Published in final edited form as:

Laryngoscope. 2016 March ; 126(3): 746–754. doi:10.1002/lary.25524.

Children with unilateral hearing loss may have lower intelligence quotient scores: A meta-analysis

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Abstract

Objective—In this meta-analysis, we reviewed observational studies investigating differences in intelligence quotient (IQ) scores of children with unilateral hearing loss compared to children with normal hearing.

Data sources—PubMed Medline, Cumulative Index to Nursing and Allied Health Literature, Embase, PsycINFO

Review methods—A query identified all English-language studies related to pediatric unilateral hearing loss published between January 1980 and December 2014. Titles, abstracts and articles were reviewed to identify observational studies reporting IQ scores.

Results—There were 261 unique titles with 29 articles undergoing full review. Four articles were identified, which included 173 children with unilateral hearing loss and 202 children with normal hearing. Ages ranged from 6 to 18 years. Three studies were conducted in the United States, and one in Mexico. All were of high quality. All studies reported full-scale IQ results; 3 reported verbal IQ results, and 2 reported performance IQ results. Children with unilateral hearing loss scored 6.3 points lower on full-scale IQ, 95% CI [−9.1, −3.5], p-value <0.001; and 3.8 points lower on performance IQ, 95% CI [−7.3, −0.2], p-value 0.04. When investigating verbal IQ, we detected substantial heterogeneity among studies; exclusion of the outlying study resulted in significant difference in verbal IQ of 4 points, 95% CI [−7.5, −0.4], p-value 0.028.

Conclusions—This meta-analysis suggests children with unilateral hearing loss have lower full-scale and performance IQ scores than children with normal hearing. There also may be disparity in verbal IQ scores. Future studies should investigate ways to reduce potential differences in intellectual achievement.

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Financial Disclosures

Conflicts of Interest: None

This study was presented at the podium for The Triological Society Combined Sections Meeting, San Diego, CA, January 22–24, 2015.

Keywords

Unilateral hearing loss; pediatric otolaryngology; intelligence test; educational achievement

Introduction

Unilateral hearing loss (UHL) is estimated to affect between 1 – 5% of school-aged children and adolescents, and prevalence may be increasing over time^{1,2}. There has been persistent uncertainty regarding the impact of UHL on educational achievement. In the 1980s, Bess & Tharpe found that children with UHL had surprisingly high rates of grade failure when compared to normal hearing peers^{3,4}. More recently, Lieu et al. found that children with UHL have worse speech and language outcomes when compared to normal hearing peers⁵. However, other studies have found that children with UHL do not significantly differ from normal hearing peers in terms of intelligence or educational achievement^{6,7}.

Perhaps because of uncertainty over the impact of UHL, debate remains regarding best practices for management of children with UHL, and providers lack evidence-based recommendations for intervention^{8,9}. The purpose of this meta-analysis was to review the existing evidence regarding whether or not there is a difference in intelligence quotient (IQ) scores between children with UHL and children with normal hearing.

Methods

Literature search strategy

Electronic database searches were conducted of PubMed Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase and PsycINFO. The search identified English-language studies of pediatric UHL published between January 1980 and December 2014. The Medline query employed both the phrase “unilateral hearing loss” and Medical Subject Headings (MeSH) term “hearing loss, unilateral.” The following age-related filters were used: “Adolescent: 13–18 years,” “Child: 6–12 years,” and “Preschool Child: 2–5 years”. Both PsycINFO and CINAHL databases were queried using the search phrase “unilateral hearing loss” and age-related filters. The Embase query consisted of the following phrase: *'unilateral hearing loss'/exp AND ([preschool]/lim OR [school]/lim OR [adolescent]/lim) AND [english]/lim*. In addition to electronic database queries, citations of relevant articles were reviewed to identify additional studies of interest.

Data collection

Two authors (P.L.P. and J.R.S.) reviewed titles and abstracts of interest, and each independently evaluated the full text of articles deemed relevant for review. Each article was coded to document characteristics of the study and data regarding outcome measures.

