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REVIEW AND SYNTHESIS

Review of Education BERA

# Academic achievement of children with unilateral or mild bilateral hearing loss: A systematic review

**Katherine Collier**

School of Education, Durham University, Durham, UK

**Correspondence**
Katherine Collier, School of Education, Durham University, Confluence Building, Lower Mountjoy, Stockton Road, Durham DH1 3LE, UK.
Email: katherine.a.collier@durham.ac.uk

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## Abstract

There has been significant research on the association between hearing loss and academic achievement. However, many studies do not disaggregate by degree of hearing loss. Therefore, the risks to school performance posed by unilateral and mild bilateral hearing loss are not well understood, despite prevalence studies suggesting that 2.4 to 23% of individuals may be affected. This study systematically reviewed the existing published and unpublished literature to understand whether an association exists between academic achievement and unilateral and mild bilateral hearing loss for children of primary school-age. Following the identification of 16,269 articles from Web of Science, ProQuest and EBSCOHost, PRISMA guidelines were followed to screen the articles and analyse those that met the pre-specified inclusion criteria. The study identified 12 reports covering nine studies that met these inclusion criteria. Across all the studies, and for both unilateral and mild bilateral hearing loss, the majority of effect sizes were negative. This indicates that children with mild and unilateral hearing loss achieved lower mean scores in the assessments compared to their fully hearing peers for the majority of measures. Of the 57 effect sizes measured, 51 were negative, with similar ratios being observed for both unilateral and mild bilateral hearing loss measures. Of the 51 negative effect sizes, 27 were substantially important, defined as an effect size of at least 0.25. None of the positive effect sizes were substantially important. However,

this analysis is based on a limited number of relatively small, heterogeneous studies. To fully understand the association between unilateral and mild bilateral hearing loss and academic achievement, more comprehensive studies that explore the association between school performance and these population groups would be a welcome addition to the current literature.

**KEYWORDS**
academic achievement, mild hearing loss, systematic review, unilateral hearing loss

**Context and implications**

- The impact of mild and unilateral hearing loss on educational outcomes is often overlooked as being too minor to be of significance.
- Using a systematic review, the study questions this view and considers whether academic achievement is associated with hearing impairment for children of primary school-age with unilateral or mild bilateral hearing loss in comparison with their fully hearing peers.
- A deeper understanding of this association would enable policymakers and educators to better comprehend the challenges faced by children with these levels of hearing loss, allowing a more aligned and effective support mechanism to be provided in schools.

## INTRODUCTION

Worldwide, 34 million children are hard of hearing (HH), with a hearing loss (HL) in excess of 20 dB (World Health Organisation, 2023). In the UK alone, more than 50 000 children have been identified as having a hearing impairment (HI) (NDCS, 2021). These figures include degrees of hearing impairment ranging from mild to profound and include hearing loss in both ears (bilateral hearing loss, BHL) or in only one ear (unilateral hearing loss, UHL). 22% of hearing-impaired children in the UK are diagnosed with unilateral hearing loss and an additional 26% receive a diagnosis for mild bilateral hearing loss (MBHL) (NDCS, 2021). Further, the figures for unilateral and mild hearing impairment could be underreported, as some children within these classifications may not yet have been formally diagnosed or even identified. With 78% of school-age children that have a diagnosis of hearing impairment attending mainstream schools in the UK (CRIDE, 2022), it is essential that schools are aware of the risk to academic achievement for students with all levels of hearing impairment.

Hearing impairment affects academic outcomes through the development of language at a slower pace, a reduced vocabulary, not hearing or mishearing communication given verbally, reduced hearing ability in the presence of elevated background noise, fatigue from lip reading affecting attention span, challenges of trying to visually multitask, such as writing notes while lipreading, and challenges engaging in discussions or conversations with multiple people (NDCS, 2015). While studies have shown an association between school

performance and hearing loss, these studies are often not disaggregated by degree of hearing loss (Cawthon et al., 2023; van der Straaten et al., 2021). Therefore, the association between academic performance and mild and unilateral hearing loss is unclear.

Technology to aid individuals with hearing-impairment is continuously being developed and improved, such as advances in hearing aid (HA) technology, cochlear implants (CI) and the development of radio aids (Holt, 2019). However, this equipment is not always appropriate for individuals with lower levels of hearing impairment (Newcastle_Hospitals, 2021), who may not, therefore, gain from these technological advances.

To ensure that affected students receive the support that they need and deserve to achieve their potential academic performance, it is important that educators and policy makers have an accurate understanding of the risks posed by UHL and MBHL. The impact of UHL and MBHL is frequently overlooked (DeGuire, 2019) and may be considered too minor to be of significance. This study questions this view by carrying out a systematic review to consider whether academic achievement is associated with hearing impairment for children of primary school-age with unilateral or mild bilateral hearing loss in comparison to their peers with normal hearing (NH). Following a review of the key literature, the protocol followed is described in detail and then the results presented. A discussion of the results and the conclusions drawn then follow. Finally, proposals for future work are made.

## LITERATURE REVIEW

UHL and MBHL have historically been regarded as inconsequential (Tharpe, 2008). Indeed, the parents of impacted children were assured by audiologists during the 1970s that they would experience 'no handicap' (Northern & Downs, 1978, p. 143). However, Bess (1985) carried out pivotal work through reviewing the available data, which questioned this view. Bess and Tharpe (1986) continued this work through a study of sixty children with UHL aged from 6–18 years. The study, although based on a limited sample size, identified that UHL was associated with significant academic implications. For example, 3.5% of students living in the geographical area of the study were found to have repeated at least one grade of school, compared with 35% of students with UHL. During the same year, Culbertson and Gilbert carried out a study of 25 fully hearing children compared with 25 of their peers with UHL. This relatively small study found the two groups to have similar scores in cognitive assessments. However, the findings echoed the higher rates of grade retention among children with UHL compared to fully-hearing children. Bess et al. (1998) continued to consider the effect of both UHL and MBHL, in combination referred to as Minimal Hearing Loss (MHL), through assessing both the prevalence of MHL and the association between school performance and these levels of hearing impairment. The study identified that 66 of the 1228 students in the study experienced MHL (5.4%), with grade retention rates among these children again being significantly greater than for their peers with full hearing. Further, communication skills were found to be lower in the children with MHL than their fully hearing peers, although the two groups achieved similar levels of education performance in Grades six and nine. A further study (Most, 2006) later found that MHL students achieved lower test scores than their peers with more severe hearing loss. Most studies attribute the lower scores achieved by MHL students to later identification and reduced levels of support in school in comparison with those with greater hearing impairment. Although this was a small-scale investigation, with 20 participants having moderate to severe hearing impairment and 13 with MHL, as well as the risk of subjectivity in those scores which were allocated by teachers, the study highlights the importance of an increased understanding of the potential impact of mild and unilateral hearing loss on school performance.

Since these initial studies, further research has been conducted that suggests varying degrees of association between mild and unilateral hearing loss and school performance, including a report from Malaysia (Khairi Md Daud et al., 2010). This investigation, involving 234 children of primary school-age, demonstrated a significant association between school performance and UHL and MBHL. The study found the prevalence of these levels of hearing impairment to be 15% of the participants. A significant association between mild hearing loss and communication and attention difficulties was also shown in a recent small-scale study of 100 children aged 6–9 years (Elbeltagy, 2020). These results were echoed in a large cross-sectional study of students aged 6–11 years (Moore et al., 2020). However, both investigations raised concerns about whether the hearing test responses from the youngest participants were accurate. A further large-scale study indicated an association between mild hearing loss and both academic achievement and behavioural difficulties (le Clercq et al., 2020). However, behavioural challenges were assessed through parent questionnaires and therefore could potentially introduce bias.

A limited number of literature reviews on MBHL and UHL have also been carried out. Wake and Poulakis (2004) researched the prevalence and effect of MHL on school performance and behaviour. This review recommended that children with delayed development be assessed for hearing loss because of the association between MHL and school performance. The effect of early interventions for those with UHL and MBHL has also been the subject of a literature review (Holstrum et al., 2009), which found that affected children received little support in school despite lowered academic performance. The impact of UHL was considered by Rohlfs (Rohlfs et al., 2017) who concluded that the provision of hearing aids to individuals with UHL would be of benefit. However, these evaluations were literature reviews rather than systematic reviews. Neither protocols nor inclusion criteria were predefined, leading to an increased risk of bias.

A number of studies have sought to assess the prevalence of MBHL and UHL. Wang et al. (2019) screened 1483 children aged 10–11 years for hearing impairment. Slight to mild hearing impairment (15–40 dB) was identified in 9.2% of this population, with a further 13.1% found to have unilateral hearing loss. This combined prevalence rate of 22.3% for MBHL and UHL highlights the importance of understanding any association between unilateral and mild bilateral hearing loss on academic outcomes. Further studies have been carried out to understand the prevalence of UHL and MBHL. However, definitions of mild hearing loss in decibels are inconsistent across these studies, which is reflected in the range of prevalence rates achieved. These prevalence rates of the sampled population experiencing mild hearing loss in at least one ear varied from 2.4% to 23% (Elbeltagy, 2020; Niskar et al., 1998; Olusanya et al., 2000; Osei et al., 2018; Rao et al., 2002; Westerberg et al., 2005).

## AIM

The aim of this study was to robustly and systematically review the existing research to respond to the research question: Is academic achievement associated with mild bilateral or unilateral hearing loss in primary school-age students?

It was anticipated that a weak to moderate negative association would be identified.

## METHOD

The study answered the research question using a systematic review of existing literature. This design was selected to robustly answer the research question through the identification, evaluation and then synthesis of all relevant and existing literature using an approach that

is methodical, reproducible, and with minimum bias. A systematic review, therefore, was selected to offer the reader a comprehensive and thorough synopsis of the current research knowledge. Objective conclusions were then drawn, based on the extracted and synthesised data (Chandler & Hopewell, 2013; Higgins et al., 2024).

UHL refers to hearing loss in one ear only. The severity of the loss can range from mild to moderate, severe or profound. Bilateral hearing loss describes hearing loss in both ears, also ranging from mild to profound loss. Some studies have also introduced the term 'slight' or 'minimal' to describe hearing loss levels that are at or near to the lower end of the mild threshold (Moore et al., 2020; Wang et al., 2019). The World Health Organisation (WHO) defines mild hearing loss as 20 dB to <35 dB, and unilateral hearing loss as <20 dB in the better ear and 35 dB or greater in the worse ear. This contrasts with the definition offered by the UK NHS of mild hearing loss as 21 to 40 dB hearing loss (NHS, 2023a) and unilateral hearing loss as hearing loss in one ear, ranging from mild to profound (NHS, 2023b). The definitions used to describe the levels of hearing loss are not consistent across studies and are therefore described for each study (Table 5). This variation in hearing loss levels between the definitions and those used in the studies is particularly significant given that the decibel scale is logarithmic. Therefore, a 3 dB increase represents a doubling of sound energy intensity, with a 10 dB increase representing a 10-fold increase of sound energy intensity (Roberts, 2003).

