Comparison of Distortion Product Otoacoustic Emission Amplitude between Normal Hearing Male and Female Subjects

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ABSTRACT

Objectives: To compare the distortion product otoacoustic emission amplitudes between normal hearing male and female subjects.

Methods: A total of 20 subjects of both sexes, aged between 18 and 25 years, mean 22 years, were studied. Inclusion criteria were normal otoscopic and tympanoscopic findings, and pure tone threshold of <20dB for 500-8000Hz frequency range. Each ear of the subjects, i.e. 40 ears, underwent distortion product otoacoustic emission recording at the Audiology Department at King Hussein Medical Centre between January 2012 and January 2013. The study was approved by the Royal Medical Services ethical committee. All subjects were not paid or otherwise reimbursed.

Results: Female subjects showed larger and stronger distortion product otoacoustic emission amplitudes' than in male subjects.

Conclusion: Sex differences in distortion product otoacoustic emissions may be due to anatomical, physiological and health status differences between males and females.

Key words: Amplitude, Distortion product otoacoustic emission, Otologically normal

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Introduction

The normal cochlea does not just 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 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). SOAEs are emitted without any acoustic stimulus (i.e., spontaneously). TOAEs or transient evoked otoacoustic emissions (TEOAEs) are emitted in response to acoustic stimuli of very short duration, usually clicks, but also tone-bursts can be employed. DPOAEs are sounds emitted in response to two simultaneous tones of different frequencies and SFOAEs are sounds emitted in response to a continuous tone.(1) Research

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studies have shown that gender differences exist in the peripheral auditory system as well as in higher level cognitive processing and hemispheric asymmetry for processing slow and fast elements of sound. Females have, on average, a better hearing sensitivity than males.[2] McFadden *et al*. reported that several studies have documented the existence of gender differences in SOAEs and TEOAEs in humans, less has been published about sex differences in DPOAEs.[3] Bowman *et al*. examined sex differences in *f*1 and *f*2 sweep DPOAEs, phase delay measures in 60 normal-hearing human adults. They found that sex differences in delay have been attributed to differences in the average length of the cochlea, where female cochleas are 13% shorter than male cochleas, and concluded that this sex difference may be attributed to sex-related anatomical difference in cochlear length.[4] O'Rourke *et al*. conducted a normative study of distortion product otoacoustic emission in six years old school children. The authors described the range of DPOAE values obtained in a large cohort's (n=1576) ears and examined the possible effect of sex and ear. They found that females in the six years old group displayed greater signal to noise ratio than males which indicates a significant DPOAE sex effect.[5] McFadden and Shubel also reported marked sex differences in OAEs between men and women. SOAEs are more numerous and stronger in women than in men, and CEOAEs were stronger in women than in men.[6] Dunckley and Dreisbach reported results in agreement with previous studies, indicating that significant interactions exist between sex and DPOAE group delay values in the lower frequencies, and between sex and DPOAE levels at the higher frequencies in favor of women.[7] Valero *et al*. measured DPOAEs in a New World primate, the common marmoset (Callithrix jacchus) by determining the optimal primary-tone frequency ratio (f_2/f_1) to generate DPOAEs of maximal amplitude between three and 24 kHz. DPOAE levels were stronger in females than males and stronger in the right ear than the left, just as in humans.[8] McFadden reported that transients and evoked transient otoacoustic emissions differ significantly between the sexes in human, rhesus and marmoset monkeys, and sheep. These differences may be attributed to the possible effect of prenatal androgen on the auditory system.[9] Pavlovcinova *et al*. conducted a normative study to examine cochlear status and possible ear asymmetry and sex effect in transient evoked and distortion product otoacoustic emissions in a group of healthy 12-year-old children in Slovakia. They found that the TEOAEs were significantly higher in girls than boys, but the ear asymmetry in TEOAE was not significant. For DPOAE responses ear asymmetry and sex did not play a role.[10] The purpose of the present study is to investigate whether there is a significant sex difference in distortion product otacoustic emission between normal otological male and female subjects of the same age and under the same testing conditions and to investigate the possible causes of this difference if present.

Method

A total of 20 subjects of both sexes aged between 18 and 25 years (mean: 22 years) were examimed. Inclusion criteria were normal otoscopic and tympanoscopic findings, and pure tone threshold of <20dB for 500-8000Hz frequency range. Each ear of the subjects, i.e. 40 ears, underwent DPOAE recording at the audiology department at King Hussein Medical Centre between January 2012 and January 2013. The study was approved by the Royal Medical Services ethical committee. All subjects were not paid or otherwise reimbursed.

Procedure

Otoscopic examination were carried out on each ear of the participants to ensure no any abnormalities that 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 (750-8000 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 of the subjects 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- 8000 Hz. In DPOAEs two different stimuli levels and two different frequencies were recorded for both ears of each subject using Scout biologic system. All measurements of DPOAEs were repeated twice to ensure repeatability and accuracy; all measurements were carried in isolated test room at the Audiology Department at King Hussein Medical Centre from January 2012 to January 2013.

Statistical analysis involved the comparison between the mean DPOAE amplitudes (emission strength) for the right and left ears for both groups male and female subjects using ANOVA one way analysis at a significance level of $P < 0.05$.

