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Wideband reflectance in Down syndrome

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ABSTRACT

Objective: Children with Down syndrome (DS) have a high incidence of middle ear disorders and congenital abnormalities of the external, middle and inner ear. Energy reflectance (ER), a wideband acoustic immittance (WAI) measurement parameter, can measure the sound energy reflected or absorbed in the ear canal over a wider range of frequencies more efficiently and faster than conventional single-tone 226 Hz tympanometry. The aim of the present study was to compare the WAI measurements of children with DS with those of typically developing, normal-hearing children according to their tympanometric findings.
Methods: Four groups of children with Down syndrome (age range: 2 years and 4 months to 16 years and 3 months; mean age: 8.5 yr) with normal tympanograms (19 ears), flat tympanograms (13 ears), mild negative pressure tympanograms (6 ears between −100 and −199 daPa at the admittance peak) and severe negative pressure tympanograms (4 ears at −200 daPa or lower at the admittance peak) were assessed. All findings were compared with data obtained from 21 ears of a healthy control group (age range: 3 years and 1 month to 13 years and 11 months; mean age: 7.9 yr). The subjects underwent tympanometry with a 226-Hz probe tone frequency and ER measurements along the 200–6,000 Hz range with a chirp stimulus using the Middle-Ear Power Analyzer (MEPA3 – HearID) by Mimosa Acoustics (Champaign, IL), software, version 3.3 [38].
Results: Statistically significant differences were observed in the ER curves for some comparisons between the studied groups. There was also a negative correlation between the static acoustic admittance at the tympanic membrane level and ER measured with a chirp stimulus at 500 and 1,000 Hz. The discriminant analysis technique, which used a chirp stimulus at 1,000 and 1,600 Hz to classify the participants' data based on ER values, achieved a correct classification rate of 59.52% for participants with DS.
Conclusion: While groups with abnormal middle ear status, as indicated by tympanometry, showed higher ER values compared to the DS tymp A group and the control group, similar reflectance curves were observed between control group and the DS tymp A group. WAI shows promise as a clinical diagnostic tool in investigating the impact of middle ear disorders in DS group. However, further research is required to investigate this issue in narrower age range group and a larger sample size.

1. Introduction

High rates of auditory disorders, such as conductive, sensorineural and mixed hearing loss, are common in individuals with Down syndrome (DS) [1–3]. Hearing impairments in DS may be linked to congenital malformations of the auditory system, such as abnormalities in the position and shape of the external ear [4–6], residual mesenchyme in the middle ear, abnormalities of the

Abbreviations: CG, control group; DS, Down syndrome; DS tymp A, DS group with type A tympanograms; DS tymp B, DS group with flat tympanograms; DS tymp C mild, DS group with mild negative middle ear pressure; DS tymp C sev, DS group with severe negative middle ear pressure; Hz, hertz; OAE, otoacoustic emission; VEEC, volume of external ear canal; Ytm, static acoustic admittance at the tympanic membrane level; TPP, tympanometric peak pressure; GRAD, gradient value; ER, energy reflectance; WAI, wideband acoustic immittance.

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stapes, a shortened cochlea, stenosis of the cochlear nerve canal and other malformations [7–9].

Tympanometry is currently the most commonly used tool for evaluating middle ear status. This method measures the impedance changes of the auditory system resulting from a pressure change presented by a probe tone frequency, typically a single-tone 226 Hz, in the external ear canal [10,11]. However, some studies have questioned the reliability of the 226 Hz probe tone frequency, as research has revealed that the 1,000 Hz probe tone shows a better sensitivity index for middle ear function in the neonatal population [12–14]. Nevertheless, middle ear is often assessed using a single probe tone frequency of 226 Hz in clinics although multifrequency tympanometry can usually test across wider range of frequencies from 200 to 2,000 Hz [15–17].

Wideband acoustic immittance (WAI) measures are a promising set of tools for evaluating middle ear status. WAI includes measurements of wideband impedance, admittance, reflectance, and absorbance [18]. With WAI measurements, it is possible to assess the middle ear status using a wider range of frequencies in only one data collection session, which results in a high-resolution evaluation [19–21].

One of the measuring parameters in the WAI family is power or energy reflectance (ER), which quantifies the sound energy reflected by the eardrum over a wide range of frequencies: between 125 and 10,700 Hz [22], 100 and 15,000 Hz [23] or 200 and 6,000 Hz [24]. The ER is the square of the pressure reflectance ($R = |R(f)|^2$), which is the ratio of the reflected energy to the incident energy at the middle ear. This value ranges from 0 when sound energy is completely transferred to the middle ear to 1 when no sound is transferred and is completely reflected back [22,23,25]. WAI is a rapid procedure and location of the probe in the external ear canal is not as critical as conventional single-tone 226 Hz tympanometry in assessing the middle ear in children and adults especially at higher frequencies. Moreover, it appears to be more sensitive for detecting conductive hearing loss than conventional tympanometry [25–27]. Most of the energy at the eardrum is reflected back at low frequencies; there are regions of lower reflectance between 1,000 and 4,000 Hz, and there is moderate reflectance at high frequencies [22]. Any value outside of the 90% normative range could indicate an abnormal condition. For example, in otosclerosis, there may be an excessively high reflectance at low frequencies [28], and in ossicular discontinuity, there may be an excessively low reflectance notch at low frequencies [19].

