# Phonological Acquisition Process in Hearing-Impaired Children: A Systematic Review

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## ABSTRACT

Phonological acquisition processes are often associated with normal-hearing children. However, the phonological acquisition process in hearing-impaired children presents interesting challenges and variation in comparison to normal-hearing children. This systematic review aims to describe the phonological acquisition processes that hearing-impaired children underwent. An extensive literature search was carried out from March until May 2023 utilising three online database, which are Scopus, PubMed and JSTOR. Several studies such as cohort, case-control studies, and human cross-sectional studies, were chosen. From the 428 papers discovered, 32 studies were incorporated based on the inclusion and exclusion criteria. The inclusion criteria focused on research papers that involved children with hearing impairment in various degrees, aged between 0 to 12 years old, and interventions that included both cochlear implant and hearing aid users. The major exclusion criteria were studies with subjects with any syndromes and studies that analysed sign languages. The results indicated that final and initial consonant deletion, fronting, stopping, vowelization, substitution, reduplication and assimilation are the phonological acquisition processes that hearing-impaired children undergo. Furthermore, it was found that word or language difference is not a factor that affects the phonological acquisition process in hearing-impaired children. Lastly, final consonant deletion is a common phonological process that both normal and hearing-impaired children undergo at their early stages of hearing. This review aids in bringing awareness to speech language pathologist on the need for early and targeted intervention for hearing-impaired children to tackle the phonological acquisition process these children undergo.

**Keywords:** hearing-impaired children; phonological acquisition process; phonemes; phonology; systematic review

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## INTRODUCTION

Phonology is the study of the patterns and organisation of speech sounds in a particular language (Threatte, 1980). The phonological acquisition is known to be a process where a child can acquire the targeted language's phonology, which includes functional aspects such as the language's specific sound differences (Tessier, 2015). Contrarily, phonological development is the gradual acquisition of an adult-like system of speech sounds that are utilised to convey meaning in a particular language (Hua & Dodd, 2006). The phonological acquisition in a child starts from the cooing stage. The cooing stage is a spontaneous vocalisation of behaviour that babies engage in when they are in a more comfortable situation. As a child grows, they undergo several key stages of phonological development. Stages such as onset and rhyme, word awareness, syllable awareness, rhyme and alliteration and phonemic awareness will be undergone by a child to develop specific phonemic awareness skills.

The processes are commonly experienced by hearing-impaired individuals. Nonetheless, various studies assert that children with hearing impairment, particularly those between the ages of 4 to 28 months, encounter challenges in acquiring phonological skills. For instance, it was found that fricative or affricate development was difficult for some toddlers with high-severity hearing loss (Moeller et al., 2007) and it was explained that the influence of sensorineural hearing loss on high-frequency information-restricted capacity given by amplification, and reduced audibility based on noise and reverberation. Nevertheless, it was revealed that children with hearing aids produce equivalent proportions of each type of speech error in mono-, di-, and multisyllabic words.

Ample of research related to phonological acquisition has been done on normal-hearing children. Lim & Chieng (2021) did a study investigating the English-Malay speech acquisition by forty Indian children between the ages of 2 and 4. From the research, it was revealed that the subjects showed similar phonological achievements together with subjects of other ethnicities acquiring similar languages. Furthermore, by the age of 4, all singleton consonants had been acquired, and apart from one consonant cluster (/dɪ/), all consonant clusters were mastered by four-year-old children. This indicates an earlier acquisition timeline compared to children from a Chinese background in a previous study. Additionally, all vowels were acquired by the age of two, with minimal observed vowel phonological patterns. It could also be stated that the foundation to research on hearing-impaired children is constructed on validated findings from such research on normal-hearing children. However, it is quite difficult to see such inclusion in certain research. Therefore, this systematic review could aid in highlighting these inclusions in a more comprehensible manner.

A study by Persson et al. (2021) also studied the effectiveness of hearing aids on phonological, vocabulary development in hearing-impaired children. From the study, it was found that there is a significant correlation between the hours spent using a hearing aid and the number of words acquired. Fitzpatrick et al. (2012) did a study comparing the phonological outcomes in the range of speech recognition and spoken language in children with hearing aids and cochlear implants. It could be seen that in moderately severe or severe hearing loss children, their development of spoken language skills is like normal hearing children. Moreover, Geers & Hayes (2011) revealed that many students with cochlear implants had strong phonological skills commensurate with hearing peers. Lastly, Ching & Cupples (2015) found that there were zero scores on elision and blending and children with hearing aids executed the tasks notably better than the ones with cochlear implants. Several extensive studies on hearing-impaired

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children's phonological acquisition process exist, and some highlight the phonological acquisition process in hearing-impaired children (Sim et al., 2019; Hur et al., 2020). But many studies also tend to overshadow these processes with findings such as Geers & Hayes (2011) that significantly highlighted the literacy level and reading growth in cochlear implant users.

Thus, putting this justification forth, the main objective of the review is "To determine the types of phonological acquisition processes of hearing-impaired children. Furthermore, the research question that will guide this review is "What type of phonological acquisition processes hearing-impaired children undergo?".

## MATERIALS AND METHODS

### LITERATURE SEARCH STRATEGIES

This review is done based on the Preferred Reporting Items for Systematic Reviews and MetaAnalyses or PRISMA guidelines and checklist. The purpose of using the PRISMA guidelines is to minimize bias by systematically identifying and selecting relevant research articles. Furthermore, the PRISMA checklist aids in enhancing the quality and consistency in a systematic review (Moher et al. 2015). The data for the current study has been mainly procured from only one resource, which is an online database source. The database search was done utilising three main databases which are PubMed, Scopus and JSTOR. These three databases were used because they have indexed high-quality and peer-reviewed research (Montoya et al. 2018). Moreover, these databases also have detailed abstracts which makes it feasible for researchers to analyse the relevance of the study. The following table showcases the search string used in this review.

