

7-2003

# Effects of Supplemental Magnesium on Temporary Threshold Shift: Distortion Product Otoacoustic Emissions

Jenifer Leonard  
*University of South Florida*

Follow this and additional works at: <https://scholarcommons.usf.edu/etd>

 Part of the [American Studies Commons](#)

---

## Scholar Commons Citation

Leonard, Jenifer, "Effects of Supplemental Magnesium on Temporary Threshold Shift: Distortion Product Otoacoustic Emissions" (2003). *Graduate Theses and Dissertations*.  
<https://scholarcommons.usf.edu/etd/1416>

This Dissertation is brought to you for free and open access by the Graduate School at Scholar Commons. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Scholar Commons. For more information, please contact [scholarcommons@usf.edu](mailto:scholarcommons@usf.edu).

THE UNIVERSITY OF SOUTH FLORIDA

COLLEGE OF ARTS AND SCIENCES

**EFFECTS OF SUPPLEMENTAL MAGNESIUM ON TEMPORARY  
THRESHOLD SHIFT: DISTORTION PRODUCT OTOACOUSTIC EMISSIONS**

BY

Jenifer Leonard

An Audiology Doctoral Project

Submitted to the Graduate Faculty of the  
Department of Communication Sciences and Disorders  
in partial fulfillment of the requirements  
for the degree of

Doctor of Audiology

Richard A. Roberts, Ph.D. Chair  
Harvey B. Abrams, Ph.D. Co-Chair  
K. Paul Boyev, M.D. Co-Chair  
Raymond Hurley, Ph.D.

July, 2003  
Tampa, Florida

Keywords: temporary threshold shift, TTS, distortion product otoacoustic emissions,  
DPOAE, supplemental magnesium, noise induced hearing loss

Copyright 2003, Jenifer Leonard

## ABSTRACT

Leonard, Jenifer, Audiology Doctoral Project, University of South Florida, July, 2003. Effects of supplemental magnesium on temporary threshold shift: Distortion product otoacoustic emissions.

Previous studies have shown that supplemental magnesium administered prior to exposure to noise has an alleviating effect on temporary threshold shift (TTS). These studies have only used audiometric thresholds to demonstrate changes in the auditory system. However, to help determine the effects on outer hair cells (OHCs), a more sensitive measure should be used. The purpose of this study was to determine if supplemental magnesium administration prior to noise exposure has a beneficial effect on acoustic overexposure using a double-blind research design. This was determined by measuring distortion product otoacoustic emissions (DPOAEs) to determine any changes in cochlear OHC function. DPOAE amplitude and signal-to-noise ratio (SNR) measurements were analyzed for two groups of twenty participants (an experimental group and a control group). The experimental group received 150 mg of magnesium gluconate one hour prior to noise exposure. The control group received a placebo pill that was identical in appearance to the magnesium pill. Following noise exposure, the greatest changes in DPOAE amplitude and SNR occurred for the frequencies that were one-half to one octave above the frequency of the stimuli used. The greatest changes in DPOAE measurements were present immediately post TTS-inducing stimulus, with only slight changes present after 30 minutes and no difference between 30 minutes and 60 minutes post-exposure. These results were the same for both groups. It was concluded that this dosage of supplemental magnesium had no apparent protective effect on DPOAEs following intense noise exposure.

## INTRODUCTION

Continuous hazardous noise in the workplace, which affects approximately 30 million workers, can result in a noise induced hearing loss (NIHL) (NIOSH, 1996). It is one of the most common occupational diseases and is second only to back pain as the most frequently reported work-related injury or illness (NIOSH, 1996). NIHL has been described as a permanent, bilateral, sensorineural hearing loss affecting the hair cells and ultimately affecting speech understanding (Lipscomb, 1994). Typically, the first frequencies affected are 3000, 4000, and 6000 Hz, with the greatest hearing loss occurring at 4000 Hz. The hearing loss is only progressive with repeated exposure to a noisy environment (<http://www.ocoem.org/position/statements.asp>). Of course, this is a major concern in industrial settings with excessive noise.

Hearing loss can also be attributed to non-occupational noise, such as loud music, power tools, or gunfire. Hearing loss acquired by non-occupational exposure is called sociocusis and this may exacerbate NIHL due to occupational exposure or may even cause NIHL on its own (NIOSH, 1998).

Despite all that is known about the effects of noise exposure on hearing, it is still difficult to determine individual effects. That is, two individuals may share the same exposure history, but one person may have little or no effect on hearing and the other may experience a significant NIHL. The factor(s) that determine the likelihood that an individual may or may not develop NIHL when exposed to excessive noise levels contributes to an individual's susceptibility to NIHL.

Henderson, Subramaniam, and Boettcher (1993) discussed both non-auditory and auditory factors that increase an individual's susceptibility to NIHL. Several non-

auditory factors, including eye color, gender, age, and smoking have been suggested as having a potential influence on an individual's susceptibility to NIHL (Henderson et al, 1993). In addition to non-auditory factors, auditory factors such as the acoustic reflex have also been reported to have some relation to susceptibility to NIHL (Henderson et al, 1993). This factor is somewhat debatable since the acoustic reflex mainly attenuates low frequencies, and NIHL typically occurs in the higher frequencies (Moller, 1965).

Another possibility that may contribute to individual susceptibility to NIHL is intracellular magnesium level (Attias et al, 1994). Magnesium is an essential nutrient in the body that is important in controlling energy utilization and cellular membrane permeability (Walden, Henselman, & Morris, 2000). When an increase in energy consumption or a decrease in energy supply occurs, there is an increased risk that cellular function (including cochlear hair cells) may be decreased either temporarily or permanently (Attias et al, 1994). Since magnesium is important in regulating energy consumption, a deficiency in an individual's magnesium level might increase the potential for NIHL.

In a study by Joachims et al. (1987), the relationship between naturally occurring magnesium and NIHL was evaluated in Israeli Air Force pilots. The investigators found that in over one-third of the subjects tested, variance in NIHL was attributable to variations in the pilot's magnesium levels. This suggests that an individual's serum magnesium level can be a factor in determining the susceptibility to NIHL.

A conflicting report on intracellular magnesium was published by Walden et al. (2000), who evaluated the influence of naturally occurring magnesium in the body on susceptibility to NIHL in soldiers. Subjects were recruited from the same unit and had

similar high-level noise exposure. Pure tone air conduction testing and blood serum testing was performed on each participant. The investigators found no significant correlation between the naturally occurring magnesium levels and audiometric information of the participants. Thus, the results indicated that blood serum magnesium level does not appear to be related to PTS in humans. Although there is a need for further study to determine if a relationship truly exists between blood serum magnesium levels and susceptibility to NIHL, this research has led to studies investigating the influence of supplemental magnesium on NIHL.

In several studies, magnesium has been found to reduce threshold shift caused by overexposure to noise (Attias et al, 1994; Gupta, 2002; Scheibe et al, 2000). Scheibe et al. (2000) exposed a group of guinea pigs to impulse noise ranging from a single impulse sound with peak of 187 dB SPL to a train of impulse sounds with peaks of 150 - 167 dB SPL. Each group received a diet with either low or high concentrations of magnesium. The low concentration was received through drinking water only containing 0.41-0.45 mmol Mg/l. The high concentration was composed of drinking water with its inherent low magnesium level plus an additional 39 mmol MgCl/l. Threshold shift was assessed by performing auditory brainstem response (ABR) testing at two hours post-exposure and one-week post exposure. Results revealed a single noise exposure resulted in a significantly lower mean TTS in the group receiving a high magnesium diet than the group receiving a low magnesium diet. For animals exposed to the train of impulses, the animals receiving the diet with a higher magnesium level also exhibited significantly lower mean TTS. This study demonstrated that supplemental magnesium can significantly reduce the threshold shift caused by impulsive noise in guinea pigs.

There have also been studies that have evaluated the effect of supplemental magnesium on NIHL in human subjects (Attias et al., 1994; Gupta, 2002). Attias et al. (1994) studied military recruits who underwent two months of basic training that included exposure to impulse noise while using earplugs. One group of recruits received magnesium-enhanced drinks (200 ml drink with 6.7 mmol Mg aspartate), while the control group received placebo drinks. Audiometric thresholds were obtained pre- and seven to ten days post-exposure. Permanent threshold shifts were determined from these. The results revealed that the noise-induced permanent threshold shift was more severe in the control group who received the placebo than the experimental group who received the supplemental magnesium.

