Sex Differences in Otoacoustic Emissions to Examine Underlying Cochlear Mechanisms

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ABSTRACT

Purpose: The purpose of this project was to describe the extent to which differences in underlying cochlear mechanisms explains why some otoacoustic emissions (OAEs) are smaller in males than in females while other OAEs are similar in both sexes.

Method: 24 females and 20 males with normal hearing were tested. In each subject, three types of OAEs were recorded: stimulus-frequency OAEs (SFOAEs), distortion-product OAEs (DPOAEs), and transient-evoked OAEs (TEOAEs).These various OAE types arise through different cochlear mechanims and can be used to test the hypothesis that sex differences will only be apparent for OAEs generated by one cochlear mechanism.

Results: Consistent with previous data, TEOAEs were significantly larger in females than in males. SFOAEs also were significantly larger in females than in males, which supported the hypothesis that SFOAEs and TEOAEs arise through the same cochlear mechanism and that it is this mechanism that is influenced by sex. In contrast, DPOAEs, which arise from a different cochlear mechanism, were not significantly different in level between the sexes.

Conclusions: The data reported here provide evidence that differences in the underlying cochlear mechanism across varying OAE types, may explain the contradictory observation that some, but not all, OAEs are larger in females than in males. SFOAEs and TEOAEs arise via the same mechanism and both show differences between the sexes. DPOAEs, in contrast, do not show differences because they arise via a different cochlear mechanism that is not affected by sex.

INTRODUCTION

An otoacoustic emission (OAE) is an internal sound that is produced by the cochlea (the sensory structure in the inner ear) in response to external sound and can be recorded with a sensitive microphone placed in the ear canal. The presence of OAEs suggests a healthy cochlea and normal (or near normal) hearing. OAEs serve as a measure for various auditory tests clinically. They are widely used to screen for hearing loss in newborns and also have been used to noninvasively test cochlear function. Additionally, OAEs have been used to explore the differences in the auditory system between sexes, with a number of studies suggesting that females have larger OAEs than males (e.g., McFadden et al., 2009a, b, 2008, 2002). This difference between the sexes has been observed for some, but not all, types of OAEs.

OAEs typically have been classified based on the external stimuli used to elicit the response. SFOAEs occur in response to a single pure-tone stimulus and DPOAEs occur in response to pairs of pure tones. In contrast, TEOAEs are evoked with a short-duration click stimulus. Modern theories of OAE generation, however, suggest that the various OAE types may differ not just in terms of the stimuli used to elicit the response but also in terms of the cochlear processes underlying the generation of the internal response (e.g., Shera, 2004). According to these theories, there are two different mechanisms that contribute to OAEs. These are a nonlinear-distortion mechanism and a coherent-reflection mechanism. DPOAEs are thought to include both mechanisms. SFOAEs are thought to be primarily generated by the coherent-refection mechanism, at least for low-to-moderate stimulus levels (Johnson, 2010). TEOAEs, similar to SFOAEs, are believed to arise primarily through the coherent-reflection mechanism. It may be important to consider the cochlear mechanisms underlying the different OAE types when interpreting the somewhat contradictory evidence that sex-differences in OAE levels have been observed for some but not all types of OAEs.

McFadden and colleagues (2008, 2009a, b) have explored the idea that OAEs differ between the sexes of humans and other animals by studying sex-differences in OAE response levels in DPOAEs and TEOAEs. These data showed no statistically significant difference in DPOAE response level (in dB SPL) between the sexes. In contrast, for TEOAEs there was a statistically significant difference between the sexes where females had larger OAE response levels than males. McFadden et al. (2009b) have argued that differences in OAE level between the sexes can be attributed to different levels of androgen exposure in *utero*; masculinized cochleae exhibit lower OAE levels than non-masculinized cochleae. Again, McFadden (2009a) has argued that the observation that TEOAEs vary with sex (and sexual orientation), while DPOAEs do not, is evidence that the cochlear mechanisms that produce TEOAEs (coherent reflection mechanism) are strongly affected by the biologic process that influences sex differences (and sexual orientation) but that the cochlear mechanism underscoring DPOAEs (primarily the distortion mechanism) is not influenced by this same process.

These data suggest that it may be possible to explain why TEOAEs show sex differences, while DPOAEs do not, based on the different cochlear mechanisms. These data, however, do not fully account for the role of cochlear mechanisms because SFOAEs, which are thought to represent the same mechanism as TEOAEs, have yet to be tested. Testing both SFOAEs and TEOAEs in the same subjects would help to describe the extent to which all coherent-reflection mechanism OAEs show the same patterns and would strengthen (or contradict) arguments that it is this mechanism that is affected in prenatal development. Moreover, the influence of prenatal androgens on cochlear mechanisms for DPOAEs is complicated by the fact that both mechanisms contribute to the DPOAEs. This has not been considered in previous work with sex differences; however, it is possible to restrict the DPOAE response to just the distortion mechanism by recording DPOAEs in such a way that only the distortion mechanism contributes. This would help to clarify the uncertainties surrounding the lack of sex differences in DPOAEs.

This paper explores two hypotheses: (1) due to similarities in the cochlear mechanisms involved in their generation, SFOAEs and TEOAEs will show evidence of differences in OAE response level between males and females, (2) when recorded with only the distortion mechanism contribution to the response, DPOAEs will be equal in level for males and females because the distortion mechanism is not influenced by prenatal androgen exposure.

