Review Article

The Effect of Sign Language on the Development of Language of Deaf and Hard-of-Hearing Children: Systematic Review

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Abstract

Objectives: To systematically review and evaluate the evidence regarding the effect of sign language on language development in deaf and hard-of-hearing children.

Method: A comprehensive search of electronic databases, including PubMed/MEDLINE, Web of Science, Scopus, EMBASE, Scholar Google, and ProQuest from 1995 until April 2024., with no language restrictions, was conducted. The two authors independently assessed the risk of bias using the Newcastle-Ottawa Scale.

Results: Six studies involving 259 participants found that sign language exposure benefits language development in deaf children with hearing aids/cochlear implants. Children exposed to sign language showed similar or even better-spoken language skills than those with limited sign language exposure. Encouraging parents to learn sign language can significantly support deaf children's communication and language development.

Conclusion: Deaf children with cochlear implants benefit most from a communication approach tailored to their needs. Early intervention, parental involvement, and a rich language environment (signed or spoken) are key. While sign language exposure shows promise, more

research is needed, especially on its long-term effects and use by hearing parents. PROSPERO registration ID: CRD42023402357
Keywords: Deaf, Hard of hearing, Language, Sign language, Systematic review

Introduction

Language development is a fundamental aspect of human communication and cognitive development, serving as the cornerstone for academic achievement, social interaction, and emotional well-being (1,2). deaf and hard-of-hearing children's journey towards linguistic proficiency often presents unique challenges as they navigate a world predominantly shaped by spoken language. Unfortunately, existing research highlights that one of the main challenges of newborn hearing screening programs is achieving timely language acquisition skills (1). Historically, two communication styles have been proposed in intervention programs for language and speech development: (a) auditory-oral, which emphasizes spoken language and peer interaction with hearing individuals, and (b) visual approach, which utilizes lipreading, sign language, and fosters Deaf culture (2). Given that over 90% of parents with hearing-impaired children are hearing themselves, rehabilitation specialists and parents often opt for spoken language and the auditory-oral approach (3). However, a crucial question arises: how can a child facing hearing difficulties effectively learn their native language from birth, relying solely on an auditory approach? While modern hearing aid technology and cochlear implant advancements have significantly improved spoken language abilities for children with severe and profound hearing loss (1,4), these technologies still fail to bridge the gap in language development before the age of one. Additionally, harmful misconceptions persist in society that hearing aids "cure" hearing loss, leading to delayed intervention during these crucial early months (5).

research demonstrates that sign languages with established grammatical rules are processed in the brain similarly to spoken languages, indicating their potential to complement each other (6,7). One study showed that children's use of signs and gestures does not negatively impact spoken language acquisition. In fact, learning and using sign language facilitates spoken language acquisition and promotes the development of appropriate thought and reasoning patterns in hearing-impaired children (8). Therefore, the American Academy of Pediatrics has concluded that sign language is a powerful tool for improving communication in young hearing-impaired children (9).

In this context, the significance of providing early exposure to sign language becomes evident as a critical intervention designed to alleviate potential linguistic and developmental disparities experienced by this vulnerable group. Unlike their typically developing peers, deaf and hard-of-hearing children encounter barriers to acquiring language naturally through auditory input. The absence of spoken language access can lead to language acquisition delays and subsequent cognitive, social, and emotional challenges (10,11). Natural sign language input does not harm and may mitigate the adverse effects of early auditory deprivation on spoken language development (12) and is essential for deaf children to develop a strong sense of identity and to participate fully in society (13). Early sign language exposure is vital for all children, regardless of their hearing status, and improved language development, enhanced cognitive development, and more vigorous social-emotional development (14).

Despite the growing recognition of the importance of early sign language exposure, the field is not without its knowledge gaps. It is essential to determine the most effective timing and intensity of early sign language exposure for different hearing-impaired populations; comparative studies are needed to assess the effectiveness of early sign language exposure

compared to other communication interventions. Limited research has examined the long-term effects of early sign language exposure on hearing-impaired children's language development, and research should explore how cultural and linguistic factors influence the effectiveness of early sign language exposure and the development of sign languages tailored to specific communities. The findings of a systematic review suggest that early sign language exposure may positively impact language development. Still, more research is needed to confirm this and identify the optimal age and intensity of sign language exposure (15).

In response to these limitations, this systematic review aims to comprehensively synthesize the existing literature on sign language and the impact of early exposure on language development in deaf and hard-of-hearing children, assess potential heterogeneity, and find its possible causes.

Methods

The protocol of the present study was registered in the International Prospective Register of Systematic Reviews (PROSPERO) with identification number CRD42023402357. There were two protocol amendments. First, considering the extended review time, we broadened the literature search to include publications up to April 2024. Second, due to insufficient information in the existing literature on the mental health assessment of sign language users, we decided to eliminate this section from our review.