TABLE 1. Search String

| **Search String** | |
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| **PubMed** | ("phonological" OR "phonology" AND "acquisition process" OR development) AND hearing AND (impaired OR loss) AND (children* OR toddlers*) |
| **Scopus** | ("phonological" OR "phonology" AND "acquisition process" OR development) AND hearing AND (impaired OR loss) AND (children* OR toddlers*) |
| **JSTOR** | ("phonological" OR "phonology" AND "acquisition process" OR development) AND hearing AND (impaired OR loss) AND (children OR toddlers) |

### ELIGIBILITY CRITERIA AND STUDY SELECTION

Cross-sectional, longitudinal, and case control that have reported the types of phonological acquisition processes children with hearing loss undergo within 20 years, from 2000 to 2023 were included. Several studies were also eliminated based on the eligibility criteria (1) only available in abstract form; (2) not written in English; (3) books, book chapters, reviews, meta-analyses, conference/ proceeding papers, letter to the editor, and commentary; (4) had subjects that were adults or teenagers; (5) subjects suffered from any syndromes; (6) analysed sign languages; or (7) without socioeconomic status or demographic characteristics. The PRISMA

Flowchart that summarises the records identified, screening, eligibility, and inclusion of articles, are depicted in Figure 1.

## STUDY EXTRACTION

Once the databases were searched, they were imported into a referencing manager called JabRef. The referencing manager allowed the researcher to screen through the articles and remove duplicates easily. Furthermore, it provided the researcher with abstracts of the research papers imported, which made the elimination process much more feasible. The researcher was able to eliminate research based on the eligibility criteria mentioned above. The data from the remaining articles were then extracted into evidence table (Table 2), based on the title and abstract, and subsequently by a full-text screening (Table 1).

The data from the studies were analysed. The first part of the analysis will discuss the primary research question of the study and the extent to which it was mapped out in the previous studies. From critical evaluation and analysis of the research, the categories of the type of phonological acquisition process the subjects underwent were identified and described, respectively. Upon identification, the potential categories are reviewed to determine whether they answer the research question. The extracted data will also be refined and supported with several analyses, concerning the extant literature.

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TABLE 2. Systematic Review Evidence Table

| No | Authors & Publication Date | Study Design | Language | Sample Size | Subjects | Phonology Assessment | Study Findings | Limitations |
|---|---|---|---|---|---|---|---|---|
| 1 | Penna et al. (2015) | Cross-sectional study | English | 110 | ● Age of 6 to 10 years old.<br>● Mild to profound hearing loss | ● GASP test performance<br>● Speech audiometry assessment<br>● Spontaneous naming task | ● Degree of hearing impairment was correlated with the difference in median age.<br>● Degree of hearing loss influences the phonology performance. | Difficulty in selecting validated tools developed in Brazil. |
| 2 | Park et al. (2013) | | English | 70 | ● 21 children with MSNH,<br>● 29 normal hearing children<br>● Chronological age: 7 to 12 years<br>● Monolingual English speaker | ● Woodcock Reading Mastery Test–Revised<br>● Comprehensive Test of Phonological Processing | ● MSNH group performed better than DYS group.<br>● CA group did better than MSNH group.<br>● MSNH children with weak phonological awareness skills rely on orthographic recognition. | ● Study cannot be generalised due to small sample size.<br>● Could not address the developmental reading skills in children with MSNH. |
| 3 | Bensaid et al. (2010) | Comparative Study | Israeli Hebrew | 6 | ● Six monolingual Israeli Hebrew<br>● 3 boys and 3 girls within 1 to 8 years<br>● Pre-lingual hearing impairment with bilateral sensorineural hearing loss | Isolated-word picture-naming task | ● Deletion of singleton onsets<br>● Reduplication- the second syllable<br>● Initial onset was reduplicated.<br>● Cluster Reduction<br>● Coalescence<br>● Consonant Production | ● Experimental evidence whether the IH r-sound is a liquid, or a glide was not deduced.<br>● Obstruent-glide clusters in the target words in the studies on clusters typical acquisition in IH was not found. |
| 4 | Medi et al. (2014) | Experimental study | Spanish | 17 | ● 17 bilingual Spanish-Catalan children with speech language impairment.<br>● 17 age match controls. | ● NEPSY (Developmental Neuropsychological Assessment<br>● Catalan adaptation of the PROLEC (Assessment Battery for Reading Processes | ● Bilingual Spanish-Catalan children scored lower in phonological awareness compared to their typically developing peers.<br>● Lower scores were obtained by bilingual Spanish-Catalan children with SLI in auditory attention. | ● Small sample size<br>● Monolingual children with SLI from the same socioeconomic context was not included as control group. |

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| 5 | Alt et al. (2011) | Cross-sectional study | English | 40 | ● 40 subjects<br>● Age 7- to 8-year-old<br>● Half with SLI (Specific language impairment) | ● Fast mapping<br>● Word-learning task<br>● Goldman-Fristoe Test of Articulation-II<br>● Phonotactic Probability Calculator | ● Children with Specific Language Impairment (SLI) exhibited phonological representations that were not noticeably less clear.<br>● The vulnerability of children with SLI seems to be related to interference, particularly when it concerns word-final details. | ● Even when SLI children effectively acquire words, they may employ somewhat distinct encoding methods compared to their non-impaired peers.<br>● It doesn't offer a clear mechanism through which children can compensate for this limitation. |
| 6 | Asad et al. (2018) | Descriptive Study | English | 30 | ● Children aged 5;0–7;6 (years; months)<br>● Mild to profound hearing loss | CASALA (Computer Aided Speech and Language Analysis) program | ● Final consonant deletion<br>● Weak syllable deletion<br>● Backing<br>● Glottal replacement- hearing aid users | ● HA users underwent a less rigorous intervention compared to children with CI.<br>● Small sample and variations in age at detection and intervention.<br>● Potential factors that might influence the phonological skill development in children with hearing loss (CWHL) were not subjected to testing. |
| 7 | Ayyad (2009) | Cross-sectional study | Kuwait Arabic | 80 | ● Monolingual Kuwaiti children<br>● Age: 3 to 5 years old.<br>● 38 males and 42 females | Goldman-Fristoe Test of Articulation | ● Consonant acquisition encompassed the acquisition of stops at various articulation points, including labial, coronal, dorsal, and glottal locations.<br>● Except for the dorsal stop /q/ and coronal /tˤ/.<br>● In multisyllabic words in word-initial unstressed syllables, the coronal /d/ sound was fronted to [b], and this change also occurred in the disyllabic length in word-final positions. | ● Expansion is necessary to include other aspects of speech and language development<br>● High need for a formal assessment tool that accommodates the environment and the culture. |