Criteria for study selection

Types of studies—The review included peer-reviewed, observational studies that contained an appropriate comparison group, including cohort, case-control, and cross-sectional studies.

Types of participants—The review included studies evaluating children and adolescents ages 2 to 18 years old with permanent, or longstanding, UHL with comparisons to normal hearing children of similar age. Articles investigating hearing loss and educational outcomes in children with syndromes or craniofacial disorders were reviewed, but excluded from the final meta-analysis.

Types of outcome measures—The final analysis included only those studies that established full-scale, verbal or performance IQ as a primary or secondary outcome measure.

Quality measurement

Studies that met the above criteria for inclusion were reviewed and given quality ratings. The studies had to be rated as “high” or “intermediate” quality by methodological quality scoring system to be included in the meta-analysis.

Scores were assigned using quality evaluation guidelines for observational studies reported by Mozurkewich et al¹⁰. The following 7 methodological parameters were evaluated within each study. Each parameter was assigned a score of 0, 1, or 2 for a potential maximum study score of 14:

- i. Clearly defined method of selection of cases and controls
- ii. Precise definition of exposure and comparison groups
- iii. Data collection method that is unlikely to generate bias
- iv. Considerations to prevent recall bias
- v. Exclusions clearly explained, and unlikely to contribute to bias
- vi. Balanced characteristics between exposed and unexposed groups
- vii. Equivalent clinical susceptibility, outcome of interest measured equally across groups

Studies scoring greater than 9 were classified as “High Quality;” studies scoring between 5–9 were classified as “Intermediate Quality,” and studies scoring 4 or lower were classified as “Poor Quality.”

Statistical analysis

IQ test results did not require additional standardization as these assessments are centered at a score of 100 with a standard deviation of 15. Studies were weighted by sample size and variance. Pooled effect size measurements of mean difference in IQ scores were determined and reported with 95% confidence intervals.

We conducted a meta-analysis for each IQ-score type separately and used fixed-effects models initially. The fixed-effects model assumes that individual studies have all been carried out under similar conditions. To evaluate the validity of this assumption, we calculated an I^2 statistic to quantify the degree of heterogeneity among studies. If the I^2 statistic was large and significant, then it was considered inappropriate to use the fixed-

effects model due to excess heterogeneity among studies. In this case, weights were calculated using random-effects model, which takes into consideration variance between studies. In the event of substantial heterogeneity¹¹, a sensitivity analysis was performed to investigate impact of outlying studies. In the event that only two studies were available for meta-analysis, a fixed-effects model was utilized due to inability to calculate between-study variance with such a small number of studies.

For all analyses, statistical significance was set at p-value <0.05. Analyses were performed using STATA version 13.1 (STATA, Inc, College Station, Tx).

Results

Initial queries identified 261 unique titles. Twenty-nine articles underwent full review. There were two studies that evaluated educational outcomes, but not IQ score, in children with aural atresia^{12,13}. Initially 7 observational studies were identified for inclusion in the meta-analysis; however, 4 of these studies occurred as part of the “Unilateral Hearing Loss in Children” study at Washington University in St. Louis. It was confirmed through contact with the research team and review of the articles that there was overlap of subjects among these 4 studies. Only the largest of these studies was included in the analysis in order to avoid redundancy. Figure 1 is a flow diagram of study selection.

Table 1 contains the characteristics of the 4 observational studies included in the meta-analysis^{14–17}. The studies included 173 children with UHL and 202 children with NH. All 4 articles reported full-scale IQ scores; 3 reported verbal IQ scores, and 2 reported performance IQ results. Based on ratings from both reviewers, all four studies were “High Quality” on methodological quality scores.

Three studies had a similar cross-sectional design, relying on matched controls recruited from either outpatient clinic or normal hearing siblings. The fourth study, based in Mexico, was performed within a larger cohort of children who had been identified as high-risk for neurological injury at birth based on risk factors such as prematurity, low birth weight, mechanical ventilation after birth and other adverse conditions. All of the studies excluded children from analysis if they had evidence of significant comorbid condition or major developmental delay at time of testing.