The systematic review was preregistered with the Open Science Framework (Foster & Deardorff, 2017), registration number yd76b, to offer transparency of the review process (Stewart et al., 2012). This platform was selected due to its alignment with the methodology adopted within this review (including the use of only one reviewer – multiple reviewers were required to register with PROSPERO) and zero cost (Pieper & Rombey, 2022). A systematic review of existing literature was performed relating to the association between academic achievement and unilateral and mild bilateral hearing impairment for children of primary school-age. Boland et al. (2017) described a 10 stage process for completing a systematic review, which was followed during this study. Following the initial planning phase of the study, a scoping search was performed to inform the protocol and refine the search terms used. The selected databases were then searched, in line with the defined protocol, to identify studies that matched the specified search terms. The title and abstract of each identified study were initially screened to assess whether it matched the given inclusion and exclusion criteria, following which the full text was obtained for all studies identified for possible inclusion. The studies were then screened again based on these full texts. Data was subsequently extracted from all the included studies and placed into a Microsoft Excel spreadsheet. Checks were performed to ensure that the data remained intact and that it was correctly assigned to the relevant study. A research synthesis was then carried out based on this extracted data. The Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement 2020 (Page et al., 2021) was selected as a foundation for the reporting of the searching, inclusion, evaluation and synthesis of the identified studies. PRISMA 2020 (Page et al., 2021) was selected due to its comprehensive style that gives the reader a full and transparent understanding of the review process. An inclusive and broad search was purposefully carried out with no geographical limitations to ensure an exhaustive search. The advanced specification of search terms, inclusion/exclusion criteria and quality assessment methods, was also implemented to minimise selection bias. The inclusion criteria applied are given in Table 1.

Studies that did not report specific results for unilateral or mild bilateral hearing loss (either through this being the focus of the study or results being disaggregated in such a way that these results could be extracted separately) were also excluded, for example Cawthon et al. (2023). Further, studies that reported only subjective results of progress were excluded to minimise bias and ensure objective assessments of academic performance. For example,

**TABLE 1** Literature review inclusion criteria.

| Inclusion criteria | Description | Justification |
|---|---|---|
| Population of interest | Primary school-age children, based on the English and Welsh primary school system (age 4–11 years, inclusive). Studies which included a population beyond this group could be included if the results were disaggregated by age or if the majority of the children were within the range given above | Primary school-age children are continuing to develop their language and communication skills and may not be able to fully verbalise the challenges they are facing |
| Geographical area of inclusion | Worldwide | To ensure an exhaustive search |
| Exposure | Children with unilateral or mild bilateral hearing impairment. Studies that considered a wider range of degrees of hearing impairment could be included if the results were disaggregated by hearing loss level or if the majority of participants fell within the definition of mild or unilateral hearing loss. Studies that did not identify the degree of hearing loss of the participants were excluded as it could not be ascertained whether the participants were within the population of interest | To answer the research question through considering the association between academic performance and unilateral and mild bilateral hearing loss |
| Comparison group | Fully hearing peers | To act as a baseline for comparison |
| Outcome | All elements of academic performance, including maths, science, reading and English/language | To allow an understanding of the association of unilateral and mild bilateral hearing loss on all aspects of academic performance |
| Study designs | Correlational studies, which may include longitudinal and cross-sectional data, that report numerical results of academic performance, and which are based on assessments | Correlational studies will be sought to align with the research question and allow an understanding to be gained on the association between academic achievement and unilateral and mild bilateral hearing impairment. Numerical results are sought to allow the calculation and comparison of effect sizes. The use of assessments is sought to ensure that objective results are used to minimise bias |
| Timeframe | December 2006 to present (November 2024) | The UN Convention on the Rights of Persons with Disabilities gives children with disabilities the right to an inclusive education (UN, 2006). It was written in December 2006 and subsequently adopted by many countries globally. This study therefore considers the global situation following the creation of this international convention |
| Language | English | To enable the researcher to fully access the articles |

**TABLE 1** (Continued)

| Inclusion criteria | Description | Justification |
|---|---|---|
| Publication types | Both unpublished and published studies, including journal articles, blogs, podcasts, websites, books, conference papers, dissertations and theses, government and official publications | To minimise any publication bias (Torgerson, 2006) |
| Content | Primarily regarding the association between academic performance and unilateral and mild bilateral hearing impairment | To align with the research question |

Elbeltagy (2020) considered the school performance of students using teacher questionnaires and was therefore excluded. The full syntax of the search terms that were employed within this systematic review was:

("hear* impair*" OR "hear* loss" OR "mild hear*" OR "unilateral hear*" OR "bilateral hear*" OR "minimal hear*" OR "slight hear*" OR "deaf" OR UHL OR MBHL OR MHL OR DHH or "hard of hearing") AND ("Academic achievement" OR "School achievement" OR "Education* achievement" OR "Academic performance" OR "School performance" OR "Education* performance" OR "Academic outcome" OR "School outcome" OR "Education* outcome" OR "Grade retention" OR "Math* score" OR "Math* result" OR "Math* outcome" OR "Math* performance" OR "Math* achievement" OR "Science score" OR "Science result" OR "Science outcome" OR "Science performance" OR "Science achievement" OR "English score" OR "English result" OR "English outcome" OR "English performance" OR "English achievement" OR read*)

The terms identified cover the range of terminology used relating to academic performance and hearing impairment. To assess the efficacy of the search terms to identify relevant pieces of research, including key studies that had previously been identified, a scoping review was initially performed. Following this successful check, the search was carried out using the same search terms for each database.

Databases from education, medicine and sociology disciplines were searched using the specified search terms to cover the range of fields in which relevant articles may be identified. Walker et al. (2016) identified that searching three major databases captured 100% of their eligible studies. Therefore, three large search platforms were chosen. Specifically, EBSCOHost (EBSCO, 2023), ProQuest (ProQuest, 2023) and Web of Science (Clarivate, 2023) were selected as being able to offer a search of a very wide range of published and grey literature. All databases available through each of these search platforms were searched, including ERIC. The searches were performed based on the title and abstract of each study to ensure an exhaustive search. The studies identified through the database searches were initially screened for duplication. An assessment of whether each study matched the inclusion criteria was then made based on the title and abstract. Studies that did not match the inclusion criteria were excluded. The full text of the retained studies was then obtained, and the screening process repeated to identify the studies that met the inclusion criteria.

Figure 1 shows the flow chart of studies excluded at each stage of the screening process. Data extraction took place from those studies that were found to have met the inclusion criteria following an assessment of the full text. Studies were coded in line with the recommendations of the Cochrane Handbook (Higgins et al., 2024), including the study design and protocol details, location and setting, participant description, sample sizes with attrition levels, outcomes, measures, results as well as hearing levels considered, and definitions of hearing impairment levels used. The strength of the evidence given by each study was

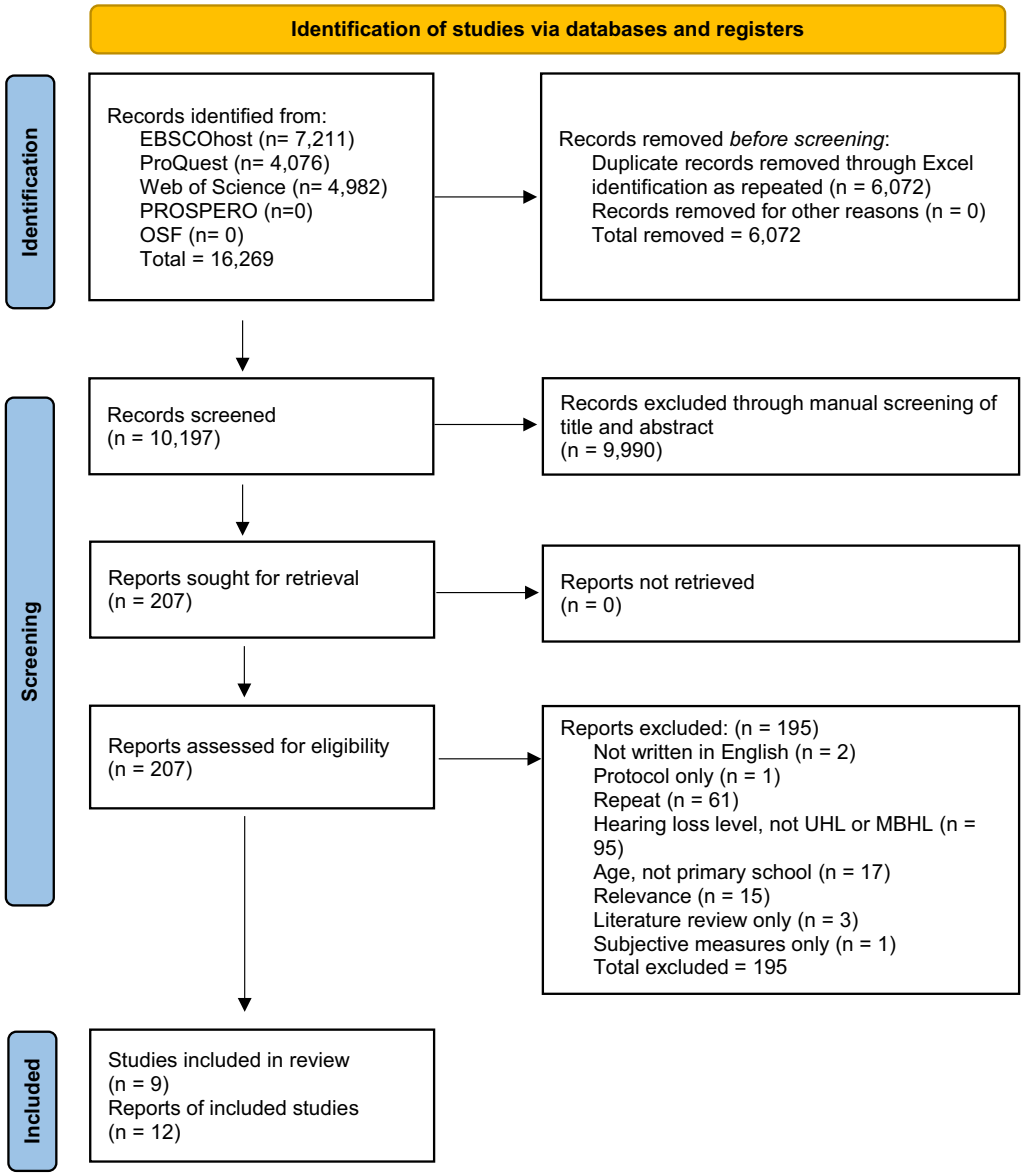


**FIGURE 1** PRISMA diagram of included studies (Page et al., 2021, p. 5).

assessed using Gorard's sieve technique (Gorard, 2014), with the results of this assessment included within the Results section (Table 4). Using this technique, studies were allocated up to four stars based on the trustworthiness of the research results through consideration of the design, scale, attrition, quality of data and other potential threats.