More recently, Gupta (2002) evaluated the effect of magnesium on temporary threshold shift in human subjects. Two groups of participants were tested, one group received 150 mg of supplemental magnesium (experimental group) and the other group received a placebo (control group). Both the placebo and magnesium were administered one hour prior to noise exposure. The noise exposure stimulus was a narrow band noise centered at 4000 Hz and presented at 100 dB SPL for 5 minutes. Audiometric air conduction testing was performed pre- and post-noise exposure. Results showed that the experimental group had significantly lower threshold shifts than the control group for some test frequencies. No significant effect was seen at frequencies lower than 4000 Hz (the center frequency of the noise stimulus). The author speculated that since the magnesium group had significantly reduced TTS from 4000-8000 Hz, the site of action of the magnesium might be at the OHCs. He reported that this could be due to temporary metabolic changes that occur at the OHCs due to the excessive noise exposure. This is in

agreement with Attias et al. (1994) who suggests that reduced levels of magnesium may lead to increased cochlear hair cell energy consumption and subsequent NIHL.

Despite the conflicting results of Joachims et al. (1987) and Walden et al. (2000) concerning blood serum levels of magnesium and NIHL, overall results appear to support a prophylactic effect of supplemental magnesium on PTS and TTS. Although animal models are available to study the effects of magnesium on PTS, this is more difficult to study in humans with the exception of studying subjects in the military (Joachims et al, 1987; Walden et al, 2000; Attias et al, 1994). A more reasonable test paradigm to study the effects of magnesium on NIHL is through determination of TTS (Gupta, 2002). Human subjects can be used in this minimal risk paradigm and inferences can be made about how supplemental magnesium may be used to induce a protective effect against permanent NIHL obtained through both occupational and non-occupational activities.

Gupta (2002) suggests that the sites of the magnesium effects are the OHCs. To investigate this hypothesis, a test that is possibly more sensitive to changes in OHCs than audiometric threshold testing should be used to determine the specific effects of supplemental magnesium on OHCs. Measurements of otoacoustic emissions (OAEs) offer this potential ability.

OAEs represent energy generated by the cochlea. These emissions are believed to originate from electromechanical processes that occur in the OHCs (Avan et al, 1996). Although four types of OAEs have been explored in previous research; transient evoked otoacoustic emissions (TEOAEs) and distortion product otoacoustic emissions (DPOAEs) are currently the only types of OAEs used in clinical assessment.

DPOAEs and TEOAEs are often used as part of the audiological test battery in clinical settings because these tests help to identify minute changes in cochlear status (Robinette & Glatke, 2002). The current investigation is concerned with DPOAEs. DPOAEs are produced by an interaction between two pure tones introduced into the ear canal that are close in frequency. These pure tones are called the primary frequencies, with the lower frequency and level labeled  $f_1$  and  $L_1$  and the higher frequency and level labeled  $f_2$  and  $L_2$ , respectively (Robinette & Glatke, 2002). The DPOAE is defined relative to the input frequencies and arises from the cochlea as a distortion due to the nonlinear properties of the inner ear. The most commonly recorded distortion product in humans is the  $2f_1-f_2$  combination tone due to the robust nature of this particular distortion product as compared to other combination tones ( $2f_2-f_1$ ,  $f_2-f_1$ , etc.).

When using OAEs to determine cochlear damage due to acoustic overstimulation, DPOAEs have been found to be more effective than TEOAEs due to the wider frequency range (between 1000 – 8000 Hz) available for assessment (Avan et al, 1996). TEOAEs are limited to a frequency range of 500 - 6000 Hz (Avan et al, 1996).

One of the primary causes of OHC damage is acoustic overstimulation. Previous studies involving cochlear-damaging agents, such as excessive noise exposure and aminoglycoside antibiotics, have demonstrated that DPOAEs are reduced when OHC damage is evident (Probst et al, 1991). Therefore, DPOAEs are helpful in assessment of damage to OHCs caused by acoustic overstimulation (Probst et al., 1991). Further, Vinck et al. (1999) have shown that OAE testing is more sensitive to changes in cochlear OHCs than audiometric threshold testing. Sutton et al. (1994) has also shown that when the appropriate parameters are used, DPOAE assessment can be as sensitive (and is more

sensitive in some cases) to TTS as pure-tone audiometry. Since OHCs are often one of the first points of damage from NIHL, OAE testing should be helpful in assessing cochlear damage in individuals exposed to excessive noise.

Previous studies on the effects of magnesium following noise exposure have only used audiometric thresholds to demonstrate changes in the auditory system. However, to help determine the effects on OHCs, a more sensitive measure should be used. Therefore, the objective of this study is to determine if supplemental magnesium administration prior to noise exposure has an alleviating effect on temporary threshold shift (TTS). This will be determined by measuring DPOAEs to determine any changes in cochlear OHC function.

## **METHODS**

### **Participants**

Forty volunteers were selected from the Tampa Bay area and University of South Florida (USF) to participate as participants in this investigation. All aspects of this study were reviewed and approved by the USF Medical Institutional Review Board (IRB#100687). Participants were between the ages of 20 - 39 (mean age of 26.45 years) with no history of hearing loss or recent excessive noise exposure. Recent excessive noise exposure was defined as an acoustic event (i.e., concert, car race, etc.) that caused tinnitus, aural pressure, or decreased hearing sensitivity. Participants were excluded if there was a past history of excessive noise exposure. This history was determined from a questionnaire developed for this study (Appendix). All volunteers chosen for this study had a negative history of consumption of daily medication or health supplements within the previous week. The following people were also excluded from this study: pregnant

women, persons with kidney disease, persons taking diuretics, laxatives and/or antacids. To be eligible for this study, participants had to have normal hearing determined by standard audiometric procedures. Normal hearing was defined as pure tone thresholds  $\leq$  20 dB HL from 250 to 8000 Hz, including inter-octave frequencies. Average audiometric data for both groups is provided in Table 1. Normal middle ear function was determined by standard tympanometry and acoustic reflex assessment. Cochlear function was assessed by measuring DPOAEs. Normal function was defined as a SNR  $\geq$  6 dB, and normal amplitudes at each frequency according to the Boys Town normative data (Gorga et al., 1997). Participants were randomly divided into two groups, experimental and control. Participants were not compensated financially, but some received extra credit if taking classes in the Department of Communication Sciences and Disorders at USF.

### **Instrumentation and Stimuli**

All instrumentation for this study was located in the USF Communication Disorders Center (CDC). Tympanometry and acoustic reflex measurements were

Table 1. Average audiometric thresholds (pre-TTS) are shown for each group in dB HL

<b>Group</b>	<b>Frequency (Hz)</b>									
	<b>250</b>	<b>500</b>	<b>750</b>	<b>1000</b>	<b>1500</b>	<b>2000</b>	<b>3000</b>	<b>4000</b>	<b>6000</b>	<b>8000</b>
<b>Control</b>	7.75	7.75	7.25	8	8.5	9	6.5	5.5	9.25	13.25
(S.D.)	(2.55)	(3.8)	(3.8)	(2.99)	(4.32)	(5.98)	(6.51)	(4.84)	(6.34)	(5.45)
<b>Experi.</b>	8.5	8.75	8	9.75	9.75	9.25	7.75	7.75	11.75	16.75
(S.D.)	(5.16)	(6.26)	(5.48)	(4.99)	(5.25)	(3.35)	(4.13)	(4.44)	(6.34)	(8.16)

performed using the GSI TymStar Middle Ear Analyzer. DPOAE measurements were conducted using the Starkey DP2000. A GSI-61 Clinical Audiometer was used for the standard audiometric procedures and to present the TTS stimulus. Pure tone air conduction testing via Etymonic ER-3A insert phones was performed using the GSI-61 Clinical Audiometer at the following frequencies: 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz using a modified Hughson-Westlake procedure. The stimulus to elicit the TTS was a narrow band noise centered at 2000 Hz presented at 105 dB SPL for 5 minutes. Real ear probe microphone measurements were performed to monitor the level of the TTS stimulus so that all subjects received the same stimulus. These measurements were obtained using the Audioscan RM500 Real Ear Measurement System.

### **DPOAE Measurement Parameters**

The 2f1-f2 DPOAEs were obtained by varying f2 at the following frequencies: 500, 750, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz. Primary levels L1 = 65 dB SPL and L2 = 40 dB SPL were used since Sutton et al. (1994) has shown that utilization of L1 - L2 = 25 increases sensitivity of DPOAEs to TTS. Emission amplitude and SNR were recorded using these stimulus parameters.

