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**Noise Exposure in High School
Aged Youths and Distortion-
Product Otoacoustic Emissions**

Independent Study Project

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May 1995

Abstract

The primary goal of this study was to provide more information on the effects of noise exposure on high school aged boys' hearing and how these effects can accurately be measured. 110 noise exposure questionnaires were given to local high school males to determine their self-reported recreational and/or vocational noise history. From these questionnaires, the five boys reporting the most and the five reporting the least amounts of previous noise exposure were chosen to participate in the study. Hearing thresholds were measured using pure-tone behavioral audiometry and each student was also evaluated with distortion product otoacoustic emissions (DPOAE). The distortion products were measured by sweeping across the frequencies at 75 dB SPL. The findings were that although the low exposure group did have better audiometric thresholds, their distortion-product otoacoustic emissions did not reflect this. There was no correlation between emission levels and previous noise exposure as there was between audiometric thresholds and previous noise exposure.

Introduction

It is well known that exposure to loud sounds can have a negative effect on one's hearing sensitivity. Because of the loud noises experienced in many industries, the federal government has dictated mandatory regulations dealing with permissible noise levels and duration periods which are designed to protect the employee. Yet these regulations do not apply to life outside of the work environment where noise exposure can still be quite hazardous. This unregulated noise does not only affect industry workers but affects people of all ages and many environments. Many experts agree that today's teenagers are in danger of suffering from a decrease in hearing sensitivity due to the noises they are exposed to in everyday life. These noises may include loud music, motorcycles, hunting/shooting, lawn equipment (mowers, leaf blowers, etc.), concerts, sporting events, boating, and construction equipment. Noise levels of many of these items may be in the range of 100 to 115 dB (Clark, 1991). Moderate exposure to loud sounds may cause temporary threshold shifts (TTS) but recurrent exposure can gradually produce permanent hearing loss. The presence, severity, and pattern of the loss is determined by the duration and intensity of the noise, the number of exposures to the noise, and the individual's susceptibility. The type of hearing loss caused by noise exposure is typically a high frequency sensorineural loss. Damage usually occurs to the outer hair cells but, with extensive exposure to high levels of sound, damage can also be done to all types of cells in the organ of Corti and other intracochlear structures (e.g., Clark and Bohne, 1984).

An otoacoustic emission is the acoustic energy generated within the cochlea which can be measured in the external ear canal by a sensitive microphone. Otoacoustic emissions reflect the sensitivity of the cochlea and are generated from active, nonlinear processes (Franklin et al, 1992). These emissions are thought to emulate the ability of the outer hair cells to supply energy to the basilar

membrane (Probst et al, 1991). Otoacoustic emissions can provide objective information on the mechanical activity within the organ of Corti, mainly the motility of the outer hair cells. These hair cells can be damaged by excessive noise levels as well as by other factors that affect cochlear function such as treatment with ototoxic drugs, hereditary losses, and anoxia (Kemp et al, 1990 and Wilson, 1984). When the outer hair cells are damaged, OAEs are usually reduced or diminished based on the amount of damage done, and hearing thresholds are raised.

There are several types of otoacoustic emissions which can then be divided into two categories; spontaneous and evoked emissions. For this study, the emissions were evoked using the distortion product otoacoustic emission (DPOAE) method. These emissions are frequency specific and frequency selective. The emission is the response to two pure-tone signals (f_1 and f_2) of different frequencies being passed through this nonlinear system of outer hair cells. Because the cochlea does function non-linearly, distortion is produced. The frequency of the distortion is directly related to f_1 and f_2 . The most commonly measured response is $2f_1 - f_2$ due to its large amplitude. In humans, the response measured is usually 60 dB lower than the level of the stimuli (Popelka et al, 1993).

Due to their representation of the outer hair cell function, DPOAEs allow for differentiation between types of hearing losses. They offer more advantages than click evoked OAEs because they are able to provide greater frequency specificity and more quantitative information about the degree of hearing impairment (Kim et al, 1989). OAEs are often absent in the frequency regions where a hearing loss exists. Clinically, DPOAEs may be very advantageous because they have the ability to provide a non-invasive, quick method to objectively measure the sensitivity and function of the cochlear biomechanics for specific frequencies.

