Human & Veterinary Medicine
International Journal of the Bioflux Society

OPEN ACCESS
Research Article

Differences in otoacoustic emissions in infants and adults with normal hearing

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Abstract. Objective: Otoacoustic emissions (OAE) are widely used as a noninvasive technique as the test can provide a glimpse into the human cochlea during the earliest segments of perinatal and postnatal life. Although the cochlea is structurally and functionally adult-like by term birth, both transient otoacoustic emissions (TEOAE) and distortion products (DPOAE) differ in newborn compared to older children and adults with normal hearing. We aim to compare the measurements of both TEOAE and DPOAE from infants that have passed the hearing screening test and to similar measurements from normal-hearing older subjects. Material and Methods: This cross-sectional study included 165 participants (126 children and 39 adults) during a period of 5 months. The infant data were obtained from children aged 0-6 months old, divided into three age groups: 0-1 month (group 1), 1-3 months (group 2) and 3-6 months (group 3). The infant subjects included in the study groups have passed the hearing screening test, were with good general health and had normal otoscopic results. The otoacoustic emissions measurements were performed during the physiological sleep. The adult data were obtained from adults (group 4) with normal hearing as shown by the pure tone audiometry and normal functioning of the middle ear and cochlea. We studied the changes of the TEOAE signal/noise ratio (SNR) and of multiple parameters of the DPOAE responses: DPOAE levels, DPOAE noise floor and DPOAE SNR. Results: We discovered significant differences of TEOAE SNRs between pediatrics groups and adult group at the frequencies of 1 and 1.5 kHz in favor of the adult group (for the right ear when comparing group 2 and 3 to group 4 at 1 kHz, p<0.001, respectively p=0.006; for the left ear when comparing group 1 and 2 to group 4 at 1.5 kHz, p<0.001, respectively p=0.001). The differences in TEOAE SNRs remained significant at the frequencies of 3 and 4 kHz in favor of the infant groups (for the right ear when comparing group 2 to 4 at 4 kHz, p=0.004; for the left ear when comparing group 1, 2 and 3 to group 4, p=0.01, p.001, respectively p=0.004). Our results recorded significant differences at 1 and 1.5 kHz for DPOAE level for both ears when comparing pediatric groups to adult group (for the right ear, between group 2 and 4 at 1 kHz, p<0.001 and at 1.5 kHz, p=0.004 and between group 3 and 4, p=0.005; for the left ear, between group 1 and 2 compared to group 4 at 1 kHz, p=0.005, respectively p=0.02 and at 1.5 kHz, for all pediatrics groups compared to adult group: group 1 and 2, p<0.001, group 3 p=0.03). There were statistically significant differences for DPOAE noise between all pediatric groups and adult group at frequency range of 2-6 kHz for both ears. When comparing DPOAE SNRs of the pediatric groups to adult group, we observed significant differences for both ears at all the frequencies tested (p<0.05) with the exception at 1 kHz for the left ear when comparing group 1 to group 4. Conclusion: The infant otoacoustic emissions remain larger at high frequencies than adult for both transient otoacoustic emissions and distortion products.

Key Words: transient otoacoustic emissions, distortion products, adult normal hearing, infant hearing.

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Introduction

There has been an increasing interest in studying OAE in order to understand and investigate the cochlear function both in adults and infants, since the first description of OAE by Kemp in 1978. There still is no complete description of the most basic aspects of audition although studies of ear development were performed even before 1970 (Abdala 2000). It is believed that the study of OAE in human beings can serve as good criterion to investigate the physiological events of cochlear maturation, because OAE provide a glimpse into the human cochlea during the earliest segments of perinatal and postnatal life. The maturational processes underlying the acoustical and mechanical functioning of the human ear and the detectable functional differences in OAE responses represent a challenging and interesting scientific problem. There is evidence that OAE (TEOAE or/and DPOAE) differ in newborn compared to older children and adults with normal hearing (Norton et al 1990; Kok et al 1992).

Studies have revealed that transient otoacoustic emissions change with age: TEOAE amplitude increase within the first days after birth (Kok et al 1992; Welch et al 1996) and remain statistically significant higher in the first year of life than in older children and adults and then rapidly decrease in the first 2-4 years of life (Norton et al 1990; Spektor et al 1991). Distortion product otoacoustic emissions measured in newborns are not adult-like in high-frequency range at 4-6 kHz (Groh et al 2006). The amplitude of otoacoustic emissions presents little variations during the first 6 months of life (Abdala et al 2008). Kon (2000) stated in his study that there are no significant changes of DPOAE

amplitude on high frequencies. The DPOAE amplitude decreases significant with age (Brook et al 2001; Dorn et al 1998).
Recently, Abdala and Keefe (2006) demonstrated that the existing differences between newborns and adults are partially explained by the immaturities of the outer and middle ear (Abdala et al 2006; Dhar & Abdala 2007). Studies reveal that the development of outer and middle ear structure continues well into infancy, but the dimensions of the human cochlea are adult-like at birth (Eby et al 1986). The diameter and the length of the outer ear canal increase from birth to 24 months (Keefe et al 1993). The mechanically functioning of the middle ear changes as a result of the constantly increasing volume of the middle ear and of the osicular chain orientation (Eby et al 1986). The ossicles and the muscles of the middle ear are completely formed around the sixth month of fetal life (Saunders et al 1983). The distance between the stapes footplate and the tympanic membrane in adults is larger than that of infants through 6 postnatal months (Eby et al 1986).
In humans, the cochlea is fully developed from prenatal period, probably from 22 weeks of gestation (Pujol et al 1990, 1991). Experimental studies on human fetal and newborn cochlea reveal that the cochlea is structurally and functionally adult-like by term birth (Pujol et al 1992; Abdala 1996; 1998; Igarashi et al 1980; Hoshino et al 1990; Eggermont et al 1996)
Although OAEs are widely used as a noninvasive technique in studying various aspects of peripheral auditory physiology and biophysics, our interest is in their use as a tool to investigate the maturation of the auditory periphery in humans. Limited data are available about the measurements of TEOAE and DPOAE from the same group of patients (Bonfils et al 1992; Smurzynski et al 1993), although test performance is similar (Abdala et al 2006). We aim to compare the measurements of both TEOAE and DPOAE from infants, that have passed the hearing screening tests and from older subjects with normal hearing, and also to study the differences between genders in otoacoustic emission measurements.