## DATA ANALYSIS

Studies were collated based on the level of hearing loss reported (unilateral and mild bilateral) to facilitate analysis and discussion of the results. The definitions used within each study for each level of hearing loss are given in Table 5.

An assessment of the methodological heterogeneity of the included studies was carried out to ascertain whether a meta-analysis of the results would be appropriate (Campbell et al., 2020). A minimum of two studies that are sufficiently similar and offer results that are able to be meaningfully combined was required to deliver the necessary evidence for a meta-analysis (R. Ryan, Cochrane Consumers and Communication Review Group, 2016a). The heterogeneity of the studies was assessed following the method described by the Cochrane Consumers and Communication Group (R. Ryan, Cochrane Consumers and Communication Review Group, 2016b). It was considered that the pooling of the results could be misleading for each subgroup due to the high levels of inconsistency across the studies in their defined and included levels of hearing loss, the use of hearing aids or other amplification during assessments and whether audiometry assessments were carried out in a sound booth or classroom. Due to this lack of homogeneity across the methodologies used across the studies, a meta-analysis was not completed. Instead, this review adopted the synthesis without the meta-analysis method described by Campbell et al. (2020). The outcomes offered by each study were inconsistent, but included oral language, reading, maths, writing and other outcomes. According to these five outcomes for each study, this synthesis then reported where the information was available. The effect size for each outcome for each study was calculated using Cohen's *d* (Cohen, 1988) to evaluate the extent to which the given hearing loss is associated with academic performance (Herbert et al., 2006). This method was selected to facilitate the inclusion of the study which reported its results in terms of Cohen's *d* rather than the mean and standard deviation (Moore et al., 2020).

The Cohen's *d* effect size was calculated using the following equation (Cohen, 1988; Rosenthal, 1991; Thalheimer & Cook, 2002):

$$d = \frac{M_1 - M_2}{S_{pooled}} \tag{1}$$

Cohen's *d* effect size.

Where:

$d$ = Cohen's *d* effect size

$M_1$ = mean of hearing-impaired group

$M_2$ = mean of control group

$S_{pooled}$ = pooled standard deviation of the two groups, calculated using the following equation (Thalheimer & Cook, 2002):

$$S_{pooled} = \sqrt{\frac{(n_1 - 1) \cdot s_1^2 + (n_2 - 1) \cdot s_2^2}{n_1 + n_2}} \tag{2}$$

Pooled standard deviation.

Where:

$s$ = standard deviation of hearing-impaired group ($s_1$) or control group ($s_2$) or the pooled combination ($S_{pooled}$)

$n$ = number of participants in hearing-impaired group ($n_1$) or control group ($n_2$)

Where studies did not report a mean and standard deviation, but instead reported outcomes using a *t* value (McSweeny et al., 2021; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2020), Cohen's *d* was estimated using the following equation: (Rosenthal & Rosnow, 2008).

$$d = \frac{t \cdot (n_1 + n_2)}{\sqrt{df} \cdot \sqrt{(n_1 \cdot n_2)}} \tag{3}$$

Estimation of Cohen's *d* effect size using *t* value.
Where:

*d* = Cohen's *d* effect size
*t* = *t* value
*n* = number of participants in hearing-impaired group ($n_1$) or control group ($n_2$)
df = degrees of freedom

This equation was selected as suitable for estimating the Cohen's *d* effect size to allow for consideration of the difference in sample size between the hearing-impaired and control groups (Rosenthal & Rosnow, 2008).

Cohen (1988) offered guidelines for interpreting the calculated effect sizes as small (0.20), medium (0.50) or large (0.80). Further, What Works Clearinghouse (WWC) proposes that effect sizes of at least 0.25 are considered 'substantially important' (2017, p. 77). This proposal has been adopted within this study when analysing the calculated effect sizes.

## RESULTS

Twelve reports met the inclusion criteria (Figure 1) and have been included in this synthesis. All of these reports were identified through the database search. The key report characteristics are given in Table 2, ordered alphabetically by report title:

However, these twelve reports covered a total of only nine studies, with two studies being reported on multiple times. The names of these two studies and the associated reports are shown in Table 3.

The Outcomes of School-Age Children who are Hard of Hearing (OSACHH) study is a continuation of the Outcomes of Children with Hearing Loss (OCHL) study, following the same families (Moeller, n.d.). Therefore, these two studies were treated as one study. Results were analysed by study (Higgins et al., 2024) with reports from identical studies being amalgamated.

The study characteristics of each of the nine studies are included in Table 4 (details of individual reports are given where different characteristics of participants are reported).

Of the nine studies, four considered MBHL (Camarata et al., 2018; Porter et al., 2013; Reynolds et al., 2024; Tomblin, Oleson, Ambrose, Walker, McCreery, and Moeller, 2020; Tomblin, Oleson, Ambrose, Walker, and Moeller, 2020; Walker et al., 2020) and three considered UHL (Lieu, 2013; Lieu et al., 2013; Lieu et al., 2012; McSweeny et al., 2021). A further two studies considered both UHL and MBHL (Moore et al., 2020; Wang et al., 2019). The hearing loss levels and the definitions of the degrees of hearing loss in each study is given in Table 5.

Table 5 highlights the variation in hearing loss definitions and levels in the included studies. As described, this variation is particularly important in consideration of the fact that decibels are measured using a logarithmic scale. Results were analysed according to the five outcomes: oral language, reading, writing, maths, and other academic measures, such as vocabulary and spelling. Hearing level subgroups of mild bilateral and unilateral hearing loss were also assessed. Cohen's *d* effect size was calculated for each outcome for mild bilateral and unilateral hearing loss, with the results shown in Tables 6 and 7.

Each of these five outcomes are considered in turn below. Forest plots have been produced showing the effect sizes relating to each outcome, disaggregated by hearing loss level (mild bilateral or unilateral). Confidence intervals have not been calculated for these data sets due to the presence of missing data and the data not being fully randomised (Gorard, 2021).

**TABLE 2** Characteristics of included reports.

| Title of report | Author(s) | Country | Published? | Year of publication |
|---|---|---|---|---|
| Academic, behavioural and quality of life outcomes of slight to mild hearing loss in late childhood/ a population-based study | J. Wang<br>J. Quach<br>V. Sung<br>P. Carew<br>B. Edwards<br>A. Grobler<br>L. Gold<br>M. Wake | Australia | Yes – Archives of Disease in Childhood | 2019 |
| Aided Hearing Moderates the Academic Outcomes of Children with Mild to Severe Hearing Loss | J.B. Tomblin<br>J. Oleson, Jake<br>S.E. Ambrose<br>E.A. Walker<br>R. McCreery<br>M.P. Moeller | USA | Yes – Ear Hear | 2020 |
| Developmental outcomes in early school-age children with minimal hearing loss | H. Porter<br>D. Sladen<br>S. Ampah<br>A. Rothpletz<br>F. Bess | USA | Yes – American Journal of Audiology | 2013 |
| Do Audiologic Characteristics Predict Outcomes in Children with Unilateral Hearing Loss? | J.E.C. Lieu<br>R.K. Karzon<br>B. Ead<br>N. Tye-Murray | USA | Yes – Otol Neurotol | 2013 |
| Early Literacy Predictors and Second-Grade Outcomes in Children Who Are Hard of Hearing | J.B. Tomblin<br>J. Oleson<br>S.E. Ambrose<br>E.A. Walker<br>M.P. Moeller | USA | Yes – Child Development | 2020 |
| Functional Consequences of Poor Binaural Hearing in Development: Evidence from Children With Unilateral Hearing Loss and Children Receiving Bilateral Cochlear Implants | C. McSweeny<br>S.L. Cushing<br>J.L. Campos<br>B.C. Papsin<br>K.A. Gordon | Canada | Yes – Trends in Hearing | 2021 |
| Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss | S. Camarata<br>K. Werfel<br>T. Davis<br>B.W.Y. Hornsby<br>F.H. Bess | USA | Yes – Exceptional Children | 2018 |
| Language and Reading Outcomes in Fourth-Grade Children with Mild Hearing Loss Compared to Age-Matched Hearing Peers | E. Walker<br>C. Sapp<br>M. Dallapiazza<br>M. Spratford<br>R. McCreery<br>J. Oleson | USA | Yes – Language, Speech and Hearing Services in Schools | 2020 |
| Longitudinal study of children with unilateral hearing loss | J.E.C. Lieu<br>N. Tye-Murray<br>Qjang Fu | USA | Yes – The Laryngoscope | 2012 |
| Minimal and mild hearing loss in children – Association with auditory perception, cognition, and communication problems | D.R. Moore<br>O. Zobay<br>M.A. Ferguson | UK | Yes – Ear Hear | 2020 |

(Continues)

TABLE 2 (Continued)

| Title of report | Author(s) | Country | Published? | Year of publication |
|---|---|---|---|---|
| Spelling Errors in Children with Mild to Moderate Hearing Loss: Relations to Linguistic and Audiologic Factors | G. Reynolds<br>K.L. Werfel<br>S. Hudgins<br>S. Camarata<br>F.H. Bess | USA | Yes – Exceptional children | 2024 |
| Unilateral hearing loss in children: speech-language and school performance | J.E.C. Lieu | USA | Yes – B-ENT | 2013 |

TABLE 3 Study name and associated report titles for duplicated studies.

| Study | Reports |
|---|---|
| Outcomes of Children with Hearing Loss (OCHL)<br>And<br>Outcomes of School-Age Children who are Hard of Hearing (OSACHH)<br>(USA) | 1. Early Literacy Predictors and Second-Grade Outcomes in Children Who Are Hard of Hearing, Tomblin, Oleson, Ambrose, Walker, McCreery, and Moeller (2020)<br>2. Aided Hearing Moderates the Academic Outcomes of Children with Mild to Severe Hearing Loss, Tomblin, Oleson, Ambrose, Walker, McCreery, and Moeller (2020); Tomblin, Oleson, Ambrose, Walker, and Moeller (2020)<br>3. Language and Reading Outcomes in Fourth-Grade Children with Mild Hearing Loss Compared to Age-Matched Hearing Peers, Walker et al. (2020) |
| Washington University School of Medicine | 1. Do Audiologic Characteristics Predict Outcomes in Children with Unilateral Hearing Loss? Lieu et al. (2013)<br>2. Unilateral hearing loss in children: speech-language and school performance, Lieu et al. (2013) |

## Oral language

Figures 2 and 3 illustrate the effect sizes for the oral language outcome for participants with mild and unilateral hearing loss, respectively. These figures highlight that all measures showed a negative effect size for this outcome, meaning that the participants with mild or unilateral hearing loss experienced lower scores in the assessments compared to their typically hearing peers. These effect sizes ranged from −0.57 to −0.19 for mild hearing loss and −0.58 to −0.40 for unilateral hearing loss.

