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Influence of age on Distortion Product of normal hearing Iraqi subjects

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ABSTRACT

The purpose of this work is to study the influence of the age, ear side and gender on the distortion product Otoacoustic emission for normal hearing subjects. The decision about whether a Distortion Product Otoacoustic Emission is present often depends on a visual assessment of the response along with certain objective criteria, such as DP1 level dB and SNR dB SPL (signal to Noise Ratio). DPOAEs were considered present when the signal was at least 3 dB above the corresponding noise level. In the present study, the overall SNR for each tested ear was more than 3 dB SPL at the overall frequency bands. The findings from this study revealed an age, ear asymmetry and gender effect on the DPOAEs (DP1 level dB) for all subjects groups. Right ears were found to produce higher DPOAEs (DPI level dB) than left ears and The DPOAEs (DP1 level dB) in the females was higher than that in males and also (DPI Level dB) in group I (2-10) years was higher than that in other groups, in group II (11-20) years (DPI Level) was higher than in groups III&IV and in groups III (DPI Level dB) was higher than that in group IV. The results show the minimum and the maximum value of the whole Distortion Product (DP1 Level) recorded for all tested (212) ear was (-3.65dB) and (20.39dB) respectively over frequency bands 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0 and 8.0 kHz.

Introduction

The discovery of otoacoustic emissions (OAEs) (Kemp, 1978) [1] has produced a totally new tool for diagnosing cochlear function. OAEs are the by-product of the non-linear sound amplification process in the cochlea [2]. Otoacoustic emissions (OAEs) are the result of microscopic biomechanical activity associated with healthy OHCs (Electro motility). This activity produces a signal within the cochlea that is transmitted "backward" through the middle ear and into the ear canal, where it can be picked up by microphone. There are two types of otoacoustic emissions: spontaneous otoacoustic emissions (SOAEs), which can occur without external stimulation, and evoked otoacoustic emissions (EOAEs), which require an evoking stimulus. Evoked otoacoustic emission used three different methodologies. Stimulus Frequency OAEs (SFOAEs) are measured during the application of a pure-tone stimulus, Transient-evoked OAEs (TEOAEs) are evoked using a click (broad frequency range) or tone burst (brief duration pure tone) stimulus. The evoked response from a click covers the frequency range up to around 4 KHz, while a tone burst will elicit a response from the region that has the same frequency as the pure tone. Distortion product OAEs (DPOAEs) are evoked using a pair of primary tones f_1 and f_2 with particular intensity (usually either 65 - 55 dB SPL or 65 for both) and ratio ($f_1 : f_2$). These tones produce a family of DPOAEs in the cochlea; the strongest emission has a frequency of $2f_1 - f_2$, the two primary tones are usually chosen with a frequency ratio of $f_2/f_1 = 1.22$, because this combination produces a relatively high amplitude $2f_1 - f_2$ DPOAE over a range of primary frequencies and levels. All of the DPOAE studies used a fixed frequency ratio (1.22) of the primary tones. The evoked responses from these stimuli occur at frequencies (f_{dp}) mathematically related to the primary frequencies, with the two most prominent being $f_{dp} = 2f_1 - f_2$ (the "cubic" distortion tone, most commonly used for hearing screening) and $f_{dp} = f_2 - f_1$ (the "quadratic" distortion tone, or simple difference tone) [3, 4].

Materials and Methods:

Subjects

The data were obtained from a sample of 106 subjects male and female aged 2–40 year, without any hearing abnormalities or any risk factors for familiar hearing loss and with good general health. All subjects had normal otoscopic results, audiometric and tympanometric parameters. There was no history of ontological diseases or ototoxic drug use among the studied subjects. None of the subjects reported that they were frequently exposed to intense leisure noise. The subjects were divided into four groups as shown in Table (1).

Procedure

Otoacoustic emissions (OAEs) are influenced by the fact that the stimulus must be transmitted to the cochlea via the middle ear and the response must be detected in the ear canal, so it is important to study the interaction of middle ear status and emission properties.

To confirm the normal outer/middle ear status of all the groups, routine procedures were used. Audiometer over a frequency range of 250 Hz-to-8000Hz and a tympanometry were performed to assess hearing ability in all subjects. All investigations were performed in low sound noise, and both ears of all subjects tested consecutively in a random order.

