

SPEECH AND LANGUAGE DEVELOPMENT FOLLOWING COCHLEAR IMPLANTATION IN PRE-LINGUALLY DEAF CHILDREN

DESENVOLVIMENTO DA FALA E DA LINGUAGEM APÓS O IMPLANTE COCLEAR EM CRIANÇAS COM SURDEZ PRÉ-LINGUAL

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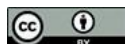
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Abstract

Background: Pre-lingual deafness significantly affects the natural development of speech and language due to early auditory deprivation. Cochlear implantation is an effective intervention; however, the age at implantation plays a crucial role in determining communication outcomes. Delayed implantation, particularly after five years of age, may limit optimal language acquisition due to reduced neural plasticity. **Objective:** This study aimed to compare speech and language outcomes in pre-lingually deaf children who received cochlear implants before and after the age of five years. **Methodology:** A comparative cross-sectional study was conducted over 12 months at the University of Lahore. A total of 14 children with pre-lingual deafness were selected through purposive sampling and divided into two groups: early implantation (1–5 years) and late implantation (after 5 years). Speech outcomes were assessed using the Speech Intelligibility Rating (SIR) scale, while language development was evaluated through the Peabody Picture Vocabulary Test (PPVT). Data were analyzed using SPSS, and group comparisons were made to determine statistical significance. **Results:** Children who underwent early cochlear implantation demonstrated significantly better speech intelligibility and receptive vocabulary scores compared to those implanted after five years. Statistical analysis revealed a significant association between earlier implantation and improved outcomes ($p < 0.05$). Although children with late implantation showed noticeable improvements, their performance remained comparatively lower. **Conclusion:** Cochlear implantation after five years of age results in measurable gains in speech and language abilities; however, early implantation yields superior outcomes. These findings highlight the importance of early diagnosis and timely intervention to optimize communication development in pre-lingually deaf children.

Keywords: Cochlear Implantation. Pre-lingual Deafness. Speech Intelligibility. Language Development. Early vs Late Intervention. Receptive Vocabulary.

Resumo

Antecedentes: A surdez pré-lingual afeta significativamente o desenvolvimento natural da fala e da linguagem devido à privação auditiva precoce. O implante coclear é uma intervenção eficaz; no entanto, a idade na qual o implante é realizado desempenha um papel crucial na determinação dos resultados de comunicação. O implante tardio, particularmente após os cinco anos de idade, pode limitar a aquisição ideal da linguagem devido à redução da plasticidade neural. **Objetivo:** Este estudo teve como objetivo comparar os resultados de fala e linguagem em crianças com surdez pré-lingual que receberam implantes cocleares antes e após os cinco anos de idade. **Metodologia:** Um estudo transversal comparativo foi realizado ao longo de 12 meses na Universidade de Lahore. Um total de 14 crianças com surdez pré-lingual foi selecionado por meio de amostragem intencional e dividido em dois grupos: implantação precoce (1–5 anos) e implantação tardia (após 5 anos). Os resultados da fala foram avaliados utilizando a escala de Classificação de Inteligibilidade da Fala (SIR), enquanto o desenvolvimento da linguagem foi avaliado por meio do Teste de Vocabulário com Imagens de Peabody (PPVT). Os dados foram analisados utilizando o SPSS, e foram feitas comparações entre os grupos para determinar a significância estatística. **Resultados:** As crianças que foram submetidas a implante coclear precoce demonstraram pontuações significativamente melhores em inteligibilidade da fala e vocabulário receptivo em comparação com aquelas implantadas após os cinco anos. A análise estatística revelou uma associação significativa entre o implante precoce e melhores resultados ($p < 0,05$). Embora as crianças com implante tardio tenham apresentado melhorias notáveis, seu desempenho permaneceu comparativamente inferior. **Conclusão:** O implante coclear após os cinco anos de idade resulta em ganhos mensuráveis nas habilidades de fala e linguagem; no entanto, o implante precoce produz resultados superiores. Esses achados destacam a importância do diagnóstico precoce e da intervenção oportuna para otimizar o desenvolvimento da comunicação em crianças com surdez pré-lingual.

Palavras-chave: Implante Coclear. Surdez Pré-lingual. Inteligibilidade da Fala. Desenvolvimento da Linguagem. Intervenção Precoce vs. Tardia. Vocabulário Receptivo.

1 INTRODUCTION

Pre-lingual deafness refers to hearing loss that occurs before the acquisition of spoken language, typically within the first few years of life. This condition significantly disrupts the natural development of speech and language skills, as auditory input plays a fundamental role in language acquisition. Children with pre-lingual deafness often face challenges in phonological development, vocabulary acquisition, and expressive communication, which can further impact their academic performance and social integration. Without timely and appropriate intervention, these deficits may persist into adolescence and adulthood, limiting overall quality of life and participation in society (Yoshinaga-Itano, 2003; Kral & O'Donoghue, 2010).