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| 8 | Lapré et al. (2016) | Comparative Study | French | 72 | ● 72 children with DPD<br>● 10 normal children for sampling<br>● French speakers | Comprehensive assessment (Phonemic Level) | ● Majority children with DPD have difficulties with phonological processing.<br>● Children with Developmental Phonological Disorders (DPD) who speak French exhibit distinct surface speech errors compared to their English-speaking counterparts with DPD. | ● No speech perception tool is readily available for French Speaking children<br>● All French-speaking children with difficulties should receive an assessment of their phonological processing skills. |
| 9 | Bruggeman et al. (2021) | Experimental study | English | 14 | ● 14 children with hearing loss<br>● 8 HA users, 5 CI users, and 1 bimodal<br>● 20 normal hearing<br>● All English-speaking pre-schoolers. | Elicited imitation task | Children with hearing loss (HL) displayed clear distinctions in voicing categories for both initial sounds (onsets) and final sounds (codas) across all three positions. | Indicating an extended process in the phonetic execution of final sounds (codas). |
| 10 | Ching et al. (2015) | Cross-sectional study | English | 104 | ● Children with hearing loss<br>● English speakers | Standardised PA tests of elision, blending words and sound matching | Enhanced performance of subjects may be related to<br>1. Early age of intervention<br>2. Current hearing technology<br>3. High-quality hearing service. | There is a lack of research on sound-matching scores among children with hearing loss, spanning from mild to profound levels of severity. |
| 12 | Coady et al. (2013) | Cross-Sectional study | English | 16 | ● Mean age of 10.2<br>● Monolingual English-speaking children<br>● 9 females and 7 males | Leiter International Performance Scale | ● Similarity had an impact on children with Specific Language Impairment (SLI).<br>● Mostly affected by word frequency<br>● Not influenced by the frequency of phonotactic patterns.<br>● Children with SLI used coarse-grained language knowledge. | The primary support for this impairment comes from nonword repetition tasks, which remove semantic and syntactic requirements. |

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| 13 | Deng et al. (2021) | Cross-sectional study | Mandarin | 146 | • Chinese students in grades 3–9<br>• Hearing impaired | • This includes tasks related to onset and rime detection, lexical tone identification, sight word reading, text reading comprehension, nonverbal intelligence, and working memory. | • Segmental phonological awareness played a dual role, in both directly and indirectly to text reading comprehension.<br>• Suprasegmental lexical tone awareness had only an influence on text reading comprehension, solely through its impact on sight word reading. | These results emphasize the crucial role of phonological awareness in enhancing reading comprehension of written text for students with hearing impairments, especially in Chinese language. |
| 14 | Dillon et al. (2004) | Experimental Study | English | 88 | • 8- to 10-year-old<br>• Experienced paediatric cochlear implant users | • Children's Test of Nonword Repetition<br>• Used non-word repetition task | • Correctly reproduce targeted consonants with coronal place<br>• Lower achievement in pronouncing labial consonants is a result of the absence of visual cues, like observing lip closure. | This contradicts earlier findings which suggested that labial consonants were articulated accurately more frequently than consonants with different articulation locations. |
| 15. | Halliday et al. (2017) | Cross-sectional study | English | 90 | • 8-16 years<br>• 46 children with mild-to-moderate hearing loss (MMHL)<br>• 44 aged-matched controls | • Word Reading and Pseudoword Decoding subtests of Wechsler Individual Achievement Test<br>• British Picture Vocabulary Scale<br>• Clinical Evaluation of Language Fundamentals (CELF) subtests Expressive Vocabulary | • Children with MMHL achieved similar results to the control group in terms of receptive vocabulary, word reading, and nonword reading.<br>• Results were associated with nonverbal intelligence, maternal educational level, and whether there was a family history of language difficulties. | Did not include further analysis on subjects that are at risk having clinically significant language difficulties. |
| 16. | Jerger et al. (2016) | Experimental study | English | 62 CHI<br>62 CNH | • 4 to 14 years.<br>• All spoke English as a native language<br>• Does not have any disabilities other than hearing impairment. | Multimodal picture-word task | • The introduction of visual speech had a notable positive impact on phonological priming in both CHI and CNH groups.<br>• In terms of lexical status, both CHI and CNH demonstrated significantly enhanced phonological priming from nonwords compared to words. | The data from this study may have practical implications for existing intervention programs that prioritize auditory-based listening approaches. |
| 17. | Jerger et al. (2002) | Experimental study | English | 159 | • 30 subjects with hearing loss (HL)<br>• 129 typically developing (TD) children | Picture-distractor pairs | • The observed effects were consistent in both the hearing loss (HL) and typically developing (TD) subgroups.<br>• Among children with hearing loss, the presence of conflicting distractors | Additional research is required to thoroughly elucidate the significant influences of various perceptual experiences and linguistic abilities. |