### **Procedure**

Two third-year audiology doctoral students conducted all aspects of the experiment under the supervision of a certified audiologist. Upon arrival, each participant filled out the case history form, a noise exposure history form, and reviewed the human subjects informed consent document. If the volunteer was eligible and agreed to participate in the experiment, the participant underwent the standard audiometric test

battery (including DPOAE testing) to determine hearing status. This informational review and standard testing took approximately 45 minutes.

If the participant had normal hearing status, the participant was given either a 150 mg magnesium pill or a placebo pill from a numbered envelope. The number of the envelope was recorded on the audiogram. This was a double blind experiment; therefore neither the investigators nor the participants knew which pill was received because the magnesium and placebo pills were identical in appearance. The chair of the audiology doctoral committee kept a log of which pill each participant received so that the group (experimental or control) could be determined at the end of the investigation. The participant waited one hour in a quiet setting following administration of the pill. After one hour, the participant was exposed to the 105 dB SPL noise stimuli for 5 minutes in the better hearing ear. DPOAEs were obtained immediately post-exposure and at thirty minutes and one hour post-exposure. The DPOAE parameters, amplitude and SNR, were used to determine TTS effects. Total test time was approximately 3 hours, including the one-hour rest period. Twelve participants returned thirty days post exposure for audiometric re-evaluation to ensure that thresholds returned to the pre-exposure level. Twenty-eight participants signed a waiver after reporting no changes in their hearing status following the TTS experiment.

## **RESULTS**

### **Audiometric Data**

Pre-exposure audiometric data were averaged for each group and analyzed with a two-way (2 X 10) Analysis-of-Variance (ANOVA). This ANOVA was performed to determine if there were any differences between the audiometric data of the control group

and experimental group for any of the test frequencies. The effect of frequency was significant [ $F(9, 30)=10.86$ ;  $p<0.01$ ]. However, neither the effect of group [ $F(1, 38)=3.61$ ;  $p=0.07$ ], nor the group X frequency interaction was significant [ $F(9, 30)=0.58$ ;  $p=0.81$ ]. These results indicated that both groups had the same thresholds although the actual thresholds varied as a function of frequency. In other words, there was no difference in terms of audiometric hearing sensitivity at the beginning of the study. Pure tone audiometric data was not assessed following TTS-stimulus exposure as a part of this investigation.

### **DPOAE Amplitude**

Pre-TTS DPOAE amplitudes were obtained and averaged for each group. This data is shown in Figure 1. To determine if the two groups were equivalent prior to TTS-stimulus exposure, a two-way (2 X 10) ANOVA was performed to determine the effects of group (experimental or control) and DPOAE frequency. The effect of frequency was significant [ $F(9, 30)=7.08$ ;  $p<0.01$ ]. Neither the effect of group [ $F(1, 38)=3.40$ ;  $p=0.91$ ], nor the group by frequency interaction was significant [ $F(9, 30)=3.40$ ;  $p=0.44$ ]. The significant effect of frequency indicates that certain frequencies had different amplitudes than others, however, the groups did not differ in this regard prior to the TTS exposure.

After exposure to the TTS-inducing stimulus, the post-stimulus DPOAE amplitudes were subtracted from the pre-stimulus DPOAE amplitudes to determine the amount of shift that occurred due to the noise exposure. DPOAE amplitude data for both groups is shown in Figures 2a-c. Descriptive data are provided in Table 2. These data were analyzed with a three-way (2 X 3 X 10) ANOVA to determine any effects of group (experimental or control), post-exposure time (immediate, 30 minutes post-exposure, or

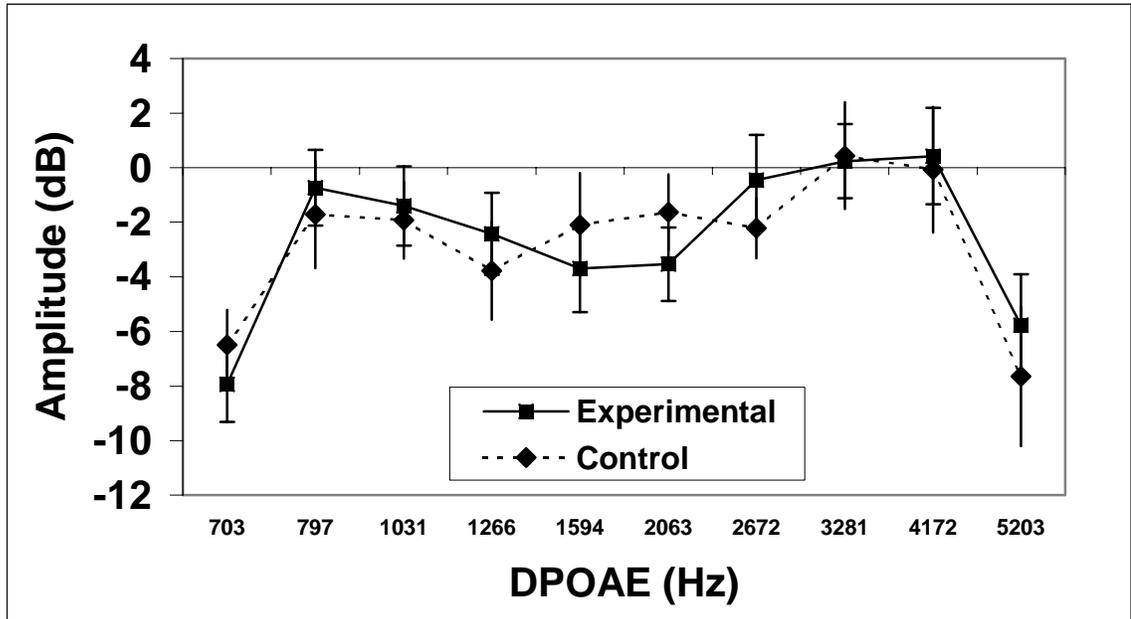


Figure 1. DPOAE amplitude prior to TTS-stimulus exposure is shown for each group as a function of  $2f_1 - f_2$  frequency. Error bars represent standard error of the mean.

60 minutes post-exposure) and DPOAE frequency. The effect of frequency was significant [ $F(9, 30)=7.04$ ;  $p<0.01$ ], as was the effect of post-exposure time [ $F(2, 37)=16.31$ ;  $p<0.01$ ]. The effect of group was not significant [ $F(1, 38)=0.88$ ;  $p=0.36$ ]. None of the interactions were significant. The greatest amplitude shift was observed for  $2f_1 - f_2$  frequencies above 1266 Hz for all post-exposure times. The amplitude shift was greatest immediately post-exposure and this shift was higher than the shift for the other two post-exposure times ( $p<0.05$ ). There was no difference between the amplitude shifts obtained at 30 minutes post-exposure and 60 minutes post-exposure ( $p>0.05$ ). This is easily observed in the data of the experimental group in Figure 3 and for the control group in Figure 4.

Table 2. Average shift in DPOAE amplitude (dB) for each group at the post-TTS stimulus exposure times.

Group	Immediate	30 min.	60 min.
<b>Experimental</b>	2.07	1.19	1.03
(range)	(-0.16 to 5.09)	(-0.38 to 2.48)	(-0.20 to 2.61)
<b>Control</b>	2.42	0.20	0.28
(range)	(-0.02 to 5.31)	(-0.55 to 1.64)	(-1.21 to 2.06)