Results

Tables I and II show the mean DPOAE amplitudes (emission strength) of 10 male and 10 female subjects for the right and left ears. Table III shows the differences in the DPOAE amplitudes (emission strength) for the right ears of both groups. It was apparent that there are significant differences in the mean amplitudes between male and female subjects. The amplitudes (emission strength) of the female subjects are larger and stronger compared with the male subjects for the right ears. The significant strength differences were respectively as follows: 16.9 dB around 750 Hz, 10.9 dB around 6000 and 8000 Hz ,7.1 dB around 4000 Hz, 5.5 dB around 3000 Hz ,4.7 dB around 2000Hz, and 4.2 dB around 1000Hz. Table IV shows the differences in the DPOAE amplitudes (emission strength) for the left ears of both groups. It was apparent that there are significant differences in the mean amplitudes between male and female subjects. The amplitudes (emission strength) of the female subjects are larger and stronger compared with the male subjects for the left ears. The significant strength differences were respectively as follows: 7.1 dB around 8000Hz, 5.4 dB around 6000 Hz and, 4.2 around dB around 4000 Hz and 1000Hz, 3.2 dB around 750Hz, 2.9 dB around 2000Hz, and 2 dB around 1000Hz.

Discussion

The purpose of this study was to investigate if there are marked and significant sex differences in the mean of means amplitude of distortion product otoacoustic emission between male and female of the same age group of normal otological subjects and under the same test conditions.

The findings of the present study are in agreement with the results obtained by Bowman *et al*., O'Rourke *et al*., Dunckley and Dreisbach, and Valero *et al*., that there is a strong sex effect on the amplitude (emission strength) of DPOAE; female subjects have larger and stronger emission amplitudes than male subjects.

On the other hand, the findings of the present study are not in agreement with the results obtained by McFadden *et al*. who concluded that the differences are not significant for the effect of sex on the DPOAE amplitude and the differences are less than the other compared with the transient otoacoustic emissions. The findings of the present study are also not in agreement with the results obtained by Pavlovcinova *et al*. that sex did not play a role.

Behaviorally, morphologically, and physiologically, sex differences have been demonstrated to exist throughout the auditory system McFadden *et al*.[3]

An explanation of the disagreement between the present study and other studies may be attributed to the subjects' status that, in our study otologically normal subjects were included whereas in the other studies subjects with infectious disease were included and that might affect the strength of DPOAEs. Possible explanation for sex differences in DPOAEs and other evoked potential responses may be attributed to peripheral and anatomical sex differences such as the head size differences between male and female; with males having a larger diameter than females. In addition to that males and females differ in cochlea size; with males having longer cochlear ducts than females, resulting in longer cochlear travel times.[2] The existence of larger and stronger click evoked otoacoustic emission and DPOAEs than males may be attributed to the hormonal role including estrogen in improving auditory function in females and differential exposure to androgens during prenatal development.[3]

Table I: The mean distortion product otoacoustic emission amplitudes (emission strength) of 10 male subjects for the right and left ears

L1 (dB)	L2 (dB)	F1(Hz)	F2(Hz)	S/N Rt ears	S/N Lt ears	Emission strength (dB) Rt ear	Emission strength (dB) left ear
66.0	55.5	6654	7966	8.5	9.7	5.9	9.8
65.1	54.8	4686	5623	11.3	15.1	5.9	9.7
65.0	55.0	3327	3983	10.9	15.2	9.1	12.8
65.2	55.1	2343	2811	12.9	10.9	10.5	10.9
65.4	55.1	1640	1968	17.7	14.9	11.5	10
65.4	54.9	1171	1406	13.8	9.7	16.9	9.8
65.2	55.1	843	1031	11	11.3	7.7	11.0

Table II: The mean distortion product otoacoustic emission amplitudes (emission strength) of 10 female subjects for the right and left ears

L1 (dB)	L2 (dB)	F1(Hz)	F2(Hz)	S/N Rt ears	S/N Lt ears	Emission strength (dB) Rt ear	Emission strength (dB) left ear
66.0	55.5	6654	7966	19.9	18.4	16.7	16.9
65.1	54.8	4686	5623	21.2	14.4	16.6	15.1
65.0	55.0	3327	3983	16.9	17.2	14.6	16
65.2	55.1	2343	2811	15.7	16.3	17.6	13.1
65.4	55.1	1640	1968	13.9	13.8	16.2	12
65.4	54.9	1171	1406	17.7	19.9	21.1	16.7
65.2	55.1	843	1031	18.5	21.2	24.6	13.2

Table III: Comparison of the distortion product otoacoustic emission amplitude (emission strength) between the right ears of males and females

L1 (dB)	L2 (dB)	F1(Hz)	F2(Hz)	Emission strength (dB) Rt ears (males)	Emission strength(dB) Rt ears (females)	Rt ear strength (dB) differences female and male
66.0	55.5	6654	7966	5.9	16.7	10.8
65.1	54.8	4686	5623	5.9	16.6	10.7
65.0	55.0	3327	3983	9.1	14.6	5.5
65.2	55.1	2343	2811	10.5	17.6	7.1
65.4	55.1	1640	1968	11.5	16.2	4.7
65.4	54.9	1171	1406	16.9	21.1	4.2
65.2	55.1	843	1031	7.7	24.6	16.9

Table IV: comparison of the distortion product otoacoustic emission amplitude (emission strength) between the left ears of males and females

L1 (dB)	L2 (dB)	F1(Hz)	F2(Hz)	Emission strength (dB) Lt ears (males)	Emission strength (dB)Lt ears (females)	Lt ear strength (dB) differences female and male
66.0	55.5	6654	7966	9.8	16.9	7.1
65.1	54.8	4686	5623	9.7	15.1	5.4
65.0	55.0	3327	3983	12.8	16	4.2
65.2	55.1	2343	2811	10.9	13.1	2.9
65.4	55.1	1640	1968	10	12	2
65.4	54.9	1171	1406	9.8	16.7	4.2
65.2	55.1	843	1031	11.0	13.2	3.2

Limitations of the study

Further studies with larger number of normal hearing males and females are needed to draw more solid conclusions.

Conclusion

Sex differences in DPOAEs may be due to anatomical, physiological and health status differences between male and females.

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