Purpose

The purpose of the study was to compare behavioral audiometric results with distortion-product otoacoustic emissions (DPOAEs) in high school males and relate these results to the amount of previous noise these boys attested to being exposed to. It was assumed that all the students would have essentially normal hearing as measured by pure-tone audiometry, but that the DPOAEs may provide a more sensitive measurement and therefore indicate early signs of hearing loss in those five students exposed to higher and more frequent levels of noise. It would be expected that these emissions in the "high-risk" group would be reduced or absent, especially in the higher frequencies, since this is the location where noise begins to damage the cochlea first. The clinical applications of OAEs are still emerging and hopefully, along with information on noise exposure of high school boys, this study will provide information on the effectiveness of these measurements.

Methods

Subjects

Noise exposure questionnaires were given to 110 high school males all from the same high school in the St. Louis area. From their responses and with their willingness to participate, the five students with the highest reported previous exposures to noise and the five with the lowest reported previous exposures were chosen as the subjects. Ages of the boys ranged from 14 to 16 years with a mean of 15.3 years. All subjects participated on a volunteer basis with confirmed assent and parental consent. Each subject was in good health.

Apparatus and Procedures

Questionnaire:

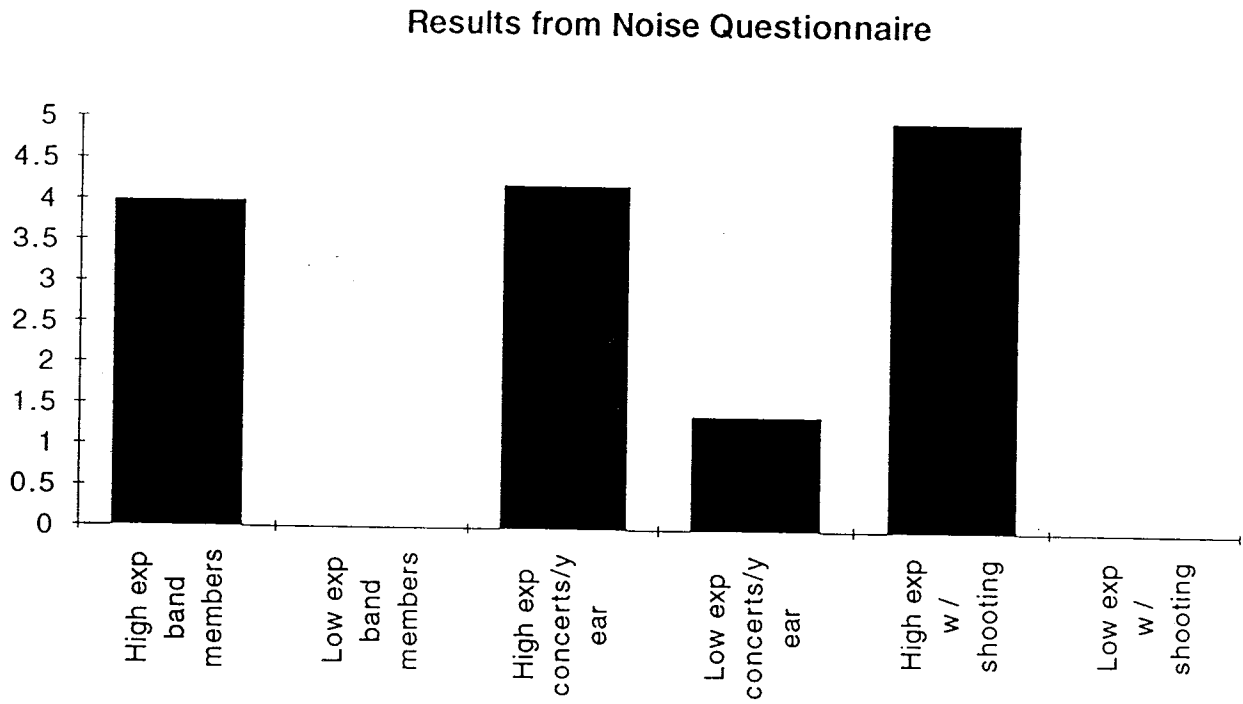
A three-page noise exposure questionnaire was given to each student to fill out. The questionnaire included questions about the

attending concerts on a frequent basis, operating loud machinery, hunting, and using loud recreational machines.