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| | | | | | | | did not impact naming when they had poorer phoneme discrimination skills.<br>● Phonological representations are highly detailed in hearing loss (HL) children with strong auditory perceptual abilities. | |
| 18. | Law et al., (2006) | Experimental Study | Cantonese | 14 | Age from 5;1 to 6;4 years. | Cantonese Phonology Test | ● CI users exhibited higher scores in consonant production compared to hearing aid (HA) users.<br>● Cantonese-speaking children with CI are expected to possess better phonological skills than children using hearing aids, provided they have a similar level of hearing loss. | Future developments in cochlear implants should focus on enhancing vowel and tone perception for users of CIs. |
| 19. | Lazarou et al., (2010) | Experimental Study | English | 2 | ● One cochlear implants user<br>● One hearing aid user | Phonetic and Phonological Development Test (PPDT) | ● Children using HA made a higher number of phonological errors compared to those using CI.<br>● Both participants used devoicing and cluster substitutions in both tasks. | ● Higher number of profoundly deaf children with CI and HA is needed to generalise findings.<br>● Error categories of frontalization and palatalization that did not occur in children with CI should be researched. |
| 20 | Lund et al., (2015) | Pilot Study | Spanish English | 37 | ● 18 kindergarten children with varying degrees of hearing impairment<br>● 19 normal hearing kindergarten children | ● Rhyme Awareness subtest of the Phonological Awareness and Literacy Screening for Preschool<br>● Initial Sound Awareness subtest of the Phonological Awareness and Literacy Screening for Kindergarten<br>● Expressive and Receptive One-Word Picture Vocabulary Tests | ● Bilingual children with hearing loss (HL) outperformed their bilingual counterparts with normal hearing.<br>● Both monolingual and bilingual children with hearing loss (HL) exhibited lower performance levels in comparison to monolingual and bilingual children with normal hearing.<br>● Both groups of children, those with hearing loss and those with normal hearing, displayed correlations between phonological awareness and vocabulary knowledge. | ● Larger sample size could be included.<br>● Assessment methods employed in this study may not have effectively evaluated the components of phonological awareness. |
| 21 | Lynce et al., (2019) | Preliminary Study | Portuguese | 18 | ● More than 2 years of implant | A formal articulation test has been validated for the Portuguese- | ● It takes a longer time for children with cochlear implants (CI) to | It is important to assess the validity of the age of |

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| | | | | | • Categorised into two groups based on hearing age (A=2.10-4.04 and B=5.04-7.03) | speaking population. | develop a complete repertoire of plosives and fricatives in their speech sounds.<br>• Results indicates that Portuguese-speaking children with typical hearing peers may exhibit immature phonological development, including patterns such as syllable omission and onset deletion. | implantation and its influence on the phonological development of children with cochlear implants who speak European Portuguese. |
| 22 | Martínez et al. (2019) | Experimental Study | English | 168 | • 8 with hearing loss<br>• 4 with implant<br>• 4 with hearing aid<br>• 160 with normal hearing | Phonological processes paradigm was adopted | • Subjects with hearing loss exhibit delayed phonological processing, including non-standard processes.<br>• Subjects with cochlear implants made more phonological errors than those using hearing aids. | It is advisable to provide early auditory stimulation for children with hearing loss, irrespective of the type of technical assistance they use (e.g., cochlear implants or hearing aids). |
| 23 | Nanthanat et al., 2020 | Descriptive Study | Malay | 6 | • 6-year-old Malay children with CI<br>• Attending the final year of preschool<br>• Malay ethnicity<br>• Malay language native language | • Multilingual Phonological Test<br>• Comprehensive Test of Nonverbal Intelligence Second Edition (CTONI-2) | • Children with CI have poor scores on school readiness skills<br>• Low vocabulary and phonological development due to the late age of cochlear implantation. | • Possible discrepancy between teachers' and parents' evaluation in the results. |
| 24. | Tse et al. (2012) | Cross-sectional study | Cantonese | 15 | • Children who speak Cantonese and have cochlear implants (CIs). | Phonological awareness task | • Syllable, phoneme, and rhyme awareness were comparable between pre-schoolers with cochlear implants (CI) and those with normal hearing.<br>• However, CI users exhibited lower proficiency in tasks related to tone awareness and phonological knowledge. | Subsequent research endeavours ought to explore the connection between tone awareness and reading proficiency in hearing-impaired children. |
| 25. | Miller et al., (2013) | Explorative Study | English | 5 | • Average (PTA) of 50 dB or greater in the better ear,<br>• Capability to comprehend some orally presented words. | Phonological Awareness Test-2nd Edition (PAT-2) | DHH children characterized by differences in communication mode, chronological age, and language ability, experienced positive outcomes from explicit instruction in phonological awareness. | Offering clear instruction in early phonological awareness skills to DHH children can provide them with the opportunity to develop functional hearing. |