Pure-tone audiometry

Each ear was examined with an otoscope prior to audiometry testing to determine if there are any blockages in the ear canal due to ear wax or other materials.

Audiometer (ATMOS SCREEN 20K-Denmark) was used to test the threshold hearing level of each ear. The results were

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recorded on a graph called an audiogram. An audiogram is a plot of threshold intensity versus frequency. The intensity scale in hearing level (HL) measured in (dB) increases downwards.

In a normal ear, most thresholds were approximately zero dB HL. Points below zero dB HL on the scale denoted louder threshold levels, whereas those above, expressed in negative decibels (-dB) with respect to the zero level, were less intense levels.

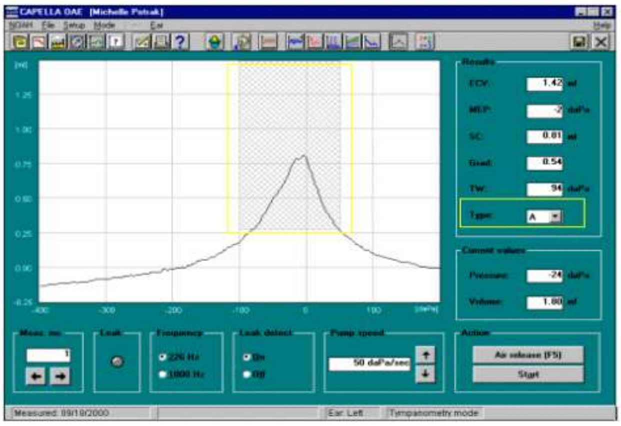
Tympanometry: is an electronic and acoustic measurement technique to assess middle ear status. It is a routine clinical procedure that involves measures of acoustic immittance in the ear canal as air pressure in the canal is varied above (+) and below (-) atmospheric level in the ear canal. (Acoustic immittance is a general term referring to either acoustic impedance or acoustic admittance).

Calibration: All OAEs and tympanometric measurements were performed by (Madsen Capella's-OAE/middle ear analyzer-GN Otometrics, Denmark)The probe system contains; manometer (pump) varies air pressure against tympanic membrane (controls mobility), speaker introduces 226 Hz probe tone, and microphone measures loudness in ear canal. The probe was calibrated before each test session. The calibration was standardized according to the manufacturer recommendations [5] (ANSI S3.39.1987) (American National Standard Institute). Calibration process was performed by measuring the acoustic immittance of standard test cavity of known and specified volume (conformed by the manufacturer). The enclosed volume of air in a test-cavity is directly related to the admittance offered by the cavity. The acoustic admittance or acoustic impedance value indicated by the monitor of the instrument must be equal to the known value for fixed test-cavity volume over the range of interest. At a probe frequency of 226 Hz, a hand-walled cavity of 1 cm^3 offers an acoustic admittance of approximately 1 acoustic mmho. The computer-based instruments provide for correction of calibration errors through software commands.

Tympanogram: The probe tip was precisely inserted into one ear of the subject where the tip of the probe faced the drum and the path to the tympanic membrane was not blocked. Then the probe turns on with a pump speed 200 dapa/sec, the pressure in the ear canal varying between +200 to -400 dapa. The tympanogram provides information regarding the compliance of the middle ear system (how well sound passes through the eardrum to the middle ear system), ear canal volume, and middle ear pressure. Compliance is plotted vertically on the tympanogram, and is measured in (ml) or (mmho).

Maximum compliance of the middle ear system occurs when the pressure in the middle ear cavity is equal to the pressure in the external auditory canal. This compliance (static acoustic admittance) is represented by the highest peak of the curve on the graph. Pressure is indicated on the horizontal axis of the graph and is measured in decaPascal. The normal tympanometric amplitude values should be >0.2 acoustic mmho for infants and >0.3 acoustic mmho for children as shown in Figure (5), [6].

Otoacoustic Emissions (OAEs): Otoacoustic emissions divided into many types according to the nature of the acoustic stimulus used to elicit them. This study was used Distortion product Otoacoustic emissions Gram (DPOAEs gram) and study the influence of age, gender and ear side on (DP1level dBSPL or amplitude).



Type A tympanogram with a 226 Hz probe tone. Notice "Type" section is filled in and the tympanogram was automatically typed "A" because of the existing normative data.

Fig 5. Normal tympanogram(type A) indicative of normal middle ear system.