Material and method

Study design

The present study took place in the Department of Otorhynolaryngology of “Iuliu Haţieganu” University of Medicine and Pharmacy Cluj-Napoca, during a period of 5 months, from October 2013 until February 2014. All patients were informed about the participation at this study and their written informed consent was obtained before the study was initiated. The study has been approved by the ethical commission of the “Iuliu Haţieganu” University of Medicine and Pharmacy Cluj-Napoca and has been conducted according to the principles in the Declaration of Helsinki revised in 2013.

Participants and General Procedures

This cross-sectional study included 165 participants (126 infants included in neonatal hearing screening whose parent agreed to freely participate in this study and 39 adults who expressed their consent to participate in this study). The subjects did not receive any payment for their participation. All participants were tested in similar conditions and using the same personnel, the same methods and equipments and the data were collected from both ears.
Infant subjects: The data were obtained from a sample of 126 children aged 0-6 months old, who passed the hearing screening test, with good general health. All subjects had normal otoscopic results. Subjects were divided into three age groups: 0-1 month (group 1, 11 subjects), 1-3 months (group 2, 98 subjects), 3–6 months (group 3, 16 subjects). Each subject was tested only once. To assess infant hearing abilities, the recording of otoacoustic emissions were performed in a sound attenuated chamber, and both ears of all subjects were tested consecutively in a random order. The measurements were performed during the physiological sleep.
Adult subjects: The data were obtained from a sample of 39 adults (group 4) and normal hearing as shown by the pure tone audiometry and normal functioning of the middle ear and cochlea as shown by tympanometric measurements and by the presence of acoustic emissions, without any hearing abnormalities or any risk factors for hearing loss. All subjects had normal otoscopic examination. There was no history of otological diseases or ototoxic drug use among the studied subjects. To assess their hearing abilities, pure tone audiometry over a frequency range of 0.125–8 kHz and recording of otoacoustic emissions were used. Tympanometry, acoustic reflex and reflex decay test were performed in order to confirm normal middle ear function. Audiological investigations were performed in a sound attenuated chamber, and both ears of all subjects were tested consecutively in the following order: audiometry, timpanometry, acoustic reflex and reflex decay test, then TEOAE and DPOAE.

Equipment, Stimulus, and Recording Parameters

All subjects underwent the following test battery: anamnesis, otoscopic examination, pure-tone audiometry, tympanometry, acoustic reflex and reflex decay test (only for the adult subjects), transient evoked otoacoustic emission (TEOAE) and distortion-product otoacoustic emission (DPOAE). Otoscopy and cleaning the external ear canal was performed if necessary. All ears in this study in both groups passed visual inspection of the tympanic membrane.
Pure tone audiometry over a frequency range from 0,125-8 kHz was performed with a Interacoustics Audiometer Affinity Suite, Assens, Denmark, calibrated yearly according to the European standards. Acoustical signals were delivered biaurally via headphones. Air conduction thresholds were obtained at frequencies 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz. Bone conduction thresholds were obtained at 0.25, 0.5, 1, 2, and 4 kHz. The hearing thresholds were detected with a resolution of 5 dB steps. Normal hearing was defined as the hearing threshold equal or less than 20 dB HL on all the frequencies tested.
Tympanometry, acoustic reflex and decay reflex test recordings were obtained using an Interacoustics Titan Suite, Wideband Tympanometry, Assens, Denmark. In order to qualify for inclusion, the following tympanometric criteria had to be met: curve type A according to Jerger’s classification, acoustic reflex present both ipsilateral and contralateral, reflex decay test at 1 kHz positive.
Otoacoustic emission measurements were done in a sound-treated room with the subject seated throughout the test session. The probe used to record the otoacoustic emissions was positioned in the subject’s ear canal by a foam ear tip. (1) Transient evoked otoacoustic emissions (TEOAE) were recorded using

Table 1. Demographic characteristics of the population included in the study

		Group 1	Group 2	Group 3	Group 4	p
Age	Average	0.26 months	1.42 months	3.67 months	37.07 years	
	Age range	0.2-0.3 months	1-2.2 months	3-5.1 months	13.3-76.9 years	
	Standard deviation	0.05	0.42	0.72	13.99	
Gender	Female	7 (63.6%)	35 (35.7%)	9 (53%)	26 (66.7%)	0.006*
	Male	4 (36.4%)	63 (64.3%)	8 (47%)	13 (33.4%)	
Environment origin	Urban	10 (90.9%)	25 (25.5%)	17 (76.5%)	36 (92.3%)	0.09
	Rural	1 (9.1%)	73 (74.5)	13 (23.5%)	3 (7.7%)	
Type of birth	Natural	4 (36.4%)	53 (54.1%)	10 (58.8%)	64 (50.8%)	0.37
	C-section	7 (63.6%)	45 (45.9%)	7 (41.2%)	62 (49.2%)	