## Reading

Figures 4 and 5 illustrate the effect sizes for the reading outcome for participants with mild and unilateral hearing loss, respectively. These figures show the wide range of effect sizes achieved within the reading outcome, which range from −0.56 to 0.14 for mild hearing loss and −0.42 to 0.24 for unilateral hearing loss. The majority (83%) of measures for this outcome showed a negative effect size, meaning that the participants with mild or unilateral hearing loss experienced lower scores in the majority of these assessments compared to their typically hearing peers. However, the assessments focused on different reading skills, including reading fluency, comprehension, and the decoding of both words and pseudowords, as described in Tables 6 and 7, with these different skills also offering a range of effect size results as illustrated in Figures 4 and 5.

**TABLE 4** Characteristics of included studies.

| Study | Reports | Study design | Outcomes reported | Number of participants analysed with NH, UHL or MBHL | Age of participants analysed | Trustworthiness level of study |
|---|---|---|---|---|---|---|
| Child Health Check Point Study within the Longitudinal Study of Australian Children (Australia) | Academic, behavioural and quality of life outcomes of slight to mild hearing loss in late childhood – a population-based study, Wang et al., 2019 | Cross-sectional sub-study of longitudinal study | Oral language, reading, maths, writing. | 137 MBHL, 195 MUHL, 1483 total inc. NH | 11–12 years, mean = 11.4 years | 3 |
| Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH) (USA) | 1. Early Literacy Predictors and Second-Grade Outcomes in Children Who Are Hard of Hearing Tomblin, Oleson, Ambrose, Walker, McCreery, and Moeller (2020); Tomblin, Oleson, Ambrose, Walker, and Moeller (2020) | Longitudinal study | Oral language, reading | 180 CHH, 80 CNH | Wave 1: Mean 5.1 years Wave 2: Mean 8.5 years | 2 |
| | 2. Aided Hearing Moderates the Academic Outcomes of Children with Mild to Severe Hearing Loss Tomblin, Oleson, Ambrose, Walker, McCreery, and Moeller (2020), Tomblin, Oleson, Ambrose, Walker, and Moeller (2020) | | Oral language, reading, maths, writing, spelling | 183 CHH, 91 CNH | Grade 2 Wave: mean 8.5 years Grade 4 Wave: Mean 10.4 years | |
| | 3. Language and Reading Outcomes in Fourth-Grade Children with Mild Hearing Loss Compared to Age-Matched Hearing Peers, Walker et al. (2020) | | Reading, vocabulary | 60 CMBHL and 69 CNH | 9–12 years, mean 10.4 years | |
| Developmental outcomes in early school-age children with minimal hearing loss (USA) | Developmental outcomes in early school-age children with minimal hearing loss Porter et al. (2013) | Longitudinal study | Oral language, vocabulary | 27 CMHL 26 CNH | 4–10 years | 2 |
| Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss (USA) | Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss, Camarata et al. (2018) | Longitudinal study | Reading, receptive language | 56 CMMHL | 6–12 years | 1 |

(Continues)

TABLE 4 (Continued)

| Study | Reports | Study design | Outcomes reported | Number of participants analysed with NH, UHL or MBHL | Age of participants analysed | Trustworthiness level of study |
|---|---|---|---|---|---|---|
| Washington University School of Medicine study (USA) | 1. Do Audiologic Characteristics Predict Outcomes in Children with Unilateral Hearing Loss? Lieu (2013)<br>2. Unilateral hearing loss in children: speech-language and school performance Lieu et al. (2013) | Cross-sectional study (case control) | Oral language, reading, maths, writing | 109 UHL and 95 sibling controls | 6–12 years | 2 |
| Longitudinal study of children with unilateral hearing loss (USA) | Longitudinal study of children with unilateral hearing loss, Lieu et al. (2012) | Longitudinal study | Oral language, reading, maths, writing | 46 CUHL | 6–8 years | 1 |
| MRC Institute of Hearing Research (UK) | Minimal and mild hearing loss in children – Association with auditory perception, cognition, and communication problems, Moore et al. (2020) | Cross-sectional study | Reading, language | 1457 children | 6–12 years | 2 |
| Functional Consequences of Poor Binaural Hearing in Development: Evidence from Children with Unilateral Hearing Loss and Children Receiving Bilateral Cochlear Implants (Canada) | Functional Consequences of Poor Binaural Hearing in Development: Evidence from Children with Unilateral Hearing Loss and Children Receiving Bilateral Cochlear Implants, McSweeny et al. (2021) | Cross-sectional study | Oral language, word reading, maths, oral language | 36 NH, 20 UHL | 5–18 years | 1 |
| Spelling Errors in Children with Mild to Moderate Hearing Loss (USA) | Spelling Errors in Children with Mild to Moderate Hearing Loss: Relations to Linguistic and Audiologic Factors Reynolds et al. (2024) | Cross-sectional study | Spelling | 29 CMMHL and 37 NH | Grade K to Grade 7 | 0 |

**TABLE 5** Hearing loss level by study.

| Title of study | Report | HL definitions used in report | HL of participants studied | Hearing aids used during assessments? | Better ear used in analysis? |
|---|---|---|---|---|---|
| Child Health Check Point Study within the Longitudinal Study of Australian Children (Australia) | Academic, behavioural and quality of life outcomes of slight to mild hearing loss in late childhood – a population-based study, Wang et al. (2019) | Mild HL: 25-40 dB HL. Slight: 16-25 dB HL when considering mean HL at 1, 2 and 4 kHz in the better and worse ear | Slight to mild bilateral and unilateral HL (majority slight) | No – HAs/CIs removed where applicable | Better ear |
| Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH) (USA) | Early Literacy Predictors and Second-Grade Outcomes in Children Who Are Hard of Hearing, Tomblin, Oleson, Ambrose, Walker, McCreery, and Moeller (2020); Tomblin, Oleson, Ambrose, Walker, and Moeller (2020) | Mild HL: 20– 44 dB HL moderate HL: 45–59 dB HL, moderate–severe HL >59 dB HL | Bilateral mild to severe HL, majority mild/moderate | Not specified | Better ear |
| | Aided Hearing Moderates the Academic Outcomes of Children with Mild to Severe Hearing Loss, Tomblin, Oleson, Ambrose, Walker, McCreery, and Moeller (2020); Tomblin, Oleson, Ambrose, Walker, and Moeller (2020) | Mild HL: 20–45 dB HL | Mild to moderately severe (better ear) | Aided and unaided hearing assessed for comparison | Better ear |
| | Language and Reading Outcomes in Fourth-Grade Children with Mild Hearing Loss Compared to Age-Matched Hearing Peers, Walker et al., 2020 | MBHL: 15-45 dB HL | Mild HL (better ear) | Aided and unaided | Better ear |
| Developmental outcomes in early school-age children with minimal hearing loss | Developmental outcomes in early school-age children with minimal hearing loss, Porter et al., 2013 | Mild HL: 20–40 dB at 0.5–4 kHz, or HL <15 dB at 0.5–2 kHz<br>UHL: >45 dB HL in one ear and <15 dB HL in other ear at 0.5–4 kHz<br>NH: HL < 15 dB at 0.5-4 kHz bilaterally | Unilateral and mild bilateral | HAs were used for assessments (except HINT-C). No other amplification | UHL – affected ear |

(Continues)

**TABLE 5** (Continued)

| Title of study | Report | HL definitions used in report | HL of participants studied | Hearing aids used during assessments? | Better ear used in analysis? |
|---|---|---|---|---|---|
| Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss | Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss Camarata et al. (2018) | Mild: 25–40 dB HL at ≥2 frequencies above 2.0 kHz. Moderate HL: 41–70 dB HL in the better ear | Mild to moderate HL (better ear), mean level is mild | With hearing aids if they owned hearing aids and without hearing aids if they did not own or use hearing aids | Better ear |
| Washington University School of Medicine | Do Audiologic Characteristics Predict Outcomes in Children with Unilateral Hearing Loss? Lieu et al. (2013) | UHL: ≥30 dB HL in the affected ear, based on an average taken at three consecutive frequencies. NH in other ear | Permanent UHL (majority profound) | Used by those who normally use them | UHL – affected ear |
| | Unilateral hearing loss in children: speech-language and school performance Lieu (2013) | NH: <20 dB, based on an average at 0.5, 1 and 2 kHz, and < 30 dB at 4 kHz. Mild HL: <40 dB HL, moderate = 40–69 dB HL, Severe = 70-89 dB HL, Profound ≥90 dB HL | Permanent UHL (majority profound) | Not defined | UHL – affected ear |
| Functional Consequences of Poor Binaural Hearing in Development: Evidence from Children with Unilateral Hearing Loss and Children Receiving Bilateral Cochlear Implants | Functional Consequences of Poor Binaural Hearing in Development: Evidence from Children with Unilateral Hearing Loss and Children Receiving Bilateral Cochlear Implants, McSweeny et al. (2021) | UHL: Hearing loss in one ear with prelingual onset, and normal hearing in the other ear (<20 dB averaged at 0.5, 1 and 2 kHz. Prelingual onset of hearing loss) with little to no hearing aid use | UHL | No – unaided UHL | UHL – affected ear |
| Longitudinal study of children with unilateral hearing loss | Longitudinal study of children with unilateral hearing loss, Lieu et al. (2012) | UHL: >30 dB in affected ear for three consecutive frequencies | >30 dB in affected ear for three consecutive frequencies | Used by those who normally use them | Hearing individually assessed across ears. Asymmetric hearing loss (\|Left PTA – Right PTA\|10 dB) |