Distortion Product Otoacoustic Emissions gram (DPOAEs gram)

DPOAEs are generated by presenting two tones of slightly different Frequencies at the same time. Because of the non-linear characteristics of the cochlea, the two tones intermediate and create combination tones (distortion products) not present in the original stimulus [7and 8].The generation of Distortion-Product otoacoustic emissions (DPOAEs), especially in humans, is adequately described by a two-source model [9and10]. Source is thought to arise from the nonlinear interactions between the f_1 and f_2 primary tones, near the peak of the f_2 traveling wave (TW) [9] referred to this constituent as the "generator" or "distortion" component, while [10] described it as a "wave-fixed" component. This component is thought to travel both apically and basally within the cochlea, when the apically traveling segment arrives at the $2f_1-f_2$ DPOAE frequency place (f_{dp}) on the basilar membrane (BM), a second component, which is presumably generated by a coherent-reflection mechanism, travels basally to produce another DPOAE source referred to as the "reflection component" or a "place-fixed" component. Thus, the prevailing view is that lower-sideband DPOAEs (e.g., $2f_1-f_2$) conform to a two-source model with the emissions arising from two discrete locations associated with distinct mechanisms of generation. Distortion Product measurements were performed in a quiet room to minimize the effect of the external noise. Acoustic probe tip was inserted deeply into each ear canal and monitor the consistency of the probe fit during the (DP OAEs) recording. The probe contains two speaker's sound generator, filter and recording microphone. The microphone output was subjected to fast Fourier Transform (FFT) for signal processing. The identification of the DPOAES against the background noise was based upon recordings obtained after spectral averaging of 1000 sweeps (i.e. Fast Fourier Transforms) at frequency range from 0.5 kHz to 8 kHz. Filtering occurs to reduce the internal body noise and external environment noises. The criteria employed to consider the presence of the responses in Distortion product Otoacoustic emissions were: response amplitude or DP1 level dB and SNR (Signal to Noise Ratio dB SPL). DPOAEs were considered present when the signal was at least 3 dB above the corresponding noise level, [11, and 12]. In the present study, the overall SNR for each tested ear was more than 3 dB SPL at the overall frequency bands.

Results and discussion:

Only normal hearing subjects were enrolled in this study and all 212 ears showed normal auditory sensitivity i.e. air conduction thresholds less than 25dB HL at octave test frequencies from 250 to 8000HZ. Furthermore, evaluation of the middle ear status by means of Tympanometry testing showed normal Tympanograms for all ears testing being characterized by an A-Type. The subjects study was divided into four groups included the mean values for each group as shown in Table (1). Each group was consisted of a number of the ears in both females and males. The total number of the ears was 212, included 104 ears in females and 108 ears in males. Data from subjects were placed into four groups based on age : Group-I (2-10) year , with total number of subjects is 26 consisted of 13 females and 13 males , Group-II (11-20) year, with total number of subjects is 26 consisted of 13 females and 13 males, Group-III (21-30) year ,with total number of subjects is 28 consisted of 13 females and 15 males, Group-IV(31-40) year, with the total number of subjects is 26 consisted of 13 females and 13 males . is shown in Table (1) including the mean values of general variables measured. The total number of subjects which completed all tests was 106 male and female with age from (2-40) year. 106 subjects contained (52) females and (54) males. In group I (2-10)year, the mean value of age for males was(5.54 year) & for females was(6.07 year), In group II (11-20)year the mean value of age for males was (14.07 year)& for females was (13.9 year),In group III(21-30) year, the mean value of age for males was(23.86 year)& for females was(25 year). The minimum and the maximum value of the whole Distortion Product (DP1 Level) recorded for all tested ears was (-3.65dB) and (20.39dB)respectively over frequency bands 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0 and 8.0 kHz. The mean value of the DP1 level in all ears for all groups was shown in Tables (2, 3, 4 and 5),the results as shown in Table (2) indicate that in group I (2-10)year; the mean value of DP1 Level for Right ears females was (14.27dB) higher than that in left ears females(12.06dB) and The mean value of DP1 level in the Right ears females was (14.27dB)higher than that in the Right ears males (12.06dB)and the mean value of DPI Level in the left ears females was(12.06dB)higher than that in the left ears males (11.09dB) while in male; the mean value of DP1 level in the Right ears males was (12.12dB) higher than that in the left ears males (11.09dB) while results as shown in table (3) indicate that in group II (11-20) years; the mean value of DP1 Level for Right ears females was (11.57dB) higher than that in left ears females (9.06dB) and The mean value of DP1 level in the Right ears females was (11.57dB) higher than that in the Right ears males (7.15dB), the mean value of DPI level in the left ears females was(9.06dB) higher than that in the left ears males (5.81)while in male; the mean value of DP1 level in the Right ears males was (7.15dB) higher than that in the left ears males (5.81dB)and the results as shown in table (4) indicate that in group III (21-30)years ; the mean value of DP1 Level for Right ears females was (8.22dB) higher than that in left ears females(7.39dB) and The mean value of DP1 level in the Right ears females was (8.22dB) higher than that in the Right ears males (5.09dB), the mean value of DPI Level in the left ears females was(7.39dB) higher than that in the left ears males (4.98dB), while in male; the mean value of DP1 level in the Right ears males was (5.09dB) higher than that in the left ears males