* Bonferroni correction

Intelligent Hearing Systems SMART-EP – SmartTEOAE, utilizing a nonlinear click stimulus at 85 dB SPL, with a 19,3 / sec rate, with a minimum of 1024 sweeps and a maximum of 2048 sweeps. The presence of TEOAE was recorded for the frequency range of 1-4 kHz. The value of SNR used was ≥ 6 dB SPL. (2) Distortion product otoacoustic emissions (DPOAE) were recorded using an Interacoustics Titan Suite – DP-gram, Assens, Denmark. The primary stimulus f1 and f2 were used with a ratio of f2/f1 fixed at 1.22, and the stimulus levels were held constant at 65 dB SPL for L1 and at 55 dB SPL for L2). The presence of DPOAE was recorded as a DP-gram as a function of f2 for the frequency range of 1-6 kHz. The value of SNR used was ≥ 6 dB SPL.

Statistical analysis

Statistical analysis was performed using Microsoft Excel 2005 and SPSS 13. The student's t test, Mann-Whitney test and Bonferroni correction were used when appropriate. The differences have been considered statistically significant when p value was less than or equal to the level of significance 0.05.

Results

This cross-sectional study included 165 participants divided in four study groups. The demographic characteristics of the participants are described in table 1.

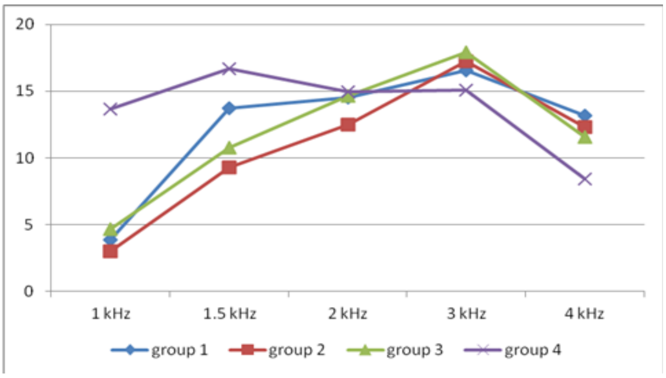
TEOAE

Comparing the mean values of TEOAE SNR between the four groups and using Bonferoni correction, we discovered more significant differences between pediatrics groups and adult group than significant differences between pediatrics groups. The only significant p value recorded was at 1.5 kHz (p=0.04) for the left ear when comparing group 1 to group 3.

The adult group presented higher SNR values than any pediatric groups at low frequencies of 1 and 1.5 kHz. Significant differences are recorded for the right ear when comparing group 2 and 3 to group 4 at 1 kHz (p<0.001, respectively p=0.006) and for the left ear when comparing group 1 and 2 to group 4 at 1.5 kHz (p<0.001, respectively p=0.001).

The highest TEOAE SNR means are recorded at 3 and 4 kHz for pediatric groups. The results from our study groups showed that the only significant difference appears when comparing group 2 to 4 at 4 kHz (p=0.004) for the right ear. There were significant differences for the mean SNR at 4 kHz when comparing each of the pediatric groups to adult group for the left ear (group1, p=0.01; group 2, p.001 and group 3, p=0.004).

Figure 1 illustrates the mean TEOAE SNR centered at 1, 1.5, 2, 3 and 4 kHz for both ears and for each age group.



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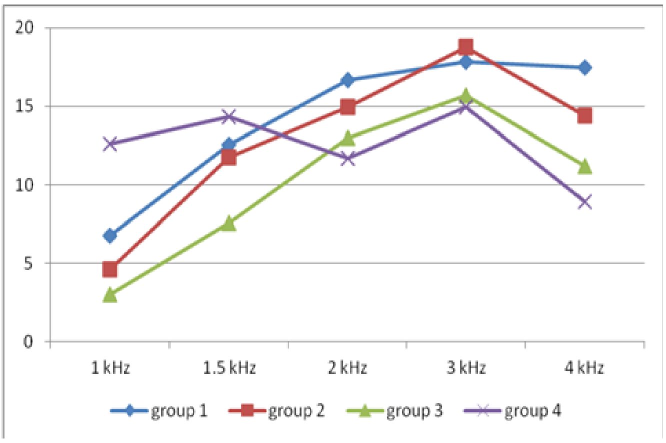


B

Figure 1. Distribution of the mean SNR for each ear for the four groups centered at 1, 1.5, 2, 3, 4 kHz; panel A – mean SNR for the right ear; panel B – mean SNR for the left ear

Our study implied also the statistical analysis gender involvement in generation of the TEOAE. Figure 2 shows the TEOAE SNR means for gender for both ears.

