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Unilateral Hearing Loss is Associated with a Negative Effect on Language Scores in Adolescents

Caroline Fischer, BA and Judith Lieu, MD, MSPH

Department of Otolaryngology, Washington University School of Medicine, St. Louis, MO

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.

Keywords

Unilateral hearing loss; adolescents; speech or language delay; cognition

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Corresponding author: Judith E. C. Lieu, MD, MSPH, 660 S. Euclid Ave., Campus Box 8115, St. Louis, MO 63110, Phone 314-747-8205, FAX 314-454-2174, lieu@wustl.edu.

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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 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 to 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 was 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 of the adolescents with UHL and their sibling controls with NH are found in Table 1. There were no statistically significant demographic

or clinical differences between those with and without UHL, except an increased prevalence of recurrent otitis media among adolescents with UHL. There were no differences between the two groups for risk factors for hearing loss. The proportion of adolescents with histories of delayed speech, receiving speech therapy, repeating grades in school, school-related behavior problems, diagnosis of ADD/ADHD, or IEP or 504C program did not differ significantly between groups.

The characteristics of adolescents with UHL are shown in Table 2. The majority of adolescents with UHL had profound hearing loss, with 20% known to have progressive hearing loss. There were no significant differences between those with right-sided and left-sided HL except average age of first spoken word—9.3 mo (SD 2.3) for right-sided UHL vs. 14 mo (SD 5.4) for left-sided UHL; p -value = 0.043). The average age of UHL identification was 4.8 years (SD 2.9) with the largest proportion being identified by an audiogram for ear infection followed by PCP screening and school screening. None were identified by newborn hearing screening; the participants had all been born prior to the implementation of newborn hearing screening programs in the region. Thus, the mean age of 4.8 years reflects identification during the preschool and early elementary school years, and congenital hearing loss at birth could not be confirmed. UHL was considered congenital if it were associated with temporal bone abnormalities found on computed tomography or MRI. The majority of adolescents had an unknown etiology of UHL with the second most common etiology being congenital. No participants had syndromic hearing loss. Five of the 20 adolescents with UHL (25%) had some trial of amplification including an FM system, traditional hearing aid, and contralateral routing of sound (CROS) aid. None of the participants wore hearing aids on a routine basis. Two adolescents were occasionally using hearing aids, but not during the testing.

Language and IQ outcomes are reported in Table 3. A statistically significant difference was observed in mean language score for adolescents with UHL compared to NH adolescents with an effect size of -1.1 . There was also a statistically significant difference between adolescents with UHL and NH for expressive language score with an effect size of -0.9 .

Similarly, cognition scores between adolescents with UHL and their NH siblings were significantly different. No subjects had a full IQ score <70 . Adolescents with UHL had a mean full IQ score of 98, while adolescents with NH had a mean full IQ score of 113. Full IQ score differed significantly between those with UHL and NH with an effect size of -0.9 . There were significant differences in verbal and performance IQ scores between adolescents with UHL and NH. UHL had an effect size of -0.8 on both verbal IQ score and performance IQ score.

Table 4 shows the bivariate effect of UHL and other possible confounding demographic and clinical variables on the speech-language and IQ scores for all subjects in the study. Adolescents with UHL had lower scores in all five categories: language, expressive language, Full scale IQ, Verbal IQ and Performance IQ. Race had a significant effect on Full scale IQ and Performance IQ but not on language score, expressive language score, or Verbal IQ. Type of health insurance had a significant effect on language score and expressive language score, but not any of the IQ scores. Family socioeconomic status was

available through family income and education level of the mother (or primary caregiver) and father (or secondary caregiver) for 22 of the 33 subjects. Family income had a significant impact on verbal IQ (Pearson $r = 0.550$, $p = 0.008$) and full IQ (Pearson $r = 0.526$, $p = 0.012$), with higher income being associated with an increase in score. Maternal education level, coded as the highest grade level completed, significantly affected Verbal IQ (Pearson $r = 0.562$, $p = 0.006$) and Full scale IQ (Pearson $r = 0.473$, $p = 0.026$), as well. Paternal education level also significantly affected language and expressive language scores, as well as full and verbal IQ (data not shown). Gender, severity of hearing loss, side of hearing loss, and premature birth did not significantly affect any of the speech-language scores or IQ. However, adolescents with a history of recurrent otitis media had significantly lower scores in all categories. Adolescents with a history of head trauma actually had higher scores in all categories.