Then the results as shown in Table(5) indicate that in group IV(31-40)year; the mean value of DP1 Level for Right ears females was (3.22dB) higher than that in left ears females(2.55dB) and its also higher than that in the Right ears males (2.54dB), the mean value of DPI Level in the left ears females was(2.55dB) higher than that left ears males (1.08dB), while in male; the mean value of DP1 level in the right ears males was (2.54dB) higher than that in the left ears males (1.08dB).The results as shown in Tables (6 and7) indicate that the mean value of DPI in young subjects(2-10)year was higher than other groups and also the mean value of DPI level in group II (11-20)years was higher than that in groups(III and IV) and the mean value of DPI level in group III (21-30)year was higher than that in group IV(31-40)year.

Table 1. Groups of subjects

Groups No.	Age year	Total No. of subject	No. of Males	No. of Females	Mean value of age for males	Mean value of age for females
I	2-10	26	13	13	5.54	6.07
II	11-20	26	13	13	14.07	13.92
III	21-30	28	15	13	23.86	25
IV	31-40	26	13	13	35.38	35.15

Table 2. Comparison between the average of DP1 level of Right and left ear side for females and males at each frequency for group (I) age between (2-10) year

No.	Frequency KHz	DP1Level FR dB	DP1Level FL dB	DP1Level MR dB	DP1Level ML dB
1	0.5	4.57	3.04	3.38	3.15
2	0.75	9.13	6.0	6.40	6.02
3	1.0	11.91	11.07	11.29	10.42
4	1.5	17.3	14.38	15.19	14.23
5	2.0	15.43	12.56	12.93	10.29
6	3.0	17.57	11.37	9.72	9.1
7	4.0	15.51	14.38	14.10	13.27
8	6.0	20.39	20.24	19.3	18.05
9	8.0	16.62	15.58	16.84	15.29
	average	14.27	12.06	12.12	11.09

The findings from the present study revealed an ear asymmetry, gender and age effect on DPOAEs level (DPI) in all subjects groups as shown in Fig (6), Right ears were found to produce higher DPOAEs level (DPI) than left ears, female ears were found to produce higher DPOAEs level (DPI) than that males ears and also the mean value of DPOAEs level (DPI) in group I (2-10) year was higher than that in other groups ,the mean value of(DPI) level in group II(11-20) years was higher than that in groups III&IV and the mean value of (DPI) level in group III(21-30)year was higher than that in group IV(30-40) years.

Table 3. Comparison between the average of DP1 level of Right and left ear side for females and males at each frequency for group (II) age between (11-20) year

No.	Frequency KHz	DP1Level FR dB	DP1Level FL dB	DP1Level MR dB	DP1Level ML dB
1	0.5	8.41	5.13	3.44	2.37
2	0.75	8.77	7.64	2.43	2.36
3	1.0	12.02	6.93	7.1	6.9
4	1.5	11.06	10.91	7.55	6.36
5	2.0	10.38	8.65	4.53	2.79
6	3.0	9.46	8.76	4.9	4.68
7	4.0	13.58	12.91	9.90	9.37
8	6.0	16.73	14.20	11.25	10.38
9	8.0	13.8	11.91	13.1	7.13
	average	11.57	9.67	7.13	5.81

The results were agreement with the fact of interest is that, in humans, OAEs exhibit sex differences [13]. DPOAES Responses are higher in females than they are in males [14 and 15]. As noted above, whenever sex differences exist at birth, they cannot be attributable to then-current differences in the levels of sex hormones, so it is common to assume that these differences are after effects of earlier differences in development [16].

