The Effect of Continuous Acoustic Reflex Decay Sound on the Amplitude of Distortion Product Otoacoustic Emissions in Adults with Normal Hearing Threshold Levels

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ABSTRACT

Objectives: To investigate the effect of acoustic reflex decay sounds on the amplitude of distortion product otoacoustic emission in adults with normal hearing threshold level.

Method: A total of 20 subjects of both sexes aged between 18 and 25 years (mean: 22 years) were examined. Inclusion criteria were normal otoscopic and tympanoscopic findings, and pure tone thresholds of <20dB for 500-2000 Hz frequency range. One ear of the subjects, i.e. 20 ears, underwent DPOAE recording followed by acoustic reflex and reflex decay testing for 500-2000Hz at the audiology department at King Hussein Medical Centre between September 2013 and August 2014 . The study was approved by the Royal Medical Services ethical committee. All subjects were not paid or otherwise reimbursed.

Results: Significant difference in the mean distortion product otoacoustic emission amplitudes were noticed before and after acoustic reflex decay testing. The maximum DPOAE reduction of approximately 12 dB in the frequency range 750-2000 Hz after exposure to continuous steady high sound for 10 seconds. The distortion otoacoustic emission strength went back to base line before exposure after 30 minutes

Conclusion: There is a strong correlation between high continuous intensity sound and the reduction in the distortion product otoacoustic emission amplitude. The function of the outer hair cells (OHCs) is impaired after exposure to high intensity. Distortion product otoacoustic emissions (DPOAEs) are useful in examination of noise-induced level shifts, reflex decay high intensity sounds may result in temporary reduction in the distortion product otoacoustic emission strength.
Further investigation to be carried out on a group of hearing impaired patients to quantify the effect of the acoustic reflex decay on the distortion product otoacoustic emission amplitude whether its the OAE amplitude reduction is temporary or permanent.

Key words: Distortion product otoacoustic emission amplitude, Ipsilateral acoustic reflex, Ipsilateral reflex decay.

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Introduction

The normal cochlea does not only receive sound, it also produces low-intensity sounds called otoacoustic emissions (OAEs). These sounds are produced specifically by the cochlea and, most probably, by the cochlear outer hair

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cells as they expand and contract. The primary purpose of OAE tests is to determine cochlear status, specifically outer hair cell function. The information can be obtained from patients who are sleeping or even comatose because no behavioral response is required. There are four types of OAEs. Spontaneous otoacoustic emissions (SOAEs), transient otoacoustic emissions (TOAEs), distortion product otoacoustic emissions (DPOAEs), and sustained-frequency otoacoustic emissions (SFOAEs). DPOAEs are sounds emitted in response to two simultaneous tones of different frequencies.[(1)]

Acoustic reflexes measure the stapedius and the tensor tympani reflex generated by an eardrum movement in response to intense sound, they can be helpful in checking for particular types of hearing loss in conditions where patient's reliability is questionable, they also, occasionally, indicate central nervous system pathology. A typical set up to measure the acoustic reflex is a tympanometer that delivers both a sound to each ear and is capable of measuring the admittance of the tympanic membrane.[(2)]

Many studies reported the effects of noise on the function of the outer hair cells (OHCs), but most of them were conducted at high noise levels that people are rarely exposed to but in industries. Distortion product otoacoustic emissions (DPOAEs) are used for the assessment of the OHCs activity; therefore, it may be used for assessing the effects of exposure to excessive noise on the OHCs function as a proxy for hearing level. Toro *et al* 2010 studied whether the DPOAE fine structures of 16 normal-hearing human subjects are systematically affected after a moderate monaural sound-exposure of 10 minutes to a 2 kHz tone normalized to an exposure level LEX, 8h of 80 dB(A). DPOAEs were measured before and in the following 70 minutes after the exposure. The experimental protocol allowed measurements with high time and frequency resolution in a 1/3 octave-band centered at 3 kHz. On average, DPOAE levels were reduced approximately 5 dB in the entire measured frequency-range. The results showed statistically significant differences in pre and post-exposure DPOAE levels were observed up to 70 minutes after the end of the sound exposure.[(3)]