Search Strategy

We employed a systematic and rigorous search strategy to identify related studies, ensuring a comprehensive literature review. This search was conducted across multiple electronic databases, including PubMed/MEDLINE, Web of Science, Scopus, EMBASE, and Scholar Google from 1995 until April 2024., with no restrictions placed on language. We translated non-English papers using Google Translate. Additionally, grey literature, including ProQuest for related theses/dissertations, Scopus and Web of Science for conference papers, and a reference list of primary studies, will be searched, and hand searching will be done for the last 6 months' publications from the Journal of Deaf Studies and Deaf Education and Frontiers in Psychology. (Supplementary file 1)

Search Terms and Keywords

The search strategy was developed using a combination of Medical Subject Headings (MeSH) terms and keywords, and we used expert opinions and previous primary and secondary studies. The following key terms and their variations were used:

- ("Sign Language" OR "Deaf Sign Language" OR "Sign Communication" OR "Manual Communication")
- ("Language Development" OR "Language Acquisition" OR "Language Skills" OR "Communication Development")
- ("Language test " OR " speech intelligibility")

Inclusion and Exclusion Criteria

Studies were included in this systematic review if they met the following criteria:

1. **Population**: Studies involving deaf and hard of hearing children (infants, children, or adolescents) aged 0-18 years old, with varying degrees of hearing loss, including those with cochlear implants or hearing aids that receive early auditory intervention before 5 years old. Both sexes were included.

2. **Intervention/Exposure:** Studies that investigated early sign language exposure, defined as exposure to sign language before or during early childhood (before 5 years old), and explored its impact on language development.
1. **Comparison/control group**: Studies were included if the comparator was other communication methods, such as auditory-oral, auditory-verbal, or late sign language exposure.
2. **Outcome Measures**: Studies that assessed language development outcomes in deaf and hard-of-hearing children, including receptive and expressive language skills, vocabulary, syntax, and literacy.
3. **Study Design**: All observational-analytical designs, including cross-sectional, case-control, and prospective and retrospective cohorts.

Exclusion criteria included studies that did not focus on deaf and hard-of-hearing children, studies exclusively involving adults, studies without a clear definition of sign language, and studies that did not investigate the effect of early sign language exposure on language development.

Study Selection

The results were saved in Mendeley 1.19.4, and duplicates were removed. One researcher initially screened titles and abstracts based on the predefined inclusion and exclusion criteria. Two reviewers assessed full-text articles of potentially eligible studies independently for final inclusion. Any disagreements between reviewers were resolved through discussion and, if necessary, consultation with a third reviewer.

Data Extraction

A standardized data extraction form was developed to collect relevant information from the selected studies. When the data was extracted, it included information about the study (its authors, year, and setup), the participants (their age and hearing loss severity), how they learned sign language, how it was used, the results, and the most crucial language development findings.

Quality Assessment

The two authors independently assessed the quality of the included studies using the Newcastle-Ottawa Scale (NOS). Any disagreements between reviewers were resolved through discussion and, if necessary, consultation with a third reviewer.

Data Synthesis

The data synthesis process involved a narrative approach, as meta-analysis was not deemed appropriate due to expected heterogeneity among included studies. The results of several studies were combined and grouped by topic to give a full picture of sign language and how it affects the language development of hearing-impaired children.

Results

Study Selection

Our comprehensive search of relevant databases yielded 4832 potentially relevant articles. After initial screening for duplicates and reviewing titles and abstracts, 4650 articles were excluded as they did not meet the inclusion criteria. The remaining 68 articles underwent a full-text review. Six studies met the eligibility criteria and were included in this systematic review. (Figure 1)