METHODS

Participants

24 females and 20 males with normal hearing with a mean age of 21 years, ranging from 19 to 37 years old, were tested.

Apparatus

Subjects sat in a reclining chair in a soundproof room. A soft-tipped probe microphone was inserted in one ear. They were instructed to remain as still and quiet as possible in order to reduce physiologic noise. Subjects were allowed to read, watch a silent (captioned) movie, or sleep.

Procedure

TEOAEs were recorded in response to click stimuli (short bursts of sound) presented at 80 dB SPL. SFOAEs were recorded in response to pairs of tones: a probe tone, used to elicit the response, and a suppressor tone, which is necessary to observe the SFOAE response. The specific stimulus conditions were chosen because they were expected to produce robust TEOAEs and SFOAEs in our subjects (Johnson & Maack 2010). The stimuli represent commonly used conditions for recording these OAEs and, in the case of TEOAEs, represent the stimulus conditions that have been used in previous investigations of sex differences (e.g., McFadden et al., 2009a).

DPOAEs were recorded in response to pairs of tones with slightly different frequencies. The stimulus protocols were set to standard conditions (Kummer et al., 1998), which are expected to produce robust DPOAEs. DPOAEs were recorded in small frequency steps across two 1/3-octave intervals. This allowed us to restrict the cochlear mechanism contributing to the DPOAE to the distortion mechanism using an approach we have used previously (Johnson et al., 2006, 2007).

Analyses

Analysis of variance was used to interpret the data statistically for the main effect of sex and the interaction between sex, stimulus levels and stimulus frequencies.

RESULTS

Because the effect of sex did not differ across the various frequencies and levels that were tested ($p > 0.05$ for all interaction terms involving sex), data were collapsed across frequencies and level for each OAE type. These results are plotted in Figs. 1-3, where the mean (± 1 standard error) emission level is plotted as a function of sex. Each figure represents data for a different OAE type. As shown in Fig. 1, there was a statistically significant difference between the sexes (*p=0.002*) for TEOAEs. There was a significant difference (*p=0.036*) between the sexes for the SFOAEs as well (Fig. 2). In both cases, females had larger OAEs than males.

On the other hand, in relation to the DPOAEs, there was no significant difference (*p=0.514*) in OAE level between the sexes (Fig. 3).

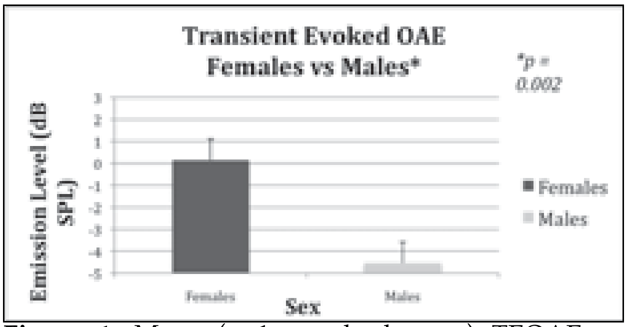

Figure 1. Mean (± 1 standard error) TEOAE response level (dB SPL) as a function of sex.

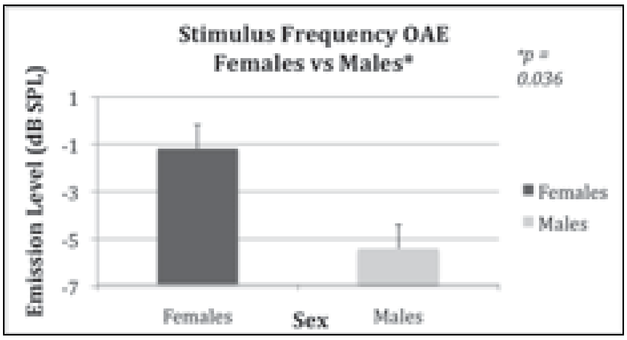

Figure 2. Mean (± 1 standard error) SFOAE response level (dB SPL) as a function of sex.

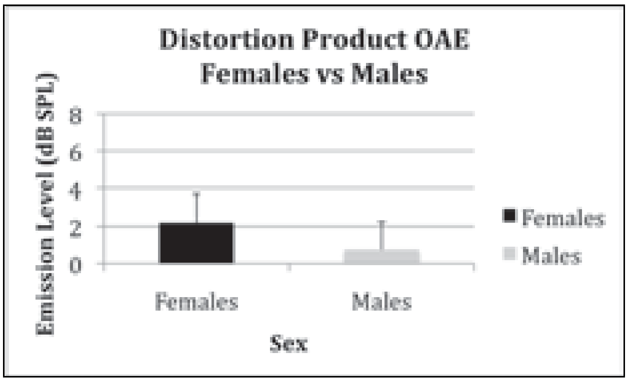

Figure 3. Mean (± 1 standard error) DPOAE response level (dB SPL) as a function of sex.

DISCUSSION

Consistent with previous reports (e.g., McFadden et al 2009a), TEOAEs exhibited sex differences. SFOAEs patterned like TEOAEs, by having sex differences, which is consistent with the hypothesis that they arise through a common cochlear mechanism. DPOAEs did not show sex differences, as was expected from previous data (e.g., McFadden et al 2009a). This is consistent with the hypothesis that DPOAEs may arise via a different cochlear mechanism than the SFOAEs and TEOAEs. Therefore, looking at differences in emission levels as a function of sex, suggests that OAEs can be segregated based on the cochlear mechanisms that underlie OAE generation.

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