Ages of children at time of IQ testing ranged from 6 to 18 years. Only the 2013 Lieu study¹⁵ reported average age at diagnosis of UHL: 4.6 years. Only 8 percent of children within that study were diagnosed based on newborn hearing screening. The other three studies did not report newborn hearing screening results.

Full-scale IQ

Meta-analysis of full-scale IQ scores using a fixed-effects model detected a significant pooled mean difference in IQ scores, p-value <0.001. Children UHL were estimated to have a mean full-scale IQ that was 6.3 points lower than that of children with NH, 95% CI [−9.1, −3.5]. A moderate amount of heterogeneity among studies was detected, $I^2 = 38.9\%$;

however, it was not significant, p-value 0.18. Therefore, it was deemed appropriate to report results using fixed-effects model, see Figure 2.

Verbal IQ Scores

Meta-analysis of verbal IQ scores using a fixed-effects model found a significant pooled mean difference in verbal IQ score, p-value <0.001. Children with UHL were estimated to have a mean verbal IQ that was 6.6 points lower than normal-hearing children, 95% CI [-9.9, -3.3]; however, substantial heterogeneity was detected, $I^2 = 86.2\%$, p-value <0.001. Based on degree of heterogeneity, results were calculated using weights assigned by random-effects model, see Figure 3. Random-effects model did not report a significant difference in verbal IQ, p-value 0.066; however, the calculated mean difference increased: Compared to normal-hearing peers, children with UHL scored 9.1 points lower on verbal IQ, 95% CI [-18.7, 0.6].

The substantial heterogeneity of the studies appeared to be due to the results of the Martinez-Cruz study¹⁶, which relied upon results from within a high-risk cohort, a different strategy than the other three studies. Therefore, to evaluate the effects of the outlying study on final results, a sensitivity analysis was performed to exclude the contribution of the Martinez-Cruz study¹⁶. With exclusion of this study, the pooled mean difference in verbal IQ score between children with UHL and children with NH became significant, p-value 0.028; however, the effect size was reduced, so that children with UHL were estimated to have a mean verbal IQ 4 points lower than that of normal hearing children, 95% CI [-7.5, -0.4], see Figure 4.

Performance IQ

Because only two studies reported performance IQ results, meta-analysis of performance IQ scores was carried out using fixed-effects model. It detected a significant pooled mean difference in IQ scores, p-value 0.037. Children with UHL were estimated to have a mean performance IQ that was 3.8 points lower than that of normal hearing children, 95% CI [-7.3, -0.2], see Figure 5.

Potential confounding conditions

Observational studies are subject to the limitations of confounding to a greater extent than randomized trials. All of the studies included in the meta-analysis made some effort to document characteristics of children with UHL and controls with NH, see Table 2. Despite efforts to match characteristics between the groups, some important differences were noted. In the study by Lieu et al.¹⁵, 15.6% of children with UHL had a history of head trauma, compared to 3.2% in the sibling matched controls, p-value 0.008. Parents also reported a history of meningitis in 3% of children with UHL, although this was not assessed in sibling controls.

A number of significant differences between children with UHL and bilateral normal hearing were noted in study by Martinez-Cruz et al.¹⁶ The authors reported the following differences: NICU stays were longer for children with UHL at 26 days, compared with 8 days for children with NH, p-value <0.001. Hospital stays were longer for children with

UHL at 47 days, compared with 25 days for children with NH, p-value 0.004. The 1 minute and 5 minute APGAR scores were lower for children with UHL, p-value 0.01. Indirect bilirubin levels were higher for children with UHL, p-value 0.004. Children with UHL were more likely to have suffered from hypoglycemia, p-value 0.04, and bronchopulmonary dysplasia, p-value 0.002.