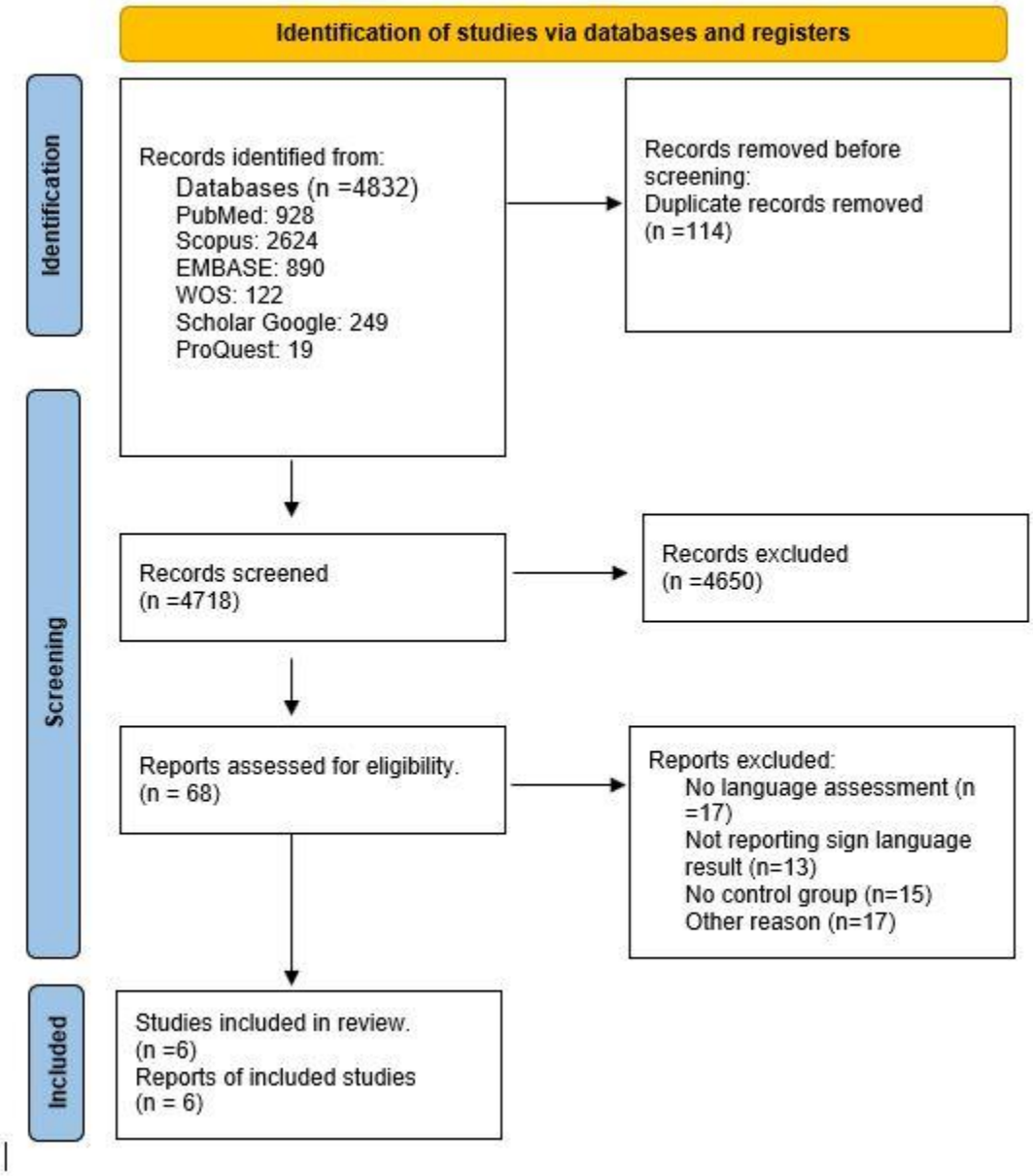

Figure 1: PRISMA flowchart

Characteristics of Included Studies

A summary of the included studies and their characteristics is provided in Table 1.

Table 1: study characteristics.

Author, year	Study type	Sample size	Participant age (y)	CI age (y)	Sign language group	Comparison group	Speech perception test	Language development tests

Delcenserie et al., 2024 [17]	Cross-section	40	5-7	2.5 -5	typically developing hearing	typically developing hearing	-	1: The Expressive One-Word Picture Vocabulary Test for expressive language 2: e Échelle de Vocabulaire en Image Peabody for Receptive vocabulary 3: Several subtests of the Clinical Evaluation of Language Fundamentals for French-speaking Canadian

Geers et al., 2017 [15]	Retrospective cohort	97	-	3	1: short-term sign 2: long-term sign	1: no sign	1: The Speech Recognition Index in Quiet 2: Early Speech Perception Test 3: Pediatric Speech Intelligibility Test 4: lexical neighborhood Test 5: Phonetically Balanced Word Lists-Kindergarten, 6: Hearing in Noise Test for Children.	1: the Core Composite standardized score on the Comprehensive Assessment of Spoken Language
Marshall et al., 2015 [20]	Cross-section	27	6-11	-	1: Native signer (sign language used from birth) 2: non-native signer (sign language use later than 2 years)	Normal hearing of the same age	-	1: Expressive One-Word Picture Vocabulary Test 2: The British Sign Language Narrative Production Test 3: The Language Proficiency Profile-2

Yanbay et al., 2014 [19]	Retrospective cohort	42	6-12	Before 4	Sign and spoken language	1: Auditoría oral 2: Auditory verbal therapy	-	1: Peabody Picture Vocabulary Test 2: Preschool Language Scale
Dettman et al., 2012 [21]	Retrospective cohort	39	5	bilingual—bicultural	bilingual—bicultural	1: aural-oral 2: auditory verbal	-	1: Peabody Picture Vocabulary Test 2: consonant-nucleus-consonant word test 3: Bamford-Kowal-Bench sentences test
Hassanzadeh, 2012 [16]	Retrospective cohort	14	8	1.5-5	Deaf children with deaf parents (sign language users)	Deaf children with hearing parents (not sign language users)	Persian Auditory Perception Test for the Hearing Impaired	Sentence Imitation Test

Study Design
All the studies in this review were cohort studies except for one, a cross-sectional study.

Participant Characteristics
The studies involved 259 deaf and hard-of-hearing children, with ages ranging from 5 to 12. The sample size in individual studies varied, with the largest study comprising 97 participants (16), while the smallest had 14 participants (17).

Outcomes Assessed regarding Language and Speech
This review examines research on how sign language exposure affects language development in deaf children with cochlear implants. Some studies focused on spoken language skills, while others looked at overall language development.

Studies showing benefits of sign language

Delcenserie et al. employed a combination of assessments, including the French adaptation of the Expressive One-Word Picture Vocabulary Test (EOWPVT) and the Échelle de Vocabulaire en Image Peabody, to find no significant difference in spoken language abilities between deaf children with CIs exposed to sign language (including a short period post-implantation) and typically-hearing children (18).
S. Hassanzadeh utilized the Persian Auditory Perception Test for the Hearing Impaired, Speech Intelligibility Rating scale, and Sentence Imitation Test to show that second-generation deaf children (exposed to sign language from birth) outperformed those with hearing parents in cochlear implant performance (17). These findings suggest early sign language exposure might aid spoken language development after implantation.

Studies with mixed results

Geers et al. assessed speech perception using the Speech Recognition Index in Quiet and speech intelligibility through recorded sentences transcribed by adults. Their study with the Comprehensive Assessment of Spoken Language and Woodcock-Johnson III Tests of Achievement reported poorer speech outcomes in children with CIs exposed to sign language (16). However, limitations exist as noted by Hall et al. (19).

Studies with neutral findings

Yanbay et al. assessed language development using post-implant standard scores for receptive vocabulary, auditory comprehension, and expressive communication. Language tests, such as the Peabody Picture Vocabulary Test (PPVT) and the fourth edition of the Preschool Language Scale (PLS-4), showed that language scores were not significantly different between three communication programs: spoken language, sign language, and auditory verbal therapy. This suggests all programs can be effective (20).

