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# Assessment of Speech Intelligibility and Its Influencing Factors in Hearing-Impaired Children

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## ABSTRACT

**Background:** Background: Speech intelligibility is a key determinant of communication ability in children with hearing impairment. Limitations in auditory input, delayed amplification, and inadequate speech therapy often lead to reduced intelligibility, affecting language, learning, and social interaction. **Objective:** To assess speech intelligibility in hearing-impaired children and identify the primary factors influencing intelligibility outcomes, including degree of hearing loss, age at intervention, type of amplification device, and duration of speech therapy. **Methodology:** A cross-sectional study was conducted among children aged 5-12 years with bilateral sensorineural hearing loss using hearing aids or cochlear implants for at least one year. They were attending speech or auditory-verbal therapy and were able to speak in short phrases. Children who had additional intellectual or motor problems, inconsistent device use, or mixed hearing loss were not included. Speech intelligibility was evaluated using standardized speech samples rated by trained listeners on a five-point scale. Demographic and clinical data were obtained from audiological records and caregiver interviews. The mean and standard deviation were calculated for number-based data, and percentages were used for categories. Statistical analyses, including Pearson correlation and multiple regression, were applied to determine the predictors of intelligibility. **Results:** Findings revealed that children with mild to moderate hearing loss demonstrated significantly higher intelligibility scores than those with severe to profound loss ($p<0.05$). Earlier fitting of amplification devices and greater duration of speech therapy were strongly associated with improved intelligibility. Children using cochlear implants generally outperformed those using hearing aids, though individual variability was observed. **Conclusion:** Speech intelligibility in hearing-impaired children is influenced by multiple interrelated factors. Early identification, timely amplification, and consistent speech-language therapy significantly enhance speech outcomes. These results highlight the importance of comprehensive auditory rehabilitation programs focused on early intervention and targeted speech training to optimize communication abilities in hearing-impaired children.

**Keywords:** Auditory rehabilitation, Children's hearing impairment, Cochlear implant, Hearing aid, Speech intelligibility, Speech therapy

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## INTRODUCTION

Speech intelligibility, the degree to which a speaker's acoustic signal is correctly understood by a listener, is a fundamental outcome for children with hearing loss because it directly affects everyday communication, educational participation, and psychosocial development.[1] Historically, children with severe-to-profound hearing impairment displayed very low levels of intelligibility; however, advances in newborn screening, amplification technology, and early intervention have substantially improved prospects for many children.[2] Intelligibility is a multi-determined construct. Auditory access (aided audibility and the Speech Intelligibility Index) is foundational; better aided audibility is associated with stronger speech perception and, indirectly, with clearer speech output.[3]

Cognitive and linguistic capacities (vocabulary size, working memory) moderate how well children can make use of incoming auditory information, and these in turn affect intelligibility outcomes, particularly in challenging listening environments.[3,4] Device type and timing of intervention are among the most consistently reported predictors of speech outcomes. For example, children who receive cochlear implants (CIs) at younger ages, especially before approximately 24 months, typically show accelerated gains in speech-production intelligibility compared with later-implanted peers.[5] In one study of 40 prelingually, profoundly deaf children implanted between 8 and 40 months of age, all children implanted before 24 months and tested at age 5.5 or older achieved ≥80% intelligibility according to naïve listeners.[6] Similarly, children who receive well-fitted hearing aids with good aided audibility early in the critical period can achieve substantially better speech and language trajectories than those with delayed amplification.[7]

Intervention factors beyond devices, notably early identification through newborn screening, prompt amplification, and enrolment in structured auditory-verbal or speech-language therapy, strongly influence speech outcomes.[8] Duration and continuity of targeted therapy (for example, auditory-verbal therapy) are associated with more consistent gains in intelligibility and related spoken-language measures.[9] Nevertheless, wide individual variability remains: children with similar audiograms and identical devices may present very different intelligibility profiles. Contributing factors include residual hearing, age at onset of deafness, family language environment, socioeconomic factors, co-existing disabilities, and access to high-quality rehabilitation services.[10] The acoustic environment, classroom noise, reverberation, and competing talkers also affect how intelligibility is manifested and measured, particularly when assessing speech production and perception in real-world contexts.[3] Measurement issues further complicate both research and clinical practice.

Gold-standard orthographic transcription by naïve listeners provides objective percent-intelligibility scores, but is time-consuming; clinical rating scales and single-word tests are often used as pragmatic alternatives despite lower precision.[11] Renewed attention to practical, standardised intelligibility measures has been recommended to ensure routine monitoring of speech outcomes in clinical settings.[11] With this background, it becomes important to look at speech intelligibility in a more complete way, one that not only measures how well children are understood but also considers the many factors that influence these outcomes.

