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Evaluation of the Middle and Inner Ear Functions of Pregnant Women

Gebelerde Orta ve İç Kulak Fonksiyonlarının Değerlendirilmesi

Leyla TÜRE[a], Tuğçe Gül ÇAĞLAR[b], Mesut KAYA[c]

[a]İstanbul Kent University Faculty of Health Sciences, Department of Speech Therapy, İstanbul, Türkiye
[b]Lokman Hekim University Faculty of Health Sciences, Department of Audiology, Ankara, Türkiye
[c]Private Physician, Ankara, Türkiye

ABSTRACT Objective: Women's' daily lives may be affected during pregnancy. To ensure that this issue is not overlooked, hearing tests should be included in routine pregnancy check-ups at certain stages. This study aimed to investigate the effects of hormonal changes occurring during the 1st, 2nd, and 3rd trimesters of pregnancy on the middle and inner ear auditory system. **Material and Methods:** A total of 43 pregnant and 27 healthy non-pregnant women were included in the study. After an otorhinolaryngology examination, all participants underwent pure tone audiometry between 125-8,000 Hz, acoustic immitance, and Transient Evoked-Otoacoustic Emission (TE-OAE) testing at 1,000-4,000 Hz. **Results:** In pure tone audiometry evaluations, bilateral hearing thresholds at 125, 250, and 500 Hz were found to be elevated in pregnant women across all trimesters compared with healthy controls. Additionally, the TE-OAE amplitude values decreased at 2,000, 3,000, and 4,000 Hz from the 1st to the 3rd trimester. This slight increase in low-frequency hearing thresholds resembles cochlear hearing loss and may be attributed to hormonal changes during pregnancy. Furthermore, the otoacoustic emission values at 2,000, 3,000, and 4,000 Hz were lower in pregnant women than in healthy women. **Conclusion:** On the basis of these results, normal findings regarding middle ear functions during pregnancy were observed, while physiological changes were noted in cochlear functions.

Keywords: Pregnancy; hearing; otoacoustic emission; otolaryngology; acoustic immitance

ÖZET Amaç: Kadınların günlük yaşamları gebelik döneminde etkilenebilmektedir. Bu durumun göz ardı edilmemesi için gebeliğin belirli dönemlerinde, işitme testlerinin rutin gebelik kontrollerine dâhil edilmesi gerekmektedir. Bu çalışma, gebeliğin 1, 2 ve 3. trimesterlerinde meydana gelen hormonal değişimlerin orta ve iç kulak işitme sistemi üzerindeki etkilerini araştırmayı amaçlamıştır. **Gereç ve Yöntemler:** Çalışmaya, 43 gebe ve 27 sağlıklı gebe olmayan kadın dâhil edilmiştir. Otorinolaringolojik muayenenin ardından tüm katılımcılara 125-8.000 Hz frekans aralığında saf ses odyometrisi, akustik immitans ve 1.000-4.000 Hz frekans aralığında Geçici Uyarılmış Otoakustik Emisyon [Transient Evoked-Otoacoustic Emission (TE-OAE)] testleri uygulanmıştır. **Bulgular:** Saf ses odyometri değerlendirmelerinde, tüm trimesterlerdeki gebe kadınlarda, 125, 250 ve 500 Hz frekanslarında bilateral işitme eşiklerinin sağlıklı kontrol grubuna göre yüksek olduğu bulunmuştur. Ayrıca 2.000, 3.000 ve 4.000 Hz'deki TE-OAE genlik değerleri 1. trimesterden 3. trimestere doğru azalma göstermiştir. Düşük frekanslı işitme eşiklerindeki bu hafif artış, koklear tip işitme kaybına benzemekte olup; gebelik süresince meydana gelen hormonal değişikliklere bağlanabilir. Ayrıca 2.000, 3.000 ve 4.000 Hz'deki otoakustik emisyon değerleri, gebe kadınlarda sağlıklı kadınlara kıyasla daha düşük bulunmuştur. **Sonuç:** Bu bulgulara dayanarak, gebelik sürecinde orta kulak fonksiyonlarının normal seyrettiği, ancak koklear fonksiyonlarda fizyolojik değişikliklerin gözlemlendiği sonucuna varılmıştır.