Studies with no adverse effects of sign language exposure

Marshall et al. evaluated speech perception and language skills using the EOWPVT and Language Proficiency Profile-2 (LPP-2). Additionally, they employed British Sign Language (BSL) narrative tasks. Their findings showed lower scores on spoken language tests for deaf children who preferred sign language (using sign-supported English or spoken English alongside BSL) than for native sign language users and hearing children. However, these children scored higher on sign language tasks (21).
Dettman et al. investigated speech perception with the Early Speech Perception (ESP) test and receptive vocabulary with the Peabody Picture Vocabulary Test (PPVT). They said that programs that focus on developing listening and spoken language (Auditory-Verbal (AV) and Auditory-Oral (AO)) might be better for language skills and speech perception than programs that focus on sign language or a bilingual-bicultural approach (Bimodal-Bilingual (BB)). However, communication mode wasn't a significant predictor when controlling for other factors (22).

Importance of sign language

The weight of evidence suggests exposure to sign language benefits deaf children with CIs on spoken language measures. Studies by Delcenserie et al. and Hassanzadeh further highlight potential advantages for cochlear implant performance. While Geers et al. reported associations with poorer speech outcomes, limitations in their design require consideration. Research by

Marshall et al. and Dettman et al. demonstrates no adverse effects of sign language exposure on spoken language development. Notably, Marshall et al. found that deaf children who preferred sign language excelled in sign language tasks. Yanbay et al.'s study adds another layer by showing no significant differences in language development across various communication programs, suggesting all approaches can be practical.

Overall, these studies underscore the importance of sign language for deaf children. Sign language is a natural and effective communication tool, especially for Deaf children, that supports language development, even with non-native exposure from hearing parents, as suggested by Hassanzadeh. These results challenge policies that discourage sign language use with deaf children. Encouraging and supporting parents in learning sign language and providing resources for access to native speakers can significantly benefit deaf children. Evidence indicates that exposure to sign language is beneficial for deaf children with cochlear implants (CIs) in terms of spoken language outcomes. Research by Delcenserie et al. and Hassanzadeh highlights potential advantages regarding cochlear implant performance. Although Geers et al. reported correlations with poorer speech outcomes, the design limitations of their study warrant careful consideration. Studies conducted by Marshall et al. and Dettman et al. reveal no adverse effects of sign language exposure on the development of spoken language. Notably, Marshall et al. found that deaf children who preferred sign language excelled in sign language tasks. Furthermore, Yanbay et al.'s research indicates no significant differences in language development across various communication programs, suggesting that all approaches can be effective.

Overall, these studies emphasize the importance of sign language for deaf children. It serves as a natural and effective communication tool that fosters language development, even when exposure comes from hearing parents who are not native signers, as highlighted by Hassanzadeh. These findings challenge policies that discourage the use of sign language with deaf children. Supporting and encouraging parents to learn sign language, along with providing access to resources and native speakers, can greatly enhance the development of deaf children.

Quality assessment

The quality assessment of the included studies was conducted using the Newcastle-Ottawa Scale. The tool assesses the risk of bias based on the following domains: selection of the study groups, comparability of the groups, and ascertainment of either the exposure or outcome of interest for cross-section or cohort studies, respectively. All six included studies were rated high quality based on the NOS score. (Table 2)

Table 2 (a): Quality assessment of cohort study using Newcastle-Ottawa Scale.

Author, year	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	outcome of interest was not present at start	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts	Total score	Overall rating
Geers et al.,	1	1	1	1	1	1	1	1	8	High quality

2017 [15]										
Yanbay et al., 2014 [19]	1	1	1	1	1	1	1	1	8	High quality
Dettman et al., 2012 [21]	1	1	1	1	1	1	1	1	8	High quality
Hassanzadeh, 2012 [16]	1	1	1	1	0	1	1	1	7	moderate-quality

Table 2 (b): Quality assessment of cross-section study using Newcastle-Ottawa Scale.

Author, year	Representativeness of the sample	Sample size	Non-respondents	Ascertainment of the exposure	Comparability	Assessment of the outcome	Statistical test	Total score	Overall rating
Delcenserie et al., 2024 [17]	1	1	1	2	1	2	1	9	High quality
Marsall et al., 2015[20]	1	1	0	2	1	2	1	8	High quality

Discussion

This review examined the impact of sign language exposure on language development in deaf and hard-of-hearing children. We analyzed six studies involving a total of 259 participants. It was found that the effects of learning sign language depend on a number of things, such as the type and amount of exposure (native vs. non-native, duration), the age of the children, their personal traits, the severity of their hearing loss, the format and quality of intervention and education programs, and how involved their families and communities are. These results are consistent with previous research, which emphasizes the diverse impacts of sign language exposure, whether positive, negative, or neutral. However, they contrast with studies that report more definitive or generalizable outcomes. This inconsistency may stem from several limitations, such as differences in study design, methodologies, and participant samples; inconsistent measurement tools; and difficulties in defining and assessing sign language exposure and its effects.

Communication Approaches for Deaf Children with Cochlear Implants

Cochlear implants (CIs) provide an encouraging technology for deaf children by enabling access to sound and the potential development of spoken language skills. However, determining the most effective communication approach to fully harness these benefits is an area of ongoing research and debate. This discussion delves into key findings and controversies related to communication strategies for deaf children who use CIs.