Discussion

Accurately measuring educational achievement can be challenging. IQ scores are reported in a standardized method, making it easier to compare results across studies. This meta-analysis suggests that children with UHL have significantly lower full-scale and performance IQ scores than normal-hearing peers. Results for verbal IQ were not quite as conclusive; however, after removal of the outlying study, we calculated a significant difference. Such results are important because, in many cases, the individual studies had failed to detect a significant difference. For example, both studies that reported performance IQ^{15,17} did not find a significant difference in score between children with UHL and children with NH; however, when pooled, a significant difference was noted. Overall, we found that children with UHL have a mean full-scale IQ that is more than 6 points lower than children with normal hearing. In terms of clinical relevance, this difference in IQ points is not quite half a standard deviation lower on the IQ scale.

There was not significant heterogeneity in reporting of full-scale and performance IQ results. However, we found substantial heterogeneity when evaluating verbal IQ scores. With exclusion of the source of the heterogeneity – the Martinez-Cruz study¹⁶, which relied upon a high-risk medical cohort – we found a significant difference in verbal IQ score between children with UHL and children with NH.

Previous studies have used a diverse array of tests to characterize the impact of UHL among children and adolescents. For example, Ead et al. used a battery of tests to find that children with UHL have reduced accuracy and efficiency of phonological processing, along with difficulty maintaining verbal information in the face of auditory distractions¹⁸. Tibbetts et al. utilized functional magnetic resonance imaging to better understand the impact of UHL on neural connectivity in auditory processing and executive function, finding differences in brain network interconnections between children with UHL and normal hearing controls¹⁹. There have also been attempts to investigate whether these abnormal networks differ based upon if a child has a right- or a left-sided hearing loss²⁰. Investigations have evaluated the functional impact of UHL on sound localization and speech discrimination and have determined that unilateral impairment is a significant handicap²¹. For example, children with UHL require significantly higher signal-to-noise ratios than normal hearing children under all listening conditions, including when a signal is delivered directly to their unimpaired ear²².

To evaluate quality of life among children with UHL, Borton et al conducted focus groups of children with UHL and their parents²³. Group discussions revealed that children with UHL perceived barriers in educational and social settings; however, many children displayed resilience in adapting to their impairment. Studies have also used the Screening

Instrument for Targeting Education Risk (SIFTER) to determine how well teachers rate performance of children with UHL when compared to normal-hearing peers. Not only did these studies find that children with UHL receive significantly lower SIFTER scores than their peers²⁴, but somewhat surprisingly, there was a negative association between degree of hearing impairment and teachers' ratings of student performance²⁵. Children with more severe bilateral hearing loss were rated as scoring better academically, participating more fully in class, communicating more effectively and demonstrating better behavior than children with minimal or UHL. The authors posited that this positive correlation between hearing threshold and SIFTER score could be due to the fact that children who are more severely affected have greater access to support services. Somewhat similarly, a large case series from Omaha, NE of 324 children and adolescents with UHL found 31 percent of the children to have scholastic or behavioral problems in school²⁶. Evidence suggests that educational disparities continue into adolescence²⁷. In summary, it appears that children with UHL face a range of difficulties in educational environments, and these challenges may be underappreciated.

Unfortunately, management of UHL remains a challenge. Variability in management is perhaps based upon the lack of definitive evidence that children with UHL differ from children with NH. Based upon the findings of this meta-analysis, IQ scores may be a relevant outcome to follow in the future. There is also a need for future studies to investigate how well various methods of hearing amplification, such as conventional hearing aids or contralateral routing of signal (CROS) devices, improve detection and localization of signal. Determining benefit can be difficult, as studies have found subjective reports of benefit with conventional hearing aids despite no change in speech perception scores²⁸. Questions regarding optimal management of UHL continue to gain importance as interest grows in surgical options such as bone conduction hearing devices and even cochlear implants^{29,30}.