Bivariate analysis was also used to determine possible risk factors for poor overall and expressive language scores and IQ within adolescents with UHL. However, no potential risk factors were identified (data not shown).

The multivariable linear regression models of the speech-language scores and IQ scores for the 33 adolescents aged 12-17 can be seen in Table 5. These models show that UHL has a consistent negative effect on speech-language scores, as well as IQ scores. Language and expressive language scores were also impacted by performance IQ and the type of health insurance. Full and performance IQ were also impacted by the type of health insurance. After adjustment for confounding variables, UHL was associated with a 10.4-point decrement in language score, 8.8-point decrement in expressive language score, 12.8-point decrement in full IQ, 11.8-point decrement in verbal IQ, and 11.3-point decrement in performance IQ. These differences translated into standardized effect sizes ranging from 0.7 to 0.8, which correlate with moderate-to-large effects. The multivariable linear regression models accounted for 11% to 46% of the variance in speech-language scores and IQ.

Within the longitudinal data there were only two time points at which speech-language and IQ scores were measured, therefore, sphericity of the subjects could not be calculated. A repeated measures ANOVA within-subject comparison determined that mean language score did not differ significantly between time points for all subjects ($F(1, 20) = 3.699$, $P = 0.069$). There was also no significant difference observed by a repeated measures ANOVA within-subject comparison in mean language score for adolescents with UHL or adolescents with NH ($F(1,20) = 2.328$, $P = 0.143$). There were no significant differences demonstrated between test times by a repeated measures ANOVA analysis of mean expressive language score, full IQ, verbal IQ, and performance IQ.

The results from the repeated measures ANOVA between-subjects analysis can be seen in Table 6. The repeated measures ANOVA between-subjects effects showed a statistically significant difference in mean language scores between adolescents with UHL and siblings with NH at both testing times ($F(1) = 8.805$, $P = 0.008$). Therefore, there is a main effect for UHL on mean language score. The between-subjects analysis was significant for expressive language score, Full scale IQ, and Performance IQ. No significant difference was observed between subjects with UHL and NH for verbal IQ. Therefore, there was a main effect for

UHL on mean expressive language score, full IQ, and performance IQ but no main effect for UHL on verbal IQ.

4. DISCUSSION

UHL is associated with a negative effect on standardized speech language scores and IQ in this study of adolescents aged 12-17 years old. Using cases and controls from within the same family helped to minimize variance from socioeconomic status and other environmental and genetic influences that may affect speech and language development. Although speech-language scores and IQ do not directly translate to school performance, the secondary measures of 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 demonstrated trends for increased incidence in adolescents with UHL, similar to what has been found in other studies of younger children with UHL [11, 12, 13].

This was the first study to look at speech-language development in adolescents (age 12-17 years) with UHL compared to their siblings with NH. This study demonstrated that the developmental gap between children with UHL and those with NH persists throughout adolescence and at worse may even widen, as the children grow older. UHL showed a consistent negative effect on overall and expressive language scores and IQ of adolescents. The effect size ranged from 0.7 to 0.8, demonstrating a negative moderate-to-large effect of UHL on these standardized scores. The effect size of UHL on children was shown to range from 0.3 to 0.7, or small-to-moderate effect sizes, in a study by Lieu, et al. [3]. This increase in effect size from childhood to adolescence indicates the gap in language scores between those with UHL and NH may be growing as children age. Socioeconomic status also impacted IQ level; higher scores were associated with higher socioeconomic status. No potential risk factors were identified for poor speech-language scores or low IQ within adolescents with UHL.

A similar negative effect of UHL on vocabulary scores was suggested in a study from Cozad [14]. Difficulty of communication was indirectly studied in a group of 18 children and young adults (age range 8-20 years) with severe to profound UHL compared to normal hearing peers by standardized tests of lip reading and vocabulary. The UHL group appeared to have lower vocabulary scores and higher lip reading scores than their NH peers, although the difference was not found to be statistically significant. These findings correlate with the negative effect of UHL on language scores and IQ demonstrated by our study.