Early Intervention is Paramount

Multiple studies emphasize the critical role of early intervention for language development in deaf children, regardless of the chosen communication method (spoken or signed) (22,23). Delays in intervention can hinder language acquisition in both spoken and signed modalities.

Sign Language Exposure: Benefits and Considerations

Exposure to sign language, particularly from deaf parents, has been linked to improved language outcomes in deaf children with CIs (17,24–27). Potential advantages of sign language include: Sign language provides a robust communication system, fostering language development before cochlear implantation (18), which can then benefit spoken language acquisition after implantation. Sign language utilizes visual cues that may enhance spatial skills and complement auditory information received through CIs (17). Deaf parents who are native signers can instinctively adapt their communication to their child's needs, leading to a more effective learning environment (17,27).

The quality of sign language exposure is crucial. Studies like Lu et al. suggest that deaf parents who are native signers provide a more optimal environment compared to hearing parents who are still learning (27). While research highlights the benefits of sign language from deaf parents, more data is needed on the long-term effects of sign language exposure for deaf children with hearing parents (16).

research suggests that sign language exposure doesn't harm spoken language development in deaf children with cochlear implants. Increased brain activity in visual regions due to sign language use might not be linked to poor spoken language, and early language access, regardless of modality, seems crucial (28–31). Even bilingualism with sign language is unlikely to hinder spoken language acquisition (32), and hearing parents can learn sign language effectively (33,34). Sign language might even benefit spoken language through knowledge transfer or preventing language deprivation in early development, as shown in studies with deaf children who used sign language with deaf parents (35–43). However, more research is needed to explore the effects of hearing parents' use of sign language on their very young deaf children.

Communication Approaches: Beyond a Single Best Method

Studies by Dettman et al. suggest that various communication approaches, including AV, AO, and BB, can lead to success with CIs. AO and AV focus primarily on spoken language development. Research suggests they can be successful, but the age of implantation seems to be a more significant predictor of language outcomes (22). BB approach combines sign language with spoken language. While it shows promise, more data is needed, especially for children under 4 (20).

Ultimately, the choice of communication approach should be individualized based on the child's needs, family preferences, and cultural context (20,22). Regardless of the chosen method, providing a rich language environment, either spoken or signed, is crucial for optimal development (21).

Conclusion

No single "best" communication approach exists for all deaf and hard-of-hearing children with cochlear implants. Early intervention, parental involvement, and a rich language environment are crucial for optimal outcomes. While sign language exposure shows benefits, more research is needed, especially regarding long-term effects and use by hearing parents. Ultimately, a

collaborative approach that considers the child's needs, family preferences, cultural context, and the latest research findings is essential for success. This collaborative approach should involve parents, audiologists, speech-language pathologists, and educators working together to create a personalized communication plan that optimizes the child's language and communication development and overall well-being.

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Authors' Contributions:
T.F. contributed to the study's conceptualization and design, performed the literature search and data extraction, and drafted the manuscript. F.J. assessed the risk of bias and critically reviewed the manuscript. F.A. contributed to the data interpretation and conducted a critical examination. All authors approved the final version of the manuscript.

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References

1. Ching TYC, Dillon H, Marnane V, Hou S, Day J, Seeto M, et al. Outcomes of Early- and Late-Identified Children at 3 Years of Age. Ear Hear. 2013 Sep;34(5):535–52.
2. Marschark M, Spencer PE. Spoken Language Development of Deaf and Hard-of-Hearing Children: Historical and Theoretical Perspectives. In: Advances in the Spoken Language Development of Deaf and Hard-of-Hearing Children. Oxford University Press; 2005. p. 3–21.
3. Mitchell RE, Karchmer MA. Chasing the Mythical Ten Percent: Parental Hearing Status of Deaf and Hard of Hearing Students in the United States. Sign Lang Stud. 2004;4(2):138–63.
4. Geers AE, Strube MJ, Tobey EA, Pisoni DB, Moog JS. Epilogue: Factors Contributing to Long-Term Outcomes of Cochlear Implantation in Early Childhood. Ear Hear. 2011 Feb;32(1):84S-92S.
5. Fitzpatrick EM, Stevens A, Garritty C, Moher D. The effects of sign language on spoken language acquisition in children with hearing loss: a systematic review protocol. Syst Rev. 2013 Dec 6;2(1):108.
6. PETITTO LA, KATERELOS M, LEVY BG, GAUNA K, TÉTREAULT K, FERRARO V. Bilingual signed and spoken language acquisition from birth: implications for the mechanisms underlying early bilingual language acquisition. J Child Lang. 2001 Jun 25;28(2):453–96.
7. Petitto LA, Zatorre RJ, Gauna K, Nikelski EJ, Dostie D, Evans AC. Speech-like cerebral activity in profoundly deaf people processing signed languages: Implications for the neural basis of human language. Proceedings of the National Academy of Sciences. 2000 Dec 5;97(25):13961–6.

