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Unilateral hearing loss is associated with a negative effect on language scores in adolescents

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ABSTRACT

Objective: To determine if adolescents with unilateral hearing loss (UHL) demonstrate worse language skills than their siblings with normal hearing (NH).
Design: Case-control study of 12–17-year-old adolescents with UHL (20 cases) compared with sibling controls with NH (13 controls).
Methods: Scores on the oral portion of the Oral and Written Language Scales (OWLS) and the Clinical Evaluation of Language Fundamentals (CELF) were the primary outcome measure. Wechsler's Abbreviated Scales of Intelligence (WASI) scores were also used as an outcome measure.
Results: Adolescents with UHL demonstrated worse overall and expressive language scores than controls, (98 vs. 114, $P = 0.001$; 100 vs. 114, $P = 0.006$) and had significantly lower full scale (98 vs. 112, $P = 0.017$), verbal (101 vs. 113, $P = 0.032$), and performance IQ (95 vs. 107, $P = 0.037$).
Conclusions: These findings suggest that UHL in adolescents is associated with a negative effect on standardized language scores and IQ. They also demonstrate that the developmental gap between children with UHL and children with NH does not resolve as the children progress into adolescence and may even widen as the children grow older. Therefore, these results strongly encourage implementation of early intervention for children with UHL to prevent speech-language delays. More studies in adolescents are warranted to evaluate educational outcomes.

1. Background

Unilateral hearing loss (UHL) in children has been associated with a negative effect on speech and language development [1]. Children with UHL often struggle with receptive listening due to background noise and difficulty with sound localization. The academic and developmental difficulties faced by children with UHL are reflected by the gap in speech-language scores that exists between them and children with normal hearing (NH) [2]. Significant hearing-related disabilities have also been demonstrated in adults with UHL [3,4]. A study by Wie et al. [5] proposed that permanent unilateral deafness in adults is often experienced as a communication handicap that has a negative effect on interactions with other people. Wie reported that the major areas of difficulty in adults with UHL were communicating in background noise, in poor acoustic surroundings, and with limited access to speech reading or direct listening. Rachakonda et al. [6] reported similar findings in adolescents with UHL, showing that they experience a poorer hearing-related QOL than their NH peers and also demonstrate lower self-esteem and higher stress levels.

However, few studies have evaluated the effect of UHL on adolescents. The prevalence of UHL in US adolescents has been reported to be as high as 14% [7]. Very little is known about how academic or developmental delays demonstrated in children with UHL translate into adolescence. Do adolescents with UHL compensate and "catch up" over time, or do they continue to have language delays that affect educational performance? This is the first study to compare adolescents with UHL to controls with NH on standardized measures of educational and behavioral risk. The primary objective of this study was to determine if adolescents with UHL continue to demonstrate worse language scores than their NH siblings.

2. Methods

Institutional review board approval through the Human Research Protection Office at Washington University School of Medicine was

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obtained before the onset of this study. All parent and child participants signed written informed consent and pediatric assent forms, respectively.

We conducted a controlled study of adolescents with UHL compared to sibling controls with NH. The use of sibling controls helped minimize confounding effects of family and environment on language development and behavior.

2.1. Inclusion criteria

Adolescents between the ages of 12 and 17 years were eligible for the study if they had severe-to-profound UHL, defined as pure tone average (PTA) of at least 70 dB hearing level (HL) in the affected ear at 500, 1000, 2000, and 4000 Hz; and NH in the better hearing ear, defined as a PTA (500, 1000, 2000 Hz) of less than 20 dB HL, with a threshold at 4000 Hz less than 30 dB. The hearing loss had to be sensorineural or mixed/conductive hearing loss considered "permanent". Sibling controls were also adolescents ages 12—17 with NH in both ears.

2.2. Exclusion criteria

Adolescents were excluded from the study if they had temporary or fluctuating conductive hearing loss or had a medical diagnosis associated with cognitive impairment (i.e., Down syndrome, chromosomal abnormality, or symptomatic congenital cytomegalovirus infection). Because the data for this study were collected in conjunction with functional connectivity MRI scanning, adolescents were also excluded if they had a contraindication to MRI scanning (i.e., metallic implant, braces).