The repeated measures ANOVA between-subject analysis demonstrated a significant difference between adolescents with UHL and NH in mean language score, expressive language score, full IQ, and performance IQ over time. From this we were able to conclude that UHL has a main effect on each of these standardized scores. No significant difference was demonstrated between adolescents with UHL and NH for verbal IQ and therefore, we could not conclude that UHL had a main effect on verbal IQ. This analysis supports our conclusion that there is a language developmental gap between adolescents with UHL and NH. The data also suggested that speech-language scores and IQ levels were improving

significantly more in adolescents with UHL versus adolescents with NH. However, adolescents with UHL are still scoring at significantly lower levels and are not catching up to their NH siblings.

The difference in performance IQ between children with UHL and their NH siblings has not been observed in previous studies. Two possible explanations may account for this finding. The first possible explanation is that UHL might affect general cognitive ability. Studies utilizing different methods of brain imaging have noted that volumes of gray matter, white matter tracts, and functional connections are different in children with UHL compared to those with NH [15-18]. These differences within the brain may ultimately explain the gap in performance IQ, but have not been definitively linked to cognitive ability as yet. The second is that it may be a spurious result due to the small sample size (i.e., a type I or false positive error). Further studies comparing adolescents with UHL to those with NH will be required to ferret out the true explanation.

There were a few limitations to our study. The relatively small sample size of 20 cases and 13 controls may have limited the ability to demonstrate differences with smaller effect sizes. Therefore, caution was taken when interpreting results due to small sample size. The different measurements of speech-language development may have introduced bias into the study. However, there was not a statistically significant difference between the scores of the two measures, and both instruments are standardized for age and normed to have a mean of 100 with a standard deviation of 15, therefore, it is unlikely that this would have introduced bias.

Another limitation of our study is that adolescents were evaluated using the standardized OWLS and CELF questionnaires and WASI IQ scores, which are not an entirely comprehensive assessment of the adolescent's potential. More thorough assessments, using entrance scores, interviews, portfolios, resumes, essays, etc. may evaluate a wider range of skills (or lack thereof) than these standardized tests were able to show. Nevertheless, the difference in standardized test scores has been able to identify potential problems in adolescents with UHL for the first time. Further study will be required to both confirm these findings and extend the understanding of why they occur.

The results of this study strongly encourage implementation of early intervention for children with UHL to prevent speech-language delays. This study demonstrated that children with UHL are not able to adjust to the hearing loss and catch up in speech-language development to their normal hearing siblings by adolescence. More studies of adolescents are necessary to analyze educational outcomes.

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Table 1

Demographic and baseline characteristics of 33 participants, including 20 adolescents with unilateral hearing loss (UHL) and 13 adolescents with normal hearing (NH).

Characteristic	UHL n (%)	NH n (%)	Total n (%)	P-value
Age (yr), mean (SD)	14.0 (1.2)	14.9 (1.8)	14.3 (1.5)	0.118
Male gender	10 (50)	8 (62)	18 (54.5)	0.722
Race				0.479
Black	5 (25)	3 (23)	8 (24.2)	
White	13 (65)	10 (77)	23 (69.7)	
Other	2 (10)	0 (0)	2 (6.1)	
Health insurance				0.509
Medicaid	5 (25)	2 (15.4)	7 (21.2)	
Private	15 (75)	11 (84.6)	26 (78.8)	
Adopted	3 (15)	0 (0)	3 (9.1)	0.261
Firstborn	8 (40)	6 (46)	14 (42.4)	1.00
Premature	5 (25)	4 (31)	9 (27.3)	1.00
Birth weight (g), mean (SD)	3282.6 (686.0) [n=19]	3310.3 (708.9) [n=32]	3293.8 (684.1) [n=32]	0.913
History of head trauma	1 (5) [n=19]	2 (15)	3 (9.4) [n=32]	0.54
Asthma	2 (10)	1 (8)	3 (9.1)	0.261
Recurrent otitis media	7 (35)	0 (0)	7 (21.2)	0.027
Received tympanostomy tubes	10 (50)	4 (31)	14 (42.4)	0.31
Someone smokes at home	5 (25)	5 (38)	10 (30.3)	0.461
Speech or language evaluation	9 (45)	2 (15)	11 (33.3)	0.132
Delayed speech	5 (25)	0 (0)	5 (15.2)	0.131
Repeated grade	5 (25)	1 (8)	6 (18.2)	0.364
Receives tutoring	4 (20)	0 (0)	4 (12.1)	0.136
Age of first spoken word mo., mean (SD)	11.29 (4.46) [n=14]	9.67 (1.75) [n=6]	10.80 (3.84) [n=20]	0.406
Age of first spoken two-words mo., mean (SD)	19.44 (5.55) [n=9]	16.17 (4.49) [n=6]	18.13 (5.25) [n=15]	0.25
Received speech therapy	7 (35)	1 (8)	8 (24.2)	0.108
IEP/504C plan	6 (30)	0 (0)	6 (18.2)	0.06
Special education class	1 (5)	0 (0)	1 (3.0)	1.00
School-related behavioral problems	11 (55)	3 (23)	14 (42.4)	0.087
ADHD or ADD diagnosis	5 (25)	1 (8)	6 (18.2)	0.364