8. Johnston JC, Durieux-Smith A, Bloom K. Teaching gestural signs to infants to advance child development: A review of the evidence. First Lang. 2005 Jun 25;25(2):235–51.
9. Jana LA, Shu J. Heading Home With Your Newborn. American Academy of Pediatrics; 2005.
10. Shojaei E, Jafari Z, Gholami M. Effect of Early Intervention on Language Development in Hearing-Impaired Children. Iran J Otorhinolaryngol. 2016 Jan;28(84):13–21.
11. Nicholas JG, Geers AE. Will They Catch Up? The Role of Age at Cochlear Implantation in the Spoken Language Development of Children With Severe to Profound Hearing Loss. Journal of Speech, Language, and Hearing Research. 2007 Aug;50(4):1048–62.
12. Davidson K, Lillo-Martin D, Chen Pichler D. Spoken English Language Development Among Native Signing Children With Cochlear Implants. J Deaf Stud Deaf Educ. 2014 Apr 1;19(2):238–50.
13. Trovato S. A Stronger Reason for the Right to Sign Languages. Sign Lang Stud. 2013;13(3):401–22.
14. Hall ML, Hall WC, Caselli NK. Deaf children need language, not (just) speech. First Lang. 2019 Aug 13;39(4):367–95.
15. Fitzpatrick EM, Hamel C, Stevens A, Pratt M, Moher D, Doucet SP, et al. Sign Language and Spoken Language for Children With Hearing Loss: A Systematic Review. Pediatrics. 2016 Jan 1;137(1).
16. Geers AE, Mitchell CM, Warner-Czyz A, Wang NY, Eisenberg LS. Early sign language exposure and cochlear implantation benefits. Pediatrics [Internet]. 2017;140(1). Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L617228624&from=export
17. Hassanzadeh S. Outcomes of cochlear implantation in deaf children of deaf parents: comparative study. J Laryngol Otol. 2012 Oct 21;126(10):989–94.
18. Delcenserie A, Genesee F, Champoux F. Exposure to sign language prior and after cochlear implantation increases language and cognitive skills in deaf children. Dev Sci. 2024 Jul 7;27(4).
19. Hall ML, Hall WC, Caselli NK. Deaf children need language, not (just) speech. First Lang [Internet]. 2019;39(4):367–95. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85063026416&doi=10.1177%2f0142723719834102&partnerID=40&md5=dc409af74d1b7895c21ffb4893657e11
20. Yanbay E, Hickson L, Scarinci N, Constantinescu G, Dettman SJ. Language outcomes for children with cochlear implants enrolled in different communication programs. Cochlear Implants Int [Internet]. 2014;15(3):121–35. Available from: https://www.embase.com/search/results?subaction=viewrecord&id=L604124570&from=export
21. Marshall C, Jones A, Denmark T, Mason K, Atkinson J, Botting N, et al. Deaf children's non-verbal working memory is impacted by their language experience. Front Psychol. 2015 May 5;6.
22. Dettman S, Wall E, Constantinescu G, Dowell R. Communication outcomes for groups of children using cochlear implants enrolled in auditory-verbal, aural-oral, and bilingual-bicultural early intervention programs. Otol Neurotol [Internet]. 2013 Apr 1 [cited 2023 Nov 5];34(3):451–9. Available from: https://europepmc.org/article/MED/23442569

23. Lyness CR, Woll B, Campbell R, Cardin V. How does visual language affect crossmodal plasticity and cochlear implant success? Neurosci Biobehav Rev. 2013 Dec;37(10):2621–30.
24. Bergeson TR, Pisoni DB, Davis RAO. Development of Audiovisual Comprehension Skills in Prelingually Deaf Children With Cochlear Implants. Ear Hear. 2005 Apr;26(2):149–64.
25. Markman TM, Quittner AL, Eisenberg LS, Tobey EA, Thal D, Niparko JK, et al. Language development after cochlear implantation: an epigenetic model. J Neurodev Disord. 2011 Dec 19;3(4):388–404.
26. Giraud AL, Price CJ, Graham JM, Truy E, Frackowiak RSJ. Cross-Modal Plasticity Underpins Language Recovery after Cochlear Implantation. Neuron. 2001 May;30(3):657–64.
27. LU J, JONES A, MORGAN G. The impact of input quality on early sign development in native and non-native language learners. J Child Lang. 2016 May 29;43(3):537–52.
28. Mushtaq F, Wiggins IM, Kitterick PT, Anderson CA, Hartley DEH. The Benefit of Cross-Modal Reorganization on Speech Perception in Pediatric Cochlear Implant Recipients Revealed Using Functional Near-Infrared Spectroscopy. Front Hum Neurosci. 2020 Aug 14;14.
29. MacSweeney M. Neural systems underlying British Sign Language and audio-visual English processing in native users. Brain. 2002 Jul 1;125(7):1583–93.
30. Finney EM, Fine I, Dobkins KR. Visual stimuli activate auditory cortex in the deaf. Nat Neurosci. 2001 Dec 12;4(12):1171–3.
31. Fine I, Finney EM, Boynton GM, Dobkins KR. Comparing the Effects of Auditory Deprivation and Sign Language within the Auditory and Visual Cortex. J Cogn Neurosci. 2005 Oct 1;17(10):1621–37.
32. Bauer E, Sánchez L, Wang Y, Vaughan A. A Transdisciplinary Lens for Bilingual Education. New York: Routledge; 2021.
33. Lieberman AM, Mitchiner J, Pontecorvo E. Hearing parents learning American Sign Language with their deaf children: a mixed-methods survey. Applied Linguistics Review. 2024 Jan 29;15(1):309–33.
34. Caselli N, Pyers J, Lieberman AM. Deaf Children of Hearing Parents Have Age-Level Vocabulary Growth When Exposed to American Sign Language by 6 Months of Age. J Pediatr. 2021 May;232:229–36.
35. Prinz PM, Strong M. ASL Proficiency and English Literacy within a Bilingual Deaf Education Model of Instruction. Top Lang Disord. 1998 Aug;18(4):47–60.
36. Scott JA, Hoffmeister RJ. Superordinate Precision: An Examination of Academic Writing Among Bilingual Deaf and Hard of Hearing Students. The Journal of Deaf Studies and Deaf Education. 2018 Apr 1;23(2):173–82.
37. Knoors H, Marschark M. Language Planning for the 21st Century: Revisiting Bilingual Language Policy for Deaf Children. J Deaf Stud Deaf Educ. 2012 Jul 1;17(3):291–305.
38. Mayer C, Wells G. Can the Linguistic Interdependence Theory Support A Bilingual-Bicultural Model of Literacy Education for Deaf Students? J Deaf Stud Deaf Educ. 1996 Apr 1;1(2):93–107.
39. Davidson K, Lillo-Martin D, Chen Pichler D. Spoken English Language Development Among Native Signing Children with Cochlear Implants. J Deaf Stud Deaf Educ. 2014 Apr 1;19(2):238–50.

