Research Article

The Influence of Skin Pigmentation on Cochlear Functioning: A Study on Individuals with Normal Hearing Sensitivity

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Highlights

- DPOAEs amplitude and slope were compared across skin pigmentations in India
- The skin pigmentation did not affect cochlear functioning in the Indian population

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ABSTRACT

Background and Aim: Melanocytes are cells in the skin, hair, and eyes that generate pigment called melanin, which is primarily responsible for the pigmentation of these structures. These melanocytes, known as the Cochlear Melanocyte, are also present in the human ears (especially in the cochlea) and play a significant role in fostering endocochlear potential and preventing the odds of hearing loss. The current study investigated the relationship of skin pigment with cochlear function through distortion product otoacoustic emission in Indian skin type.

Methods: A total of 120 participants aged between 17 to 25 were included using a purposive sampling technique. The subjects were further grouped based on a questionnaire on Fitzpatrick Skin Phototype (FSP) developed by Thomas Fitzpatrick (1975) and categorized as type III- type VI suitable for Indian skin types. Along with routine audiometric evaluations, the cochlear functioning was assessed using distortion product otoacoustic emissions. The standard group research design was used, and as data was normally distributed, multivariate analysis of variance was used to compare across groups.

Results: The results of multivariate analysis of variance (MANOVA) showed no significant differences across the four groups for both amplitude and the slope of distortion product otoacoustic emissions.

Conclusion: The present study using otoacoustic emissions revealed that the skin pigmentation did not affect cochlear functioning in the Indian population (type III through type VI) as seen in type I and II.

Keywords: Melanocytes; hearing loss; cochlear function; skin pigmentation

Introduction

Melanocytes are melanin-generating cells at the deepest part of the skin's epidermis, determining the skin colour of an individual. Melanocytes are present in various parts of the human body, including the auditory system, especially in the inner ear (cochlea) and organs of the vestibular system. Melanocytes were also found in parts of the central and peripheral nervous systems [1]. These cells are present abundantly in more vascularised areas, mainly serving metabolic functions. The melanin produced by strial melanocytes (intermediate cells) in the cochlea may act as a metal chelator, free radical scavenger, or a regulator of calcium homeostasis in the stria vascularis, which is in charge of establishing and preserving the endolymphatic potential necessary for normal hearing [2]. It is reported in the literature that the number of melanocytes varies depending on the skin pigmentation levels [3]. The general pigmentation of the body has been shown to correlate positively with the amount of melanin present in the cochlea [3]. The inner ear melanocytes have been found to play an important role in the normal functioning of the stria vascularis and cochlea by maintaining the ion gradient between endolymph and perilymph. This, in turn, is essential for the development of endocochlear potential as well as hair cell survival inside the cochlea [3-5].

Studies in literature have utilised various audiological tests to establish the link between melanin concentration and auditory functions. A study done by Helzner et al. [6] compared the pure tone thresholds between African adults and Caucasians. They found better hearing thresholds among Africans than Caucasians and attributed the difference to the skin pigmentation variation between the two groups. Further, studies have reported that individuals with high melanin pigments are less susceptible to hearing impairment than those with low melanin [7, 8]. It is also reported that the incidence of noise-induced hearing loss and age-related hearing loss is greater among those with less melanin composition than those with large melanin composition identified using skin pigmentation [9-12]. Further, a few studies have suggested that races with higher melanin levels have stronger or higher amplitude in Otoacoustic Emissions (OAEs), indicating robust cochlear functioning among them [13-15]. However, a study by Chan and McPherson [16] reported no such differences in overall Spontaneous OAEs (SOAEs) and Transient Evoked OAEs (TEOAEs) between races varying in skin pigmentations. From the above reports, there are inconclusive and contradictory findings regarding the skin pigmentation varying the auditory functioning [17, 18].