**TABLE 5** (Continued)

| Title of study | Report | HL definitions used in report | HL of participants studied | Hearing aids used during assessments? | Better ear used in analysis? |
|---|---|---|---|---|---|
| Minimal and mild hearing loss in children- Association with auditory perception, cognition, and communication problems | Minimal and mild hearing loss in children- Association with auditory perception, cognition, and communication problems, Moore et al. (2020) | Minimal HL: 15–20 dB HL in either ear, Mild HL 20–40 dB HL<br>UHL: \|Left PTA – Right PTA\| ≥ 10 dB, NH: <15 dB HL in both ears | Mild and slight, bilateral and unilateral HL | Not specified | No – hearing individually assessed across both ears. Children with asymmetric hearing identified (\|Left PTA – Right PTA\| ≥ 10 dB) |
| Spelling Errors in Children with Mild to Moderate Hearing Loss | Spelling Errors in Children with Mild to Moderate Hearing Loss: Relations to Linguistic and Audiologic Factors Reynolds et al. (2024) | Not specified | Mild to moderate HL | Not specified | Better ear |

**TABLE 6** Effect sizes for mild hearing loss subgroup.

| Study | Outcome | Measure | Effect size (Cohen's *d*) (to 2 d.p) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Oral language | Reading | Maths | Writing | Other |
| Child Health Check Point Study within the Longitudinal Study of Australian Children | Reading | NAPLAN[a] | | −0.16 | | | |
| | Writing | NAPLAN[a] | | | | −0.08 | |
| | Maths | NAPLAN[a] | | | −0.12 | | |
| | Vocabulary | NAPLAN[a] | | | | | −0.14 |
| | Sentence repetition | CELF[b] | | | | | −0.19 |
| Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH) | Oral language | PLAI-2[c], CELF-4[d], PPVT-4[e] | −0.57 | | | | |
| | Reading (decoding) | WJ III[f] | | −0.56 | | | |
| | Reading (comp.) | GORT-5[g] | | −0.53 | | | |
| | Reading (fluency) | GORT-5[g] | | −0.48 | | | |
| | Maths | WJ III[f] | | | −0.02 | | |
| | Reading (comp.) | GORT-5[g] | | −0.20 | | | |
| | Reading (fluency) | GORT-5[g] | | 0.00 | | | |
| | Oral language | WJ III[f] CELF[b] | −0.43 | | | | |
| | Spelling | WJ III[f] | | | | | −0.2 |
| | Reading (decoding) | WJ III[f] | | 0.14 | | | |
| | Writing | WJ III[f] | | | | −0.04 | |
| | Vocabulary | WJ III[f] | | | | | −0.31 |
| | Understand Directions | WJ III[f] | | | | | −0.56 |
| | Reading | GORT-5[g] | | −0.12 | | | |
| Developmental outcomes in early school-age children with minimal hearing loss | Oral language | TACL-3[h] | −0.38 | | | | |
| | Vocabulary | PPVT-3[i] | | | | | −0.32 |
| | Reading | WRMT-R[j] | | 0.04 | | | |

**TABLE 6** (Continued)

| Study | Outcome | Measure | Effect size (Cohen's *d*) (to 2 d.p) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Oral language | Reading | Maths | Writing | Other |
| Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss | Oral language | CELF-4[d] | −0.31 | | | | |
| | Reading (basic skills) | WRMT-III[k] | | −0.28 | | | |
| | Reading (comp) | WRMT-III[k] | | −0.14 | | | |
| | Reading (overall) | WRMT-III[k] | | −0.11 | | | |
| MRC Institute of Hearing Research | Oral language (mild HL) | NEPSY[l] | −0.19 | | | | |
| | Reading (words) (mild HL) | TOWRE[m] | | −0.47 | | | |
| | Reading (pseudo.) (mild HL) | TOWRE[m] | | −0.48 | | | |
| | Oral language (slight HL) | NEPSY[l] | −0.24 | | | | |
| | Reading (words) (slight HL) | TOWRE[m] | | −0.09 | | | |
| | Reading (pseudo.) (slight HL) | TOWRE[m] | | −0.12 | | | |
| Spelling Errors in Children with Mild to Moderate Hearing Loss | Spelling | TWS-4[n] | | | | | −0.3 |

[a]NAPLAN – National Assessment Program – Literacy and Numeracy (ACARA, 2024).
[b]CELF – Clinical Evaluation of Language Fundamentals 4th edition (Australian version) (Semel et al., 2006).
[c]PLAI-2 – Preschool Language Assessment Instrument 2nd edition (Blank et al., 2003).
[d]CELF-4 – Clinical Evaluation of Language Fundamentals 4th edition (Eleanor Semel et al., 2003).
[e]PPVT-4 – Peabody Picture Vocabulary Test 4th edition (Dunn & Dunn, 2007).
[f]WJ III – Woodcock-Johnson III Tests of Achievement (Woodcock et al., 2001).
[g]GORT-5 – Grey Oral Reading Tests-5 (Wiederholt, 2012).
[h]TACL-3 – Test of Auditory Comprehension of Language 3rd edition (Carrow-Woolfolk, 1999).
[i]PPVT-3 – Peabody picture vocabulary test- III (LM Dunn, 1997).
[j]WRMT-R – Woodcock reading mastery test – revised (Woodcock, 1987).
[k]WRMT-III – Woodcock Reading Mastery Test, 3rd Edition (Woodcock, 2011).
[l]NEPSY – Neuropsychological assessment (pseudoword repetition) (Korkman, 1998).
[m]TOWRE – Test of Word Reading Efficiency (words and pseudowords) (Torgesen & Rashotte, 1999).
[n]TWS-4 – Test of Written Spelling– Fourth Edition (Larsen et al., 1999). The cohen's *d* value given in the article is 0.3 referring to the number of spelling errors, which was higher for the HI students. However, the scoring is inverse – a lower score means fewer spelling errors indicating a higher level of spelling accuracy. The value has therefore been negated to indicate the lower spelling accuracy achieved by the hearing-impaired students.

**TABLE 7** Effect sizes for unilateral hearing loss subgroup.

| Study | Outcome | Measure | Effect size (Cohen's *d*) (to 2 d.p) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Oral language | Reading | Maths | Writing | Other |
| Child Health Check Point Study within the Longitudinal Study of Australian Children | Reading | NAPLAN[a] | | −0.07 | | | |
| | Writing | NAPLAN[a] | | | | −0.11 | |
| | Maths | NAPLAN[a] | | | −0.07 | | |
| | Vocabulary | NAPLAN[a] | | | | | −0.11 |
| | Sentence repetition | CELF-4[b] | | | | | −0.06 |
| Washington University School of Medicine study | Reading | WIAT-II-A[c] | | −0.10 | | | |
| | Maths | WIAT-II-A[c] | | | −0.16 | | |
| | Writing | WIAT-II-A[c] | | | | −0.13 | |
| | Oral language (listening comprehension) | OWLS[d] | −0.40 | | | | |
| | Oral language (expression) | OWLS[d] | −0.43 | | | | |
| | Oral language (oral composite) | OWLS[d] | −0.52 | | | | |
| Longitudinal study of children with unilateral hearing loss | Oral language (comprehension) | OWLS[d] | −0.42 | | | | |
| | Oral language (expression) | OWLS[d] | −0.44 | | | | |
| | Oral language (composite) | OWLS[d] | −0.56 | | | | |
| | Reading | WIAT-II-A[c] | | 0.24 | | | |
| | Maths | WIAT-II-A[c] | | | 0.24 | | |
| | Writing | WIAT-II-A[c] | | | | 0.24 | |
| MRC Institute of Hearing Research | Oral language | NEPSY[e] | −0.53 | | | | |
| | Reading (words) | TOWRE[f] | | −0.35 | | | |
| | Reading (pseudowords) | | | −0.27 | | | |
| Functional Consequences of Poor Binaural Hearing in Development | Reading (words) | WIAT-III[g] | | −0.42 | | | |
| | Reading (pseudowords) | WIAT-III[g] | | −0.41 | | | |
| | Maths | WIAT-III[g] | | | −0.35 | | |
| | Oral language | CELF-5[h] | −0.58 | | | | |

[a]NAPLAN – National Assessment Program – Literacy and Numeracy (ACARA, 2024).
[b]CELF-4 – Clinical Evaluation of Language Fundamentals 4th edition (Australian version) (Semel et al., 2006).
[c]WIAT-II-A – Wechsler Individual Achievement Test 2nd Edition, Abbreviated (Wechsler, 2005).
[d]OWLS – Oral Written and Language Scales (Goldblatt & Friedman, 1999).
[e]NEPSY – Neuropsychological assessment (pseudoword repetition) (Korkman, 1998).
[f]TOWRE – Test of Word Reading Efficiency (words and pseudowords) (Torgesen & Rashotte, 1999).
[g]WIAT-III – Wechsler Individual Achievement Test 3rd Edition (Wechsler, 2009).
[h]CELF-5 – Clinical Evaluation of Language Fundamentals 5th Edition (Wiig et al., 2017).

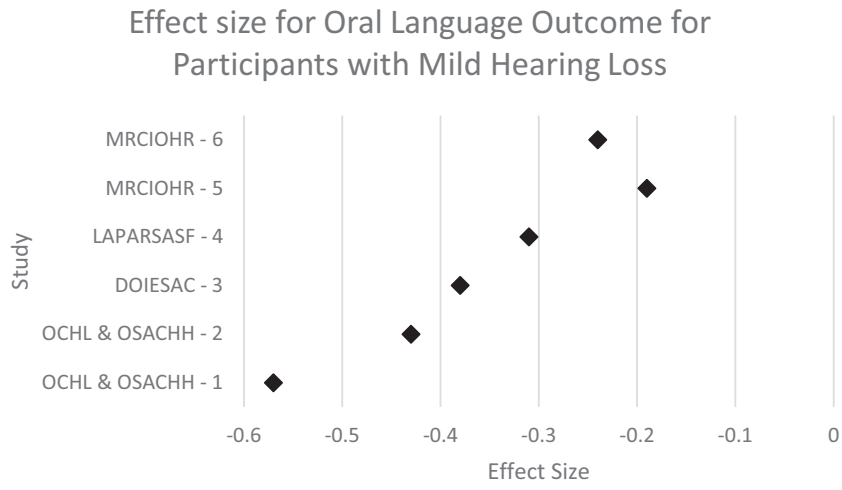


**FIGURE 2** Effect size for Oral Language Outcome for Participants with Mild Hearing Loss. 1: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), PLAI-2, CELF-4, PPVT-4. 2: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), WJ III, CELF. 3: Developmental outcomes in early school-age children with minimal hearing loss, TACL-3. 4: Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss, CELF-4. 5: MRC Institute of Hearing Research, NEPSY, mild HL. 6: MRC Institute of Hearing Research, NEPSY, slight HL.