The students exposed to high levels of noise averaged 4.2 concerts per year, playing in a band for 6.8 hours a week for 2.5 years, and all had operated loud machinery such as lawn mowers, power tools, and motorcycles. All five of the students also had hunted or shot guns previously.

The students exposed to low levels of noise averaged 1.4 concerts per year, playing in a band for 0 hours a week, and had much less exposure to loud machinery. Only one student had experience shooting any type of guns. (See figure 1).

Figure 1



2. Audiometric Results:

For average audiograms of both groups of students see figure 2 for the left ears and figure 3 for the right ears.

The high level exposure students had a -1.42 dB threshold average for their right ears for all frequencies tested and a -1.08 dB threshold average for their left ears. The average threshold for both the right and left ears was -1.25 dB .

The low level exposure students had a -3.34 dB threshold average for their right ears and a -3.12 dB threshold average for their left ears. The average threshold for both ears was -3.23.

The low exposure males had a 1.98 dB better thresholds than the high exposure males. Both groups showed the right ear to have a 0.22 dB to a 0.36 dB better threshold than the left ear.

Figure 2

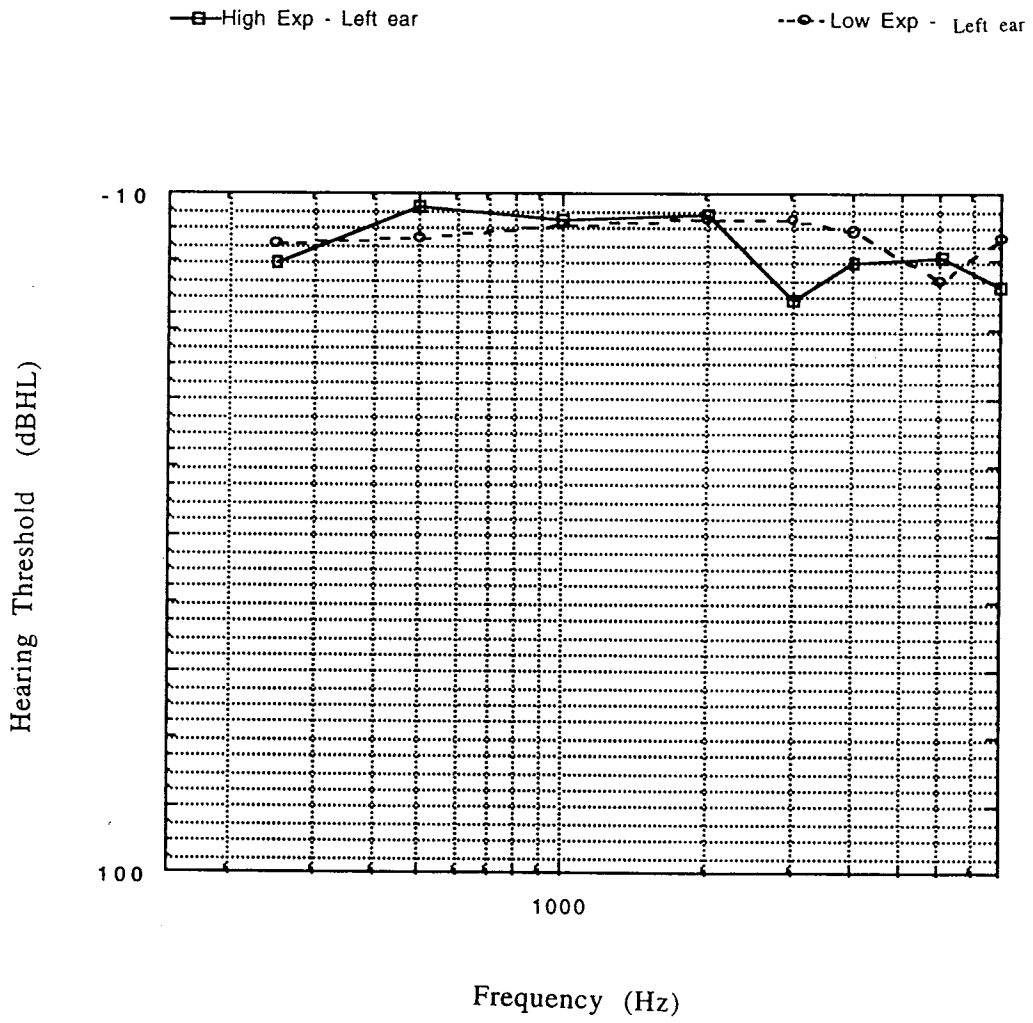


Figure 3

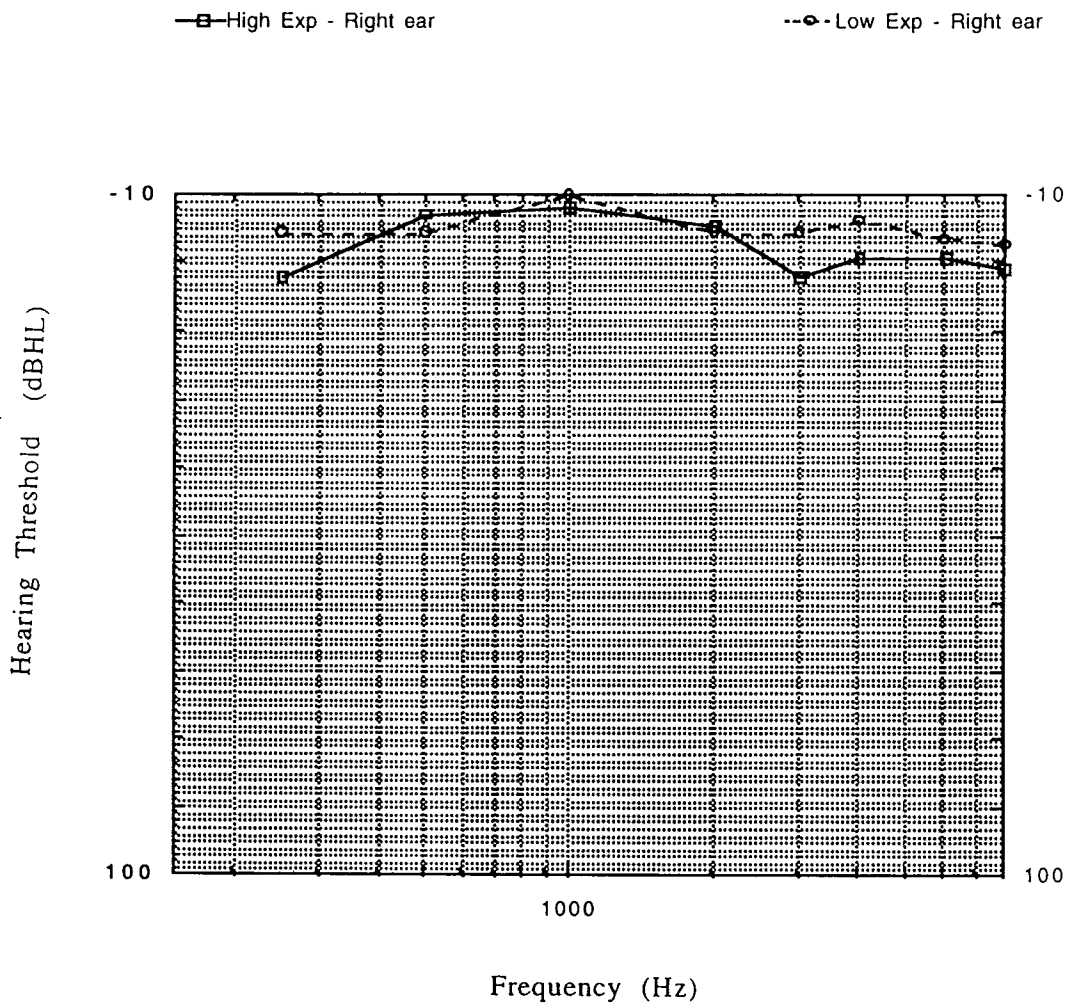


Table 1 shows the comparisons for 3, 4, and 6 kHz on the left ear. There was no statistically significant correlation between the high and low exposure groups yet the low exposure students did have average thresholds 5 dB lower than the high exposure students.