Hence, to determine whether the melanin concentration influences the hearing abilities of an individual, the hearing function can be tested among individuals with varying levels of skin pigmentations. OAEs, being an objective test, provide a direct way to assess the functioning of the outer hair cells. It gives us a better insight into the biomechanical aspects of auditory stimulus by recording changes in the amplitude of emissions that can be influenced by the level of melanin [19]. Further, it is noteworthy that Chan and McPherson [16] reported that there were significant differences in TEOAE amplitudes at higher frequencies between the two racial groups varying in skin pigmentation, although there was no overall effect seen. Hence, Distortion Product OAEs (DPOAEs) were chosen in the present study that can be used to assess higher frequencies than clinically utilized TEOAEs. Also, India has vast and varying skin phototypes, and there is a dearth of studies that examine the variation in amplitude of OAES across Indian skin phototypes. Hence, the current study explored how the functioning of outer hair cells or OAE amplitudes may be modulated by skin pigmentation among Indian skin pigmentations. The study aimed to analyse the association of DPOAE in individuals across multiple categories of skin pigmentation in the Indian population.

Methods

A cross-sectional design with a non-random convenient sampling technique was utilised. 120 female participants of age ranging between 17–25 years (mean age=19.6; SD=3.5) with different skin types were recruited in this study. All the participants included in the study were university students. The research was advertised in colleges and the students volunteered for the study on self-interest. The participants were grouped based on a questionnaire on Fitzpatrick Skin Phototype (FSP) developed by Fitzpatrick, (1975) [20, 21]. The FSP includes six different skin tones by the amount of melanin the skin has and the skin's reaction

to sun exposure. The Indian skin falls under type III to type VI [22], with type III, type IV, type V, and type VI consisting of individuals with light brown skin, moderate brown skin, dark brown skin, and intensely pigmented dark brown to black skin, respectively. Based on the responses from the questionnaire, they were sub-grouped accordingly. In each group, 30 participants were included. Only female participants were included in this study because the DPAOE findings are reported to vary across genders [23]. In addition, none of the participants reported any significant history of otological, neurological, or cognitive deficits, noise exposure, or previous ear surgery to exclude its effect on the results. All the participants initially underwent standard pure tone audiometry and immittance evaluation to confirm normal peripheral hearing sensitivity and middle ear functioning, followed by DPOAE.

Equipment

All the testing procedure was done using a standard protocol in an acoustically treated room, and the permissible noise level of the room was as per ANSI S3.1-199 (R2013) standards. Pure tone audiometry (PTA) was measured using a calibrated clinical audiometer, Inventis Piano (Inventis Padova, Italy). Immittance evaluation was administered using a clinical tympanometer, Inventis Clarinet (Inventis Padova, Italy). DPOAE measurements were recorded for both ears using the Intelligent Hearing Systems Duet (IHS, Miami, FL).

Procedure

Initially, written informed consent was obtained from all the participants by explaining the procedure and need of the study in detail. Also, the study was initiated only after obtaining appropriate clearance from the institutional ethical committee. Prior to the audiological evaluation, a detailed case history was obtained from all the participants to rule out hearing loss, history of noise exposure, and any otological symptoms. Participants with a history of significant otological problems, prolonged or frequent loud noise exposure, hearing loss and other medical history were excluded from the study. An otoscopic evaluation ruled out external ear and ear canal anomalies. Only individuals with intact tympanic membranes with a cone of light in both ears were included in the study. PTA was done to estimate the hearing thresholds of the individuals. The air conduction thresholds, bone conduction thresholds, speech recognition thresholds, and speech identification scores were estimated using a calibrated clinical audiometer (Inventis Padova, Italy) with Telephonics Dynamic Headphones 39 earphones enclosed in MX-41/AR supra-aural ear cushions and Radio Ear B-71 bone vibrator transducers. Only individuals with normal pure tone thresholds (≤15 dB HL) for the air conduction at the octave frequencies from 250–8000 Hz and bone conduction at the octave frequencies from 250–4000 Hz were included. Immittance evaluation was carried out using a calibrated Inventis Clarinet (Inventis Padova, Italy) middle ear analyser. Only individuals with bilateral 'A' type tympanogram with reflexes present were considered to have normal middle ear functioning and were included in the present study.

Initially, TEOAEs were measured for the frequencies 1000 to 4000 Hz for both ears using the calibrated Intelligent Hearing Systems Duet (IHS, Miami, FL) Transient. The stimulus presented was clicks at the presentation level of 85 dB peSPL. TEOAEs were considered present based on the criteria of 80% reproducibility and +3 dB Signal-to-Noise Ratio (SNR) at any three consecutive frequencies [24]. All tests were administered in a randomised manner for the right and left ears. Only the participants who met the above inclusion criteria were further subjected to DPOAE testing.