Table 4. Comparison between average of DP1 level of Right and left ear side for females and males at each frequency for group (III) age between (21-30) year

No.	Frequency KHz	DP1Level FR dB	DP1Level FL dB	DP1Level MR dB	DP1Level ML dB
1	0.5	-2.3	-2.12	0.82	-0.72
2	0.75	3.11	1.87	2.03	2.57
3	1.0	5.32	6.87	4.95	6.87
4	1.5	9.86	8.85	7.33	5.97
5	2.0	6.96	8.51	5.12	1.75
6	3.0	8.70	7.28	2.45	4.35
7	4.0	13.11	11.83	8.52	8.65
8	6.0	16.30	13.36	10.95	9.56
9	8.0	13.0	10.13	9.09	5.90
	average	8.22	7.39	5.69	4.98

Table 5. Comparison between average of DP1 level of Right and left ear side for females and malesat each frequency for group (IV) age between (31-40) year

No.	Frequency KHz	DP1Level FR dB	DP1Level FL dB	DP1Level MR dB	DP1Level ML dB
1	0.5	-0.72	-2.10	-1.36	-3.65
2	0.75	2.53	0.8	0.15	-1.03
3	1.0	3.66	3.4	3.06	1.02
4	1.5	3.61	3.22	2.94	1.2
5	2.0	4.39	3.58	3.17	1.46
6	3.0	4.29	3.58	3.25	1.95
7	4.0	5.04	4.45	4.14	2.58
8	6.0	5.09	4.74	4.6	3.56
9	8.0	5.02	4.30	2.94	2.6
	average	3.66	2.55	2.54	1.08

Table 6. Comparison between the average of DP1 level of Right ear side for females and males at each frequency for all groups

No.	Frequency KHz	DP1Level FR dB 2-10	DP1Level FR dB 11-20	DP1Level FR dB 21-30	DP1Level FR dB 31-40	DP1Level MR dB 2-10	DP1Level MR dB 11-20	DP1Level MR dB 21-30	DP1Level MR dB 31-40
1	0.5	4.57	8.41	-2.3	-0.72	3.38	3.44	0.82	-1.36
2	0.75	9.13	8.77	3.11	2.53	6.40	2.43	2.03	0.15
3	1.0	11.91	12.02	5.32	3.66	11.29	7.1	4.95	3.06
4	1.5	17.3	11.06	9.86	3.61	15.19	7.55	7.33	2.94
5	2.0	15.43	10.38	6.96	4.39	12.93	4.53	5.12	3.17
6	3.0	17.57	9.46	8.70	4.29	9.72	4.9	2.45	3.25
7	4.0	15.51	13.58	13.11	5.04	14.10	9.90	8.52	4.14
8	6.0	20.39	16.73	16.30	5.09	19.3	11.25	10.95	4.6
9	8.0	16.62	13.8	13.0	5.02	16.84	13.1	9.09	2.94
	average	14.27	11.57	8.22	3.66	12.12	7.13	5.69	2.54

Table 7. Comparison between average of DP1 level of left ear side for females and males at each frequency for all groups

No.	Frequency KHz	DP1Level FL dB 2-10	DP1Level FL dB 11-20	DP1Level FL dB 21-30	DP1Level FL dB 31-40	DP1Level ML dB 2-10	DP1Level ML dB 11-20	DP1Level ML dB 21-30	DP1Level ML dB 31-40
1	0.5	3.04	5.13	-2.12	-2.10	3.15	2.37	-0.72	-3.65
2	0.75	6.0	7.64	1.87	0.8	6.02	2.36	2.57	-1.03
3	1.0	11.07	6.93	6.87	3.4	10.42	6.9	6.87	1.02
4	1.5	14.38	10.91	8.85	3.22	14.23	6.36	5.97	1.2
5	2.0	12.56	8.65	8.51	3.58	10.29	2.79	1.75	1.46
6	3.0	11.37	8.76	7.28	3.58	9.1	4.68	4.35	1.95
7	4.0	14.38	12.91	11.83	4.45	13.27	9.37	8.65	2.58
8	6.0	20.24	14.20	13.36	4.74	18.05	10.38	9.56	3.56
9	8.0	15.58	11.91	10.13	4.30	15.29	7.13	5.90	2.6
	average	12.06	9.67	7.39	2.55	11.09	5.81	4.98	1.08

The best-documented sex differences during prenatal development are the differential exposure to androgens in male and female fetuses. To be specific, one reasonable explanation is that prenatal androgen exposure acts to weaken the cochlear amplifier in males and thus weaken their OAEs [17].