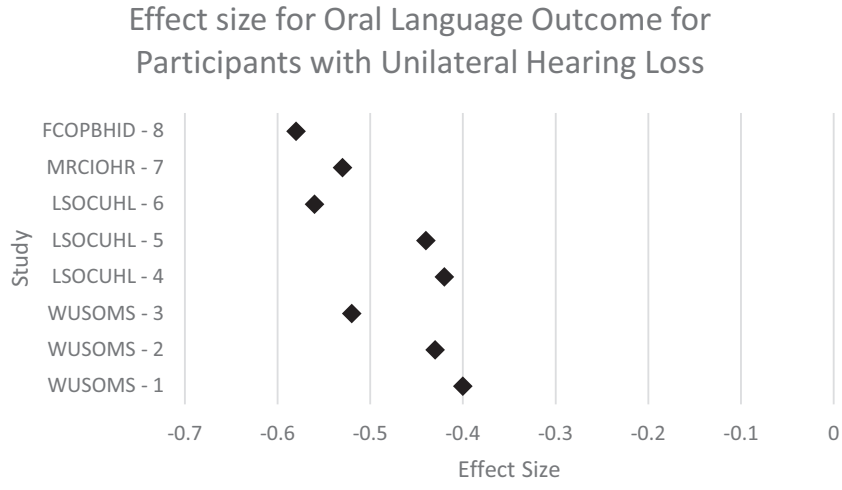


**FIGURE 3** Effect size for Oral Language Outcome for Participants with Unilateral Hearing Loss. 1: Washington University School of Medicine study, OWLS. 2: Washington University School of Medicine study, OWLS. 3: Washington University School of Medicine study, OWLS. 4: Longitudinal study of children with unilateral hearing loss, OWLS. 5: Longitudinal study of children with unilateral hearing loss, OWLS. 6: Longitudinal study of children with unilateral hearing loss, OWLS. 7: MRC Institute of Hearing Research, NEPSY. 8: Functional Consequences of Poor Binaural Hearing in Development, CELF-5.

## Maths

Figures 6 and 7 illustrate the effect sizes for the maths outcome for participants with mild and unilateral hearing loss, respectively. These figures highlight that the majority of the combined measures (83%) showed a negative effect size, meaning that the participants with mild or

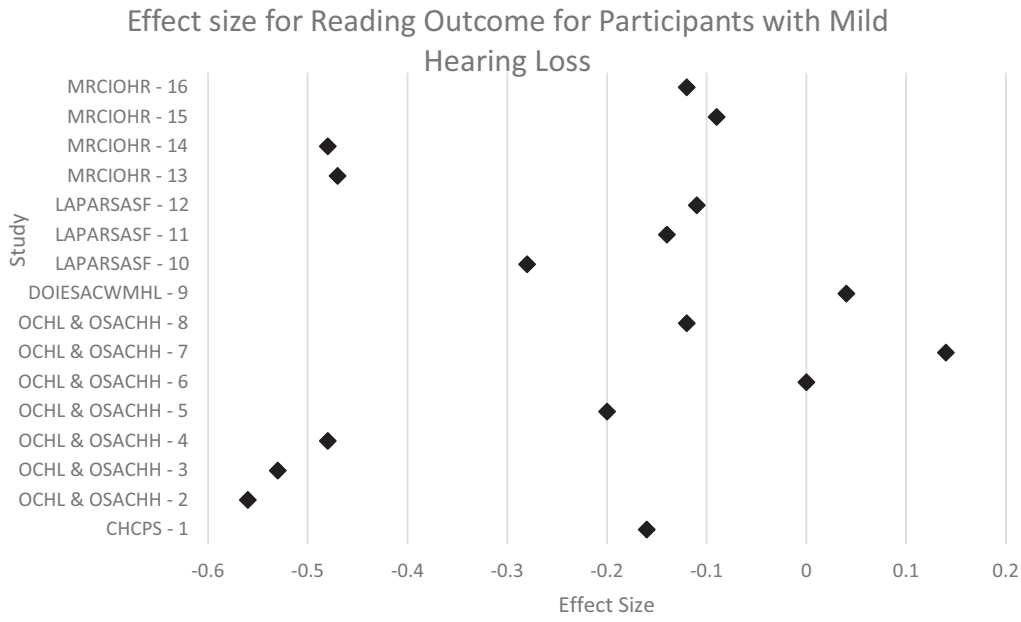


**FIGURE 4** Effect size for Reading Outcome for Participants with Mild Hearing Loss. 1: Child Health Check Point Study within the Longitudinal Study of Australian Children, NAPLAN, Reading. 2: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), WJ III, Reading decoding. 3: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), GORT-5, Reading comprehension. 4: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), GORT-5, Reading fluency. 5: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), GORT-5, Reading comprehension. 6: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), GORT-5, Reading fluency. 7: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), WJ III, Reading decoding. 8: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), GORT-5, Reading. 9: Developmental outcomes in early school-age children with minimal hearing, WRMT, Reading. 10: Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss, WRMT III, Reading basic skills. 11: Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss, WRMT III, Reading comprehension. 12: Language Abilities, Phonological Awareness, Reading Skills, and Subjective Fatigue in School-Age Children with Mild to Moderate Hearing Loss, WRMT III, Reading overall. 13: MRC Institute of Hearing Research, TOWRE, Reading pseudowords, Mild HL. 14: MRC Institute of Hearing Research, TOWRE, Reading words, Mild HL. 15: MRC Institute of Hearing Research, TOWRE, Reading pseudowords, Unilateral HL. 16: MRC Institute of Hearing Research, TOWRE, Reading words, Unilateral HL.

unilateral hearing loss experienced lower scores in this outcome compared to their typically hearing peers. However, the number of studies that reported maths outcomes was very low (two measures for MBHL and four measures for UHL). The effect sizes for this outcome ranged from −0.12 to −0.02 for mild hearing loss and −0.35 to 0.24 for unilateral hearing loss.

## Writing

Figures 8 and 9 illustrate the effect sizes for the writing outcome for participants with mild and unilateral hearing loss, respectively. These figures show that most of the measures (80%) gave a negative effect size, meaning that participants with mild or unilateral hearing loss experienced lower scores in these assessments compared to their typically hearing

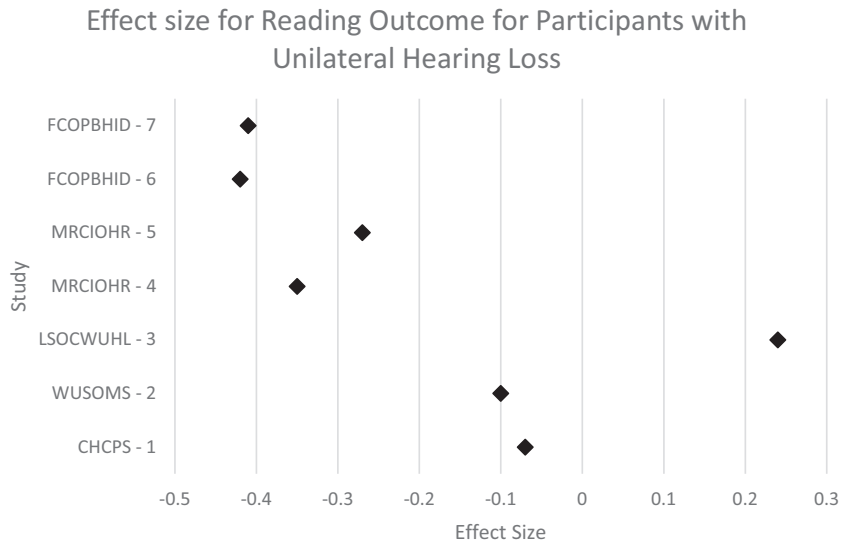


**FIGURE 5** Effect size for Reading Outcome for Participants with Unilateral Hearing Loss. 1: Child Health Check Point Study within the Longitudinal Study of Australian Children, NAPLAN, Reading. 2: Washington University School of Medicine study, WIAT-II-A, Reading. 3: Longitudinal study of children with unilateral hearing loss, WIAT-II-A, Reading. 4: MRC Institute of Hearing Research, TOWRE, Reading words. 5: MRC Institute of Hearing Research, TOWRE, Reading pseudowords. 6: Functional Consequences of Poor Binaural Hearing in Development, WIAT-III, Reading words. 7: Functional Consequences of Poor Binaural Hearing in Development, WIAT-III, Reading pseudowords.

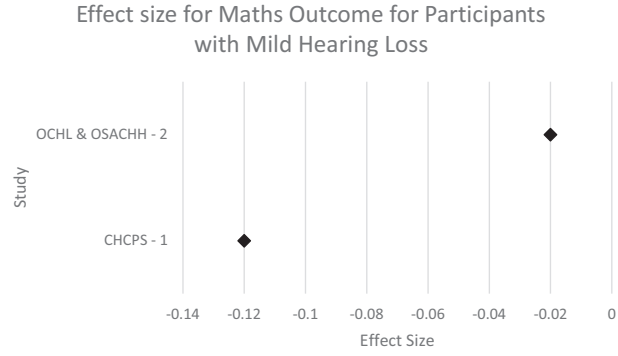


**FIGURE 6** Effect size for Maths Outcome for Participants with Mild Hearing Loss. 1: Child Health Check Point Study within the Longitudinal Study of Australian Children, NAPLAN. 2: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), WJ III.

peers in most measures. However, the number of measures that reported writing outcomes was again very low (two measures for MBHL and three measures for UHL). The effect sizes for the available measures ranged from −0.08 to −0.04 for mild hearing loss and −0.13 to 0.24 for unilateral hearing loss.