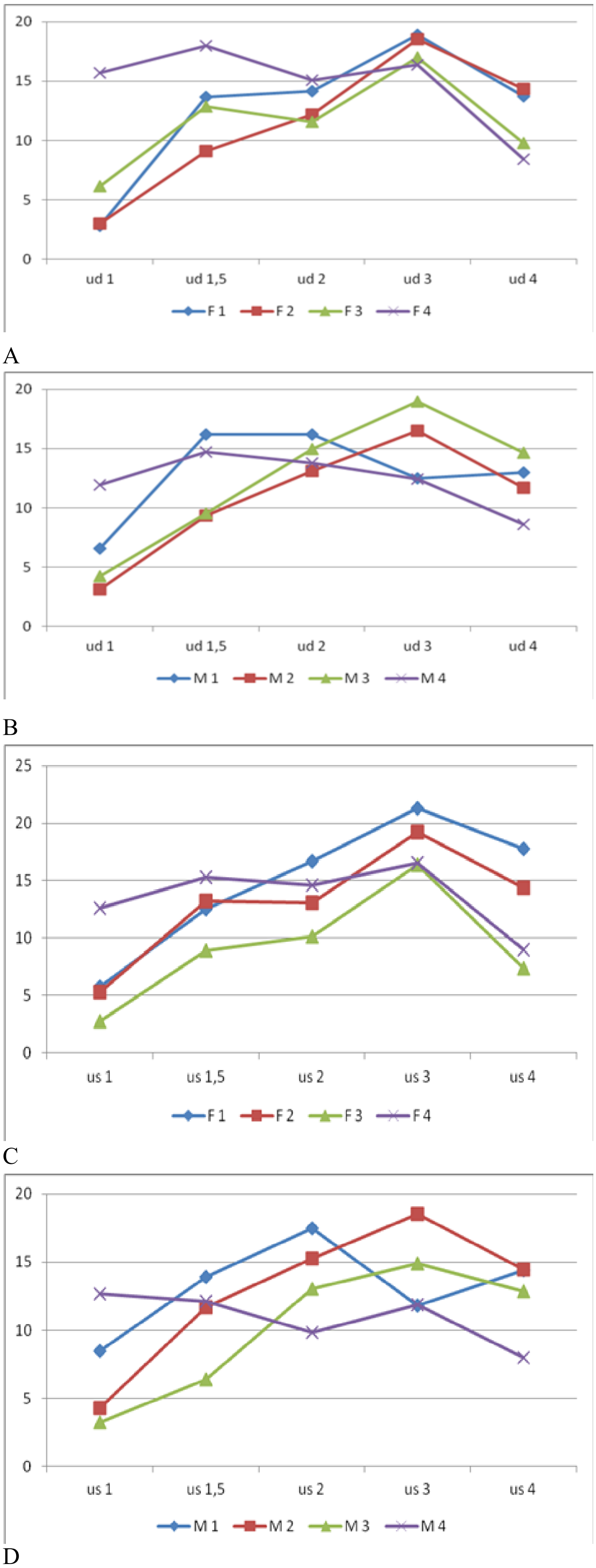


Figure 2. Distributions of the TEOAE SNR means depending on gender for each ear, centered at 1, 1.5, 2, 3 and 4 kHz. Panel A and B for the right ear, for female (F), respectively male (M); panel C and D for the left ear, for female, respectively male.

It can be seen that SNR is higher at 1 kHz for the adult group both in females and males. Using the student's t test we found significant differences between females and males at 3 kHz for both ears (right ear, p=0.03, left ear, p=0.02) in group 1. Our results showed that there are not significant differences between sexes for SNR means for both ears in group 2 and 3. We encountered the highest SNR values in favor of females at 3 and 4 kHz in group 2 for the right ear. In group 3, we observed higher SNR means at 2, 3 and 4 kHz in favor of males for the right ear. We observed that in group 4, females presented higher SNR means for the right ear, though significant differences are noted only at 1 kHz (p=0.03). The SNR means are significant different for the left ear at 2 and 3 kHz (p=0.01, respective p=0.02) in favor of females of the group 4.

DPOAE

DPOAE responses were registered as DPOAE level, noise and DPOAE SNR. The overall DPOAE responses showed significant differences only for the noise at 1 and 1.5 kHz for the left ear (p<0.001).

DPOAE level

Figure 3 displays the distribution of the DPOAE level means in the four study groups.

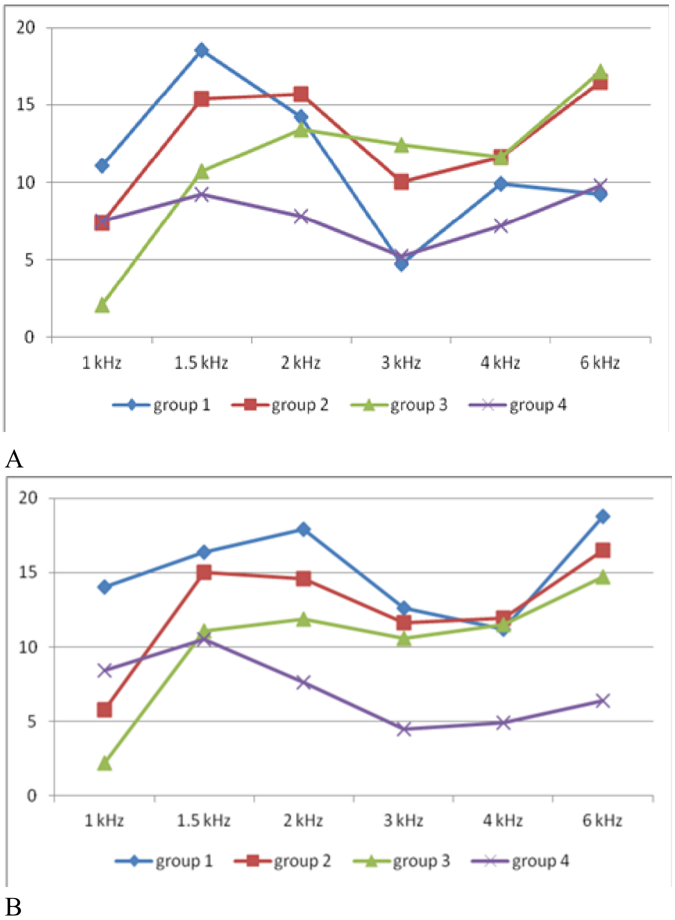
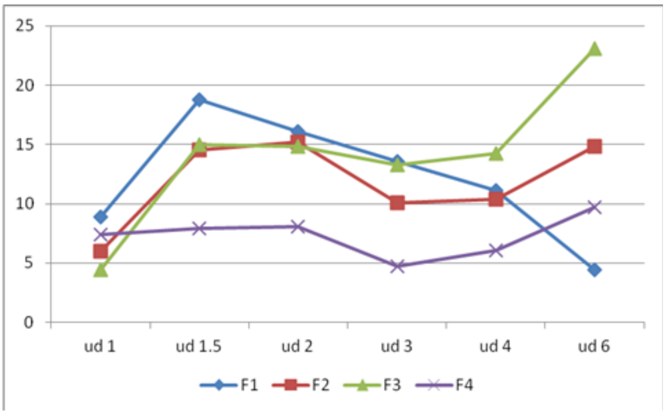