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| 26. | Nazir et al. (2022) | Cross-sectional comparative study | English | 100 | ● 4-5 years old children<br>● Both genders<br>● Hearing aids with moderate hearing loss<br>● Divided into early & late amplified. | Test for Articulation and Phonology | ● Children with moderate hearing impairment at 4 to 5 years exhibit enhanced phonological development when introduced to amplification at an earlier stage.<br>● Final Consonant Deletion (p =.005)<br>● Initial Consonant Deletion (p = .826).<br>● Among substitution processes Fronting persisted.<br>● Harmony structure processes of Reduplication and Assimilation persisted. | Incorporate elicitation probes or administer a formal test specifically focusing on verb tense marking. |
| 27. | Nittrouer et al., (2014) | Cross-sectional study | English | 40 | ● Completed pre-school<br>● 19 individuals with normal hearing (NH) and 21 individuals with cochlear implants (CIs) | Systematic Analysis of Language Transcripts (SALT) | ● The average scores of children with NH is higher than CI.<br>● Significantly, only the age at the initial implantation correlated with the observed differences, with no discernible impact from other factors. | It was not feasible to separately examine specific types of conjunctions and bound morphemes. |
| 28. | Quriba et al. (2019) | Cross-sectional study | Arabic | 43 | ● Children using cochlear implants<br>● 23 males and 20 females<br>● Age ranged between 4 to 10 years old | ● Modified Preschool Language Scale<br>● Stanford Binet 5th edition<br>● Ain Shams Assessment Protocol | ● Sounds located toward the front precede those at the back, oral sounds come before nasal ones, and stops come before fricatives.<br>● Delayed acquisition was observed in the case of glides and laterals. | The gradual improvement of both segmental and supra-segmental disturbances was evident with the consistent utilization of cochlear implants and active engagement in speech therapy programs. |
| 29. | Sabri et al., (2018) | Longitudinal Study | English & Arabic | 2 | ● 3 years-old<br>● 2 years of hearing age<br>● Bilingual Arabic–English-speaker<br>● Bilateral CIs to age 4<br>● 3 years of hearing age | ● Phon software<br>● Percent Consonants Correct–Revised | ● Typical and atypical error patterns gradually diminished, leading to increased segmental accuracy with maturation.<br>● Bilingual children with Cis demonstrated the ability to learn both of their languages and exhibited comparable performance to monolingual children with | ● The generalisation of these results to the broader population of bilingual kids with CIs is constrained.<br>● Lack of studies in the monolingual and bilingual Arabic speakers which prevented them from making comparisons |

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| | | | | | | | CIs. | with these populations. |
| 30. | Shadi et al. (2022) | Cross-sectional study | Arabic | 30 | ● 5 and 11 years old<br>● Unilateral cochlear implants with or without a unilateral hearing aid | ● Modified Preschool Language Scale-4th edition (PLS–4)<br>● Phonological Awareness Test (PAT)<br>● Arabic Reading Screening Test (ARST) | ● Correlation between phonological awareness (PA) and reading skills exist.<br>● These skills demonstrated a moderate correlation with language development.<br>● The age of implantation exhibited a correlation with reading development specifically among older participants. | A longitudinal study that tracks phonological awareness (PA) and reading skills in children with CI from the preschool period to adulthood is important for gaining a understanding in the developmental trajectory of these skills over time. |
| 31. | Tang et al., (2006) | Cross sectional study | Vietnamese | 4 | ● Ages 4;4 to 5;5<br>● Vietnamese-speaking children | Independent and Relational analyse | ● The frequent presence of velar sounds in Vietnamese may provide insight into the backing process observed in the retroflex fricative /Z/, shifting towards the velar fricative [X].<br>● The progression towards the velar position [X] signifies a heightened level of complexity in the backing process of the retroflex fricative /Z/. | ● There may be a requirement for the development of clinical materials designed to evaluate speech and language development.<br>● To effectively address the speech and language requirements of Vietnamese-speaking children, it is essential to establish research-based test batteries and clinical materials. |
| 32. | Tiwari et al., (2017) | Cross sectional Study | Kannada | 15 | ● Three groups of children (SLI & age-matched and language-matched control groups)<br>● Native speakers of Kannada<br>● Attended Kannada medium schools. | ● Linguistic Profile Test<br>● Spontaneous Speech Task<br>● Phonological awareness Test<br>● Meta phonological Test | ● Demonstrated common deficits in phonological processing during a non-word repetition task among children with Specific Language Impairment (CwSLI) learning English.<br>● Kannada-speaking children with SLI did not exhibit deficiencies in syntactic morphology relative to language-matched peers. | Further investigation is necessary to corroborate the results of this study in additional languages. |

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# RESULTS

## SEARCH RESULTS AND STUDY SELECTION

The database search was done utilising three primary databases which are PubMed, Scopus and JSTOR. By utilising a specific search string (Table 1), PubMed was able to index 215, and Scopus 181, while JSTOR indexed 113 studies. 428 records were identified after removing 81 duplicates. Then the 428 articles underwent screening and 143 were omitted as they were not related to the study. Furthermore, 54 were excluded due to it not being a research study, 32 book chapters were omitted and 67 studies were excluded because of timeframe. 132 articles that comply with the criteria were evaluated for eligibility. After analysing the full text, the researcher has excluded 100 articles, where 26 of them had no sociodemographic status or demographic characteristics, 28 analysed sign languages, 35 studies did not have children as their subjects and 11 of the research had subjects that suffered from other syndromes. Finally, 32 articles were included in this systematic review.