The age at which an intervention is applied may also affect outcome. For example, Johnstone et al. found that children who received hearing amplification earlier in life were more likely to show bilateral benefit with sound localization; however, children who were fit with hearing aids later in childhood or adolescence were more likely to experience bilateral interference with localization with hearing aids in place³¹. Such results reinforce the notion that critical brain development occurs early in life; therefore, if a child with UHL does not receive early intervention during the appropriate time window, the child may be less successful with future attempts at management. Studies suggest that universal newborn hearing screening has reduced the average age at diagnosis of UHL³², which may improve efforts to provide early intervention³³. Although in the 2013 study by Lieu et al.¹⁵, only 8 percent of the 107 children with UHL had been diagnosed through newborn hearing screening, perhaps indicating a need to further optimize newborn screening for children with UHL.

Apart from amplification, there is evidence that educational support services benefit school-aged children with UHL. In a separate longitudinal study, Lieu et al found improvement in language scores when schools provided children with UHL individualized education plans over a 3-year period³⁴. Preferential seating at the front of the class is another option for educational support. It has been found that individuals with UHL must sit approximately

half the distance away from a speaker as an individual with NH to have similar speech discrimination³⁵.

While this meta-analysis suggests that children with UHL have lower IQ scores, it is important to consider the limitations of the study. First, only four observational studies were identified for inclusion in the meta-analysis. It is possible that publication bias could play a role by limiting the publication of studies that did not find a significant difference in results.

Heterogeneity among studies was detected when investigating verbal IQ. The Martinez-Cruz study¹⁶ differed from the others in terms of its results, detecting a greater degree of difference between IQ scores of children with UHL and children with normal hearing. The study was conducted in Mexico, while the other three studies were performed in the United States. It is possible that differences in available resources to support children with hearing loss might be contributing to some of the variation that was identified. With the Martinez-Cruz study¹⁶ excluded, the meta-analysis calculated a significant difference in verbal IQ score.

In addition, this meta-analysis did not include studies that primarily evaluated educational outcomes in children with craniofacial disorders such as aural atresia. Two studies were identified that investigated children with atresia. The results of the studies were mixed: One found that children with atresia seemed to perform better academically than children with unilateral SNHL¹², while the other found similar risks of speech and learning difficulties as children with unilateral SNHL¹³. Additional research is needed to evaluate educational impact of UHL associated with craniofacial disorders.

It is possible that duration of UHL may also affect educational achievement. Only the 2013 Lieu study¹⁵ reported on the method of UHL detection and average age at diagnosis. Interestingly, only 8 percent of children with UHL in that study were detected by newborn hearing screening, so it is possible that some of the children could have developed progressive hearing loss in a more delayed fashion. All of the studies included in the meta-analysis attempted to limit enrollment to long-standing UHL. Schmithorst et al.¹⁴ were unable to determine time of diagnosis for 4 of the children included in their study, although all of the children with UHL were confirmed to have SNHL.

In addition, IQ testing is only one method for measuring educational development. There are a number of other methods for assessing speech and language skills and cognitive growth. Some other possibilities include age at first word or two-word sentence, presence or absence of special education requirements, and specific speech and language standardized testing. We attempted to analyze these other markers of educational development, but did not find enough consistency between studies to perform additional meta-analyses. Future studies could investigate these other measures to better quantify the developmental burden associated with UHL.

Finally, because it relies upon observational studies, this meta-analysis cannot confirm causation. It is quite possible that children with UHL are at risk for comorbid conditions, such as birth complications or syndromes, which may also contribute to difficulties with educational development. Important differences in the frequency of comorbid conditions

were noted between the groups in two of the studies included in the meta-analysis. In the 2013 Lieu study¹⁵, children with UHL were more likely to have a history of head trauma, which could have an effect on IQ score. The Martinez-Cruz study¹⁶ reported a number of differences, ranging from length of NICU stay to indirect bilirubin levels, all of which could indicate underlying medical issues.