Cochlear implantation has emerged as one of the most effective interventions for individuals with severe to profound sensorineural hearing loss. Unlike conventional hearing aids, cochlear implants bypass damaged hair cells in the cochlea and directly stimulate the auditory nerve, thereby enabling access to sound. This technology has revolutionized auditory rehabilitation, particularly in children, by facilitating the development of spoken language skills. Over the past few decades, numerous studies have demonstrated that cochlear implants can significantly improve speech perception, speech production, and language outcomes in children with pre-lingual deafness, especially when combined with appropriate auditory-verbal therapy (Nicholas & Geers, 2007; Sharma *et al.*, 2002).

One of the most critical factors influencing the success of cochlear implantation is the age at which the implant is received. Early implantation, typically before the age of five years, is associated with more favorable outcomes due to the heightened neuroplasticity of the developing brain. During early childhood, the auditory cortex is highly adaptable and responsive to sensory input, allowing children to develop near-normal speech and language skills when provided with timely auditory stimulation. In contrast, delayed implantation may result in suboptimal outcomes, as prolonged auditory deprivation can lead to reduced neural responsiveness and reorganization of auditory pathways (Sharma *et al.*, 2002; Kral & Sharma, 2012).

Despite the well-documented benefits of early cochlear implantation, many children in developing countries experience delays in diagnosis and intervention due to

limited healthcare resources, lack of awareness, and socioeconomic barriers. As a result, a significant number of children receive cochlear implants after the critical period for language development has passed. Although late implantation still provides auditory benefits, these children often exhibit slower progress in speech intelligibility and language acquisition compared to their early-implanted counterparts. Understanding the extent of these differences is crucial for guiding clinical decision-making and setting realistic expectations for families and clinicians (Dettman *et al.*, 2007; Niparko *et al.*, 2010).

Speech intelligibility and receptive vocabulary are key indicators of successful communication outcomes in children with cochlear implants. Speech intelligibility reflects the clarity of spoken language and the ability to be understood by listeners, while receptive vocabulary indicates the child's ability to comprehend spoken words. Both measures are essential for effective communication and are commonly used in clinical and research settings to evaluate the outcomes of cochlear implantation. Previous research has shown that children who receive implants at an earlier age tend to achieve higher scores in these domains, highlighting the importance of early auditory exposure (Geers, 2006; Nicholas & Geers, 2007).

Given the variability in outcomes associated with the timing of cochlear implantation, there is a need for further research comparing speech and language development in children who receive implants at different ages. Such studies are particularly important in local contexts where late implantation is more prevalent. By examining the differences in speech intelligibility and receptive vocabulary between early and late implanted children, researchers can better understand the impact of delayed intervention and contribute to evidence-based clinical practices. This study aims to address this gap by comparing speech and language outcomes in pre-lingually deaf children who received cochlear implants before and after the age of five years (Niparko *et al.*, 2010; Dettman *et al.*, 2007).

2 METHODOLOGY

This study employed a comparative cross-sectional research design to evaluate and compare speech and language outcomes in pre-lingually deaf children who received

cochlear implants at different ages. The design was selected to identify differences between early and late implantation groups at a single point in time, providing insight into the impact of age at implantation on communication outcomes. The study was conducted over a period of 12 months at the Department of Rehabilitation Sciences, University of Lahore, in collaboration with affiliated audiology and speech therapy centers.

A purposive sampling technique was used to recruit participants who met the inclusion criteria. A total sample of 14 children diagnosed with pre-lingual severe to profound sensorineural hearing loss and who had undergone unilateral cochlear implantation were included in the study. Participants were divided into two groups based on the age at implantation: the early implantation group (children implanted between 1–5 years of age) and the late implantation group (children implanted after 5 years of age). Each group consisted of seven participants to ensure equal representation for comparison.

The inclusion criteria required participants to have pre-lingual deafness, a minimum of one year of cochlear implant use, and regular attendance in speech and language therapy sessions. Children with additional disabilities such as cognitive impairment, autism spectrum disorder, or neurological disorders were excluded to avoid confounding variables that could influence speech and language outcomes. Furthermore, only those children whose parents or caregivers provided informed consent were included in the study.

Data collection was carried out using standardized assessment tools to measure speech and language abilities. Speech intelligibility was assessed using the Speech Intelligibility Rating (SIR) scale, which is a widely used five-point scale that evaluates the clarity of a child's speech in everyday communication. Language development, specifically receptive vocabulary, was measured using the Peabody Picture Vocabulary Test (PPVT). These tools were selected due to their established reliability and validity in assessing communication outcomes in children with hearing impairment.