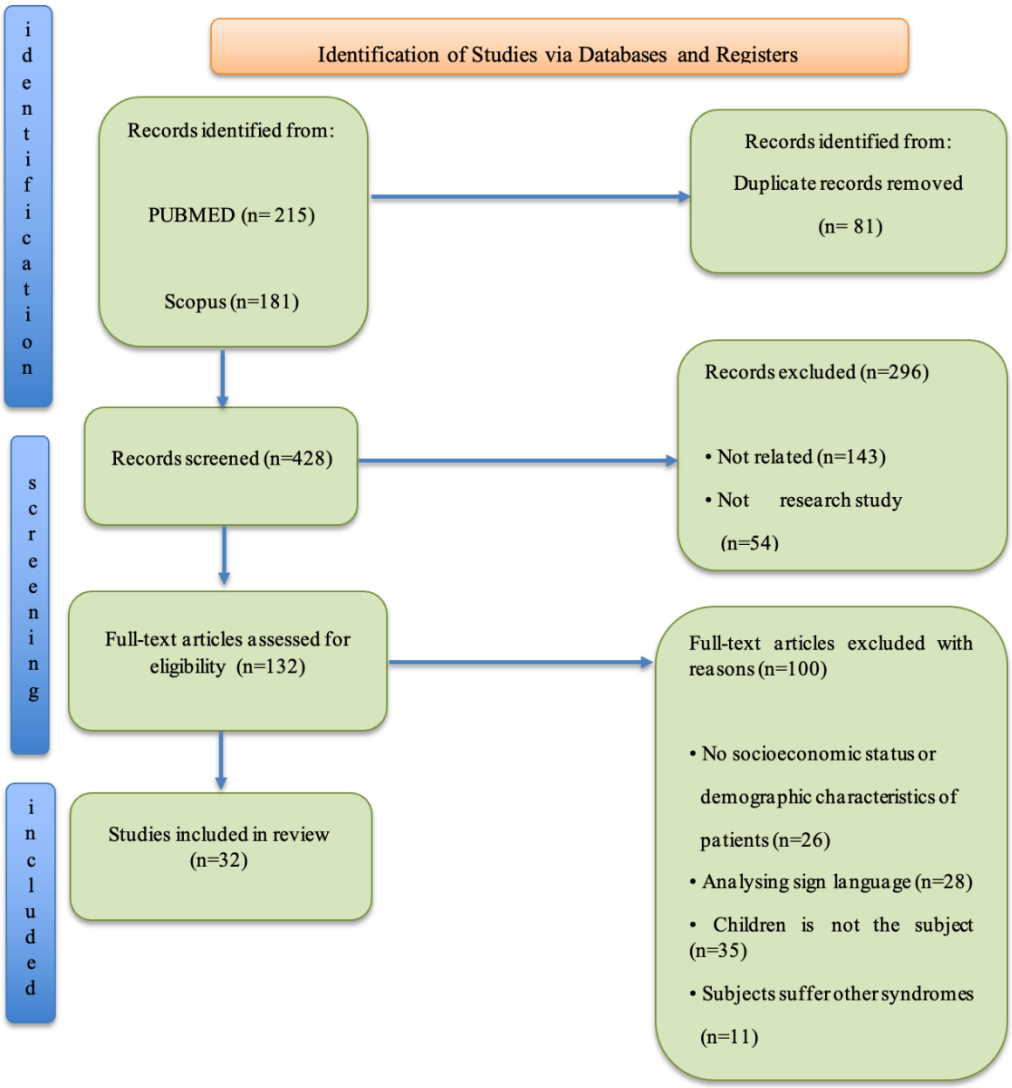


FIGURE 1. Prisma Flowchart

**STUDY CHARACTERISTICS**

The studies that were included in this systematic review were published between 2002 and 2022, whereby 17 of the articles were cross-sectional studies, 3 comparative studies, 9 experimental studies, 1 descriptive study, 1 pilot study, 1 preliminary study and 1 longitudinal study. Studies selected for this review have also analysed several languages. From the evidence table, from 32 journals selected nearly 55.6% of them conducted their phonological acquisition analysis on English-speaking children. Furthermore, 11.1% of the studies are conducted on Spanish and Arab-speaking children. 8.3% of the studies utilised Chinese dialect-speaking children such as Cantonese and Mandarin and 2.8% of studies used Indian dialects, French and German respectively. The total number of participants was nearly 150 for 3 of the studies and 100 for 4 other studies However, approximately 80 participants were used for 7 studies, and 5 studies used 20 subjects. Lastly, 5 qualitative studies have utilised only 5 subjects. The participants in all these studies are mainly children and young learners suffering from mild to severe hearing loss with amplification of cochlear implants and hearing aids.

In this review, 19 studies have investigated the phonological acquisition process in children with hearing impairment and specifically one of them studied the developmental stages of word-initial consonant clusters (CCs) and another determined if children with hearing impairment can produce the /s/word-initial and /s/ stop cluster. Similarly, a study by Dillon (2004) has also investigated the non-word responses of subjects and extracted the phonological acquisition process that they underwent. However, despite 11 of the studies providing phonological acquisition processes, their primary aim was to investigate the association between the phonological acquisition process and its subject's sociodemographic factors such as bilingualism, fitting age, gender, linguistic ability and more. Even so, the studies could still provide several data that highlighted the phonological processes.

In terms of the subjects, most studies included children from the age of 4 to 10 years old. Furthermore, there were also more children with hearing aids compared to ones with cochlear implants. This could be because of the high availability of subjects with hearing aids compared to ones with cochlear implants. The degree of hearing loss of the subjects could also have determined the influx of children with hearing aids. Some of the studies have also included bilingual children to analyse whether bilingualism has a significant impact in their phonological development.

Two of the studies have utilised the Goldman-Fristoe Test of Articulation II as their phonological assessment tool, whereas one of them has used the Phonetic and Phonological Developmental Test (PPDT). A common test used by another three studies was the Phonological Awareness Test, which is an informal assessment of phonological awareness in children. In studies that analysed the linguistic profiles, the Developmental Neuropsychological Assessment was used. Coady et al. (2013) utilised the Leiter International Performance Scale which is a useful item for assessing those with cognitive delays, and speech or hearing problems, whereas Dillon et al. (2004) opted to use the Children's Test of Nonword Repetition. For other language studies, Law et al. (2006) utilised an adapted Phonology Test in the Cantonese language, whereas Lund et al. (2015) used the Rhyme Awareness subtest of the Phonological Awareness and Literacy Screening Test for Spanish speakers. Certain studies that had over 100 subjects have also used the Test for Articulation and Phonology.