DPOAEs were measured on the following Fdp frequencies: (2f1-f2) –356, 498, 703, 996, 1416, 1992, 2827, 3994, and 5645 Hz with primary tones f1 and f2 at the input intensity level of L1=65 dB SPL and L2=55 dB SPL with a ratio (f2/f1) equal to 1.22 respectively. Testing lasted for about 5 minutes for each ear across the frequencies. For DPOAE recordings, amplitudes greater than 0 dB SPL at each frequency were considered accurate responses and included in the analysis. The results were displayed in a DP Gram. DPOAE input-output (I/O) functions were recorded on the following frequencies: 703, 1060, 1416, 2114, 2827 and 4243 Hz. In the DPOAE I/O function, an average of three responses was determined for each response. Using the linear trend model, the slope was estimated. The DPOAE I/O data were fitted with linear functions for the stimulus ranging from 55 to 37 dB SPL. Once a linear fit was obtained, the slope was calculated at 2 points of the x coordinate equal with x2=55 dB SPL and x1=37 dB SPL. Given

the corresponding points of the DPOAE amplitude as y2 and y1, the slope of the fitted linear function was defined as b=(y2–y1)/(x2–x1). The DPOAE amplitudes and the calculated slope of the DPOAE I/O function were considered for statistical analysis.

Statistical analysis

SPSS Statistical Package for the Social Sciences version 21.0 was used for the data analysis. Shapiro Wilk test of normality was done to check whether the data were normally distributed. The results showed that the data was normally distributed across the four pigmentations of type III, type IV, type V, and type VI ($p>0.05$). Further multivariate analysis of variance was done individually for amplitude of DPOAEs and I/O slope of DPOAEs to check for differences across groups.

Results

The present study aimed to assess the association between skin pigmentation and the cochlear functioning using DPOAEs. The results are provided regarding the amplitude and input-output function of DPOAEs across different groups with varying skin pigmentation.

The amplitude of distortion product otoacoustic emissions across the different skin types

Initially, descriptive statistical analysis was done to determine mean, median, and range for DPOAE amplitude (dB SPL) for the frequencies 356, 498, 703, 996, 1416, 1992, 2827, 3994, and 5645 Hz for different skin types. The mean and standard deviation of the DPOAE amplitudes were not found to vary much across the four groups, as seen in Figure 1.

A MANOVA was done across the groups for all DPOAE frequencies to check for any significant difference between the groups on DPOAE amplitude. The results of MANOVA revealed there was no statistically significant difference [$F_{(27,228)}=2.18$, $p=0.34$] across the four groups on DPOAE amplitude from the frequencies 356 to 5645 Hz. Hence, no further statistical analysis was done.

The input-output slope of distortion product otoacoustic emissions across the different skin types

DPOAE I/O function was recorded from participants with different skin pigmentation types. Descriptive