Prior to data collection, ethical approval was obtained from the Research Ethics Committee (REC) of the University of Lahore. Permission was also sought from relevant rehabilitation centers and cochlear implant clinics. The parents or guardians of the participants were informed about the purpose, procedures, and potential benefits of the

study, and written informed consent was obtained. Confidentiality and anonymity of the participants were strictly maintained throughout the research process.

The data collection procedure involved individual assessment sessions conducted in a quiet and controlled clinical environment to ensure accuracy of results. Each child was assessed separately to minimize distractions and enhance performance reliability. The SIR scale ratings were determined based on direct observation and interaction with the child, while the PPVT was administered according to standardized guidelines. Each assessment session lasted approximately 30 to 45 minutes per participant.

Data were entered and analyzed using the Statistical Package for Social Sciences (SPSS) version 25.0. Descriptive statistics, including mean and standard deviation, were calculated to summarize the data. Inferential statistics were applied to compare the outcomes between the two groups. An independent sample t-test was used to determine statistically significant differences in speech intelligibility and receptive vocabulary scores between early and late implanted children. A p-value of less than 0.05 was considered statistically significant.

To ensure the validity and reliability of the findings, standardized procedures were followed during data collection, and all assessments were conducted by trained professionals. The use of validated tools such as the SIR scale and PPVT further strengthened the reliability of the results. Additionally, efforts were made to control extraneous variables, such as therapy duration and device usage, to ensure that the observed differences were primarily attributable to the age at implantation.

Despite careful planning, certain limitations were acknowledged. The relatively small sample size may limit the generalizability of the findings. Moreover, the use of purposive sampling may introduce selection bias. However, the study provides valuable preliminary insights into the impact of implantation timing on speech and language outcomes in pre-lingually deaf children.

3 RESULTS

The study presents the demographic characteristics of the participants, which included a total of fourteen children with pre-lingual deafness who underwent cochlear implantation. The chronological age of the children ranged from 4.50 to 8.50 years, with

a mean age of 6.17 years ($SD = 1.46$), indicating that most participants were within early to middle childhood. In terms of hearing age, which reflects the duration of auditory experience following cochlear implantation, the participants showed a range from 1.50 to 3.50 years, with a mean of 2.50 years ($SD = 0.67$), suggesting relatively consistent exposure to auditory input across the sample. Regarding the age at the time of implantation, children received cochlear implants between 1.50 and 5.50 years, with an average age of 3.67 years ($SD = 1.53$). This variation in implantation age allowed for the comparison of outcomes based on early versus relatively later intervention. Overall, the demographic profile highlights a moderately homogeneous sample in terms of hearing experience, while maintaining variability in implantation age, which is critical for examining its impact on speech and language outcomes, as shown in Table No. 1.

Table 1

Demographic Characteristics of Participants

	N	Minimum	Maximum	Mean	Std. Deviation
Chronological Age of Children	14	4.50	8.50	6.1786	1.46244
Hearing Age of Children	14	1.50	3.50	2.5000	.67937
Age at Time of Implant	14	1.50	5.50	3.6786	1.53932

The table 2 presents the distribution of Peabody Picture Vocabulary Test (PPVT) scores across early and late cochlear implantation groups, along with the level of statistical significance. Among children who received early cochlear implantation (1–5 years), the majority demonstrated higher levels of receptive vocabulary performance. Specifically, most participants ($n = 5$) fell within the *extremely high score* range (130–160), while a smaller number were categorized as having *average* ($n = 1$) and *moderately high* scores ($n = 1$). Notably, none of the early implanted children were in the *moderately low score* category. In contrast, children in the late implantation group (5–7 years) showed comparatively lower performance on the PPVT. The majority of participants ($n = 5$) were classified within the *moderately low score* range (70–85), while only a few ($n = 2$) achieved *average scores* (85–115). No participants in this group attained *moderately high* or *extremely high* score levels.

Overall, the distribution clearly indicates that early implantation is associated with better receptive vocabulary outcomes compared to late implantation. The difference between the two groups was found to be statistically significant ($p = 0.010$), suggesting that the age at cochlear implantation has a significant impact on language development. These findings highlight the advantage of early auditory intervention in achieving higher levels of vocabulary acquisition, as shown in Table No. 2

Table 2

*Cochlear Implant Group * Peabody Picture Vocabulary Test Score*

		Peabody Picture Vocabulary Test Score				P-Value
		Moderately Low Score (70-85)	Average Score (85-115)	Moderately High Score (115-130)	Extremely High Score (130-160)	
Cochlear Implant Group	Early Implanted (1-5)Years	0	1	1	5	0.010
	Late implanted (5-7) years	5	2	0	0	
Total		5	3	1	5	