Figure 3. Distribution of the DPOAE level means for the right ear (panel A) and for the left ear (panel B) centered at 1, 1.5, 2, 3, 4, 6 kHz, for all the four groups.

Comparing DPOAE levels between groups we found that there are more significant differences between the pediatric groups and the adult group than between the three pediatric groups. Using Bonferoni correction, we found significant differences between pediatric groups only for DPOAE level at 1 kHz for the left ear when comparing group 1 to group 2 (p=0.04) and group 1 to group 3 (p=0.03). There were not any differences between group 2 and 3.

Our results recorded significant differences for DPOAE level at 1 and 1.5 kHz between group 2 and 4 (1 kHz p<0.001, 1.5 kHz p=0.004) and between group 3 and 4 (p=0.005). For the left ear, our results showed significant differences only at low frequencies of 1 kHz for groups 1 and 2 compared to group 4 (p=0.005, respectively p=0.02) and of 1.5 kHz for all pediatrics groups compared to adult group (group 1 and 2 p<0.001, group 3 p=0.03).

Figure 4 shows that higher DPOAE levels are encountered both in females and males at the frequency range of 1.5-6 kHz compared to adult group in all pediatric groups. There were not any significant differences for DPOAE levels between genders in any of the study groups.



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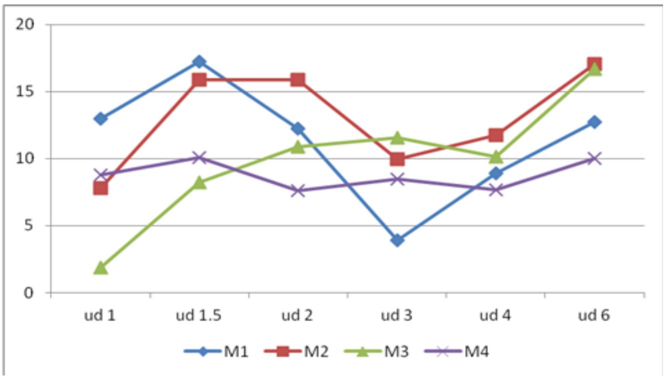

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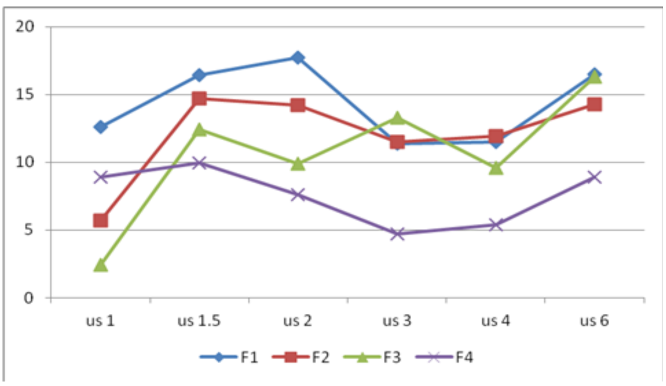

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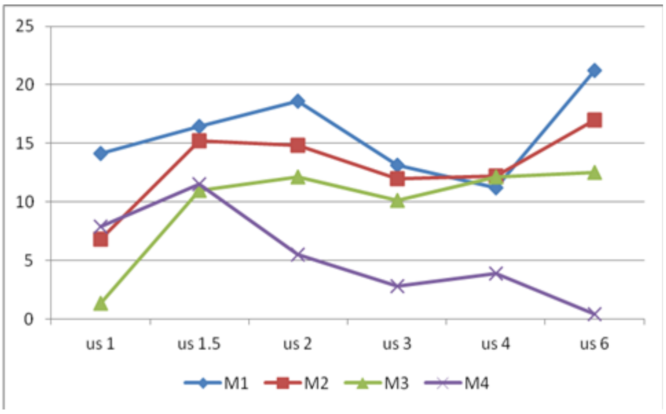


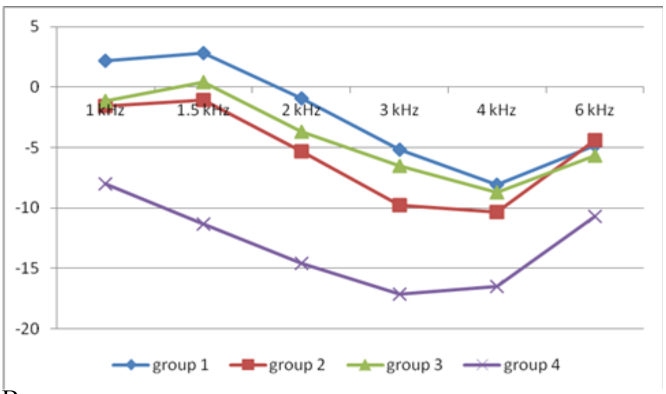
D

Figure 4. Distribution of the DPOAE level means centered at 1, 1.5, 2, 3, 4 and 6 kHz depending on gender for both ears for each study group. Panel A and B represent the distribution of DPOAE level for the right ear for both sexes, panel C and D represent the distribution of DPOAE level for the left ear for both sexes.