Toro investigated methodological aspects of DPOAE measurements that might improve hearing diagnosis and detection of hearing loss. He concluded that the continuous exposure had a more impact on DPOAE levels, with a maximum DPOAE shift of approximately 5 dB in the frequency range 2−3.15 kHz during the first 10 minutes of recovery.[(4)]

Najarkola *et al* investigated the function of OHCs by DPOAE temporary and permanent level shifts in rabbits exposed to white noise at realistic levels typically found in industrial settings over a broad range of frequencies. The function of OHCs was examined by DPOAE level (Ldp) in different occasions. The study groups were compared for DPOAE temporary and permanent level shifts to assess the effect of noise on OHCs function. They found that noise-induced DPOAE levels (Ldp) were decreased up to 20.65 dB (on day 8) and 18.93 dB (on day 11) at 5888.50 Hz ($p=0.081$). TLSdp and PLSdp were significantly decreased up to 17.99 dB and 16.27 dB, respectively. The most and least Ldp were significantly different ($p<0.05$); they occurred at 5888.50 and 588.00 Hz, respectively. There were significant differences between temporary and permanent threshold shifts at various frequencies ($p<0.05$). These differences were mainly related to 5888.50 Hz compared to other frequencies in each ear ($p<0.05$).[(5)]

Prell *et al* investigated the effect of a real-world digital music exposure that reliably induces temporary threshold shift (TTS) in 33 subjects of normal hearing human in which subjects selected either rock or pop music, which was then presented at 93–95 (n=10), 98–100 (n=11), or 100–102 (n=12) dBA in-ear exposure level for a period of four hours. Distortion product otoacoustic emissions were measured prior to and after music exposure. DPOAE amplitudes were measured at 9 different sound levels for 6 different f1/f2 frequency pairs, with tests conducted pre-music and at multiple post-music test times. Statistically reliable decreases in OAE amplitude were observed for the f2=3 kHz ($p<0.05$) and f2=4 kHz ($p<0.01$). The most robust decreases in OAE amplitude were observed within 15–20 dB of threshold (with threshold defined as the level at which OAE amplitude is 5 dB greater than the measured noise floor).

In addition of the DPOAEs findings they found that total of 5 subjects reported perceived symptoms of tinnitus at the first post-music test.[(6)]

In our clinic acoustic reflex testing is routinely used for diagnostic purposes for differential diagnosis and in particular patients who complains of vertigo, facial palsy, and specific problems. Middle ear analyzer or tympanometer is used to perform this test. During testing in which the patient is instructed to be quite and to undergo some different intense sound above the threshold of hearing levels at different frequencies. the intense sound is about 90 db SPL above the threshold of hearing at the tested frequency. After estimation of the acoustic reflex threshold the patient is instructed to hear a continuous intense sound (in which 10 dB sound pressure level SPL is added to the acoustic reflex threshold) for 10 seconds, and the results displayed on the screen of the tympanometer. Many patients who underwent this test reported ear fullness, feeling of ear blockage, restlessness and transient tinnitus. Students who are trained at our audiology clinic at King Hussein medical centre reported feeling of ear blockage and transient tinnitus after stopping the stimulus.

The purpose of the present study is to investigate the effect of acoustic reflex decay on the amplitude of the distortion product of otoacoustic emission that may explain complains of some patients. We select a group normal hearing adults of para- medical students from the Prince Aisha Bent Al Hussein College for medical allied sciences to perform the present study to rule out any other medical status that may explain the undesirable complaints.

Method

A total of 20 volunteers of both sexes aged between 18 and 25 years (mean: 22 years) were examined. Inclusion criteria were normal otoscopic and tympanoscopic findings, and pure tone threshold of <20dB for 500-2000 Hz frequency range. We examined one ear for each volunteer, i.e. 20 ears, underwent DPOAE recording followed by acoustic reflex and reflex decay testing for 500-2000Hz at the audiology department at King Hussein Medical Centre between September 2013 and August 2014. The study was approved by the Royal Medical Services ethical committee. All volunteers were not paid or otherwise reimbursed.