2.3. Demographic and baseline variables

The subjects' demographic information, medical history, and educational history were obtained through either a parental interview or questionnaire.

2.4. Outcome variables

The primary measure of outcome for analysis was the subjects' scores on two standardized tests of language: the oral portion of the Oral and Written Language Scales (OWLS) [8] and Clinical Evaluation of Language Fundamentals (CELF) [9]. The OWLS listening comprehension (LC) scale measures the understanding of spoken language. The OWLS Oral Expression (OE) scale measures understanding and use of spoken language. The OWLS Oral Composite (OC) scale combines the LC and OE scores into an overall score. The CELF Core language score is a measure of general language ability and quantifies overall language performance. The CELF expressive language (EL) index is an overall measure of expressive language skills. The OWLS and CELF scaled scores are all normed to have a mean of 100 and a standard deviation of 15 by age.

Cognitive ability was measured using Wechsler's Abbreviated Scale of Intelligence (WASI) [10], which provided the three traditional Verbal, Performance, and Full-scale IQ scores. The IQ scores are also normed to have a mean of 100 and standard deviation of 15 by age.

Secondary outcome measures consisted of parent's account of speech/language delays, speech-language therapy, repeated grades in school, teacher's report of school-related behavioral problems, and specification of individualized education plans (IEPs) or Section 504c accommodations for hearing disability at school.

2.5. Test protocol

Participants were alert and voluntarily assented to the study before testing. All of the standardized tests were administered in a quiet, private room. The research personnel who administered the tests were experienced in relating to children, and underwent training and practice under supervision for each test before beginning actual testing. The tester and participant sat across from each other with a table between them so that testing items could be presented if necessary. Participants were offered breaks between tests, especially if they seemed fatigued or distracted. Snacks and drinks were on hand if they required food. Restrooms were readily available to participants.

The research personnel administering the tests were not blinded to the hearing status of the participant.

2.6. Analysis

Descriptive statistics were acquired for each group, which included means and standard deviations for continuous variables and frequency distributions for categorical variables. Group differences were examined using a student's *t*-test or one-way analysis of variance (ANOVA) for continuous variables, and a chi-square or Fisher's exact test was used for categorical variables. Bivariate analysis was applied to examine speech-language score outcomes associated with patient's demographic, baseline clinical, and risk factor variables. A 2-tailed alpha level of 0.05 was considered statistically significant.

Either the OWLS or the CELF questionnaire was administered to the subjects to measure language outcomes. In order to analyze these outcomes across the entire sample population, subsets of the OWLS and CELF scores were combined to create new variables. Because both questionnaires are standardized, normed to have a mean of 100 with a standard deviation of 15, and measure the same outcome, we combined the comparable outcomes. The OWLS Oral Composite standard scores and the CELF Core scores were combined in the overall outcome "language score"; a student's *t*-test showed no significant difference between the scores. Similarly, the OWLS Oral Expression (OE) standard score was comparable to the CELF expressive language (EL) standard score, showing no statistically significant difference when analyzed with a student's *t*-test. Therefore, these two were combined in the outcome "expressive language score." By creating the language score and expressive language score, analysis of the entire sample population for language development was possible.

Multivariable linear regression was used to control for the effect of multiple independent predictors of speech-language scores and IQ. Type of health insurance was coded as being Medicaid or private insurance. Regression diagnostics including tolerance and variance inflation factor were done to assure multiple regression model assumptions were met.

Outcome measures from at least two or more points in time were available for 22 of 33 participants, which included 15 adolescents with UHL and 7 controls. Many of the participants involved in this study had also enrolled in a previous study [4] that measured speech and language development in children with UHL compared to children with NH. The instrument used in the previous study was the OWLS questionnaire. We were able to incorporate these previous measures into our study to compare speech-language scores within subjects over a period of time. This allowed longitudinal analysis to be completed on the data sets. A repeated measures ANOVA was implemented to examine the longitudinal data.

Statistical analysis was performed using IBM SPSS Statistics software version 19 (SPSS, Inc. Armonk, New York).

3. Results

Thirty-three participants consisting of 20 adolescents with UHL and 13 controls with NH were included in the analysis. Characteristics