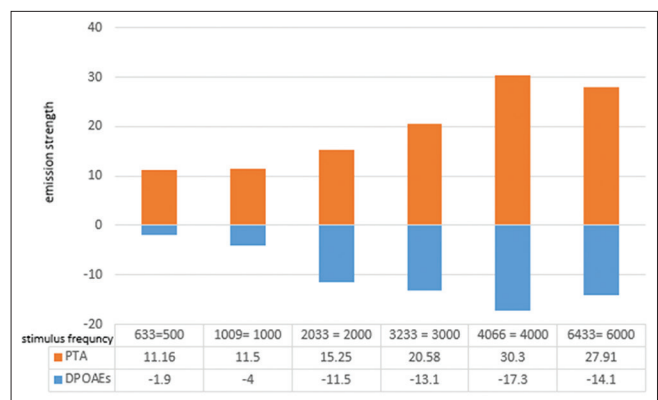


Figure 5: The results of mean DPOAEs and PTA responses for left ear in NIHL workers

showed high sensitivity and accuracy of OAE in diagnosis and monitoring of Coclé caused by exposing to the noise which is in accordance with the present study.^[16] Baradarnfar *et al.* in their study with the topic of range changing in OAE after exposing to industrial noise concluded that DPOAEs is a sensitive method compare to PTA for early diagnosis of Coclé and can be used for screening NIHL in occupational environments. Similar to above study, although there was no evidence indicating NIHL in PTA test of people without NIHL (normal group), OAE test indicates hear loss in hair

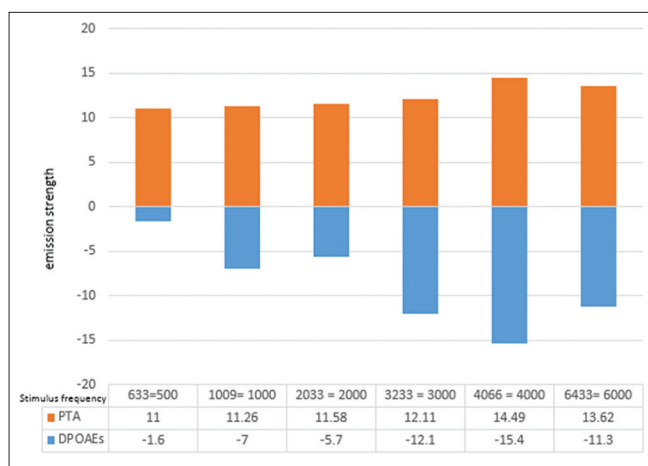


Figure 6: The results of mean DPOAEs and PTA responses for left ear in non NIHL workers

cells.^[6] Similar to the results of present study, in the study of Boger *et al.*^[15] with the topic of emission distortion in normal hearing of labor exposed to noise, DPOAEs has a high sensitivity in early diagnosis of changes in Coclé caused by noise compare to PTA. The matter has been also confirmed in the studies of other researchers.^[21-24] Vieira Peron *et al.* in their study concluded that there is a significant difference between PTA test and DPOAEs test in the group of people exposed to the noise and with normal hearing. In the present study, significant reduction was observed in DPOAEs ranges at high frequencies for the group without NIHL. The results of Mink's study on using the map of emission distortion levels of DPOAEs in Coclé damaged by noise and healthy Coclé showed that the DPOAEs range of group with NIHL is significantly weaker with $P \leq 0.01$ compare to the healthy group.^[25] According to the results of the present study and previous studies, it seems that DPOAE detects hearing loss caused by noise one phase earlier compare to PTA. However, future studies should try to provide more valid documents on the levels of DPOAE and controlling variables such as duration of exposition, smoking, and blood pressure levels.

CONCLUSION

According to the results of present study, it seems that DPOAE can be used as a conventional test for behavioral audiogram in a population exposed to the noise and gathering basic data to utilize from this test with more accuracy and confidence in a population exposed to the noise. The function of PTA findings is only a behavioral test. OAE test can be used as a useful tool when people malingering to deafness, as well as it can be used as a general index of the hearing loss degree. One of the most important usages of the present study is confirming the DPOAE mean levels of mid and high frequencies of hear loss caused by noise and is proper to surely determining of compensation for people with NIHL. In the statistical and scientific terms, the result of the present study confirms that OAE measuring can be a valuable tool for

assess hear losing caused by noise. The result of the present study is in accordance with the results of previous studies about the matter that DPOAEs test is more sensitive in early diagnosis of inner ear damage compare to the traditional audiometry, but it cannot estimate the hearing thresholds. In general, OAE can diagnosis Coclé damage earlier than PTA. Therefore, it can be used in screening hearing system of labor exposed to the noise and evaluating the effectiveness of using protection equipment of hearing.

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