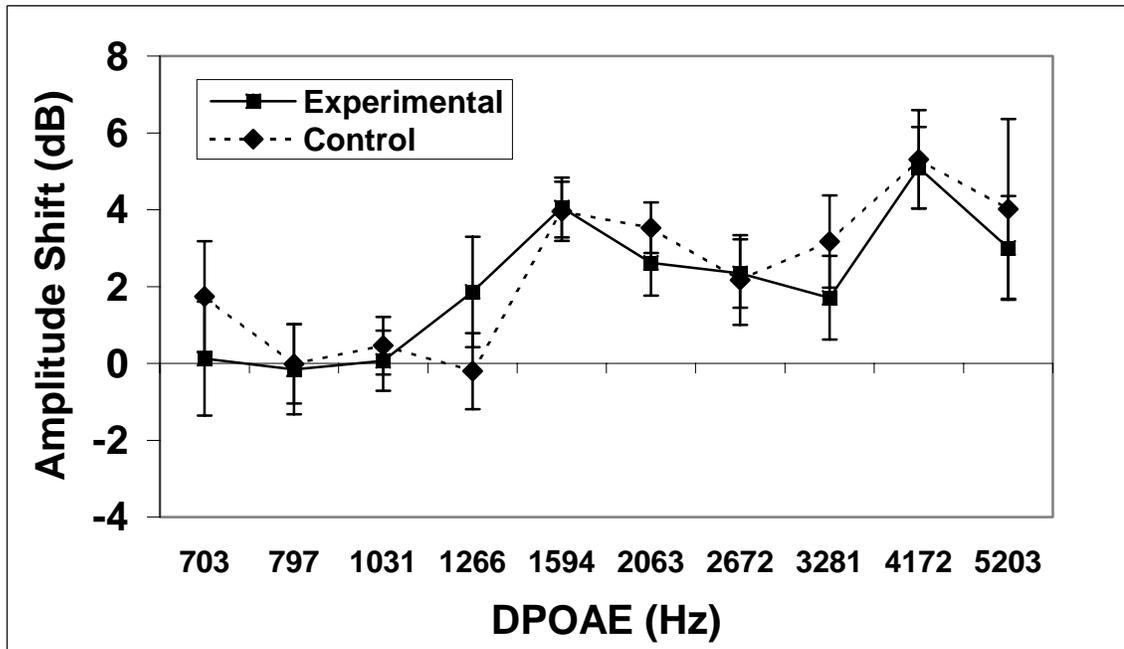


Figure 2a. DPOAE amplitude shift is shown for each group as a function of  $2f_1 - f_2$  frequency. Data is for the amplitude shift immediately post-TTS stimulus. Error bars represent standard error of the mean.

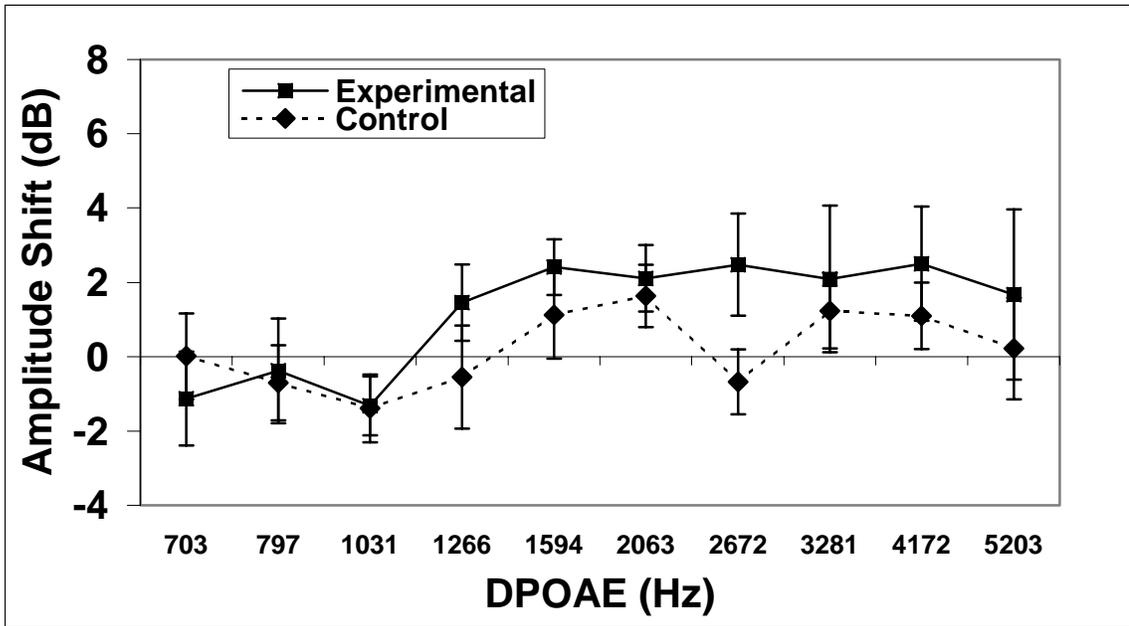


Figure 2b. DPOAE amplitude shift is shown for each group as a function of  $2f_1 - f_2$  frequency. Data is for the amplitude shift 30 minutes post-TTS stimulus. Error bars represent standard error of the mean.

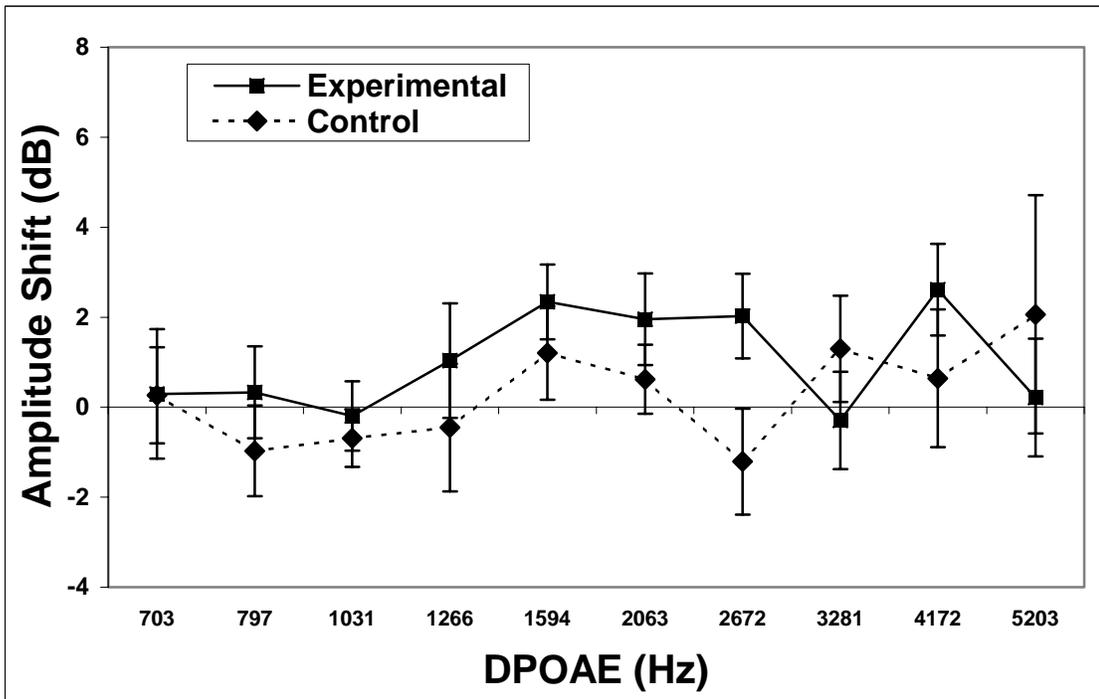


Figure 2c. DPOAE amplitude shift is shown for each group as a function of  $2f_1 - f_2$  frequency. Data is for the amplitude shift 60 minutes post-TTS stimulus. Error bars represent standard error of the mean.

## DPOAE SNR

Pre-TTS stimulus DPOAE SNRs were also obtained and averaged for each group. This data is shown in Figure 5. To determine if the two groups were equivalent in terms of SNR prior to TTS-stimulus exposure, a two-way (2 X 10) ANOVA was performed to determine the effects of group (experimental or control) and DPOAE frequency. The effect of frequency was significant [ $F(9, 30)=8.40; p<0.01$ ]. Neither the effect of group [ $F(1, 38)=0.99; p=0.33$ ], nor the group by frequency interaction was significant [ $F(9, 30)=0.38; p=0.93$ ]. The significant effect of frequency indicates that certain frequencies had different SNR than others, however, the groups did not differ in this regard prior to TTS. Thus, the groups were equivalent in terms of audiometric threshold, DPOAE amplitude and DPOAE SNR prior to exposure to the TTS-inducing stimulus.