The right ear advantage has been reported in the auditory processing literature for more than 50 years [18]. The essence of the right ear advantage discussion says that the left hemisphere is dominant for speech and language processing and the contra lateral auditory pathways are stronger. Therefore, when sounds from the right ear sent to the left hemisphere (via contra lateral pathways) a right ear advantage is often apparent regarding speech, language, and dichotic presentation of language-based sounds, particularly in younger people. The findings from the present study also revealed an age effect on DPOAEs level (DPI) in all subjects groups, Results are similar to early study described adult–infant age differences in the context of a DP-Gram [19].

Clearly, the difference in DPOAEs amplitudes (DP1 level dB) among age groups was due to factors other than differences in hearing thresholds. It is very likely that the Cochlea that accompany aging and affect basilar membrane mechanics, resulting in Reduction of the cochlear amplifier. Physiologic changes in the aged cochlea Hearing loss were detected. Previous studies found Progressive age-related OHC loss in the cochlea from normal hearing population [20 and 21], and other studies reported the atrophy of the organ of Corti in older subjects normal hearing [22]. The age-laded changes in cochlear physiology found in those Histological studies might be able to be detected by an instrumentation developed in Recent years that measures sounds generated in the cochlear amplification process, may be responsible for the observe difference in DPOAE amplitudes.

Even before hearing loss is detected by conventional audiometric testing, physiologic change seems to occur in the aged cochlea [21].Thus, the smaller DPOAE amplitude from the old subjects may reflect an aging, Three different types of physiological Changes in the cochlea were identified: (1) sensory cell loss at high frequency region; (2) atrophy of the striavascularis; and (3) calcification and stiffening of the BM.

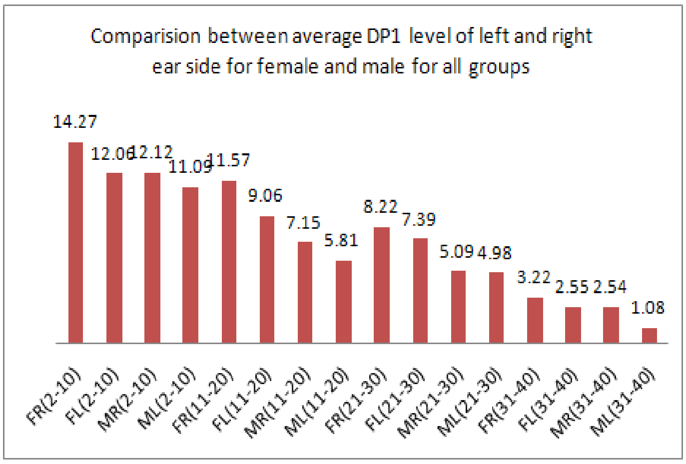


Figure 6

Conclusion

1-DPOAEs have considerable clinical relevance because it can be obtained in almost normal subjects.

2-Signal to noise ratio (SNR) equal or more than (3.0 dB SPL) at frequency bands (0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0 and 8.0 KHz) can be taken as an indicator of DPOAEs responses compared to the noise floor.

3-The present investigations have found an age effect in DPOAEs (DPI level dB) obtained from 106 subjects age (2-40 year). An age effect was clearly observed, group I (2-10) year displaying higher DPOAEs (DPI Level dB) compared with other groups, while group IV (31-40) year displaying smaller (DPI level dB)compared with other groups.

4-The decreasing of DPOAEs amplitudes (DP1level dB) among age groups was due to factors other than differences in hearing thresholds is that the Cochlea accompany aging and affect basilar membrane mechanics, resulting in Reduction of the cochlear amplifier.

5-In all groups a gender effect was clearly observed, with females displaying higher DPOAEs amplitudes compared with males.

6-The presence of DPOAEs amplitudes in right ear is more than that in left ears for all groups.

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