## Other academic measures

A range of other academic outcomes were assessed as part of the included studies, including vocabulary and spelling. Figures 10 and 11 illustrate the effect sizes for

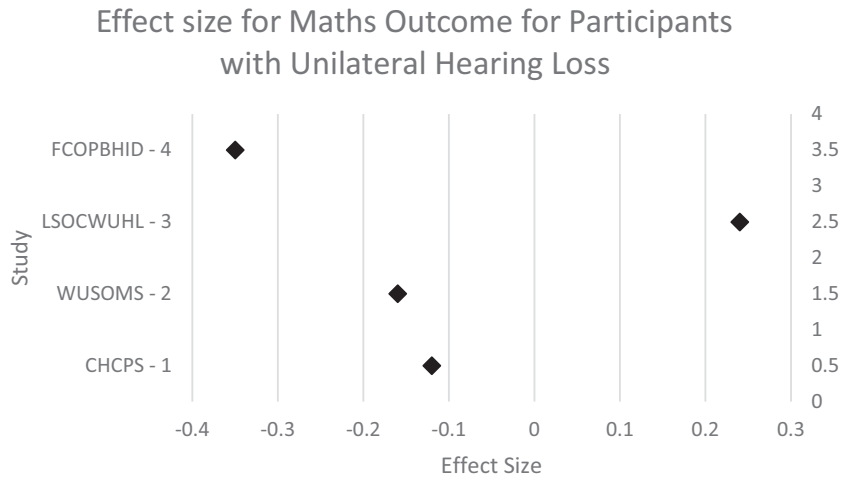


**FIGURE 7** Effect size for Maths Outcome for Participants with Unilateral Hearing Loss. 1: Child Health Check Point Study within the Longitudinal Study of Australian Children, NAPLAN. 2: Washington University School of Medicine study, WIAT-II-A. 3: Longitudinal study of children with unilateral hearing loss, WIAT-II-A. 4: Functional Consequences of Poor Binaural Hearing in Development, WIAT-III.

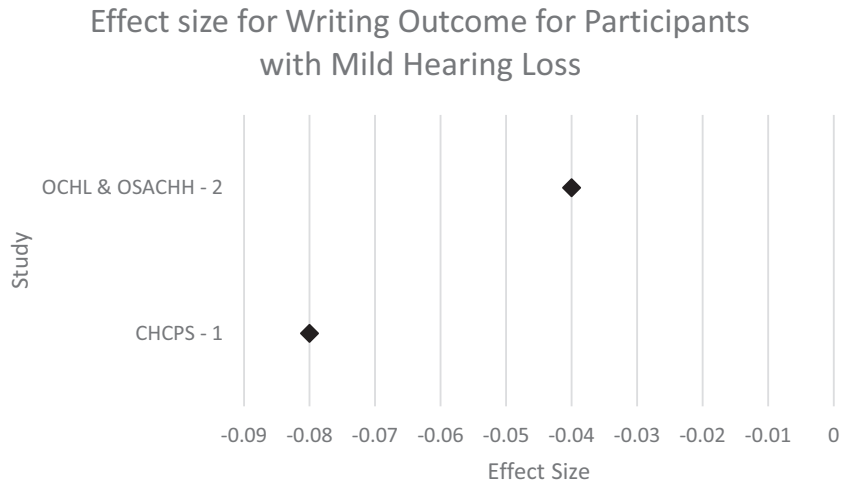


**FIGURE 8** Effect size for Writing Outcome for Participants with Mild Hearing Loss. 1: Child Health Check Point Study within the Longitudinal Study of Australian Children, NAPLAN. 2: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), WJ III.

these other academic outcomes for participants with mild and unilateral hearing loss, respectively. These figures show that all of the measures had a negative effect size, meaning that the participants with mild or unilateral hearing loss experienced lower scores in all of these assessments compared to their typically hearing peers. The effect sizes for the available studies ranged from −0.14 to −0.56 for MBHL and −0.06 to −0.11 for UHL.

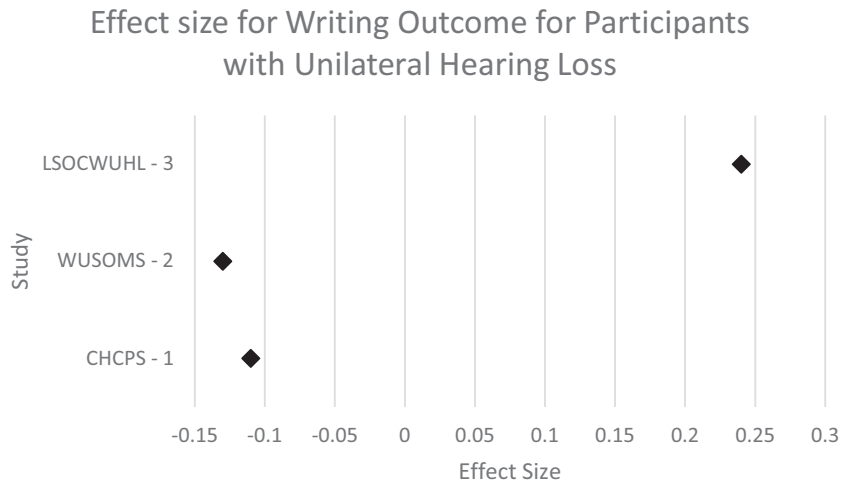


**FIGURE 9** Effect size for Writing Outcome for Participants with Unilateral Hearing Loss. 1: Child Health Check Point Study within the Longitudinal Study of Australian Children, NAPLAN. 2: Washington University School of Medicine study, WIAT-II-A. 3: Longitudinal study of children with unilateral hearing loss, WIAT-II-A.

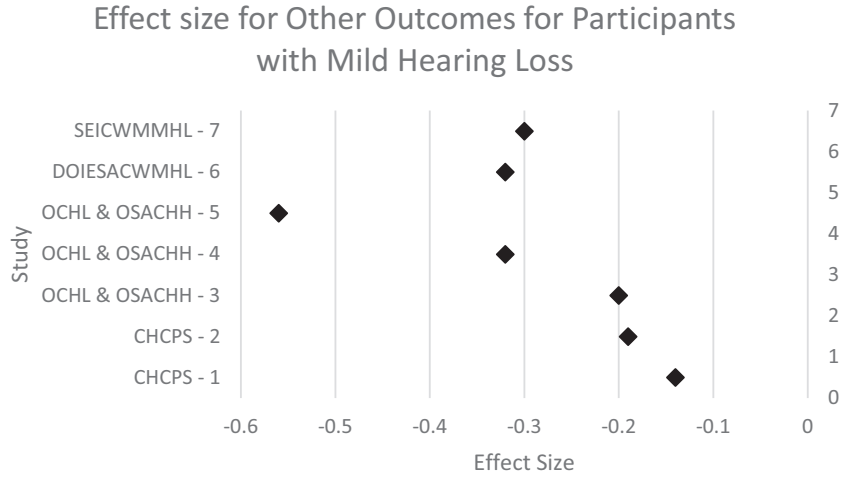


**FIGURE 10** Effect size for Other Academic Outcomes for Participants with Mild Hearing Loss. 1: Child Health Check Point Study within the Longitudinal Study of Australian Children, NAPLAN, Vocabulary. 2: Child Health Check Point Study within the Longitudinal Study of Australian Children, CELF, Sentence repetition. 3: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), WJ III, Spelling. 4: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), WJ III, Vocabulary. 5: Outcomes of Children with Hearing Loss (OCHL) And Outcomes of School-Age Children who are Hard of Hearing (OSACHH), WJ III, Understanding directions. 6: Developmental outcomes in early school-age children with minimal hearing loss, PPVT-3, Vocabulary. 7: Spelling Errors in Children with Mild to Moderate Hearing Loss, TWS-4, Spelling.

## DISCUSSION

This study set out to determine whether academic achievement is associated with hearing impairment for children of primary school-age with unilateral or mild bilateral hearing loss in comparison to their peers with full hearing. A literature search of three large databases from 2006 to 2024 yielded 12 reports covering nine studies that matched the inclusion criteria.

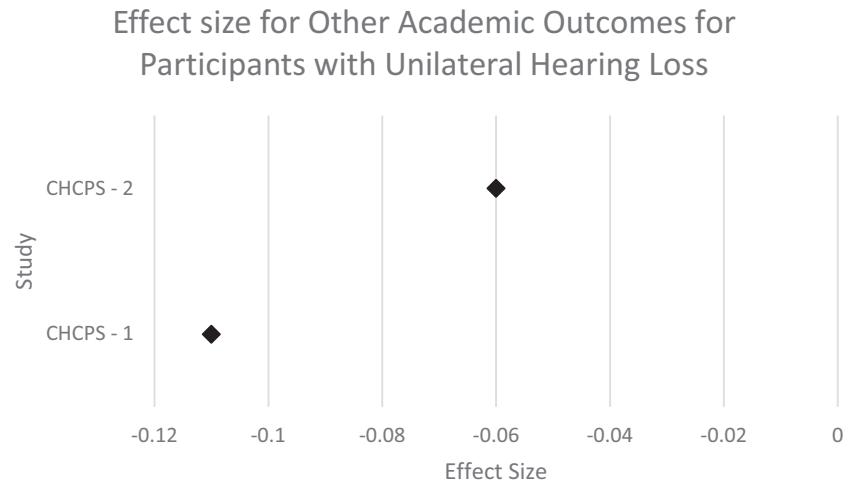


**FIGURE 11** Effect size for Other Academic Outcomes for Participants with Unilateral Hearing Loss. 1: Child Health Check Point Study within the Longitudinal Study of Australian Children, NAPLAN, Vocabulary. 2: Child Health Check Point Study within the Longitudinal Study of Australian Children, CELF-4, Sentence repetition.

**TABLE 8** Percentage of all effect sizes that were negative and substantially important for each outcome and each hearing loss level.

| % | Oral language | Reading | Maths | Writing | Other academic achievement | Overall |
|---|---|---|---|---|---|---|
| Mild | 67 | 38 | 0 | 0 | 57 | 42 |
| Unilateral | 100 | 57 | 25 | 0 | 0 | 54 |
| Overall | 86 | 43 | 17 | 0 | 44 | 47 |

Within these studies, the outcomes of oral language, reading, maths, writing and other academic outcomes were considered. Cohen's *d* effect sizes were calculated to answer the research question through determining whether an association existed between the described hearing loss to robustly answer the research question.

Across all the studies, and for both mild and unilateral HL, the majority of effect sizes were negative, meaning that children with mild and unilateral hearing loss achieved lower mean scores in the assessments compared to their fully hearing peers for the majority of measures. Of the 57 effect sizes measured, 51 were negative, with similar ratios being experienced for both UHL and MBHL measures; 30 out of 33 effect sizes relating to MBHL were negative, compared with 21 out of 24 effect sizes relating to UHL. Of the 51 negative effect sizes, 27 were substantially important, defined here by an effect size of at least 0.25 (WWC, 2017). None of the positive effect sizes were substantially important.