Anahtar Kelimeler: Gebelik; işitme; otoakustik emisyon; otorinolaringoloji; akustik immittans

Despite being a natural process, pregnancy involves complex periods in which women are affected biologically, physiologically, physically, and mentally. Many structural and functional changes occur in the human body during pregnancy. In particular, in the 3rd trimester, changes in the mother's body due to estrogen and progesterone increase.

During a normal pregnancy, changes occur in the metabolic, cardiovascular, hematologic, respiratory, urinary, gastrointestinal, and endocrine systems to meet the needs of the rapidly developing fetus.

During pregnancy, total body water increases by about 8.5 liters in the last weeks. The extracellular fluid increased by about 6.5 liters.[1] Despite the de-

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Correspondence: Tuğçe Gül ÇAĞLAR
Lokman Hekim University Faculty of Health Sciences, Department of Audiology, Ankara, Türkiye
E-mail: tugcegulcaglar@gmail.com

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crease in the plasma osmotic pressure, the cells did not swell. The mean erythrocyte volume does not change. There are not many studies in the literature on changes in cochlear function during pregnancy, but there are limited studies on the menstrual cycle.

Pregnancy consists of periods called trimesters, each lasting about 3 months. Each of these trimesters is a special milestone. Knowing the changes in each trimester is important for a healthy pregnancy.[2]

In this study, considering these periods, pregnant women were evaluated based on the following phases.

- First Trimester Period (between weeks 0-12)
- Second Trimester Period (between weeks 13-28)
- Third Trimester Period (between weeks 29-40)[3]

First Trimester (between weeks 0-12): During this period, the woman gets used to and adapts to pregnancy. Physiological changes that become evident during pregnancy can affect daily life and cause some limitations. In the early stages of pregnancy, the woman tries to adapt to conditions such as nausea, vomiting, breast tenderness, physical changes, diet, and exercise.[4]

Second Trimester Period (between weeks 13-28): During this period, the mother can feel the fetus and hear the baby's' heartbeat, and the fetus can be monitored by ultrasound. The biological bond between the mother and the infant is strongly felt. Changes such as sudden anger, restlessness, irritability, slowing down, and hypersensitivity can be seen.[5]

Third Trimester Period (between weeks 29-40): The most common physical and emotional complaints in pregnant women during this period are nausea, vomiting, frequent urination, increased or reduced appetite, diarrhea, acid reflux, sensitivity to odors, edema, muscle cramps, lower back pain, and headache.[4]

It has been reported that women complain of hearing loss during pregnancy. Changes in hearing sensitivity in pregnant women in the postpartum period are pregnancy-associated.[6]

In line with this information, this study aimed to evaluate the effects of the changes that occur in the 1st, 2nd, and 3rd trimesters of pregnancy on the middle and inner ear hearing systems and to examine the relationship between hormonal changes during pregnancy and cochlear functions.

MATERIAL AND METHODS

ETHICAL APPROVAL

This study was conducted at the Audiology and Speech Disorders Unit of Turgut Özal University. Ethics committee approval dated August 10, 2015 and numbered 99950669/219 was granted by Turgut Özal University Faculty of Medicine Clinical Research Ethics Committee.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Written informed consent has been obtained from the patients who agreed to take part in the study to publish this paper.

PARTICIPANT RECRUITMENT

The study was conducted with 70 women, including 43 pregnant women followed up in the obstetrics and gynecology department and 27 nonpregnant healthy women. The mean age of the pregnant women was 28.25, whereas the mean age of the healthy women was 23. Pregnant and healthy women who participated in the study underwent an audiological examination after an otorhinolaryngology examination. Pure tone audiometry, immitancemetric examination, ipsi- and contralateral acoustic reflex tests at 500 to 4,000 Hz, and the Transient Evoked Otoacoustic Emission (TE-OAE) test were performed for all women.

The inclusion criteria for pregnant women to be included in the study were as follows: no history of systemic disease, normal otoscopic findings in otorhinolaryngology examination, and no ear-related complaints before pregnancy. The inclusion criteria for the control group were as follows: no history of systemic disease, normal otoscopic findings in otorhinolaryngologic examination, and not being in the menstrual period.

In the evaluation of the pregnant women, the following stages were taken into consideration, and the women were divided into groups. Audiologic evaluations of pregnant women in the 1st, 2nd, and 3rd trimesters were performed.

DATA COLLECTION METHOD

Audiologic Examinations: were performed using clinical audiometers Interacoustics AC40 (Assens, Denmark), TDH 39 headphones, and MX 41/AR cushions in the quiet rooms of the Industrial Acoustic Company (Illinois, USA). Airway hearing thresholds were measured at 125-8,000 Hz, and bone conduction hearing thresholds were measured at 250-4,000 Hz.