DPOAE NOISE

Apllying student's t test we recorded significant differences for DPOAE noise between pediatric groups and adult group at frequency range of 2-6 kHz: differences between group 1 and 4 was recorded at 2 (p<0.001), 4 (p=0.006) and 6 kHz (p<0.001) for the left ear; between group 2 and 4 at 2 (p=0.002), 3 (p=0.006), and 4 (p=0.001) kHz for the right ear and at frequency range of 2-6 kHz (p<0.001) for the left ear; between group 3 and 4 at 3 and 4 kHz (p=0.02) for right ear and at 2 (p=0.002), 4 (p=0.01) and 6 kHz (p<0.001) for left ear (see figure 5). There were no significant differences between the pediatric groups.

A



B

Figure 5. Distributions of the means DPOAE noise for each group and for each ear (panel A for the right ear, panel B for the left ear).

Table 2. p values with Bonferoni correction for the comparison of the pediatric groups to adult group for each frequency

	Comparison between groups 1 and 4		**Comparison between groups 2 and 4**		**Comparison between groups 3 and 4**	
	p		**p**		**p**	
	Right ear	**Left ear**	**Right ear**	**Left ear**	**Right ear**	**Left ear**
1 kHz	0.001	not significant	<0.001	0.001	<0.001	0.01
1.5 kHz	0.009	<0.001	<0.001	<0.001	<0.001	<0.001
2 kHz	0.004	<0.001	<0.001	<0.001	<0.001	0.001
3 kHz	0.001	0.001	<0.001	<0.001	<0.001	0.002
4 kHz	0.02	0.004	<0.001	<0.001	0.008	<0.001
6 kHz	0.03	<0.001	<0.001	<0.001	<0.001	<0.001

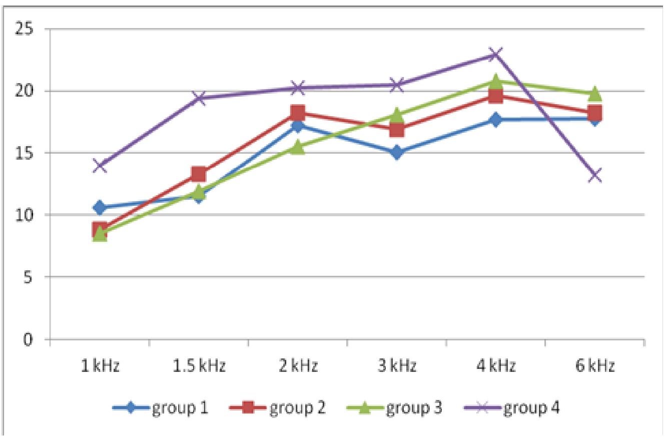
Applying the Mann-Whitney test for group 1 we found no significant differences between genders, but in group 2 we discovered significant differences between genders at 4 kHz for both ears (right ear p=0.04, left ear p=0.02) and at 6 kHz (p=0.01) for the left ear in favor of males. Females presented significant differences in group 3, but only for the right ear at 1.5 (p=0.007), 2 (p=0.03) and 6 kHz (p=0.01). The adult group presented differences that were statistically significant for both ears (right ear at 3 and 4 kHz – p=0.04, in favor of males, left ear at 1, 1.5 and 2 kHz p=0.007, respectively p=0.02, in favor of females).

DPOAE SNR

We used as a criterion for pass the value of SNR of 6 dB SPL, but as it can be seen from figure 6, SNR values were higher than 6 dB SPL for normal hearing.

Comparing the three pediatric groups the only significant difference was recorded at 1 kHz for the left ear (p=0.03). In contrast with DPOAE levels, the adult group presented higher DPOAE SNRs at the frequency range of 1-4 kHz for the right ear and 1-3 kHz for the left ear as seen in figure 6. The table 2 shows p values using Bonferoni correction when comparing pediatric groups to adult group.

Another goal of the present study was to investigate the changes in DPOAE SNRs for the four groups depending on gender and we discovered that in group 1, 3 and 4 there were no significant differences (see figure 7). The DPOAE SNR at 3 kHz for the right ear was found to have statistically significance (p=0.02) in favor of males in group 2.