After exposure to the TTS stimulus, the post-stimulus DPOAE SNRs were subtracted from the pre-stimulus DPOAE SNRs to determine the amount of change that occurred due to the noise exposure. This data is shown for both groups in Figures 6a-c. As described above for the amplitude data, SNR data were analyzed with a three-way (2 X 3 X 10) ANOVA to determine any effects of group (experimental or control), post-exposure time (immediate, 30 minutes post-exposure, and 60 minutes post-exposure), and DPOAE frequency. The effect of frequency was significant [ $F(9, 30)=3.07; p<0.05$ ], as was the effect of post-exposure time [ $F(2, 37)=4.22; p<0.05$ ]. The effect of group was not significant [ $F(1, 38)=0.16; p=0.69$ ]. None of the interactions were significant. Descriptive data for change in SNR is provided in Table 3. Similar to the amplitude data, the greatest shift in SNR was observed for 2f1-f2 frequencies above 1266 Hz for all post-exposure

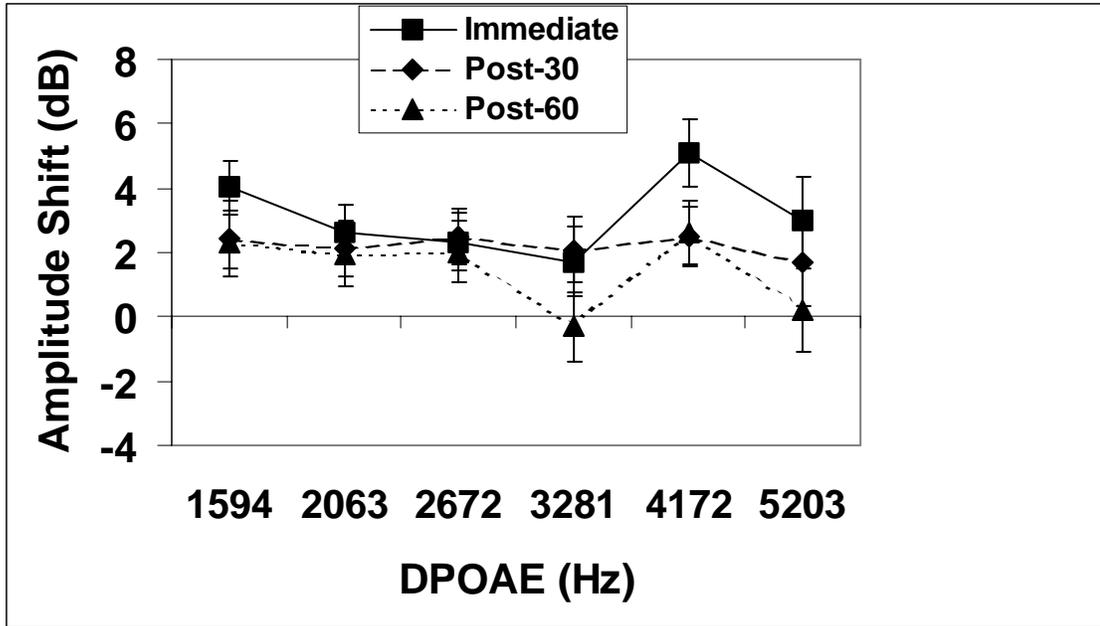


Figure 3. DPOAE amplitude shift is shown for the experimental group as a function of  $2f_1 - f_2$  frequency. Data obtained immediately, 30-minutes, and 60-minutes post-TTS stimulus are shown. Error bars represent standard error of the mean.

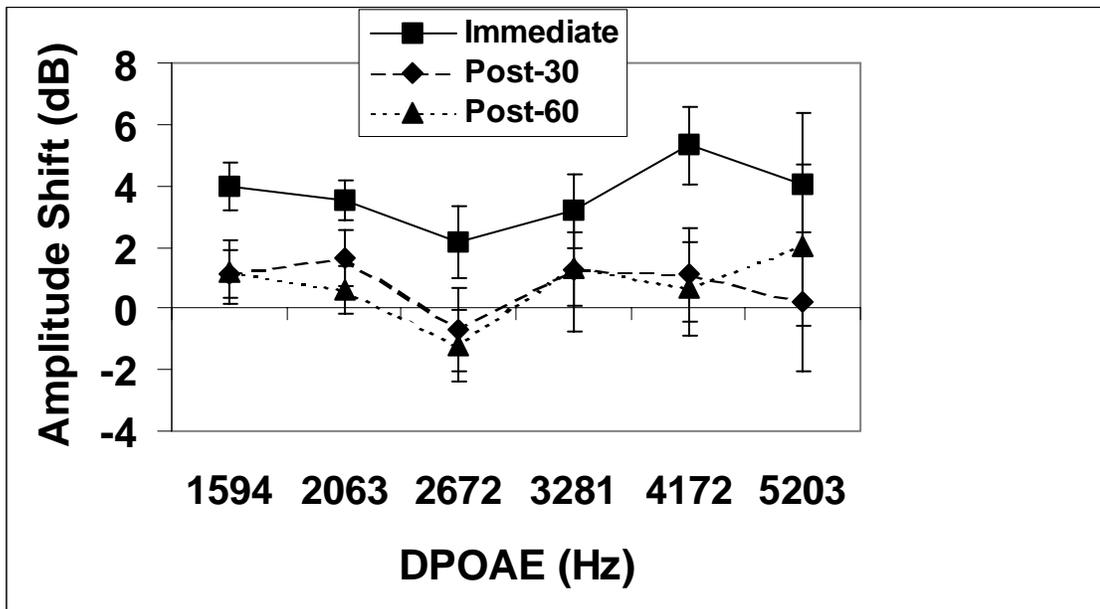


Figure 4. DPOAE amplitude shift is shown for the control group as a function of  $2f_1 - f_2$  frequency. Data obtained immediately, 30-minutes, and 60-minutes post-TTS stimulus are shown. Error bars represent standard error of the mean.

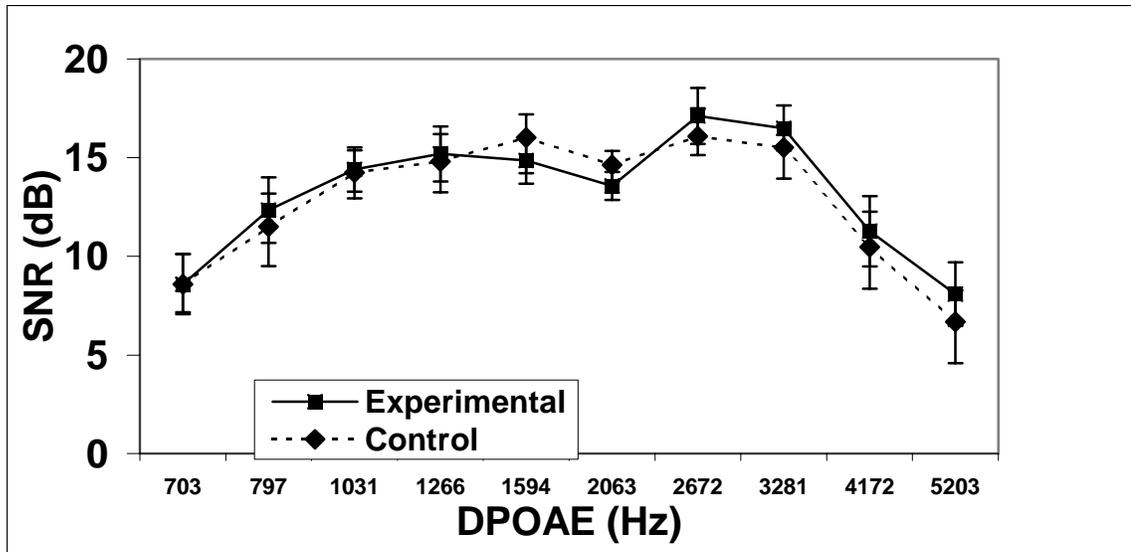


Figure 5. DPOAE SNR prior to TTS-stimulus exposure is shown for each group as a function of  $2f_1 - f_2$  frequency. Error bars represent standard error of the mean.

times. Also, shift in SNR was greatest immediately post-exposure and this shift was higher than the shift observed for the other two post-exposure times ( $p < 0.05$ ). There was no difference between the SNR shifts obtained at 30 minutes post-exposure and 60 minutes post-exposure ( $p > 0.05$ ). This is easily observed in the data of the experimental group in Figure 7 and for the control group in Figure 8.

## DISCUSSION

The purpose of this study was to determine if a single dose of supplemental magnesium administered prior to noise exposure would have an alleviating effect on TTS. This was determined by measuring DPOAEs to evaluate any potential changes in cochlear OHC function. Results indicated that the two groups of participants, experimental and control, were equivalent in terms of audiometric threshold, DPOAE amplitude, and DPOAE SNR, prior to TTS-inducing stimulus exposure. Exposure to the intense noise stimulus resulted in shifts of DPOAE amplitude and changes in DPOAE

Table 3. Average change in SNR (dB) for each group and post-TTS stimulus exposure time.