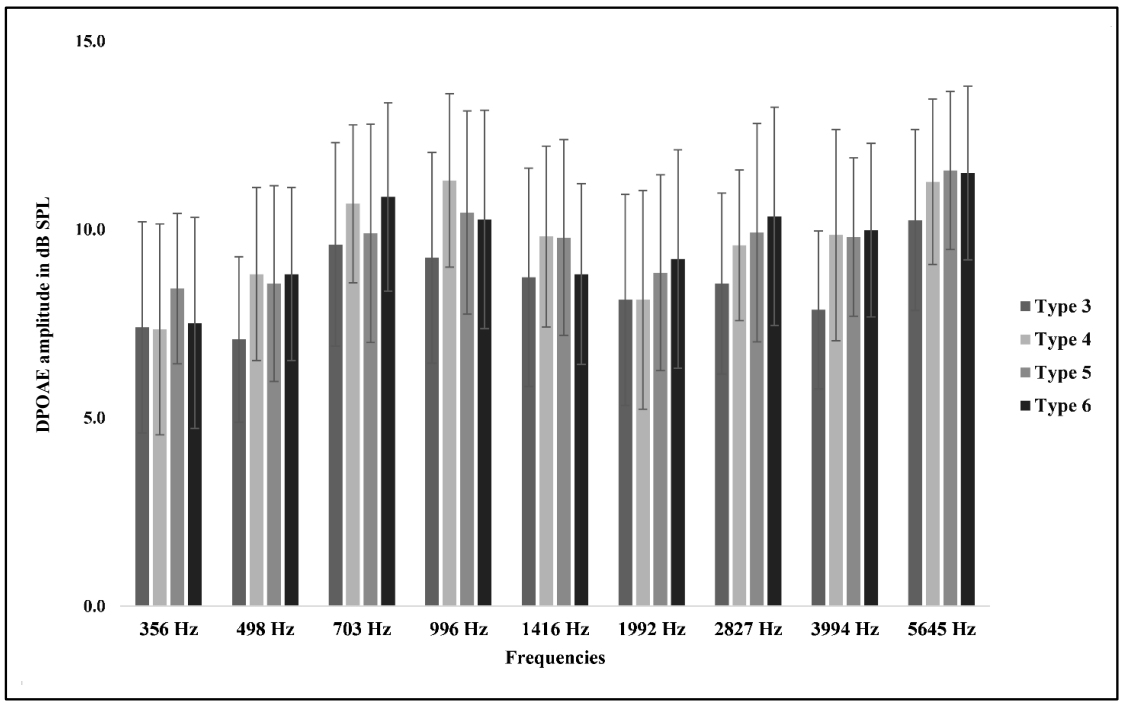

Figure 1. The mean and standard deviation of distortion product oto acoustic emission amplitude from the frequencies 356 Hz to 5645 Hz across the four groups. DPOAE; distortion product oto acoustic emissions

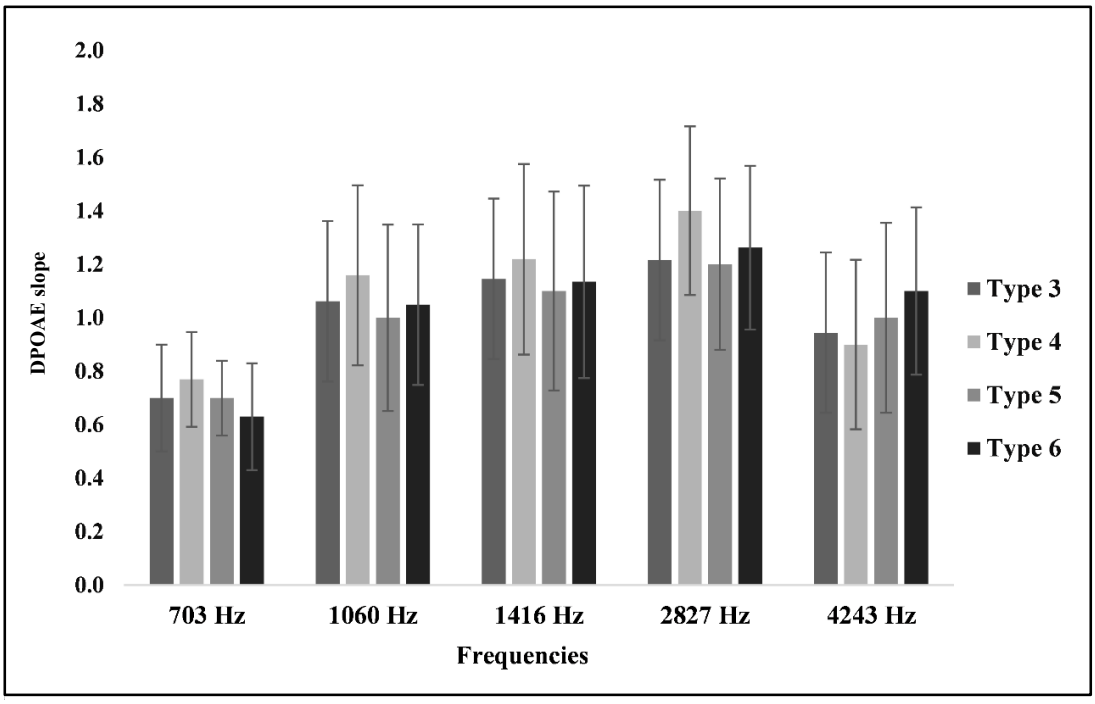

Figure 2. The mean and standard deviation of the distortion product oto acoustic emission input output slope from the frequencies 356 Hz to 4243 Hz across the four groups. DPOAE; distortion product oto acoustic emissions