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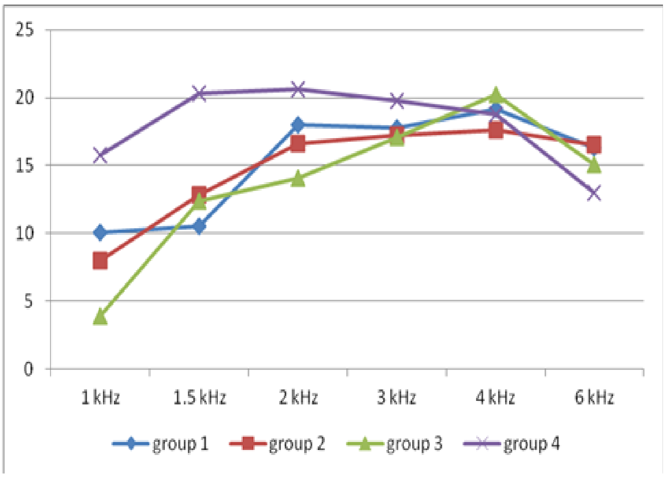

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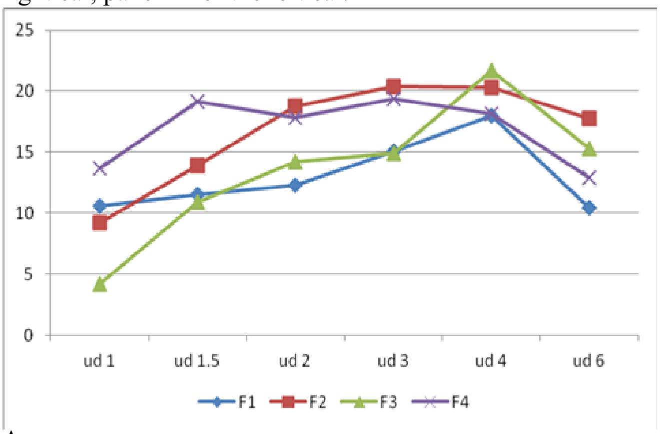
Figure 6. Distribution of the means DPOAE SNRs centered at 1, 1.5, 2, 3, 4 and 6 kHz for the study groups: panel A for the right ear, panel B for the left ear.



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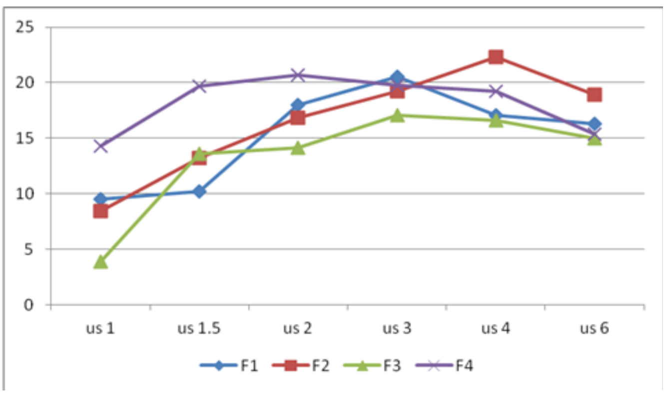

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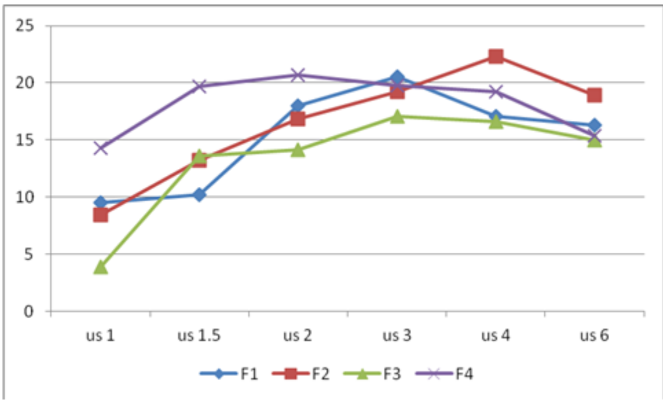

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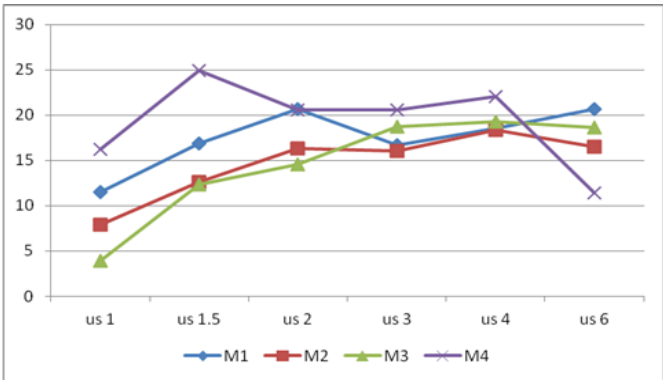

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Figure 7. Distribution of the DPOAE SNR means centered at 1, 1.5, 2, 3, 4 and 6 kHz depending on gender for both ears and for all study groups. Panel A and B represent the distribution of DPOAE SNR for the right ear for both sexes, panel C and D represent the distribution of DPOAE SNR for the left ear for both sexes.

Discussions

OAEs are used to understand the maturation of the cochlear structure and function (Abdala et al 2006). There is a large interest in studying the differences between the characteristics of OAEs in infants and in adults (Groh et al 2006). OAEs are highly dependent on the integrity of the conductive pathway thus any immaturity of outer and middle ear will influence the measurement of OAEs in the ear canal. Any comparison between cochlear responses of infants and adults has to take into account the properties of the entire conducting apparatus.

Studies that describe changes of the OAEs in infants and adults can provide guidelines for audiologists who use OEAs to monitor infant hearing status as a part of hearing assessment or of the hearing screening program or to monitor ototoxicity.

The present study analyzes the hearing status of a group of 126 infants and 39 adults and highlights the changes of the hearing function using both TEOAE and DPOAE.

Most studies used TEOAE to monitor the maturation of the cochlear structure and function. It is proven that the overall amplitude of TEOAE changes with age. There are studies that show that the overall amplitude TEOAE increases within the first days after birth (Kok et al 1992; Welch et al 1996) at frequency range of 1.5-3 kHz (Welch et al 1996). For the same frequency range, Mazlan (2007) found that overall TEOAE level and SNR increase between birth and six weeks of life.