One Factor ANOVA X₁ : NOISE LEVEL Y₁ : AVG, 3,4,6, LE

Group	Count	Mean	Std Dev	Std Error
HI	5	3	8	4
LO	5	-2	8	4

One Factor ANOVA X₁ : NOISE LEVEL Y₁ : AVG, 3,4,6, LE

Comparison	Mean Diff	Fisher PLSD	Scheffe F-test	Dunnnett t
HI vs LO	5	12	1	1

Table 2 compares the two groups for 3, 4, and 6 kHz on the right ear. Again there was no correlation but the low exposure students did have thresholds averaging 6 dB lower than the high exposure students.

One Factor ANOVA X₁ : NOISE LEVEL Y₂ : AVG, 3,4,6 RE

Group	Count	Mean	Std. Dev	Std. Error
HI	5	2	8	3
LO	5	-4	6	3

One Factor ANOVA X₁ : NOISE LEVEL Y₂ : AVG, 3,4,6 RE

Comparison	Mean Diff	Fisher PLSD	Scheffe F-test	Dunnett t
HI vs. LO	6	10	2	1

Table 3 shows that there was only a mean difference of 2 dB between groups when comparing their averaged results for the left ear.

One Factor ANOVA X₁ : NOISE LEVEL Y₁ : AVG LE

Group	Count	Mean	Std Dev	Std Error
HI	5	-1	6	3
LO	5	-3	7	3

One Factor ANOVA X₁ : NOISE LEVEL Y₁ : AVG LE

Comparison	Mean Diff	Fisher PLSD	Scheffe F-test	Dunnett t
HI vs LO	2	9	3E-1	1

AVG HL HI/LO

For the averaged audiometric results in the right ear table 4 shows that there was a mean difference of 3 dB between groups and again, no significant correlation .

One Factor ANOVA X 1 : NOISE LEVEL Y 2 : AVG RE

Group	Count	Mean	Std Dev	Std Error
HI	5	-1	5	2
LO	5	-4	5	3

One Factor ANOVA X 1 : NOISE LEVEL Y 2 : AVG RE

Comparison	Mean Diff.	Fisher PLSD	Scheffe F-test	Dunnett t
HI vs LO	3	8	SE-1	1

AVG HL HI/LO

3. Distortion Product Otoacoustic Emissions Results:

The high exposure students had average emissions of 8.42 dB for the right ear and 11.14 for the left ear. The combined averages for both ears was 9.78 dB.

The low exposure students had average emissions of 8.76 dB for the right ear and 4.28 dB for the left ear. The combined averages were 6.52 dB.

There was a total difference of 3.26 dB with the high exposure students having greater emissions.

Table 5 shows that when comparing the DPOAE's in the left ear at 3110, 3920, and 6220 Hz there was a statistically significant correlation between the two groups. The mean difference in emissions between the two exposure groups.

One Factor ANOVA X 1 : NOISE LEVEL Y 3 : AVG,DP3110,3920,6220 LE

Group	Count	Mean	Std. Dev	Std. Error
HI	5	10	3	2
LO	4	5E-1	8	-

One Factor ANOVA X 1 : NOISE LEVEL Y 3 : AVG,DP3110,3920,6220 LE

Comparison	Mean Diff	Fisher PLSD	Scheffe F-test	Dunnett t
HI vs LO	10	9*	6*	2

* Significant at 95%

When looking at the same frequencies (3110, 3920, and 6220) in table six for the right ear, there was not a significant correlation nor was there any mean difference between the two groups.