TE-OAE Measurements: were performed binaurally using Otometrics MADSEN Capella² (Taastrup, Denmark) portable OAE device and OTOsuite software. TE-OAE tests were performed at 1,000, 1,500, 2,000, 3,000, and 4,000 Hz. For each frequency, the signal-to-noise ratio (SNR) was used as the study parameter. Otoacoustic emission was detected for the measured frequency when the SNR was +6 dB and above. The intensity was set at 80±3 dBSPL and the reproducibility was set at 70% and above.

In the Immitancemetric Examination: Interacoustics AZ26 tympanometry (Assens, Denmark) was used. Ear canal volumes, static admittances, middle ear pressures, and gradient values of all women were determined. Ipsi- and contralateral acoustic reflex thresholds at 500-4,000 Hz were automatically measured with the same device.

STATISTICAL ANALYSIS

SPSS for Windows 20.0 (New York, USA) was used for the statistical analyses. The Kruskal-Wallis test was performed for the comparison of groups that did not show normal distribution.

RESULTS

In this study, 86 ears of 43 pregnant women and 54 ears of 27 nonpregnant healthy women were evaluated. Pregnant women were aged between 18-35 years with a mean of 28.76±6.4. The control group was aged between 18-32 years with a mean of 23±4.6. All participants in both groups were female.

All women underwent an audiological examination after an otorhinolaryngologic examination. The mean and standard deviation values of pregnant women and nonpregnant women in the control group

TABLE 1: Hearing threshold means and standard deviation values (dB) of the pregnant and control groups at 125-250-500-1,000-2,000-4,000-6,000-8,000 Hz

Ears	1st trimester $\bar{X}$±SD	2nd trimester $\bar{X}$±SD	3rd trimester $\bar{X}$±SD	Control group $\bar{X}$±SD	p value
Right ear 125 Hz	20.58±5.60	19.36±4.69	21.36±5.98	12.06±3.40	p<0.05*
Left ear 125 Hz	21.02±6.04	20.03±5.64	19.89±5.03	11.69±4.23	p<0.05*
Right ear 250 Hz	21.25±6.40	20.63±6.80	20.45±6.87	14.11±5.28	p<0.05*
Left ear 250 Hz	19.38±8.68	17.29±5.51	17.73±9.04	13.57±4.88	p<0.05*
Right ear 500 Hz	18.13±5.93	17.29±5.51	16.36±5.62	10.18±5.09	p<0.05*
Left ear 500 Hz	18.13±4.58	16.46±4.77	17.00±7.94	10.71±5.04	p<0.05*
Right ear 1,000 Hz	11.25±3.53	12.08±3.58	11.36±3.93	10.17±3.72	p>0.05
Left ear 1,000 Hz	12.50±4.62	12.50±5.10	11.36±4.52	10.35±4.06	p>0.05
Right ear 2,000 Hz	7.50±5.34	9.58±5.50	8.63±3.93	7.85±5.51	p>0.05
Left ear 2,000 Hz	8.75±5.82	10.83±8.29	9.09±3.75	7.85±5.68	p>0.05
Right ear 4,000 Hz	13.12±10.66	11.25±4.48	12.27±7.86	9.28±6.76	p>0.05
Left ear 4,000 Hz	11.25±6.40	13.33±10.28	13.63±8.68	9.96±3.92	p>0.05
Right ear 6,000 Hz	16.87±7.98	15.00±9.55	15.90±9.95	12.85±7.38	p>0.05
Left ear 6,000 Hz	14.37±10.15	15.00±9.32	15.00±8.66	11.42±6.50	p>0.05
Right ear 8,000 Hz	12.50±10.00	14.37±7.70	15.90±8.89	12.85±7.25	p>0.05
Left ear 8,000 Hz	11.87±7.03 1	17.29±10.42	17.72±8.47	12.32±6.59	p>0.05

*p<0.05 a statistically significant difference was obtained. SD: Standard deviation (dB)

at 125-250-500-1,000-2,000-4,000-6,000-8,000 Hz are shown in Table 1.

There was a statistically significant difference between the hearing thresholds of pregnant women and nonpregnant control group women at 125-250-500 Hz ($p<0.05$).