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**TYPES OF PHONOLOGICAL ACQUSITION PROCESESSES IN CHILDREN WITH HEARING IMPAIRMENT**

There are several phonological acquisition processes that children with hearing impairment undergo. Bensaid (2010) found that deletion of entire clusters such as singleton onsets, reduplication of onset from second syllable, cluster reduction such as obstruent-obstruct target cluster, and coalescence. In a descriptive study by Asad et al. (2018), it was revealed that school-aged children suffering from hearing impairment underwent phonological acquisition processes such as final consonant and weak syllable deletion, glottal replacement and backing. The study suggests that both developmental and non-developmental phonological processes endure in the speech of children experiencing mild to profound hearing loss. Furthermore, Bruggeman (2021) conducted an elicited imitation task and inferred that child with hearing loss had acoustically visible voicing categories in terms of the onsets and codas at every position. In contrast to this, Dillon (2004) reported that cochlear implant users at the age of 8 to 10 years old imitated 33% of the target consonants accurately, 25% of the target consonants were deleted, and 42% of the target consonants had substitutions. From this, it can be deduced that the subjects underwent consonant deletion and substitution processes.

In terms of Cantonese-speaking children with cochlear implants, it was found that most children used stopping, deaspiration, fronting, backing, consonant deletion and destabilisation. Similarly, syllable deletion was also a phonological process undergone by Cantonese-speaking children (Tse et al., 2012). To further explore this, Law et al. also examined the phonological skills in Cantonese-speaking children with hearing impairment and it was discovered that they undergo similar phonological processes as stated above such as fronting, backing, consonant deletion and more. To further add to this finding, deaspiration, affrication and final and initial consonant deletion.

Lazarou et al. (2010) also deduced that both hearing aid and cochlear implant child users undergo similar phonological processes such as cluster simplification, stopping, devoicing and cluster substitution through a naming simple picture task. The researchers also conducted a complex picture describing tasks and found that they undergo fronting, cluster substitution, palatalization, cluster simplification and omission of final consonants.

In the Arab language, Ayyad (2009) investigated the development of speech sounds among monolingual Arab-speaking children with hearing impairment. It was concluded that stops across all places of articulation such as labial, coronal, dorsal and glottal were acquired by 90% of the children. However, they could not acquire dorsal stops for /q/ and /tʃ/. The coronal /d/ had also been fronted to [b] in the word-initial position (unstressed syllable) in multisyllabic words and at the disyllabic length in the word-final position. Correspondingly, a cross-sectional study by Quirba et al. (2019) found that Egyptian Arabic-speaking children with cochlear implants disclose that the phonological processes they undergo are developmental ones such as cluster reduction, final consonant deletion, assimilation, weak syllable deletion, substitution (fronting, stopping) and non-developmental processes like glottal replacement and backing.

In terms of bilingual Arabic-speaking children, Sabri et al. (2018) stated that they undergo final consonant deletion and weak syllable deletion while speaking the English language. Stopping and cluster reduction were found while conversing in both languages. There was also more gliding in the English language whereas labialization was highly found in the Arabic language.

Lynce et al. (2019) conducted a preliminary study on Portuguese-speaking children with 2 years of implant. It was found that dentoalveolar segments are absent. Furthermore, some of them produced non-ambient segments. 24.6% of the subjects also underwent the syllable-final omission and 47.4% of them did cluster reduction. There were also signs of segmental

substitutions where 14.4% of them experienced palatalization and only a few underwent gliding of liquids, fronting, backing, onset deletion and devoicing.

Similarly, Martinez et al. (2019) reported on Spanish-speaking children with hearing aids and cochlear implants. It was concluded that most of the subjects undergo vowel substitution and vowel omission processes. There was also a high frequency of omission of liquid consonants and final consonant deletion. In addition to this, the subjects with cochlear implants also use fronting of fricatives and voiced stops. In a recent study, Millasseau et al. (2022) revealed that children with hearing loss had consonant omissions such as /s/. Final consonant deletion, initial consonant deletion, substitution, fronting, reduplication, and assimilation were also phonological processes undergone by 4-5-year-old children with hearing impairment (Nazir et al., 2022).

In the Asian geographic region, Tang et al. (2006) evaluated the sound system of monolingual Vietnamese-speaking children and through this research, they were able to locate several phonological processes the subjects have undergone, which are, final consonant deletion, initial consonant deletion, fronting, backing, glottal stop. There were also a few indications of denalisation, assimilation, and reduction.

## DISCUSSION

There are several types of phonological acquisition processes that hearing-impaired children undergo based on the current evidence. The results of this review revealed that hearing-impaired children undergo several phonological acquisition processes, most commonly are final and initial consonant deletion, fronting, stopping, vowelization, substitution, reduplication, and assimilation.

In the field of phonology, it is essential to identify the phonological process, especially in hearing-impaired children. These findings are interesting as most of the processes are quite like the ones children with normal hearing undergo. It was asserted that children with hearing impairment tend to produce a high proportion of vocalisation with glottal stops or glides (Stoel-Gammon & Otoma, 1986). These claims are like one of the findings in this review where it was found that hearing-impaired children had high glottal stops where there was a substitution of the /h/ (Tang et al., 2006). The similarity in findings is interesting as both research have used different types of words and language as how Stoel-Gammon & Otoma (1986) used multisyllabic English words whereas Tang et al. (2006) utilised monosyllabic Vietnamese words. Thus, it could be concluded that the word or language difference is not a factor that affects the phonological acquisition process that hearing-impaired children undergo.