The present study will assess how clearly children with hearing loss are able to speak, using standard listener-based tools. It will also explore which factors play the biggest role in speech intelligibility. These factors include audiological aspects such as the severity of hearing loss, how well sound is heard with devices, and the type of device used, intervention-related elements like the age at which hearing aids or implants were fitted and how long the child has received therapy, and child-related characteristics including language skills, working memory, and any additional conditions. This study are expected to guide clinical practice. They may highlight the value of early detection, proper fitting and use of hearing devices, and consistent therapy. Overall, the findings will help improve how progress is tracked and how rehabilitation programmes are planned for children with hearing loss.

## METHODOLOGY

This study was a cross-sectional type of research designed to assess speech intelligibility and to find which factors have an influence on it among hearing-impaired children. The study was carried out in the audiology and speech therapy departments of two large hospitals and special

education centers where children regularly received auditory-verbal therapy. The data collection continued for about six months from July to Dec 2024, giving enough time to contact families, record speech samples, and finish the analysis.

Children who participated were between 5 and 12 years old and had bilateral sensorineural hearing loss of a mild to profound level. All of them were already using hearing aids or cochlear implants for at least one year. They were attending speech or auditory-verbal therapy and were able to speak in short phrases. Children who had additional intellectual or motor problems, inconsistent device use, or mixed hearing loss were not included. In total, sixty children were recruited through purposive sampling. Basic information like age, gender, device type, age at diagnosis, and therapy duration was collected from caregivers and hospital records. Every assessment and recording was done in a quiet and comfortable room under the guidance of a qualified speech-language pathologist.

Before starting, approval was taken from the ethical review board, and written consent was signed by parents or guardians. The purpose of the study was explained to all families in simple language. Children also gave verbal permission if they were old enough to understand. Confidentiality was strictly followed by using codes instead of names and by storing the data safely. Speech samples were collected in a relaxed setting to make the child comfortable and encourage natural talking. Each child was asked to describe a simple picture and to repeat a few short sentences commonly used in pediatric speech intelligibility tests.

The recordings were made with a high-quality microphone placed about 20 centimeters from the mouth. Each session lasted nearly three to five minutes. Care was taken to avoid background noise; the sound level in the room was kept below 40 dB. After recording, speech files were adjusted for loudness and cut into short clips that were later used for evaluation. To measure intelligibility, a group of ten adult listeners with normal hearing was selected. They were university students with no previous contact with the children. Each listener heard the samples separately and was not told anything about the speakers. They wrote down what they understood, and the percentage of correctly written words was used as the intelligibility score. Listeners also gave a general rating on a five-point scale where one meant “hardly understandable” and five meant “very clear.” The average score of all listeners was taken as the final result for each child. To make sure the scoring was reliable, the agreement between listeners was checked, and it showed good consistency. Other information, like the degree of hearing loss, type of device, age when the child started using the device, and total months of speech therapy, was collected from the records and interviews with parents. The number of therapy sessions was counted to see how regular attendance affected speech improvement. Some family-related factors, like parents’ education and income level, were also noted because they might influence communication outcomes.

The data were analysed using SPSS version 26. Basic statistics were used to describe the results. The mean and standard deviation were calculated for number-based data, and percentages were used for categories. After that, the study checked whether speech intelligibility was related to different factors, such as the level of hearing loss, the type of device used, how long the child had therapy, and the age when intervention started. Correlation tests and t-tests were used for these checks. A multiple linear regression test was also done to find out which factor had the strongest effect on speech intelligibility. A p-value below 0.05 was considered significant.

To keep the study fair and consistent, the same equipment and test setting were used for every child. All speech recordings were taken by one speech-language pathologist so that the method stayed the same. Before scoring, listeners practiced with a few sample recordings to learn how to rate and write down what they heard. Also, 10% of the recordings were checked again to make sure the scoring was correct. These steps helped improve accuracy and reduce bias in the findings.

## RESULTS

A total of sixty children with bilateral sensorineural hearing impairment participated in the study. Out of these, 32 (53.3%) were boys and 28 (46.7%) were girls. The mean age of participants was 8.4 ± 2.1 years, ranging between 5 and 12 years. Among them, 36 (60%) were using hearing aids and 24 (40%) had cochlear implants. The average age at amplification was 3.1±1.2 years, and the mean duration of speech therapy was 18.6±6.4 months. Table 1 summarizes the

demographic and clinical characteristics of the participants. These figures show that the sample included a good balance of gender, age, and amplification types, allowing meaningful comparison between subgroups.