GROUP	IMMEDIATE	30 MIN.	60 MIN.
<b>Experimental</b>	1.27	1.05	0.66
<b>(range)</b>	(-1.06 to 4.45)	(-1.48 to 2.99)	(-1.21 to 4.02)
<b>Control</b>	1.74	0.10	0.24
<b>(range)</b>	(-1.41 to 4.24)	(-0.86 to 1.27)	(-1.95 to 2.69)

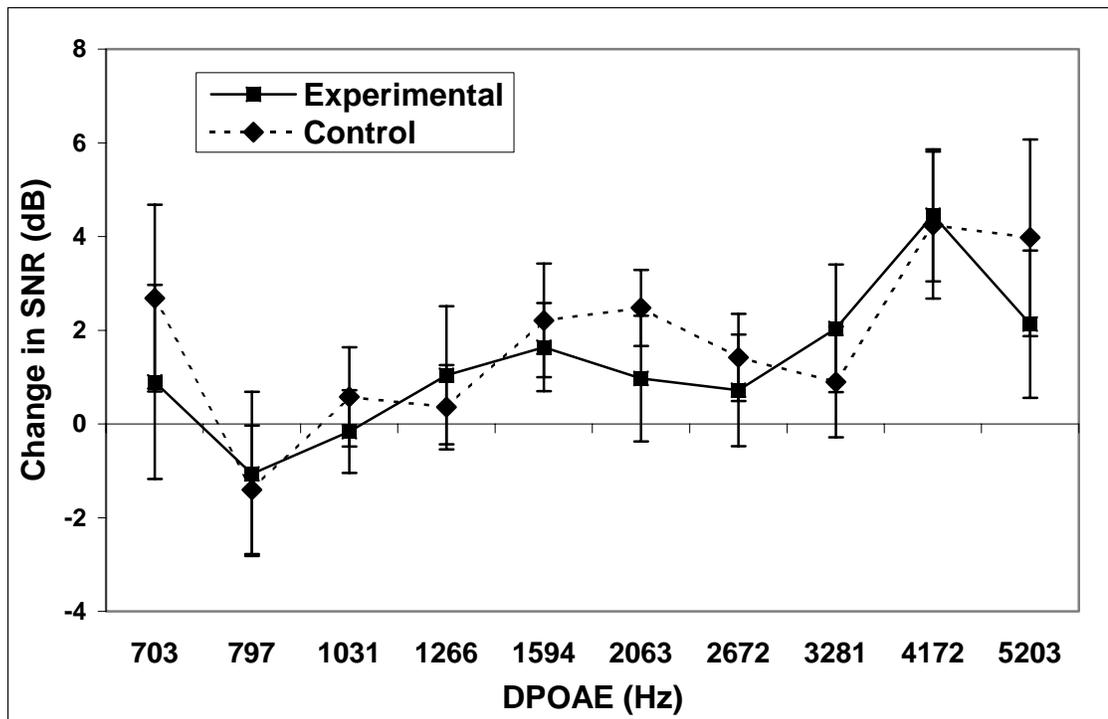


Figure 6a. DPOAE change in SNR is shown for each group as a function of  $2f_1 - f_2$  frequency. Data is for the amplitude shift immediately post-TTS stimulus. Error bars represent standard error of the mean.

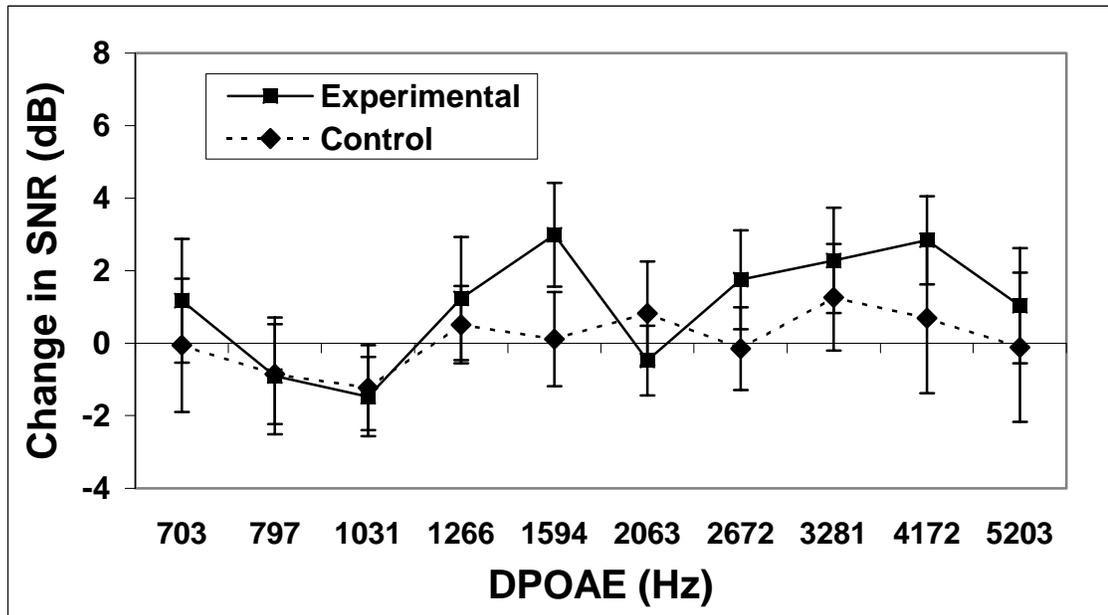


Figure 6b. DPOAE change in SNR is shown for each group as a function of  $2f_1 - f_2$  frequency. Data is for the amplitude shift 30 minutes post-TTS stimulus. Error bars represent standard error of the mean.

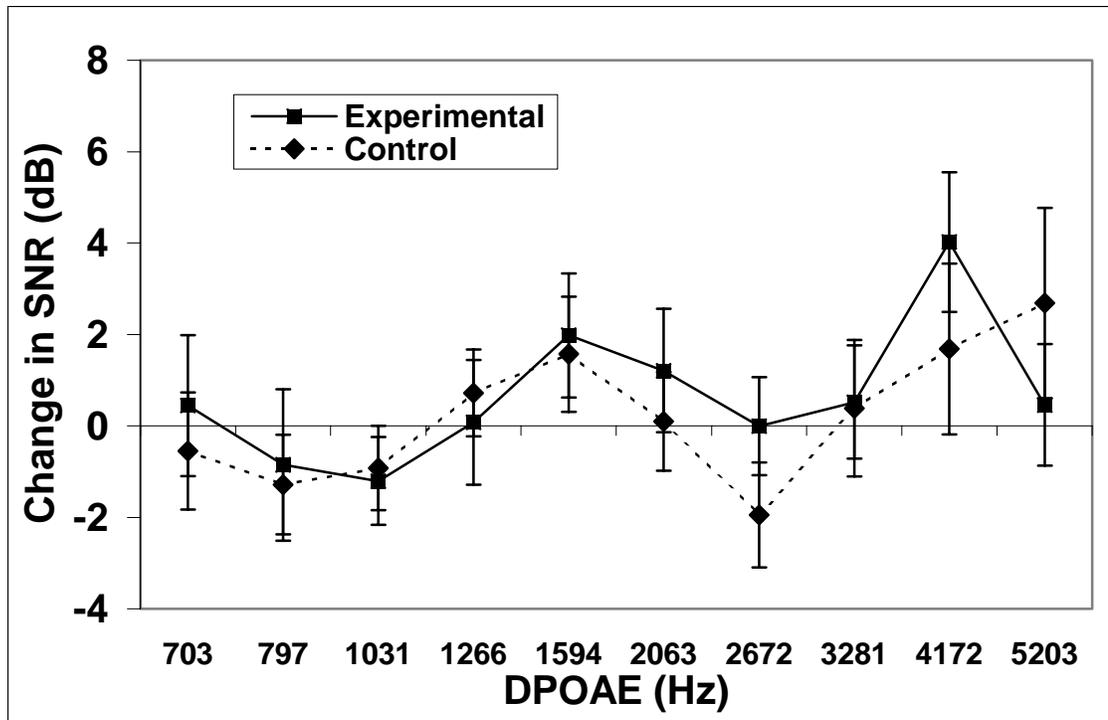


Figure 6c. DPOAE change in SNR is shown for each group as a function of  $2f_1 - f_2$  frequency. Data is for the amplitude shift 60 minutes post-TTS stimulus. Error bars represent standard error of the mean.