Table 2

Demographic and baseline characteristics of 20 adolescents with unilateral hearing loss (UHL), 9 with right UHL and 11 with left UHL.

	Right- UHL, n (%)	Left UHL, n (%)	Total, n (%)	P-value
Age (yr) of hearing loss, mean (SD)	5.3 (2.4)	4.4 (3.3)	4.8 (2.9)	0.484
Severity of hearing loss				0.720
Severe	2 (25)	2 (18)	4 (21)	
Profound	6 (75)	9 (82)	15 (79)	
Hearing loss was progressive				0.389
Yes	5 (56)	8 (73)	4 (20)	
No	3 (33)	1 (9)	13 (65)	
Not sure	1 (11)	2 (18)	3 (15)	
Identification of hearing loss				0.163
School screening	2 (22)	1 (9)	3 (15)	
PCP screening	1 (11)	2 (18)	3 (15)	
Parental suspicion	4 (44)	1 (9)	8 (40)	
Audiogram for ear infection	2 (22)	3 (27)	5 (27)	
Other	0 (0)	4 (36)	4 (20)	
Etiology of hearing loss				0.478
Otitis media	1 (11)	1 (9)	2 (10)	
Trauma	0 (0)	1 (9)	1 (5)	
Meningitis	0 (0)	2 (18)	1 (5)	
Congenital	2 (22)	4 (36)	7 (35)	
Unknown	6 (67)	3 (27)	9 (45)	
Other	0 (0)	1 (9)	1 (5)	
Trial of amplification				0.690
FM system	2 (22)	1 (9)	3 (15)	
Hearing aid	1 (11)	1 (9)	2 (10)	
CROS aid	1 (11)	0 (0)	1 (5)	

Table 3

Outcome measures of 33 participants, including 20 adolescents with unilateral hearing loss (UHL) and 13 adolescents with normal hearing (NH).

Outcome	UHL mean (SD)	NH mean (SD)	P-value	Mean difference (95% CI)
Language score	98 (16.5)	114 (9.8)	0.001	16 (7.3-26.0)
Expressive language score	100 (15.9)	114 (10.3)	0.006	14 (4.7-25.0)
Full scale IQ	98 (15.1)	112 (15.0)	0.017	14 (2.6-24.4)
Verbal IQ	101 (16.1)	113 (12.5)	0.032	12 (1.1-22.5)
Performance IQ	95 (15.5)	107 (15.9)	0.037	12 (0.8-23.5)
CELF sum	96 (18.1) [n=13]	111 (8.0) [n=7]	0.019	15 (2.9-27.6)
CELF EL	97 (15.4) [n=13]	110 (8.4) [n=7]	0.056	13 (-0.4-26.2)
OWLS OC	101 (13.7) [n=7]	118 (11.1) [n=6]	0.032	17 (1.7-32.6)
OWLS OE	104 (16.9) [n=7]	120 (10.4) [n=6]	0.082	16 (-2.3-32.8)

EL indicates expressive language; CELF, clinical evaluation of language fundamentals; OWLS, oral and written language scales; OC, oral composite; OE, oral expressive

Table 4

Bivariate analysis of UHL and other confounding variables on outcome measures.