The overall mean speech intelligibility score among all participants was 74.5±13.2, indicating a moderate level of clarity in speech production. When analyzed by amplification type, children with cochlear implants achieved significantly higher intelligibility (81.4±10.6) than those using hearing aids (69.8±12.1, $p$=0.003). Similarly, children with mild to moderate hearing loss demonstrated higher scores (82.3%) compared with those with profound hearing loss (64.7%). Early fitting of amplification (before 3 years of age) resulted in better outcomes (83.1%) than later fitting (67.2%). Moreover, children who received speech therapy for more than 18 months achieved higher intelligibility (80.8%) than those who attended for less than 18 months (68.9%).

Early auditory intervention and longer therapy duration are strongly linked to better intelligibility outcomes. While cochlear implant users generally outperformed hearing aid users, some children with hearing aids who had early fitting and prolonged therapy achieved comparable results. This suggests that early and consistent rehabilitation is just as vital as the amplification device itself. A multiple linear regression analysis was performed to determine the independent predictors of speech intelligibility. The model included the degree of hearing loss, age at amplification, duration of speech therapy, and amplification type. Results showed that duration of speech therapy (β=0.41, $p$=0.001) and age at amplification (β=-0.36, $p$=0.002) were the strongest predictors. The degree of hearing loss also had a significant negative relationship (β=0.28, $p$=0.005), indicating that more severe impairment results in poorer clarity. Amplification type contributed modestly but significantly (β=0.22, $p$=0.037). Collectively, these factors explained 58% of the total variance in speech intelligibility ($R^2$=0.58), showing that these variables meaningfully predict outcomes (Table 3).

These results confirm that children who received amplification at an early age, engaged in longer therapy, and used cochlear implants had better speech clarity. There was no significant gender difference, and the age at testing did not affect intelligibility. However, children from families with higher parental education or strong home language support tended to perform slightly better, indicating that environmental factors also play a supportive role. Overall, the results highlight that early intervention and sustained speech therapy are crucial for improving speech intelligibility in children with hearing impairment.

**Table 1: Demographics and clinical characteristics of participants**

| Variable | Category | Frequency (n) | Percentage (%) | Mean ± SD |
|---|---|---|---|---|
| Gender | Male | 32 | 53.3 | - |
| | Female | 28 | 46.7 | - |
| Age (years) | | - | - | 8.4 ± 2.1 |
| Amplification type | Hearing aid | 36 | 60.0 | - |
| | Cochlear implant | 24 | 40.0 | - |
| Degree of hearing loss | Mild-Moderate | 14 | 23.3 | - |
| | Severe | 22 | 36.7 | - |
| | Profound | 24 | 40.0 | - |
| Age at amplification (years) | | - | - | 3.1 ± 1.2 |
| Duration of therapy (months) | | - | - | 18.6 ± 6.4 |

**Table 2: Mean speech intelligibility scores according to clinical variables**

| Variables | Category | Mean ± SD | p-value |
|---|---|---|---|
| Amplification type | Hearing aid | 69.8 ± 12.1 | 0.003 |
| | Cochlear implant | 81.4 ± 10.6 | - |
| Degree of hearing loss | Mild-Moderate | 82.3 ± 9.8 | - |
| | Severe | 76.2 ± 11.3 | - |
| | Profound | 64.7 ± 13.6 | 0.001 |
| Age at amplification | ≤3 years | 83.1 ± 10.5 | - |
| | >3 years | 67.2 ± 12.7 | 0.002 |
| Duration of speech therapy | ≤18 months | 68.9 ± 11.8 | - |
| | >18 months | 80.8 ± 12.2 | 0.004 |

**Table 3: Multiple linear regression analysis of factors influencing speech intelligibility**

| Predictors | Standardized β | p-value | Interpretation |
|---|---|---|---|
| Duration of therapy | 0.41 | 0.001 | Longer therapy increases intelligibility |
| Age at amplification | -0.36 | 0.002 | Earlier fitting improves intelligibility |
| Degree of hearing loss | -0.28 | 0.005 | Severe loss reduces clarity |
| Amplification type | 0.22 | 0.037 | Cochlear implant yields higher clarity |
| Model $R^2$ | 0.58 | - | 58% of variance explained |