Otoscopic examination were carried out on each ear of the participants to ensure that no abnormalities which may interfere with the results, followed by hearing threshold determination using diagnostic audiometer type Interacoustic AC 40+, to ensure that all subjects have normal hearing threshold levels across the frequency range (500-2000 Hz), each subject demonstrated hearing threshold level less than 20 dB HL, then each ear underwent tympanometry to ensure no middle ear disorders or middle ear pressure variation that may affect the results. Each ear has middle ear pressure between +50 to -50 dapascal, after that each ear of the subject underwent DPOAE testing using biologic otoacoustic emission diagnostic protocol from 750- 2000 Hz. In DPOAEs two different stimuli levels and two different frequencies were recorded for one ear of each subject using Scout biologic system. All measurements of DPOAEs were repeated twice to ensure repeatability and accuracy, and then the ear which underwent DPOAEs immediately underwent acoustic reflex testing to determine the threshold of the reflex and reflex decay testing for the frequency range 500-2000Hz. For reflex decay testing, estimation of acoustic reflex threshold levels was determined at each tested frequency and then the threshold of acoustic reflex level at each frequency was increased by 10 dB SPL. Measurements were repeated twice to confirm and reliability and repeatability of the results. All measurements were carried in isolated sound proof test room at the Audiology Department at King Hussein Medical Centre from September 2013 to August 2014.

Statistical analysis involved the comparison between the mean DPOAE amplitudes (emission strength) for the ear tested of the 20 subjects before and after reflex decay testing using ANOVA one way analysis at a significance level of $P < 0.05$.

Results

T-test value at P value < 0.05 was used to calculate the significance of comparison Table I shows the mean acoustic reflex and reflex decay threshold levels of the right ear for 10 males and 10 females for the frequency 500-2000 Hz.

Table I: Mean acoustic reflex and acoustic reflex decay threshold levels for 10 males and 10 females

Frequency Hz	Mean Acoustic reflex threshold levels 10 males	Mean Acoustic reflex threshold levels 10 females	Mean acoustic reflex decay threshold levels 10 males	Mean acoustic reflex decay threshold levels 10 females
500	90	85	100	105
1000	100	90	110	100
2000	95	90	105	100

Table II: Comparison of the distortion product otoacoustic emission amplitude (emission strength) before and after reflex decay testing for the Rt ear of the 10 Males subjects.

L1 (dB)	L2 (dB)	F1(Hz)	F2(Hz)	Emission strength (dB) Rt ear males before reflex decay testing	Emission strength (dB Rt ears (males) After reflex decay testing	Rt ear male emission strength (dB) differences before and after reflex decay testing
65.4	55.1	1640	1968	17	10.6	6.4
65.4	54.9	1171	1406	16.9	10.1	6.8
65.2	55.1	843	1031	13.4	2.3	11.1

Table III: Comparison of the distortion product otoacoustic emission amplitude (emission strength) before and after reflex decay testing for the Rt ear of the 10 females subjects.

L1 (dB)	L2 (dB)	F1(Hz)	F2(Hz)	Emission strength (dB) Rt ear females) before reflex decay testing	Emission strength (dB) Rt ears females After reflex decay testing	Rt ear female emission strength (dB) differences before and after reflex decay testing
65.4	55.1	1640	1968	20.3	14.2	6.1
65.4	54.9	1171	1406	22	12	10
65.2	55.1	843	1031	15.7	6	9.7

Table II shows the mean differences in the DPOAE amplitudes (emission strength) for the right ear of 10 males before and after reflex decay testing for the frequency range 500-2000 Hz. Table III shows the mean differences in the DPOAE amplitudes (emission strength) for the right ear of 10 females before and after reflex decay testing for the frequency range 500-2000 Hz.