In the current study, we found statistical significant differences for the TEOAE SNRs at 1.5 kHz for the left ear when comparing group 1 to group 3. Our results are not similar to the studies of Berninger (2007) and Thorthon (2003) who reported that the right ear of newborns had significantly higher TEOAE than those in the left ears. Also we discovered significant differences of TEOAE SNRs between pediatrics groups and adult group at low frequencies in favor of the adult group and at high frequencies in favor of the infant groups. Significant differences were recorded at 1 kHz for the right and at 1.5 and 4 kHz for the left ear.

TEOAE level is significant higher in the first year of life (Spektor et al 1991). Studies showed a rapid decrease in the first years of life due to development changes of the external and middle ear (Spektor et al 1991; Kon et al 2000; Satoh et al 1998; Kemp et al 1990; Lafreniere et al 1993; Prieve et al 1997), followed by a more slower decrease over the next years, predominantly caused by spontaneous impairment of the hearing function.

We have found significant differences between females and males only in the youngest and the oldest group in favor of the females. In the youngest group we found significant differences at 3 kHz for both ears. In the oldest group we recorded significant differences at 1 kHz for the right ear and at 2 and 3 kHz for the left ear. Our results are different from the study of Prieve that found no significant gender differences (Prieve et al 2009). On the other hand, we found similar results as the studies of Berninger (2007) and Thorthon (2003) who demonstrated that female newborns had significant higher TEOAE than male newborns.

In our study we reported only the changes of the TEOAE SNR, not TEOAE level or noise. This might be considered a limit of our study because we cannot prove if the changes are due to increasing of the TEOAE level or decreasing of the noise floor.

DPOAE are present in 90-100% of normal hearing newborns and adults (Bonfils et al 1992; Lonsbury-Martin et al 1990). Various studies described the differences between DPOAE in infants and in adults. DPOAE have a tendency to be higher in neonates than adults at low and mid frequencies (Smurzynski et al 1993). Abdala (2008) and Zang (2007) concluded that there were no significant changes in DPOAE levels between birth and 1 mo of age. Abdala (2008) and Prieve (1997) showed that between birth and 6 months of age there is little change in OAE level and that children aged 1–3 years have higher mean DPOAE levels than do teens and adults (Abdala et al 2008, Prieve et al 1997).

Our study observed the changes for multiple parameters of the DPOAE responses: DPOAE levels, noise floor and SNR. Comparing the DPOAE levels in pediatric groups (group 1 to 2 and group 1 to 3), our study showed significant differences at 1 kHz for the left ear. Comparing the difference for the DPOAE level in infants and adults, our results recorded significant differences at 1 and 1.5 kHz. The study of Abdala (2008) showed higher DPOAE level in infants than adults mostly due to immature conductive pathway, although they do not exclude that the differences between infants and adults can be explained by the auditory system functioning (Abdala et al 2008). Abdala (2006, 2008) and Keefe (2007) estimated that there is a stimulus difference between infants and adults of 15dB (the stimulus getting to the newborn cochlea is approximately 15 dB less than that for adults) due probably because of the developmental changes of the outer and middle ear. Dhar (2007) found in his study that the average of DPOAE level was higher in the newborns by approximately 7 dB than adults.

In general, studies showed that infants under 6 months of age are noisy and thus require more time to test (McPherson et al 1998). We recorded significant differences for DPOAE noise between pediatric groups and adult group at frequency range of 2-6 kHz. There were no significant differences between the pediatric groups, but the differences are significant when comparing pediatric groups to adult group at frequency range of 2-4 kHz. The study of Lasky (1998) demonstrated that noise levels in the canal were 5-15 dB lower for adults at frequencies less than 3 kHz.

Our study recorded significant differences for DPOAE SNRs at 1 for the left ear when comparing the pediatric groups. The adult group presented higher DPOAE SNRs at frequency range of 1-4 kHz for the right ear and 1-3 kHz for the left ear.

Differences between genders in DPOAE had been long studied. We did not find any significant differences for DPOAE levels between genders in contrast to Dhar's study (2007) that observed a trend toward higher DPOAE levels in females. We found no significant gender differences between DPOAE noise for group 1, but in group 2, we discovered significant differences between genders at 4 kHz for both ears and at 6 kHz for the left ear in favor of males. Differences of DPOAE noise between genders were also present in group 3, but only for the right ear at 1.5, 2 and 6 kHz in favor of females. The adult group presented differences that were statistically significant for both ears (right ear at 3 and 4 kHz in favor of males, left ear at 1, 1.5 and 2 kHz in favor of females). Our results showed that males presented significant differences at 3 kHz for the right ear when usind DPOAE SNRs. The existence of these differences is partially explained by the anatomical differences in outer, middle and inner ear structures between sexes (Sato et al 1991, Don et al 1993) or by sex differences in cochlear physiology, as observed through features of the OAEs (Burns et al 1992, McFadden et al 1993).

Conclusions

The infant otoacoustic emissions remain larger at high frequencies than adult for both transient otoacoustic emissions and distortion products. Female newborns had significant higher SNRs than male newborns only for transient otoacoustic emissions.

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Citation	Stamate MC, Bondor CI, Cosgarea M. Differences in otoacoustic emissions in infants and adults with normal hearing. HVM Bioflux 2015;7(3):126-134.
Editor	Stefan C. Vesa
Received	12 May 2015
Accepted	26 May 2015
Published Online	29 May 2015
Funding	None reported
Conflicts/ Competing Interests	None reported