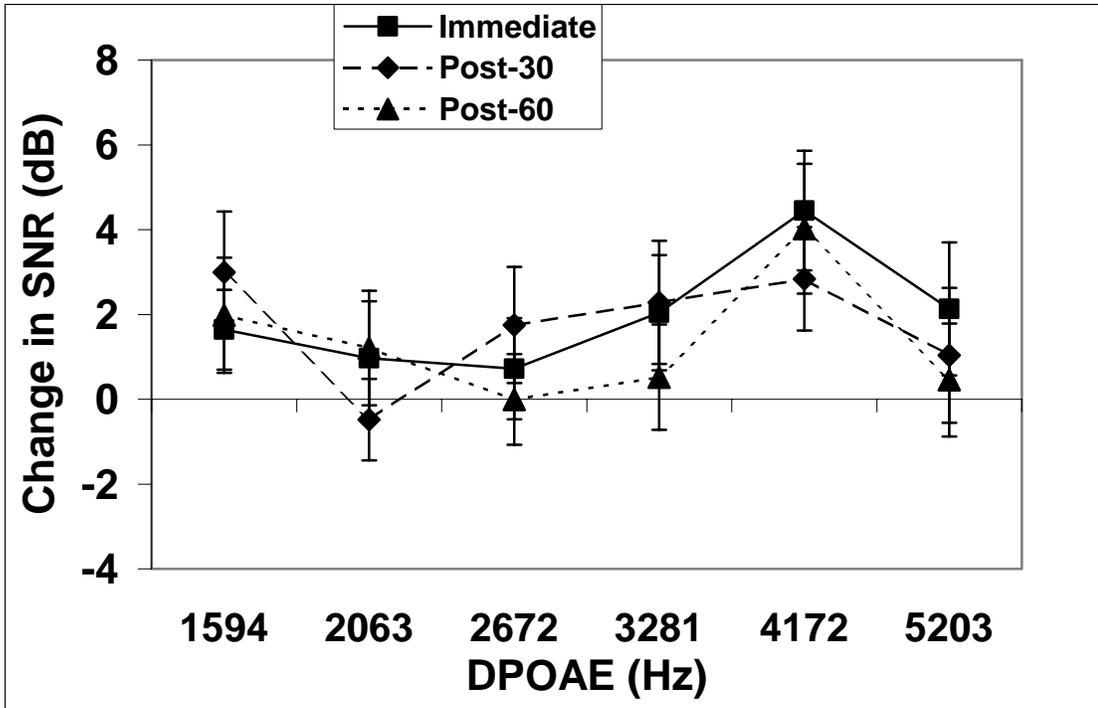


Figure 7. DPOAE change in SNR is shown for the experimental group as a function of  $2f_1 - f_2$  frequency. Data obtained immediately, 30-minutes, and 60-minutes post-TTS stimulus are shown. Error bars represent standard error of the mean.

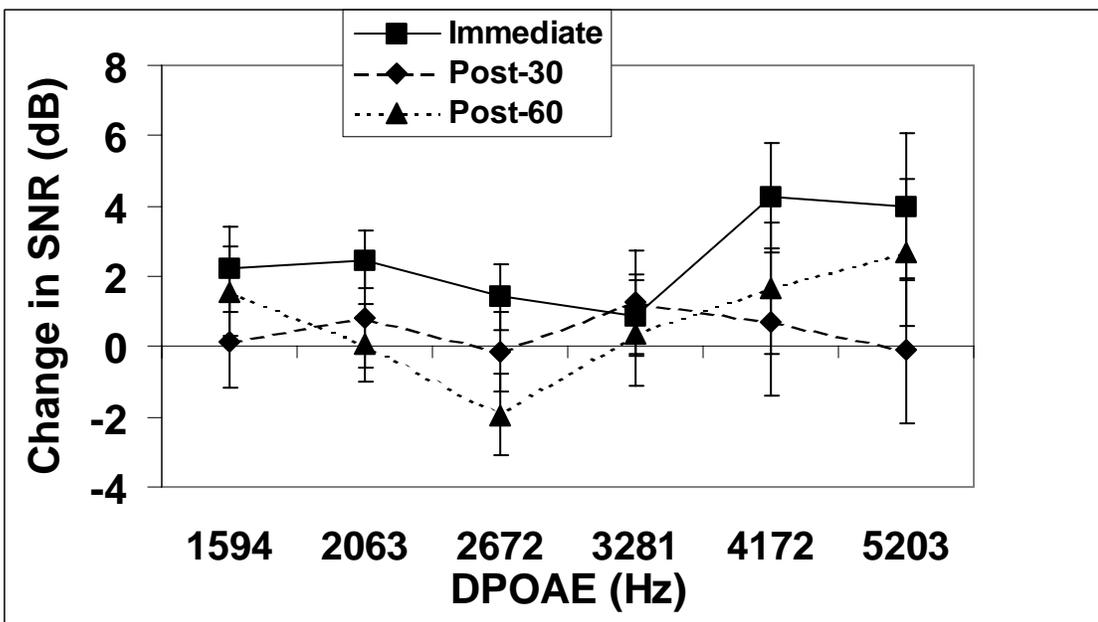


Figure 8. DPOAE change in SNR is shown for the control group as a function of  $2f_1 - f_2$  frequency. Data obtained immediately, 30-minutes, and 60-minutes post-TTS stimulus are shown. Error bars represent standard error of the mean.

SNR, primarily for the higher frequencies. The alterations in DPOAEs were more pronounced immediately following noise exposure and declined within 30 minutes. The alterations in DPOAEs were no different 30 minutes post-exposure compared to 60 minutes post-exposure. There was no difference in the results of the two groups. Thus, the results of this study indicate that supplemental magnesium has no apparent protective effect on DPOAEs following intense noise exposure.

The finding of a consistent frequency effect in the DPOAE data was expected. The TTS-inducing stimulus used in the current study was a narrow-band noise centered at 2000 Hz. The greatest effects of noise on hearing are typically observed one-half to one octave above the frequency of the noise (Lipscomb, 1994). In the current study, the greatest changes in DPOAE amplitude and SNR occurred for the higher frequencies tested with little effect in the lower frequencies since there was no energy present at that point in the spectrum of the TTS-inducing stimulus. This finding is also consistent with Gupta (2002) who observed that most threshold shift occurred at and above the frequency of their TTS-inducing stimulus (NBN centered on 4 kHz); they reported no effect in the lower frequencies.

Another finding that was expected was the effect of post-exposure time. In this study, the greatest changes in DPOAE measurements were present immediately post TTS-inducing stimulus. There were only slight changes present after 30 minutes and no difference between 30 minutes and 60 minutes post-exposure. Sutton et al. (1994) exposed human subjects to a 2000 Hz pure tone presented at 105 dB SPL. The greatest changes in DPOAEs occurred within the first 15 minutes and there was little change evident 20 minutes post-exposure. It is certainly possible that greater and longer lasting

effects may have been measured with more intense stimulation, but we were unwilling to risk the hearing sensitivity of our subjects beyond levels that were tested.

The main purpose of this investigation was to determine any beneficial effects of supplemental magnesium on the effects of noise exposure by measuring cochlear function. No differences were observed between our experimental group who received 150 mg of magnesium and the control group who received a placebo. This differs from the report by Gupta (2002) and other studies (Attias et al, 1994; Schiebe et al, 2000), which have investigated the effects of supplemental magnesium on NIHL. Specifically, the report by Gupta (2002) found that after administering 150 mg of Magnesium Gluconate (experimental group) or placebo (control group) and waiting one hour, the participants in the experimental group had significantly less TTS than those participants given the placebo.

The lack of an effect of supplemental magnesium in the current study could potentially be attributed to differences in stimuli, test measures, magnesium dosage, and study design. In our study, a 2000 Hz NBN was used to induce the TTS. This is compared to a 4000 Hz NBN stimulus that was used in the Gupta (2002) study. Although Gupta reported significant threshold shifts, these were confined to 4000 – 8000 Hz. A NBN stimulus centered on a lower frequency was used in the current study to increase the potential range of frequencies that may be affected by the TTS stimulus. In Sutton et al. (1994), a 2000 Hz pure tone stimulus was used to cause a TTS in human subjects. Sutton et al. was able to prove that DPOAEs were sensitive to changes in cochlear function for that particular stimulus. Since the goal of the current report was to investigate cochlear function with DPOAEs (as in Sutton et al.), we decided to use a

similar stimulus. It is possible that differences in stimulus bandwidth led to more pronounced changes in the Gupta (2002) study and that supplemental magnesium is only beneficial for these greater changes or for the higher frequencies affected by their stimulus. We note that measurable changes in DPOAE amplitude and SNR were recorded, so there was a TTS effect of our noise stimulus. There was simply no group effect for this amount of supplemental magnesium.