40. Hoffmeister R, Henner J, Caldwell-Harris C, Novogrodsky R. Deaf Children's ASL Vocabulary and ASL Syntax Knowledge Supports English Knowledge. The Journal of Deaf Studies and Deaf Education. 2021 Dec 16;27(1):37–47.
41. WOLL B. The consequences of very late exposure to BSL as an L1. Bilingualism: Language and Cognition. 2018 Nov 20;21(5):936–7.
42. Hassanzadeh S. Outcomes of cochlear implantation in deaf children of deaf parents: comparative study. J Laryngol Otol. 2012 Oct 21;126(10):989–94.
43. Park GY, Moon IJ, Kim EY, Chung E wook, Cho YS, Chung WH, et al. Auditory and Speech Performance in Deaf Children with Deaf Parents After Cochlear Implant. Otology & Neurotology. 2013 Feb;34(2):233–8.

Supplementary file 1

Search strategy

PubMed

((Language[all] AND sign[all]) OR "Sign language"[all] OR (Communication[all] AND manual[all]) OR "Manual communication"[all] OR "American sign language"[all] OR "ASL"[all] OR "Communication mode"[all] OR "Manual communication*"[all] OR (Communication*[all] AND Manual[all]) OR "Oral-aural communication"[all] OR "Total communication"[all] OR "Total Communication Method*"[all] OR ("Communication Method"[all] AND Total[all]) OR (Method*[all] AND "Total Communication"[all]) OR "Auditory verbal training"[all] OR "Auditory verbal"[all] OR "Bilingual-Bicultural Education"[all] OR "Cued speech"[all] OR (Cued[all] AND speech[all]) OR "Speech reading"[all] OR ("Disabled Education"[all] AND Hearing[all]) OR "Education of Persons with Hearing Impairments"[all]) AND ("Language test*"[all] OR "Vocabulary test*"[all] OR "Language comprehension test"[all] OR "Language acquisition"[all] OR (Acquisition[all] AND language[all]) OR ("articulation test"[all] AND speech[all]) OR "Speech articulation test"[all] OR (Test[all] AND articulation[all]) OR (Intelligibility[all] AND speech[all]) OR "speech intelligibility"[all] OR (perception[all] AND speech[all]) OR "spoken language"[all]) AND 1995/01/01:2022/12/30[dp]

CENTRAL

((Language:ti AND sign:ti,ab) OR 'Sign language':ti OR (Communication:ti AND manual:ti,ab) OR 'Manual communication':ti OR 'American sign language':ti OR 'ASL':ti OR 'Communication mode':ti OR 'Manual communication*':ti OR (Communication*:ti AND Manual:ti) OR 'Oral-aural communication':ti OR 'Total communication':ti OR 'Total Communication Method*':ti OR ('Communication Method':ti AND Total:ti) OR (Method*:ti AND 'Total Communication':ti) OR 'Auditory verbal training':ti OR 'Auditory verbal':ti OR 'Bilingual-Bicultural Education':ti OR 'Cued speech':ti OR (Cued:ti AND speech:ti) OR 'Speech reading':ti OR ('Disabled Education':ti AND Hearing:ti) OR 'Education of Persons with Hearing Impairments':ti) AND ('Language test*':ti OR 'Vocabulary test*':ti OR 'Language comprehension test':ti OR 'Language acquisition':ti OR (Acquisition:ti AND language:ti) OR ('articulation test':ti AND speech:ti) OR 'Speech articulation test':ti OR (Test:ti AND articulation:ti) OR (Intelligibility:ti AND speech:ti) OR 'speech intelligibility':ti OR (perception:ti AND speech:ti) OR 'spoken language':ti)

EMBASE

((Language:ti,ab AND sign:ti,ab) OR 'Sign language' OR (Communication:ti,ab AND manual:ti,ab) OR 'Manual communication' OR 'American sign language' OR 'ASL' OR 'Communication mode' OR 'Manual communication*' OR (Communication* AND Manual) OR 'Oral-aural communication' OR 'Total communication' OR 'Total Communication Method*' OR ('Communication Method' AND Total) OR (Method* AND 'Total Communication') OR 'Auditory verbal training' OR 'Auditory verbal' OR 'Bilingual-Bicultural Education' OR 'Cued speech' OR (Cued AND speech) OR 'Speech reading' OR ('Disabled Education' AND Hearing) OR 'Education of Persons with Hearing Impairments') AND ('Language test*' OR 'Vocabulary test*' OR 'Language comprehension test' OR 'Language acquisition' OR (Acquisition AND language) OR ('articulation test' AND speech) OR 'Speech articulation test' OR (Test AND articulation) OR (Intelligibility