It is not possible to control for all confounders in observational studies, and there is no way to conduct a randomized trial to investigate the association between UHL and IQ score. Based upon our methodological criteria, all studies received a high quality rating in part because they endeavored to match children with UHL with controls based on a wide range of factors. However, limitations remain. For example, the Schmithorst study¹⁴ did not describe any attempt to match on socioeconomic status, which is an important consideration when evaluating educational achievement. Additional variables could affect a child's IQ score by shaping access to educational support services; these variables include family education level, socioeconomic status, and early identification of hearing loss. It is difficult to assess this information in the current meta-analysis as there is inconsistent reporting of this data across the studies. In addition, the study by Klee et al.¹⁷ was published prior to wide implementation of newborn and early hearing screening, which may impact timely implementation of services.

However, even if it is not UHL alone, but rather a combination of UHL, comorbid conditions, and demographic factors that lead to lower IQ scores, it seems quite possible that children with UHL stand to benefit from improved management of their impairment. For this reason, future studies should investigate potential ways to reduce disparities in educational achievement.

Conclusions

Available evidence suggests there are significant differences in full-scale and performance IQ scores between children with UHL and those with NH. Results for verbal IQ are not quite as conclusive; however, after accounting for heterogeneity, a significant difference was detected. Future studies should investigate whether early intervention, hearing amplification and other support services can reduce the disparity in IQ scores between children with UHL and children with NH.

Acknowledgments

The authors would like to acknowledge Fred Wolf, PhD, of Medical Education and Biomedical Informatics at the University of Washington, for his contribution to the conception, design and initial review of this investigation. They would also like to acknowledge Joshua Purcell who created the figures. This study was supported by Grant# 2T32DC000018, Institutional National Research Service Award for Research Training in Otolaryngology from the National Institute on Deafness and Other Communication Disorders.

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Figure 1.
Flow diagram of study selection

Figure 2.

Meta-analysis of full-scale IQ scores. There was no significant heterogeneity among studies, $I^2 = 38.9\%$, p -value 0.18, so a fixed-effects model was used. Children with unilateral hearing impairment are estimated to have mean full-scale IQ that is 6.3 points lower than that of normal hearing children, 95% CI [-9.1, -3.5].

WMD = weighted mean difference

Figure 3.

Meta-analysis of verbal IQ scores. There was substantial heterogeneity among studies, $I^2 = 86.2\%$, p -value 0.001, so a random-effects model was used. Children with unilateral hearing loss are estimated to have mean verbal IQ that is 9.1 points lower than that of children with normal hearing, 95% CI [-18.7, 0.6].

WMD = weighted mean difference

Figure 4.

Sensitivity analysis of verbal IQ scores. With exclusion of outlying study, the pooled mean difference in verbal IQ score became significant, p -value 0.028; however, the effect size was reduced, so that children with UHL were estimated to have a mean verbal IQ 4 points lower than that of normal hearing children, 95% CI [-7.5, -0.4].

Figure 5.

Meta-analysis of performance IQ. Because there were only two studies, a fixed-effects model was used. Children with unilateral hearing impairment are estimated to have a mean performance IQ that is 3.8 points lower than that of normal hearing children, 95% CI[-7.3, -0.2], p-value 0.04.

WMD = weighted mean difference

Table 1

Characteristics of studies included in meta-analysis

Author & Year	Study location	Outcome measured	No. of children with UHL/ Average age at testing (SD)	No. of controls with NH/ Average age at testing (SD)	Source of control group	Type of IQ score reported	Average quality score with categorical rating
Schmithorst, 2014 ¹⁴	Cincinnati, OH	Weschler Intelligence Scale for Children IV	N = 21/9.2 years (1.48)	N = 23/9.7 years (1.73)	Matched from clinic population	Full-scale only	10.5/High
Lieu, 2013 ¹⁵	St. Louis, MO	Weschler Abbreviated Scale of Intelligence	N = 107/8.62 years (1.87)	N = 94/9.25 years (2.4)	Matched siblings	Full-scale, verbal, & performance	13/High
Martinez-Cruz, 2009 ¹⁶	Mexico	Stanford-Binet IQ test	N = 21/7 years (0.6)	N = 60/6.9 years (0.7)	Identified within pediatric cohort 'at-risk' for neurological injury	Full-scale, verbal	10/High
Klee, 1986 ¹⁷	Nashville, TN	Weschler Intelligence Scale for Children	N = 24/9.6 years ^a (2.14)	N = 25/9.5 years (2.23)	Matched from clinic population	Full-scale, verbal, & performance	12/High