Furthermore, it could be seen that most of the research reviewed revealed that children with hearing impairment undergo final consonant deletion. It is a common fact that in 1- and 2-year-old children, a final consonant deletion is expected, and it happens due to it being the age at which a child is developing its speech system (James et al., 2008). Most of the research that had final consonant deletion in this review used hearing-impaired children within the chronological age of 3 to 12 years old with a hearing age of 1-3 years old. This shows that the hearing-impaired children were in the early stages of hearing and developing stage of their speech system. Therefore, it could be inferred that final consonant deletion is a common phonological process that both normal and hearing-impaired children undergo at their early stages of hearing. Nevertheless, in the speech pathology world, it was discovered that the softness of the voice is mistaken as a final consonant deletion. Thus, it is hoped that future research could further study this. Moreover, the results also revealed that children with hearing loss had consonant omission of the consonant /s/ (Millasseau et al., 2022). This could be since sounds such as /s/, /ʃ/, /f/, /t/, or /k/ have higher frequencies and are difficult to hear. Due to the

consonants transmitting the majority of the meaning in speech, it could be deduced that those with high-frequency hearing loss may have trouble conversing (Edwards et al., 2015).

It can also be seen that there are several studies analysing the phonological process in the Arabic language. The results above highlight both monolingual and bilingual speakers of the language. One major difference bilingual speaker had with monolingual Arabic speakers is that bilingual speakers had a high frequency of glides. Glide emphasises the features of movement (or 'glide') of [w] from the [u] vowel position to the middle vowel position (Rosenthal., 1997). The significant difference here could be explained by the influence of the speakers' second language which is English. Glides are a common phonological process in the English language (Polgárdi, 2015); hence this may have influenced bilingual speakers to apply similar phonological features in the Arabic language too. Furthermore, monolingual Arabic speakers could not acquire dorsal stops for /q/ and /tʃ. This phenomenon could happen because the speakers have a Palmyran dialect and the *q is maintained and ǧ is devoiced to č, ensuing in a system that lacks voiced dorsal stops; hence partially resolves the voicing asymmetry for stops (Masrai, 2019).

Certain studies in this review have also revealed that the subjects with cochlear implants had more phonological errors than the ones who use a hearing aid (Harris & Terlektsi, 2010). This is quite true as Fitzpatrick et al., (2012) reported that children with hearing aids got higher marks than ones with cochlear implants in domains such as language, reading comprehension and phonological memory. To further support this, Ching & Cupples (2015) asserted that children with hearing aids performed significantly better compared to children with cochlear implants in terms of the included measure of cognitive ability, the WNV ($F [1,39] = 9.79$, $p = .003$). However, Geers & Hayes (2011), stated that children with cochlear implants had strong literacy skills commensurate with hearing peers. Similarly, Tomlin et al., (2005) asserted that expressive language development was better in children with cochlear implants depending on their fixation age with the youngest children between 10 to 15 months of age. Thus, some results in the review contradict several pieces of literature.

As mentioned above, apart from English language analysis several other language analyses were also included. It could be noticed that not many languages have readily available tools to measure speech perception, which caused many studies to adapt existing tools to their language. Several researchers from this review have reported the high need to have a formal assessment tool which accommodates the environment and culture (Ayyad, 2009; Brosseau-Lapré & Rvachew, 2016; Tang & Barlow, 2006). In Malaysian geography, the Malay Version of the Phonological Awareness Instrument Screening Test (MAPAS) which is a screening tool that is used to test the phonological awareness of 8-year-old children was used in a study by Syed et al. (2010).

However, it was reported that the process of adaptation could be risky as adapting a particular tool may have biases or errors. The errors could derive from each language having its own distinct variation. For instance, the French language has four nasal vowels, and the final phonemes are not pronounced. Furthermore, word stress often falls on the last syllable only. In terms of vowels, they are also not reduced to schwa /ə/ and /ɪ/, and syllables tend to be open (Griffiths, 2014). Thus, if these phonological features are not considered, this could reduce the reliability of the results of the studies (Ceron et al., 2018). From the discussion above it could be asserted that the development of a universal speech assessment tool or one based on certain cultures and environments could be done to resolve this issue.

From this review, it was also noticed that one of the studies that conducted a comparative study did not include a control group. A control group is important in a comparative study as it would have aided the researchers in detecting whether the differences found were associated with the study's variable (Zondervan et al., 2002). Aguilar et al., (2014) did a study analysing the phonological development of bilingual Spanish children with speech

impairment. It was reported that a control group of monolingual children with speech impairment from similar socioeconomic backgrounds was not included. However, a study by Tiwari et al., (2017) had three groups of children and one of them acted as a control group.

Despite most studies using a huge sample size, there are a few in this review that have conducted their studies with smaller sample sizes. For instance, Lazarou et al., (2010) and Sabri et al., (2018) had a sample size of only 2 participants in their study. Similarly, Tang et al., (2006) also conducted a study with only 4 subjects. The researchers explained that having a small sample size allows the study to be conducted more feasibly. However, this has resulted in the study outcomes being indicative and not valid to be generalised. The generalisation of findings to a bigger population of bilingual children with cochlear implants is limited according to Sabri et al. (2010). This is because it is a case study of only one subject. Moreover, Lund et al., (2015) asserted that having a bigger sample size could have allowed for a thorough evaluation of the relationship between phonological awareness and vocabulary development. Therefore, this shows that having a large sample size is essential in research studies.

## CONCLUSION

In conclusion, the main objective of the current study has been achieved where the current literature suggests that final and initial consonant deletion, fronting, stopping, vowelization, substitution, reduplication and assimilation are the phonological acquisition processes that children with hearing impairment undergo. Moreover, word or language difference is not a factor that affects the phonological acquisition process that hearing-impaired children undergo. It was also found that final consonant deletion is a common phonological process that both normal and hearing-impaired children undergo at their early stages of hearing. Furthermore, speech assessment tools that facilitate other languages are also needed. Lastly, it is significant to consider the sample sizes utilised in the research for the findings to be generalizable. From the current systematic review, the phonological acquisition processes are highlighted clearly from many studies that usually overshadow these processes with other findings. This review may also aid speech language pathologist in providing targeted interventions for hearing-impaired children based on the type of phonological acquisition process that they commonly undergo. Thus, it is hoped that future research could take these findings into account and further expand the research scope in this field of study.

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