AND speech) OR ‘speech intelligibility’:ti,ab OR (perception AND speech) OR ‘spoken language’:ti,ab) AND [1995-2022]/py

Proquest

((AB,TI(Language) AND AB,TI(sign)) OR AB,TI("Sign language") OR (AB,TI(Communication) AND AB,TI(manual)) OR AB,TI("Manual communication")OR AB,TI("American sign language") OR AB,TI("ASL") OR AB,TI("Communication mode") OR AB,TI("Manual communication*") OR (AB,TI(Communication*) AND AB,TI(Manual)) OR AB,TI("Oral-aural communication") OR AB,TI("Total communication") OR AB,TI("Total Communication Method*") OR (AB,TI("Communication Method") AND AB,TI(Total)) OR (AB,TI(Method*) AND AB,TI("Total Communication")) OR AB,TI("Auditory verbal training") OR AB,TI("Auditory verbal") OR AB,TI("Bilingual-Bicultural Education") OR AB,TI("Cued speech") OR (ALL (Cued) AND AB,TI(speech)) OR AB,TI("Speech reading") OR (AB,TI("Disabled Education") AND AB,TI(Hearing)) OR AB,TI("Education of Persons with Hearing Impairments")) AND (AB,TI("Language test*") OR AB,TI("Vocabulary test*") OR AB,TI("Language comprehension test") OR AB,TI("Language acquisition") OR (AB,TI(Acquisition) AND AB,TI(language)) OR (AB,TI("articulation test") AND AB,TI(speech)) OR AB,TI("Speech articulation test") OR (AB,TI(Test) AND AB,TI(articulation)) OR (AB,TI(Intelligibility) AND AB,TI(speech)) OR AB,TI("speech intelligibility") OR (AB,TI(perception) AND AB,TI(speech)) OR AB,TI("spoken language")) **AND** YR(19950101-20221230)

Scopus

((TITLE-ABS (Language) AND TITLE-ABS (sign)) OR TITLE-ABS ("Sign language") OR (TITLE-ABS (Communication) AND TITLE-ABS (manual)) OR TITLE-ABS ("Manual communication")OR TITLE-ABS ("American sign language") OR TITLE-ABS ("ASL") OR TITLE-ABS ("Communication mode") OR TITLE-ABS ("Manual communication*") OR (TITLE-ABS (Communication*) AND TITLE-ABS (Manual)) OR TITLE-ABS ("Oral-aural communication") OR TITLE-ABS ("Total communication") OR TITLE-ABS ("Total Communication Method*") OR (TITLE-ABS ("Communication Method") AND TITLE-ABS (Total)) OR (TITLE-ABS (Method*) AND TITLE-ABS ("Total Communication")) OR TITLE-ABS ("Auditory verbal training") OR TITLE-ABS ("Auditory verbal") OR TITLE-ABS ("Bilingual-Bicultural Education") OR TITLE-ABS ("Cued speech") OR (ALL (Cued) AND TITLE-ABS (speech)) OR TITLE-ABS ("Speech reading") OR (TITLE-ABS ("Disabled Education") AND TITLE-ABS (Hearing)) OR TITLE-ABS ("Education of Persons with Hearing Impairments")) AND (TITLE-ABS ("Language test*") OR TITLE-ABS ("Vocabulary test*") OR TITLE-ABS ("Language comprehension test") OR TITLE-ABS ("Language acquisition") OR (TITLE-ABS (Acquisition) AND TITLE-ABS (language)) OR (TITLE-ABS ("articulation test") AND TITLE-ABS (speech)) OR TITLE-ABS ("Speech articulation test") OR (TITLE-ABS (Test) AND TITLE-ABS (articulation)) OR (TITLE-ABS (Intelligibility) AND TITLE-ABS (speech)) OR TITLE-ABS ("speech intelligibility") OR (TITLE-ABS (perception) AND TITLE-ABS (speech)) OR TITLE-ABS ("spoken language")) AND PUBYEAR > 1994 AND PUBYEAR < 2023

WOS

((TI= (Language) AND TI = (sign)) OR TI = ("Sign language") OR (TI = (Communication) AND TI = (manual)) OR TI = ("Manual communication") OR TI = ("American sign language") OR TI = ("ASL") OR TI = ("Communication mode") OR TI = ("Manual communication*") OR (TI = (Communication*) AND TI = (Manual)) OR TI = ("Oral-aural communication") OR TI = ("Total communication") OR TI = ("Total Communication Method*") OR (TI = ("Communication Method") AND TI = (Total)) OR (TI = (Method*) AND TI = ("Total Communication")) OR TI = ("Auditory verbal training") OR TI = ("Auditory verbal") OR TI = ("Bilingual-Bicultural Education") OR TI = ("Cued speech") OR (TI = (Cued) AND TI = (speech)) OR TI = ("Speech reading") OR (TI = ("Disabled Education") AND TI = (Hearing)) OR TI = ("Education of Persons with Hearing Impairments")) AND (TI = ("Language test*") OR TI = ("Vocabulary test*") OR TI = ("Language comprehension test") OR TI = ("Language acquisition") OR (TI = (Acquisition) AND TI = (language)) OR (TI = ("articulation test") AND TI = (speech)) OR TI = ("Speech articulation test") OR (TI = (Test) AND TI = (articulation)) OR (TI = (Intelligibility) AND TI = (speech)) OR TI = ("speech intelligibility") OR (TI = (perception) AND TI = (speech)) OR TI = ("spoken language")) AND PY=(1995-2022)