^a average age includes one child who did not complete IQ testing

UHL = unilateral hearing loss

NH = normal hearing

IQ = intelligence quotient

Table 2

Comparison of enrollment criteria, demographic characteristics, and comorbidities

Author & Year	Inclusion criteria	Exclusion criteria:	Demographic characteristics considered:	Comorbid conditions reported:	Characteristics that are significantly different between children with UHL and controls with NH
Schmithorst, 2014 ¹⁴	<ul style="list-style-type: none"> - Age 7–12 - UHL for 2 years or greater^a - UHL defined as SNHL >40 dB HL in impaired ear 	<ul style="list-style-type: none"> - Mixed or conductive hearing loss - History of head trauma - History of ADHD/developmental disorder/autism - Otologic disease and/or surgery (except ear tubes) - History of infections (CMV, meningitis) 	<ul style="list-style-type: none"> - Gender - Age 	None	No significant differences reported in characteristics that were considered
Lieu, 2013 ¹⁵	<ul style="list-style-type: none"> - Age 6–12 - “Permanent” hearing loss - UHL defined as 30 dB HL in impaired ear 	<ul style="list-style-type: none"> - Temporary or fluctuating conductive hearing loss - Medical diagnosis associated with cognitive impairment - Cognitive impairment per parent report 	<ul style="list-style-type: none"> - Gender - Age - Adoption status - First-born status - Prematurity - Birth weight - Birth complication 	<ul style="list-style-type: none"> - Head trauma - Asthma - Recurrent otitis media - ADHD - Need for corrective lenses 	Head trauma
Martinez-Cruz, 2009 ¹⁶	<ul style="list-style-type: none"> - Age 6 - History of Neonatal ICU stay - Unilateral SNHL defined as 	<ul style="list-style-type: none"> - Syndromic and non-syndromic inherited SNHL - Maternal infection during first trimester 	<ul style="list-style-type: none"> - Gender - Age - Birth weight - Apgar score - Length of NICU and hospital stay 	<ul style="list-style-type: none"> - Hyperbilirubinemia - Asphyxia - Sepsis - Meningitis - Hypoglycemia 	<ul style="list-style-type: none"> - Hyperbilirubinemia - Hypoglycemia - Bronchopulmonary dysplasia - Exposure to Furosemide

Author & Year	Inclusion criteria	Exclusion criteria:	Demographic characteristics considered:	Comorbid conditions reported:	Characteristics that are significantly different between children with UHL and controls with NH
	<ul style="list-style-type: none"> >40 dB HL in impaired ear >40 dB HL in impaired ear 	<ul style="list-style-type: none"> (including CMV, HIV) Metabolic diseases 	<ul style="list-style-type: none"> Parental education Parental occupation 	<ul style="list-style-type: none"> Use of ototoxic medications Persistence of fetal circulation Seizures Intraventricular hemorrhage Bronchopulmonary dysplasia 	<ul style="list-style-type: none"> Length of NICU and hospital stay Duration of mechanical ventilation 1-min & 5-min Apgar score
Klee, 1986 ¹⁷	<ul style="list-style-type: none"> Age 6–18 UHL for 3 or more years UHL defined as 45 dB HL in impaired ear IQ within normal range 	<ul style="list-style-type: none"> History of middle ear disease in the normal ear 	<ul style="list-style-type: none"> Gender Age Race Socioeconomic status 	<ul style="list-style-type: none"> Otitis media 	No significant differences reported in characteristics that were considered

^a Authors unable to confirm date of diagnosis for 4 children

UHL = Unilateral hearing loss

SNHL = Sensorineural hearing loss

NH = Normal hearing