One Factor ANOVA X 1 : NOISE LEVEL Y 4 : AVG, DP3110,3920,6220 RE

Group	Count	Mean	Std Dev	Std Error
HI	5	8	7	3
LO	5	8	6	2

One Factor ANOVA X 1 : NOISE LEVEL Y 4 : AVG, DP3110,3920,6220 RE

Comparison	Mean Diff	Fisher PLSD	Scheffe F-test	Dunnett t
HI vs LO	0	9	0	0

Discussion

This study showed that at ages as early as 14 years old there is already a difference between audiometric thresholds of students exposed to large amounts of noise and those who are not as frequently exposed. It can be assumed that many of the findings were not clinically significant due in part to the small number of subjects used in the study. This small sample makes it difficult to make comparisons and to find any statistically significant correlations. The fact that a strong correlation between noise exposure history and DPOEAs was not indicated may be due to many factors. Again, the most obvious factor affecting this portion of the study was the small number of subjects tested. The study may also have been affected by the fact that the boys are young enough not to have been exposed to enough noise yet to cause permanent damage to their hearing. It may also be the case that noise exposure and hearing loss do not have a linear relationship. In other words, the noise experienced today may not cause a significant or even measurable loss for many years. The results may also have been affected by the levels at which the emission measurements were taken. At this time there is no universal agreement as to the most effective level to be used and this too requires further investigation.

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Appendix A

NOISE EXPOSURE QUESTIONNAIRE

Please circle any of the following conditions that you have today or have had in the last six months:

- A. Cold
- B. Dizziness
- C. Ear pressure
- D. Ear drainage
- E. Ear infection
- F. Ear pain
- G. Allergies
- H. Ear wax
- I. Ringing in ear

Family History:

Please circle any of the following relatives who have suffered from hearing loss before the age of 50:

- A. Father
- B. Mother
- C. Sister
- D. Brother

Please circle all diseases and injuries that you have suffered:

- A. Measles
- B. Chicken Pox
- C. Diabetes
- D. High Blood Pressure
- E. Mumps
- F. Meningitis
- G. Ear Drum Puncture
- H. Skull Fracture
- I. Hearing Loss
- J. Concussion
- K. Kidney Infection

What prescription medicines have you used in the past or are now using?

.....

.....

.....

.....

Have you ever been to the doctor for ear trouble?

Why?.....

.....

Have you ever had ear surgery?..... If yes, what type of surgery and when?

.....

.....

1. Have you ever played in a band?

If "yes":

type of band
instrument played.....
hours played per week.....
how long have you been in the band.....

2. Do you occasionally attend concerts?.....

If "yes":

how often (concerts per year).....
for how many years.....
type of music.....

3. Have you ever participated in any hunting or gun shooting?.....

If "yes":

type of gun(s) used.....
number of shots fired per year.....
did you wear any ear protection.....

4. Have you ever had a job which exposed you to loud noises such as construction or a factory job?.....

If "yes":

type of job.....
hours per week that you worked.....
number of weeks worked.....
type of noise you worked near
did you wear ear protection
type of protection.....

5. Have you ever operated noisy machinery?.....

If "yes" check machine and tell number of hours per week and number of weeks:

lawn mower.....
power tools.....
motorcycles.....
chain saws.....
farm machinery.....
other.....

6. Have you participated in any noisy recreational activities on a regular basis?.....

If "yes":

type of activity (ex: snowmobiling, speed boating,
private flying , auto racing

.....

.....

hours per week.....

years in activity

I am conducting an experiment designed to investigate typical noise exposures experienced by high school students. Being involved in the project would require you to have testing done at Central Institute for the Deaf. The tests are routine hearing tests performed daily in the clinic that are not associated with any risks. As a participant in the study, you would be asked to wear a small personal noise meter which monitors your sound environment for one to two days. Based on your answers to these questions, some students will be asked to participate in the testing aspect of the study. If you would be interested and willing to be a participant please sign your name. If you do not wish to be involved with the testing, please answer the questions but do not sign your name. Thank you.

I agree to participate:

NAME:

DATE:

Appendix B

Leq Measurements

High Exposure Students:

1. 77.9 dB
2. < 60 dB
3. 87.6 dB
4. 94.2 dB

Average 79.9 dB

Low Exposure Students:

1. 76.0 dB
2. 75.5 dB
3. < 60 dB
4. 78.3 dB

Average 72.5 dB