There was no statistically significant difference in the hearing thresholds at 1,000-2,000-4,000-6,000 Hz between the pregnant and nonpregnant control group women ($p>0.05$).

There was no statistically significant difference between the hearing thresholds of the pregnant and nonpregnant women in the control group at 8,000 Hz ($p>0.05$). However, the mean hearing thresholds of pregnant women were higher in the 2nd and 3rd trimesters compared with those of healthy women and those in the 1st trimester.

Table 2 shows the mean and standard deviation values of pregnant and nonpregnant women obtained from TE-OAE at 1,000-1,500-2,000-3,000-4,000 Hz.

There was no statistically significant difference between the TE-OAE values of pregnant women and nonpregnant control group women at 1,000-1,500 Hz ($p>0.05$).

There was no statistically significant difference between the TE-OAE values of pregnant and healthy women at 2,000-3,000-4,000 Hz ($p>0.05$). However, the TE-OAE values decreased from the 1st to the 3rd trimester.

There was no statistically significant difference between the ear canal volume, compliance values, middle ear pressure values, and gradient values of pregnant and nonpregnant control group women in the immitancemetric evaluation ($p>0.05$).

DISCUSSION

During pregnancy, changes occur in the genital, cardiovascular, and endocrine systems of the body.[7] In addition, the baby meets all of its needs from the mother, which also affects the metabolic system. Changes occur in fluid-electrolyte balances due to hormonal changes in women's' menstrual cycles. These changes can affect the inner ear.[7]

There are not many studies in the literature in which the hearing functions of women during pregnancy have been evaluated. The effects of menopause, menstrual cycle, and hormonal differences between men and women on hearing functions have been explored. Studies have suggested that sex hormones in the circulatory system affect the sensory and neural systems and that the hearing system is especially affected by estrogen secretion, which is mediated through acetylcholine synthesis.[7] Changes in the hormonal system during pregnancy affect water and salt metabolism and may cause changes in the hearing system.[8] As a result of the overall studies, changes in hearing sensitivity in pregnant women during pregnancy can be pregnancy-associated.[6]

TABLE 2: 1,000-1,500-2,000-3,000-4,000 Hz TE-OAE and standard deviation values (dB) of nonpregnant women in the pregnant and control groups

Ears	1st trimester $\bar{X}$±SD	2nd trimester $\bar{X}$±SD	3rd trimester $\bar{X}$±SD	Control group $\bar{X}$±SD	p value
Right ear 1,000 Hz TE-OAE	5.96±4.69	7.11±7.27	6.51±4.11	7.88±6.96	p>0.05
Left ear 1,000 Hz TE-OAE	5.83±4.98	6.22±7.16	4.77±6.10	7.92±4.67	p>0.05
Right ear 1,500 Hz TE-OAE	10.23±3.89	10.43±6.74	9.71 ±6.17	13.17±7.52	p>0.05
Left ear 1,500 Hz TE-OAE	11.96±5.55	10.54±9.63	11.89±6.05	12.09±6.62	p>0.05
Right ear 2,000 Hz TE-OAE	11.55±3.83	8.18±6.72	7.50±4.85	12.28±6.54	p>0.05
Left ear 2,000 Hz TE-OAE	11.02±5.96	8.39±6.46	7.14±4.37	11.16±5.69	p>0.05
Right ear 3,000 Hz TE-OAE	8.26±3.83	7.35±4.53	4.97±4.74	9.57±7.22	p>0.05
Left ear 3,000 Hz TE-OAE	7.35±3.99	6.31±5.91	5.40±4.40	10.44±6.34	p>0.05
Right ear 4,000 Hz TE-OAE	6.76±5.59	4.85±4.92	3.50±5.17	7.47±6.40	p>0.05
Left ear 4,000 Hz TE-OAE	5.85±4.00	4.05±4.74	2.50±3.40	8.26±9.64	p>0.05

TEOAE: Transient-evoked otoacoustic emissions. SD: Standard deviation (dB)

In the study of Sennaroglu and Belgin, hearing thresholds at 125-16,000 Hz, auditory brainstem responses (ABR), and immitancemetric measurements were examined in the audiologic evaluation of 20 pregnant women during the 1st, 2nd, and 3rd trimesters and between 3-6 months postpartum. No difference was found between pregnant women and healthy women in terms of ABR and immitancemetric measurements. However, an increase was observed in the hearing thresholds at 125, 250, and 500 Hz, mimicking the cochlear pathology. These changes in hearing thresholds returned to normal limits in the postpartum 3rd-6th month evaluation.[9]

Otoacoustic emission tests were also performed in our study. OAE objectively reflect inner ear functions, especially the function of the outer hairy cells. In the study, lower amplitude emission values were obtained from pregnant women compared to healthy women in the OAE results. These results again indicate that the inner ear is affected during pregnancy.