It is apparent that the acoustic reflex threshold levels of male patients are slightly higher than the female patients; this may be attributed to sex anatomical differences.

It is apparent that the mean distortion product otoacoustic emission amplitude for the Rt ear of 10 males subjects are reduced by 6 dB at 2kHz, 6.8 dB at 1kHz and the maximum reduction was 11.1 at 750 Hz

It is apparent that the mean distortion product otoacoustic emission amplitude for the Rt ear of 10 females subjects are reduced by 6.1 dB at 2kHz, 10 dB at 1kHz and the maximum reduction was 9.7 at 750 Hz.

In both groups after 30 minutes of ending the test the emission strength went back to base line as before exposure.

Discussion

Finding of the present study showed there is a significant reduction in the emission strength after exposure to the high intensity sound compared to the emission strength before the exposure. The differences in the emission strength were 6 dB at 2kHz, 6.8 dB at 1kHz and the maximum reduction was 11.1 at 750 Hz for the male group and were 6.1 dB at 2kHz, 10 dB at 1kHz and the maximum reduction was 9.7 at 750 Hz for the female group. In both groups there were significant differences apart from the effect of age and sex. This study assessed the effect of scientific diagnostic test used routinely in the clinics which differ from other studies that used environmental sounds. The findings of this study are in agreement with the findings of Toro *et al* 2010, Toro 2010, Najarkola 2012, Prell *et al* 2012 studies in that the effect of high intensity sound has a significant effect on the distortion product otoacoustic emission amplitude where significant reduction occurs post exposure to high intensity sounds compared to pre exposure.

An explanation of the reduction in the emission strength may be attributed to a decrease in stiffness of stereocilia secondary to contraction of rootlet structures, which are anchored to the cuticular plate of hair cells, intracellular changes within the hair cells including metabolic exhaustion and microvascular changes, edema of the auditory nerve endings, and degeneration of synapses within the cochlear nucleus.[5]

Recommendation

Further investigation to be carried out on a group of hearing impaired patients to quantify the effect of the acoustic reflex decay on the distortion product otoacoustic emission amplitude whether its reduction is temporary or permanent.

Conclusion

There is a strong correlation between the high continuous intensity sound and the reduction in the distortion product otoacoustice mission amplitude. The function of the outer hair cells (OHCs) is impaired after exposure to high intensity. Distortion product otoacoustic emissions (DPOAEs) are useful in examination of noise-induced level shifts. Reflex decay high intensity sounds may result in temporary reduction in the distortion product otoacoustic emission strength.

References

1. **Al-Tamimi S, Alsarhan M, Alqasem H, *et al.*** Comparison of distortion product otoacoustic emission amplitude between normal hearing male and female subjects. *JRMS* 2014; 21(1): 6-10 / DOI: 10.12816/0002571.
2. **Hain TC.** Acoustic reflex. www.dizzinessand balance.com-testing/ acoustic reflex .page last modified 15. April 2014
3. **Toro MAA, Rodrigo ON, Karen R, Dorte H.** Recovery of distortion product otoacoustic emissions after a 2-kHz monaural sound-exposure in humans: effects on fine structures. *J Acoust Soc Am* 2010.
4. **Toro MAA.** Effects of noise overexposure on distortionproduct otoacoustic emissions-Auditory hazard from impulsive occupational exposures- Thesis for the degree of doctor of Philosophy, 2010.
5. Section of Acoustic Department of Electronic Systems Aalborg UniversityAalborg, Denmark 2010
6. **Najarkola SAM, Khavanin A, Mirzaei R, *et al.*** Temporary and permanent level shifts in distortion product otoacoustic emissions following noise exposure in an animal model. *The International Journal of Occupational and Enviromental Medicine* 2012; 3(3).
7. **Prell CGL, Dell S, Hensley B, *et al.*** Digital music exposure reliably induces temporary threshold shift (TTS) in normal hearing human subjects. *Ear Hear* 2012; 33(6): e44-e58 .