Another stimulus factor that differed between studies was the intensity of the stimulus used during the exposure. A 105 dB HL stimulus was presented and real ear measurements were performed to ensure that each participant received the same stimulus intensity in the current study. The intensity of the stimulus had to be adjusted on the audiometer to ensure that 105 dB SPL was delivered to the participant's ear canal. In some cases, the level had to be adjusted at the audiometer by as much as 10 dB to ensure the same level of presentation. To our knowledge, the stimulus in the Gupta (2002) study was not monitored in this way. The actual SPL level in the Gupta study may have been higher (and potentially lower for some subjects) than the intended 100 dB SPL, accounting partially for the difference in the results of the two studies.

Other studies that have shown a beneficial effect of supplemental Mg used higher stimulus intensities for the exposure. For example, the Attias et al. (1994) study used a noise exposure of 164 dBA. Scheibe et al. (2000) exposed a group of guinea pigs to impulse noise with an intensity of 167 dB SPL to 187 dB SPL. It is unclear whether the intensity of noise is related to the prophylactic effect of magnesium on TTS. This should be considered when comparing the results of this study to the results of past studies.

The dosage of magnesium used in the current study is also important to consider when interpreting our results. One possible explanation of why this study did not yield more favorable results could be due to the fact that the magnesium was given in only one dose, only one hour prior to the exposure to the noise. The current study and Gupta (2002) are the only two studies that evaluated the prophylactic effects of magnesium after administering only one dose of magnesium. In previous studies, magnesium was given to the subjects as a dietary supplement for a longer period of time, one week in Scheibe et al. (2000) and two months in Attias et al. (1994). It is possible that more magnesium (greater than 150 mg) is needed over a longer time course to observe benefits to cochlear function.

Another potential difference between the current study and others that have shown an effect of supplemental magnesium is the research design. In this study, the examiners and the participants were blind to which participants received the magnesium and the placebo. The content of the pills was unknown until after completion of the study. The pills were prepared by a compounding pharmacist and placed into labeled bottles, Bottle 1 and Bottle 2. The pharmacist enclosed a letter identifying the contents of the bottles in a sealed envelope. This double-blind protocol ensures the greatest control over investigator bias. The study conducted by Schiebe et al. (1999) did not utilize a double-blind protocol. The Scheibe et al. study evaluated if magnesium reduces the amount of threshold shift observed following impulsive noise exposure in guinea pigs. Gupta (2002) and Attias et al. (1994) also used similar double-blind protocols but did report an effect of magnesium.

## **SUMMARY AND CONCLUSIONS**

The purpose of this experiment was to determine if a single dose of supplemental magnesium administered prior to noise exposure would have an alleviating effect on TTS. This was determined by measuring DPOAEs to evaluate any potential changes in cochlear OHC function. Specific conclusions were: 1) the greatest changes in DPOAE amplitude and SNR occurred for the higher frequencies tested (above 1266 Hz), with little effect in the lower frequencies; 2) the greatest changes in DPOAE measurements were present immediately post TTS-inducing stimulus, with only slight changes present after 30 minutes and no difference between 30 minutes and 60 minutes post-exposure; 3) and 150 mg of supplemental magnesium has no apparent protective effect on DPOAEs following intense noise exposure.

**REFERENCES**

- American College of Occupational and Environmental Medicine. (1989). *Position statements/guidelines: Occupational noise-induced hearing loss*. Retrieved July 7, 2002, from [http://www.acoem.org/position/statements.asp?CATA\\_ID=16](http://www.acoem.org/position/statements.asp?CATA_ID=16)
- Attias, J., Weisz, G., Almog, S., Shahar, A., Wiener, M., Joachims, Z., et al. (1994). Oral magnesium intake reduces permanent hearing loss induced by noise exposure. *American Journal of Otolaryngology*, *15*(1), 26-32.
- Avan, P., Bonfils, P., & Loth, D. (1996). Effects of acoustic overstimulation on distortion-product and transient-evoked otoacoustic emissions. In A. Axelsson, H. Borchgrevink, R. Hamernik, P. Hellstrom, D. Henderson, & R. Salvi (Eds.), *Scientific basis of noise-induced hearing loss* (pp. 65-81). New York: Thieme.
- Gorga, M. P., Neely, S. T., & Ohlrich, B. (1997). From laboratory to clinic: A large scale study of distortion product otoacoustic emissions in ears with normal hearing and ears with hearing loss. *Ear and Hearing*, *18*(6), 440-455.
- Gupta, B. H. (2002). *Effect of oral magnesium on temporary threshold shift*. Unpublished Masters thesis.
- Henderson, D., Subramaniam, M., & Boettcher, F. A. (1993). Individual susceptibility to noise-induced hearing loss: An old topic revisited. *Ear and Hearing*, *14*(3), 152-168.
- Joachims, Z., Ising, H., & Gunther, T. (1987). Noise-induced hearing loss in humans as a function of serum Mg concentration. *Magnesium Bulletin*, *9*, 130-131.
- Lipscomb, D. M. (Ed.). (1994). *Hearing conservation in industry, schools, and the military*. San Diego: Singular.

- Moller, A. R. (1965). An experimental study of the acoustic impedance of the middle ear and its transmission properties. *Acta Otolaryngol*, 59, 1-19.
- NIOSH (1996). Preventing occupational hearing loss – a practical guide. Cincinnati, OH: U.S Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 96-110.
- NIOSH (1998). Criteria for a recommended standard: Occupational noise exposure—revised criteria. Cincinnati, OH: U. S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-126.
- Probst, R., Lonsbury-Martin, B. L., & Martin, G. K. (1991). A review of otoacoustic emissions. *Journal of the Acoustical Society of America*, 89, 2027-2067.
- Robinette, M. S., & Glatke, T. J. (Eds.). (2002). *Otoacoustic emissions: Clinical applications*. New York: Thieme.
- Scheibe, F., Haupt, H., & Ising, H. (2000). Preventative effect of magnesium supplement on noise-induced hearing loss in the guinea pig. *European Archives of Otorhinolaryngology*, 257, 10-16.
- Silman, S. & Gelfand, S. A. (1981). The relationship between magnitude of hearing loss and acoustic reflex threshold levels. *Journal of Speech and Hearing Disorders*, 46, 312-316.
- Sutton, L. A., Lonsbury-Martin, B. L., Martin, G. K., & Whitehead, M. L. (1994). Sensitivity of distortion-product otoacoustic emissions in humans to tonal over-

exposure: Time course of recovery and effects of lowering L2. *Hearing Research*, 75, 161-174.

Vinck, B. M., Van Cauwenberge, P. V., Leroy, L., & Corthals, P. (1999). Sensitivity of transient evoked and distortion product otoacoustic emissions to the direct effects of noise on the human cochlea. *Audiology*, 38, 44-52.

Walden, B. E., Henselman, L. W., & Morris, E. R. (2000). The role of magnesium in the susceptibility of soldiers to noise-induced hearing loss. *Journal of the Acoustical Society of America*, 108(1), 453-456.

**APPENDIX**

**Noise History Form**

**Effects of Oral Magnesium on Temporary Threshold Shift as Measured by Distortion Product Otoacoustic Emissions**

**P.I.: Jenifer Leonard, B.S.  
Faculty Advisor: Richard A. Roberts, Ph.D.**

**When answering these questions, please consider your past and current history with regard to exposure to loud sounds. Use as much space as you need to answer the questions.**

**Are you or have you ever been exposed to:**

**Firearms**\_\_\_\_\_ **Where?**\_\_\_\_\_ **How Often?**\_\_\_\_\_

**Loud Music**\_\_\_\_\_ **Where?**\_\_\_\_\_ **How Often?**\_\_\_\_\_

**Recreational Vehicles (i.e., boats, motorcycles, etc.)**\_\_\_\_\_ **How Often?**\_\_\_\_\_

**Power Tools**\_\_\_\_\_ **Where?**\_\_\_\_\_ **How Often?**\_\_\_\_\_

**Heavy Machinery**\_\_\_\_\_ **Where?**\_\_\_\_\_ **How Often?**\_\_\_\_\_

**Tractor**\_\_\_\_\_ **Where?**\_\_\_\_\_ **How Often?**\_\_\_\_\_

**Have you ever served in the military?**\_\_\_\_\_ **When?**\_\_\_\_\_

**Were you exposed to noise?**\_\_\_\_\_ **What?**\_\_\_\_\_

**Is there any other sound exposure that should be disclosed?**