Tympanic membrane perforations [25], different ethnic groups [29], abnormal middle ear conditions due to effusion or middle ear pressure [30] and different age groups [31] also exhibit different ER patterns than normally hearing control groups without middle-ear pathology.

In the first published scientific research about WAI measures in DS, Kaf [32] found that 63% of individuals with DS with normal middle ear status as measured by conventional single-tone 226 Hz tympanometry showed an ER pattern that differed from that of the control group. The sound energy in the ears of participants with DS was also significantly lower than in the ears of the control group between 5,700 and 8,000 Hz; according to the author, this finding may be linked to congenital abnormalities of the middle ear in the DS population. It has also been shown that the middle ear mechanics of children with histories of otitis media may change [33] and that their cochlear function at extended high frequencies may also be affected [34].

Given the high rates of hearing disorders and anatomical abnormalities in the auditory systems of people with DS, more information must be obtained about their hearing function to verify the absorption and reflection of acoustic energy properties. The almost inexistence of research on WAI in children with Down syndrome point out the relevance of this investigation. It is also important to investigate whether the mechano-acoustical properties of middle ear in children with significant history of otitis media such as DS is any different from normal hearing children. The specific goal of this study was to compare ER measurements between children with DS and a group of typically developing children with normal hearing and middle ear condition using a chirp stimulus from 200 to 6000 Hz.

2. Materials and methods

2.1. Participants

Data from 45 participants were collected: 30 participants with DS (age range: 2 years and 4 months to 16 years and 3 months) comprised the study group (SG), and 15 typically developing participants (age range: 3 years and 1 month to 13 years and 11 months) with normal hearing and middle ear condition comprised the control group (CG). To be included in this study all participants in the CG had to meet the following inclusion criteria: Normal otoscopic examination; conventional single-tone 226 Hz tympanometric results including normal equivalent ear canal volume between 0.3 and 1.4 ml [35,36]; normal peak compensated acoustic admittance (Ytm) of equal or greater than 0.2 ml [32,37]; normal gradient value (GRAD) between 0.2 and 1.0 [38] and normal tympanometric peak pressure (TPP ≥ -99 daPa) using positive to negative pressure direction [39]. Moreover, all participants in the CG also had: a) normal transient otoacoustic emission (TEOAE) based on Lonsbury-Martin et al. passing criterion [40], considering signal-noise ratio equal or higher than 3 dB at each frequency (in this study three out five frequencies of 1,000, 1,500, 2,000, 3,000 and 4,000 Hz); b) ipsilateral acoustic reflexes at 500, 1,000, 2,000 and 4,000 Hz, at 70–90 dB above the hearing threshold [41] and c) normal air conduction thresholds between 250 and 4000 Hz ($\leq$15 dB HL) according to Northern and Downs [42].

The study was performed at the Department of Physical Therapy, Speech Therapy, and Occupational Therapy at the School of Medicine at the University of Sao Paulo. The study was approved by the Ethics Committee for the Analysis of Research Projects (CAPPesq), Hospital das Clinicas, School of Medicine, University of Sao Paulo (143/2010). The parents of the participants provided their written informed consent.

The study group consisted of participants referred by the Laboratory for Hearing Research Syndromes and Sensory-Motor Changes in Speech Pathology at the University of Sao Paulo, where they received speech-language therapy on a weekly basis. The CG individuals were enrolled in the study after their parents responded to advertisements at the Department of Physical Therapy, Speech Therapy, and Occupational Therapy or at two daycare centers at the University and the Center for Research and Teaching in Physical Therapy, Speech Therapy, and Occupational Therapy (CDP).

After data collection, data obtained from some ears were excluded from CG participants who did not meet the inclusion criteria and from study group participants for whom both conventional single-tone 226 Hz tympanometry and ER measurements could not be performed. Twenty-two children with DS (age range: 2 years and 4 months to 16 years and 3 months; mean age: 8.5 yr; 10 male and 12 female) and 12 typically developing children with normal hearing and middle ear condition (age range: 3 years and 1 month to 13 years and 11 months; mean age: 7.9 yr; 7 male and 3 female) were included in the final analysis. Depending on whether they had met the inclusion criteria one or both ears of each participant were included in the final analysis.