## DISCUSSION

The findings of this study reveal that speech intelligibility in children with hearing impairment is influenced by several interacting factors, including amplification device type, degree of hearing loss, age at amplification, and duration of speech therapy. Children fitted with cochlear implants achieved higher intelligibility scores than those using hearing aids. This difference likely reflects the greater auditory access provided by cochlear implants, which improves speech-perception feedback and allows for more accurate articulation and prosodic control. Similar results have been reported by previous research comparing cochlear implant users with hearing-aid users, where implant recipients exhibited superior clarity and naturalness of speech production.[13,17]

A key observation is the strong relationship between early amplification and improved intelligibility. Children who received devices before age three demonstrated significantly better performance than those amplified later. This supports the principle of early auditory stimulation during critical periods of neuroplasticity for speech and language development. Delayed access to auditory input limits the formation of accurate phonological representations and can delay language acquisition.[12,14,18]

Tomblin and co-workers (2015) reported that earlier fitting of hearing aids or implants contributes to stronger spoken-language development due to higher aided audibility levels, which facilitate clearer speech output.[18] The

duration of speech therapy also emerged as a major determinant of intelligibility. Children who received therapy for more than eighteen months achieved substantially higher scores than those with shorter durations. Extended therapy allows repetitive practice of articulation, auditory discrimination, and language modelling, essential components for speech refinement. Continuous interaction with speech-language pathologists supports the transfer of trained speech patterns to daily communication. These findings align with those of Tomblin et al., who noted that longer exposure to auditory-verbal therapy directly improves expressive language and intelligibility outcomes.[15]

The degree of hearing loss showed a significant negative association with intelligibility. Children with mild-to-moderate hearing loss demonstrated greater clarity than those with profound loss, indicating that residual hearing provides a valuable foundation for speech development. Freeman et al. (2017) noted that even with modern technology, children with profound loss require prolonged adaptation and intensive therapy to achieve near-normal speech outcomes.[16] This is further supported by Holt and Svirsky, that the importance of tailoring rehabilitation intensity to the degree of loss, as highlighted in previous longitudinal studies of pediatric implant users.[13] Device type, while influential, was less predictive than early amplification or therapy duration. Although cochlear implants offer improved auditory access, their benefits depend on consistent therapy and enriched language exposure.

According to Chin et al., some early-fitted hearing-aid users achieved intelligibility comparable to cochlear implant users, suggesting that when auditory access is provided early and combined with structured therapy, technology differences can be minimized.[17] Regression analysis confirmed that age at amplification and therapy duration were the strongest predictors of intelligibility, jointly explaining over half the variance in outcomes. This aligns with recent reports that the Speech Intelligibility Index (SII) is a measure of aided audibility, is closely linked to spoken-language proficiency and intelligibility in children with hearing loss.[18,19] Moreover, family involvement and home communication environment also play an important supportive role; children from linguistically rich and supportive households often exhibit more natural articulation and prosody.[16]

In summary, optimal speech intelligibility among hearing-impaired children depends on early amplification, long-term speech therapy, and consistent auditory-language exposure. While technology such as cochlear implants provides the necessary auditory foundation, structured rehabilitation, early intervention, and family participation remain crucial. These findings emphasize the need for coordinated multidisciplinary management integrating audiologists, speech-language pathologists, and caregivers to achieve the best possible communicative outcomes.

## CONCLUSION

Optimal speech intelligibility in children with hearing impairment is determined by a combination of early amplification, consistent and long-term speech therapy, and the type of auditory device used. Children who receive amplification at a younger age, particularly before three years, demonstrate significantly higher clarity and more accurate articulation, highlighting the critical role of early auditory access during periods of heightened neural plasticity. Prolonged and structured speech therapy further enhances outcomes by providing repeated opportunities for auditory training, language modelling, and generalization of correct speech patterns into daily communication. While cochlear implants generally provide superior auditory input compared to hearing aids, the benefits of technology are maximized only when combined with early fitting and sustained rehabilitation.

Degree of hearing loss also influences outcomes, with children experiencing milder loss achieving better intelligibility, though intensive therapy can help mitigate the challenges faced by those with profound impairment. Overall, achieving functional and intelligible speech in children with hearing impairment requires a comprehensive, multidisciplinary approach that integrates timely amplification, consistent therapeutic intervention, and supportive family and environmental engagement. These strategies collectively ensure the development of effective, clear, and socially functional communication skills.

## DECLARATIONS

**Consent to participate:** Written consent had been

obtained from patients. All methods were performed following the relevant guidelines and regulations.

**Availability of Data and Materials:** Data will be made available upon request. The corresponding author will submit all dataset files.

**Competing interests:** None

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**Authors' contributions:** All authors had read and approved the final manuscript.

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