	Language score	EL score	Full IQ	Verbal IQ	Performance IQ
UHL	**	**	*	*	*
No (n = 13)	114 (9.8)	114 (10.3)	111 (15.0)	113 (12.4)	107 (15.9)
Yes (n = 20)	98 (16.5)	100 (15.9)	98 (15.1)	101 (16.0)	95 (15.5)
Race			*		**
White (n = 23)	108 (15.3)	109 (14.1)	107 (15.5)	108 (16.1)	104 (14.2)
Black (n = 8)	95 (17.8)	96 (18.6)	89 (12.7)	96 (13.1)	84 (15.5)
Other (n = 2)	104 (11.3)	105 (5.0)	112 (5.0)	113 (2.1)	109 (10.6)
Gender					
Male (n = 18)	105 (16.4)	104 (16.5)	105 (17.0)	108 (15.7)	102 (18.5)
Female (n = 15)	104 (16.7)	107 (15.0)	100 (15.4)	103 (15.9)	97 (14.0)
Health Insurance	*				
Medicaid (n = 7)	93 (15.3)	96 (13.0)	96 (23.1)	101 (16.7)	91 (28.2)
Private (n = 26)	107 (15.6)	108 (15.6)	105 (13.8)	107 (15.5)	102 (11.6)
HL severity					
Severe (n = 4)	94 (15.7)	93 (13.3)	99 (7.3)	102 (10.0)	96 (10.7)
Profound (n = 15)	100 (16.1)	103 (15.5)	99 (15.9)	101 (18.0)	97 (13.0)
Side of HL					
Right (n = 9)	99 (17.9)	101 (19.0)	98 (14.2)	101 (13.2)	95 (19.6)
Left (n = 11)	96 (16.0)	99 (13.8)	98 (16.4)	101 (18.7)	95 (12.1)
History of recurrent otitis media	*	*	*		*
No (n = 26)	108 (15.3)	108 (15.3)	106 (15.3)	108 (15.4)	103 (14.8)
Yes (n = 7)	92 (14.7)	95 (12.7)	92 (15.4)	96 (13.2)	89 (19.4)
History of head trauma		*	*	*	*
No (n = 29)	102 (15.8)	103 (14.7)	101 (15.1)	103 (14.6)	97 (15.6)
Yes (n = 4)	119 (5.0)	122 (5.2)	123 (16.8)	124 (19.0)	99 (16.7)
Premature birth					
No (n = 24)	105 (17.2)	105 (16.4)	105 (17.0)	107 (15.9)	101 (18.3)
Yes (n = 9)	103 (14.6)	106 (14.4)	99 (13.7)	101 (14.9)	97 (10.9)

*
 $p < 0.05$;**
 $p < 0.01$

Table 5

Multivariable linear regression Models on Speech-Language scores and IQ in a sample of 33 adolescents aged 12-17

Outcome	Parameter estimate	SE	T	P	Adjusted R ²
Language score					0.46
Intercept	52.1	16.2	3.2	0.003	
Performance IQ	0.45	0.14	3.2	0.003	
UHL	-10.4	4.5	-2.3	0.030	
Health insurance	7.6	5.3	1.4	0.159	
Expressive language					0.42
Intercept	55.6	16.1	3.4	0.002	
Performance IQ	0.46	0.14	3.2	0.003	
UHL	-8.8	4.6	-1.9	0.064	
Health insurance	5.5	5.3	1.0	0.304	
Full IQ					0.15
Intercept	97.3	12.5	7.8	<0.001	
UHL	-12.8	5.4	-2.4	0.024	
Health insurance	7.6	6.4	1.2	0.246	
Verbal IQ					0.11
Intercept	112.7	4.1	27.5	<0.001	
UHL	-11.8	5.3	-2.2	0.032	
Performance IQ					0.13
Intercept	90.1	12.9	7.0	<0.001	
UHL	-11.3	5.5	-2.0	0.050	
Health Insurance	9.1	6.6	1.4	0.178	

Table 6

Repeated measures ANOVA tests of between UHL and NH subject effects

ANOVA	UHL time 1, mean (SD)	UHL time 2, mean (SD)	UHL mean difference	NH time 1, mean (SD)	NH time 2, mean (SD)	NH mean difference	P-value
Language score	94 (17)	101 (16)	7	117 (14)	118 (10)	1	0.008
Expressive language score	99 (21)	102 (17)	3	120 (14)	119 (10)	-1	0.015
Full IQ	100 (17)	101 (14)	1	114 (12)	114 (14)	0	0.045
Verbal IQ	102 (19)	103 (16)	1	115 (15)	115 (15)	0	0.096
Performance IQ	99 (13)	99 (11)	0	111 (11)	109 (11)	-2	0.038