Table 8 shows the percentage of the total effect sizes for all measures that were both negative and substantially important, disaggregated by outcome and hearing level. The results show that for primary school-age students with unilateral hearing loss, negative effect sizes that were substantially important were calculated in all measures relating to oral language, with over half of the measures relating to reading (57%) and a quarter of the measures relating to maths (25%). For children of primary school-age with mild bilateral hearing loss, it was found that two-thirds of measures relating to oral language (67%), over half of measures relating to other academic achievement (57%) and a little over one third of measures relating

to reading (38%) had negative effect sizes that were substantially important. In writing, neither group experienced any substantially important effect sizes.

The outcome with the highest percentage of effect sizes that were negative and substantially important for both MBHL and UHL was oral language. All measures for UHL and 67% of measures for MBHL were shown to have a substantially important negative effect size for this outcome. Research has identified oral language as a foundational skill in the development of reading (Kendeou et al., 2009; NICHD_Early_Child_Care_Research_Network, 2005). The development of oral language is also important for early school performance, with research showing that poor oral language is associated with reduced academic achievement (Catts et al., 2008; NICHD_Early_Child_Care_Research_Network, 2005). This reduced language development may be caused by a reduction in both the quantity and quality of the auditory signals being received by the affected ears (Lieu et al. (2013)).

The mechanisms that result in UHL and MBHL being associated with reduced academic achievement are not clear. It has been hypothesised that the affected individuals are required to expend additional listening effort, draining cognitive resources (Hornsby et al., 2017). This affects both children with UHL (Bess et al., 2020) and those with mild to moderate bilateral HL (Hornsby et al., 2017). Individuals with UHL could also be experiencing impaired localisation of sound, and therefore be required to work harder to locate the sound instead of focusing on language comprehension (Snapp & Ausili, 2020). Further, background noise may reduce incidental learning through inhibiting heard speech and thereby impairing language development (Lieu et al. (2013)). Children with UHL and MBHL are usually taught in conventional, oral classrooms (Porter et al., 2016). Studies have shown that these typical classrooms can have high noise levels during lessons of 70.1 dB (Kapetanaki et al., 2018), with poor acoustics (Sala & Rantala, 2016), which may further impact learning for students with hearing loss.

## EVALUATION

Through using a systematic review, which offers a methodical, transparent, and reproducible design (Petticrew & Roberts, 2008), the research question was answered robustly and reliably. Systematic reviews are able to search existing studies methodically, evaluate them critically and then summarise and synthesise the extracted data to offer defensible findings (Gopalakrishnan & Ganeshkumar, 2013), making this 'scientific tool' (Petticrew & Roberts, 2008, p. 10) an effective method for responding to the correlation question. The protocol for the study was well defined and pre-registered, including pre-defined inclusion and exclusion criteria, search terms and quality assessment criteria. These were used to undertake an exhaustive search of the literature using three large databases, with data being extracted from all of the included studies. Conclusions were drawn objectively, based on the full set of extracted data (Chandler & Hopewell, 2013; Higgins et al., 2024). The selected design is therefore considered optimal for robustly answering the research question using the currently available research data. This study achieved a systematic, robust and repeatable review of the existing knowledge regarding whether academic achievement is associated with hearing impairment for children of primary school-age with unilateral or mild bilateral hearing loss in comparison to their peers with full hearing. However, limitations exist within this study.

The study identified that, while many studies consider the association between hearing loss and academic achievement, few focused on mild or unilateral hearing loss, or disaggregate the results to allow this analysis to take place. The number of relevant studies that met the inclusion criteria was relatively small, at nine studies. Also, less than five measures were

identified for each hearing loss level for the maths, writing and other academic achievement (for UHL) outcomes (Tables 6 and 7).

Of the nine studies that satisfied the inclusion criteria, the protocols used—and the outcomes assessed—varied significantly. For example, while two studies included an assessment of the prevalence of MBHL or UHL (Moore et al., 2020; Wang et al., 2019), the remainder based their analysis on recruits from hearing clinics or similar, where the children had already been identified as hearing-impaired. However, not all children with MBHL or UHL may have been identified or diagnosed, as children that are struggling may be more likely to seek support (Wang et al., 2019). Therefore, the lower degrees of hearing loss may not be fully represented in such studies. Further, as described in Table 5, four of the included studies carried out assessments while participants wore their usual hearing aids (if any) (Camarata et al., 2018; Lieu et al. (2013); Lieu et al., 2012; Porter et al., 2013; Rohlfs et al., 2017) while two studies asked participants to remove any aids (McSweeny et al., 2021; Wang et al., 2019). One study carried out assessments both aided and unaided (Tomblin, Oleson, Ambrose, Walker, McCreery, and Moeller (2020); Tomblin, Oleson, Ambrose, Walker, and Moeller (2020); Walker et al., 2020), while two studies did not specify whether any hearing aids were used by participants (Moore et al., 2020; Reynolds et al., 2024). Also, the settings for the audiometry assessments were inconsistent. Although not reported for seven studies, one study carried out audiometry assessments in a classroom (Moore et al., 2020) while another used a sound-treated room (Porter et al., 2013). A meta-analysis was therefore considered unsuitable due to this heterogeneity (R. Ryan, 2016b).

The data offered by each included study was also not consistent. For example, the mean HL was available for only five reports (Camarata et al., 2018; Lieu et al. (2013); Reynolds et al., 2024; Walker et al., 2020; Wang et al., 2019). This limited the analysis that could be performed on the data.

Further, the definitions of MBHL and UHL used across the included studies encompasses a range of levels of hearing loss (Table 5). The extent to which this generates different outcomes across the range is not known. The inconsistency of these definitions also made comparisons of the data from the studies and analysis of the available data challenging. In addition, the hearing levels of the participants included within each of the studies varied. For example, within the UHL studies, participants ranged from a majority with mild UHL (Moore et al., 2020) to a majority of participants with profound UHL (Lieu et al., 2013). Therefore, the definitions of hearing loss used by each study and descriptions of the hearing levels of the participants were extracted and documented (Table 5).

A further limitation of this study is that only one researcher was involved in the screening of studies, the assessment of the trustworthiness of each included study and the extraction of data from the included studies. Ideally, two or more researchers would have independently carried out these activities, with any differences agreed through discussion. This limitation excluded this systematic review from registration with PROSPERO, which requires a minimum of two reviewers for inclusion in this platform (National_Institute_for_Health_Research, n.d.).

## IMPLICATIONS AND FUTURE WORK

The study aligns with the ethos of seeking to achieve inclusive education for all described by the UN Convention on the Rights of Persons with Disabilities (UN, 2006). Through understanding any association between unilateral and mild bilateral hearing loss and academic achievement for children of primary school-age compared to their peers with full hearing, policy makers and educators would be in a stronger position to support children with MBHL

and UHL and be aware of the challenges they face. This would benefit the hearing-impaired population group through having a support mechanism that is more aligned with their needs.

It would be useful to carry out a systematic review and, if appropriate, a meta-analysis, of the association between academic achievement and the full range of hearing losses, disaggregated by level. This would allow a consideration of the risks associated with MBHL and UHL as well as moderate, severe and profound HL, compared to students with full hearing. It would also be useful to assess and understand whether the provision of sound amplification technology or other support mechanisms reduces the impact of hearing loss on school performance, including whether an association exists between academic performance and age of diagnosis of hearing loss. It would further be beneficial to extend the range considered beyond primary school-age to understand whether affected students catch up over time.

It is recommended that the grades of hearing loss presented by WHO (2021) are adopted in future studies to address the encountered issues of heterogeneity. WHO proposes that normal hearing levels reach up to 20 dB, with mild hearing loss extending from 20 to <35 dB. All measurements are in the better ear and are assessed using headphones in a quiet environment. Unilateral hearing loss is further stated as <20 dB in the better ear with 35 dB or greater in the worse ear (WHO, 2021, p. 38). Carrying out hearing assessments in line with these thresholds, without hearing aids but using headphones in a quiet environment, would further reduce the heterogeneity of studies. The use of standardised academic measures and large sample sizes with clear definitions of children selected for the studies would also enhance the homogeneity of included studies.

To achieve a best practice approach to the teaching and supporting of students with MBHL and UHL, it would also be advantageous to understand how these students are taught globally with an assessment of the effectiveness of the different support mechanisms adopted. Consideration of the association between degrees of hearing loss and social and emotional development and well-being is also proposed as something to focus on in the future, due to the range of challenges experienced by young people with hearing loss.

## CONCLUSION

This systematic review has examined existing literature to understand whether academic achievement is associated with hearing impairment for children of primary school-age with unilateral or mild bilateral hearing loss in comparison to their peers with full hearing. However, a meta-analysis was not considered appropriate due to the heterogeneity of the protocols from the included studies. Across the nine included studies, the majority of effect sizes were negative for both unilateral and mild bilateral hearing loss, indicating an overall negative association between academic performance and hearing impairment for children of primary school-age with unilateral or mild bilateral hearing impairment compared to their peers with full hearing. This indicates that children with mild and unilateral hearing loss achieved lower mean scores in the majority of assessments compared to their fully hearing peers. Of the 57 effect sizes measured, 51 were negative, with similar ratios being observed for both unilateral and mild bilateral hearing loss. Of the 51 negative effect sizes, 27 were substantially important with an absolute effect size of at least 0.25. None of the positive effect sizes were substantially important.

The review also considered the five outcomes: oral language, reading, maths, writing and other academic outcomes. A substantially important negative association between oral language and hearing loss was identified for all UHL measures and the majority of MBHL measures (67%). For the other outcomes (reading, maths, writing and other academic achievements), most of the results indicated negative associations with hearing loss for both

UHL and MBHL. However, only some (0–57%) of the negative effect sizes for each of these outcomes were substantially important.

This analysis is based on a limited number of relatively small, heterogeneous studies. To fully understand the association between MBHL and UHL and academic achievement, more comprehensive studies that explore the association between academic performance and these population groups would be a valuable addition to the existing body of literature.

## AUTHOR CONTRIBUTIONS

**Katherine Collier:** Writing – review and editing; writing – original draft; formal analysis; conceptualization; data curation; methodology; project administration.

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## CONFLICT OF INTEREST STATEMENT

The author has no conflicts of interest to declare.

## DATA AVAILABILITY STATEMENT

The supporting research data are published in the Durham University research data repository. DOI: http://doi.org/10.15128/r273666454s

## ETHICS STATEMENT

Ethical approval for the study was gained from Durham University prior to commencing any work relating to this research. The University's ethics procedure was followed throughout the study.

## ORCID

*Katherine Collier* https://orcid.org/0009-0005-7482-8876

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