statistics for the DPOAE I/O function slope from 356 to 4243 Hz were analysed.The slope was similar across the different skin type groups. The mean and standard deviation (SD) of the DPOAE input output slope from the frequencies 356 to 4243 Hz across the four groups is shown in Figure 2.

A MANOVA was done across the groups for all DPOAE frequencies to check for any significant difference between the groups on DPOAE amplitude. The results of MANOVA revealed there was no statistically significant difference [$F_{(15,232)}$=11.50, p=0.09] across the four groups on the DPOAE I/O slope from the frequencies 356 to 4243 Hz.

Discussion

The present study sought to investigate the impact of melanin on outer hair cells functioning in individuals with normal hearing, particularly focusing on the DPOAE amplitude at various frequencies. Contrary to some previous research, the findings of this study revealed no significant differences in DPOAE amplitudes across the four different skin type groups, encompassing individuals from type III to type VI. These results challenge earlier studies that suggested a potential link between skin pigmentation and hearing loss, with some proposing that individuals with lower skin pigmentation may be more susceptible to hearing impairment [8, 25].

However, it is worth noting that the majority of the earlier studies pointing to the role of melanin in hearing loss were conducted in western countries, which may have different population demographics and genetic predispositions compared to the Indian population. This divergence in findings is exemplified by the research of Varghese and Kottaramveettil [18], conducted in an Indian context, which indicated a reduction in OAE amplitude in individuals with lower skin pigmentation. They specifically compared individuals from type I and type VI skin types, with the former having notably low skin pigmentation.

Varghese and Kottaramveettil [18] specifically focused on type I individuals, which may not be widespread among the Indian population [22], which is one explanation for the discrepancy in results between the present study and their findings. This could account for some of the difference. In contrast, the present study considered individuals from type III to type VI, which are more prevalent skin types in India [22]. Consequently, the results of the current study imply that cochlear

functioning is consistent in the Indian population and that skin pigmentation may not have a measurable impact on outer hair cell activity in this population.

In conclusion, this study discovered no significant correlations between skin pigmentation and cochlear functioning in the Indian population (type III through type VI), despite the fact that skin pigmentation has been connected to cochlear functioning in those individuals belongs to type I or type II. The results emphasise the significance of taking regional and population-specific factors into account when examining how skin pigmentation affects hearing function. The complex relationship between skin pigmentation and hearing may be better understood with further research conducted in a wider range of populations and environments.

Conclusion

Consequently, the current study is an initial attempt to document the impact of skin pigmentation on cochlear functioning in normal population. The present study using otoacoustic emissions revealed that the skin pigmentation did not affect cochlear functioning. Although otoacoustic emissions are sensitive to cochlear alterations, it is essential to note that other electrophysiological tests that would better understand auditory functioning must be used in a larger sample size to establish the results.

Ethical Considerations

Compliance with ethical guidelines

In the current study, all of the testing procedures were accomplished using a non-invasive technique and adhered to the conditions of the institutional ethical approval committee. The institutional ethical approval committee approved the current study Holy Cross College Ethical Committee (HCC EC) Reference No: (HCC/ERB/EC/PB-04/2023-2024). The test procedures were clearly explained to the participants before testing. Prior informed consent was taken from the participants for their willingness to participate in the study.

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Authors' contributions

SD: Study design, drafting the manuscript, interpretation of the results, critical revision of the manuscript, statistical analysis; KK, PNS, SST: Study design, acquisition of data, drafting the manuscript, interpretation of the results, critical revision of the manuscript; PP: Study design, supervision, interpretation of the results, critical revision of the manuscript and statistical analysis; BK: Study design, supervision, critical revision of the manuscript.

Conflict of interest

The authors report no conflicts of interest.

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