Kenny et al. reported that unilateral, low-frequency sensorineural hearing loss is rarely seen during pregnancy. The low hearing thresholds at low frequencies determined in our study are consistent with the results of this study, but the fact that it was bilateral rather than unilateral is contradictory. Kenny et al. suggested that the reversible sensorineural hearing loss in pregnant women was due to mechanical pressure on the hairy cells in the inner ear as a result of changes in the tissues caused by physiologic events during pregnancy and attributed the normalization of hearing after pregnancy to the elimination of mechanical pressure.[10]

In their study on sudden sensorineural hearing loss during pregnancy in 2011, Hau and Wang attributed this condition to the disruption of cochlear circulation and cochlear fluid homeostasis by changes in the cardiovascular system, hematologic system, and endocrine system.[11] In the study, they stated that a new diagnosis, namely pregnancy-induced sudden hearing loss, could be established.[11]

In the study conducted by Yang et al. with 102 pregnant women in 2023, it was reported that pregnant women with sudden sensorineural hearing loss had more severe hearing loss and encountered greater difficulties in treatment.[8]

When Dağ et al. compared the resonance frequency values of pregnant women in the 3rd trimester with healthy women of similar age, they found that the middle ear resonance frequency values of pregnant women were significantly lower than those of healthy controls. The authors stated that this decrease in the resonance frequency value may be due to the increase in pressure in the oval window and inner ear structures and changes in middle ear impedance due to reasons such as weight gain and edema during pregnancy.[12]

Hypertension during pregnancy can cause damage to the inner ear hair cells, which is called inner ear tenderness due to vasospasm and microthrombus. However, hearing loss recovers to normal in the postpartum period.[13]

Cyclical changes in female sex hormones are observed during pregnancy, menopause, and the menstrual cycle. Due to fluctuations in estrogen and progesterone levels, physiological changes occur in the female body, and these changes may also affect ear physiology.[14]

In conclusion, the increase in pure tone hearing thresholds at low frequencies and the decrease in the mean otoacoustic emission values at 2,000, 3,000, and 4,000 Hz indicate that the inner ear may be affected during pregnancy. The decrease in the pure tone hearing thresholds and TE-OAE amplitudes did not reach the pathologic levels. These changes were within the physiologic limits.

In human physiology, hearing loss has different etiologies, and environmental, ototoxic, hereditary, and individual differences play a role in the development of hearing loss. Therefore, our study has some limitations. A relatively small number of women were evaluated, and the study was conducted at a single center.

CONCLUSION

In conclusion, there may be differences in the inner ear values of women during pregnancy. Changes in the inner ear starting from the 1st trimester of pregnancy increase toward the last stages of pregnancy. The pure tone hearing thresholds and otoacoustic emission values show changes in the 1st, 2nd, and 3rd trimesters of pregnancy. However, there was no

change in the middle ear functions. The hearing thresholds of pregnant and nonpregnant control group women at 1,000-8,000 Hz were similar. This study will be a source of up-to-date information for future audiology examinations and new studies to be conducted on pregnant women. Hearing thresholds should be checked during pregnancy.

In our study, resonance frequency measurement using multifrequency tympanometry was not performed. However, such an assessment is important for monitoring changes during pregnancy and evaluating normalization in the postpartum period. Therefore, it is recommended that future studies include multifrequency tympanometric evaluations.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Leyla Türe;* ***Design:*** *Leyla Türe;* ***Control/Supervision:*** *Tuğçe Gül Çağlar, Mesut Kaya;* ***Data Collection and/or Processing:*** *Leyla Türe, Tuğçe Gül Çağlar;* ***Analysis and/or Interpretation:*** *Leyla Türe;* ***Literature Review:*** *Tuğçe Gül Çağlar, Leyla Türe;* ***Writing the Article:*** *Leyla Türe, Tuğçe Gül Çağlar;* ***Critical Review:*** *Mesut Kaya;* ***References and Fundings:*** *Leyla Türe;* ***Materials:*** *Tuğçe Gül Çağlar.*

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