The table 3 presents the distribution of Speech Intelligibility Rating (SIR) scale scores across cochlear implant groups and age at the time of implantation, along with the corresponding statistical significance. In terms of cochlear implant groups, children who received early implantation (1–5 years) demonstrated better speech intelligibility outcomes. Among these participants, a notable proportion were categorized as completely intelligible ($n = 3$) and mostly intelligible ($n = 3$), while only one child fell into the understandable with effort category, and none were reported as frequently unintelligible. In contrast, children in the late implantation group (5–7 years) exhibited comparatively poorer speech outcomes. The majority of these participants were classified as understandable with effort ($n = 5$), while the remaining ($n = 2$) were frequently unintelligible, with none achieving completely or mostly intelligible speech levels. The difference between early and late implantation groups was found to be statistically significant ($p = 0.014$), indicating that earlier implantation is associated with superior speech intelligibility. Furthermore, when examining speech intelligibility in relation to the age at time of implantation, a trend can be observed where children implanted at younger ages (1.50–3.00 years) predominantly achieved higher intelligibility levels, including completely and mostly intelligible speech. As the age at implantation increased,

particularly beyond 3.50 years, speech outcomes tended to decline, with more children falling into the understandable with effort and frequently unintelligible categories. However, this association was not statistically significant ($p = 0.128$), suggesting that while a pattern is evident, it did not reach statistical significance within this sample.

Overall, the findings indicate that early cochlear implantation contributes to better speech intelligibility outcomes, although the relationship between exact age at implantation and speech performance requires further investigation, as shown in Table No. 3.

Table 3

*Cochlear Implant Group * Speech Intelligibility Rating Scale*

		Speech Intelligibility Rating Scale				P-Value
		Completely Intelligible	Mostly Intelligible	Understandable with Effort	Frequently Unintelligible	
Cochlear Implant Group	Early Implanted (15) Years	3	3	1	0	0.014
	Late implanted (5-7) years	0	0	5	2	
Total		3	3	6	2	

Table 4 presents the relationship between age at the time of cochlear implantation and speech intelligibility outcomes measured through the Speech Intelligibility Rating (SIR) scale. The results show that children implanted at younger ages (1.5 to 3.0 years) demonstrated better speech intelligibility outcomes, with most of these participants falling in the “Completely Intelligible” and “Mostly Intelligible” categories. Specifically, the majority of children implanted at 1.5 years achieved completely intelligible speech, while those implanted at 2.0 to 3.0 years were distributed between completely and mostly intelligible categories. In contrast, children implanted at older ages (3.5 to 5.5 years) showed comparatively poorer outcomes, with most falling in the “Understandable with Effort” category. Notably, the 5.0-year implantation group had the highest concentration of children in the “Understandable with Effort” and “Frequently Unintelligible” categories, indicating reduced speech clarity in later-implanted cases. The statistical analysis revealed a non-significant association between age at implantation and speech

intelligibility ($p = 0.128$). This suggests that although there is a visible trend toward better speech intelligibility with earlier implantation, the relationship was not statistically significant in this sample. Overall, the findings indicate that earlier cochlear implantation is associated with better speech intelligibility outcomes, but the difference across age groups did not reach statistical significance.

Table 4

*Age at Time of Implant * Speech Intelligibility Rating Scale*

		Speech Intelligibility Rating Scale				P-Value
		Completely Intelligible	Mostly Intelligible	Understandable with Effort	Frequently Unintelligible	
Age at Time of Implant	1.5 0	2	0	0	0	0.128
	2.0 0	1	1	0	0	
	2.5 0	0	1	0	0	
	3.0 0	0	1	0	0	
	3.5 0	0	0	1	0	
	5.0 0	0	0	4	2	
	5.5 0	0	0	1	0	
Total		3	3	6	2	

Table 5 presents the association between age at the time of cochlear implantation and Peabody Picture Vocabulary Test (PPVT) scores among the participants. The results indicate a clear variation in receptive vocabulary outcomes across different ages at implantation. Children implanted at younger ages (1.5 to 3.0 years) predominantly achieved higher PPVT performance levels, particularly in the *Average (85–115)*, *Moderately High (115–130)*, and *Extremely High (130–160)* categories. Notably, the Extremely High score category was observed mainly in children implanted at 1.5 and 2.0 years, suggesting stronger language acquisition outcomes with earlier implantation. In contrast, children implanted at older ages (5.0 to 5.5 years) showed a higher concentration in the Moderately Low score range (70–85), indicating comparatively weaker receptive vocabulary development. The statistical analysis revealed a significant association between age at implantation and PPVT scores ($p = 0.022$). This indicates that age at

implantation has a meaningful impact on receptive vocabulary outcomes, with earlier implantation being associated with better language performance.

Overall, the findings suggest that earlier cochlear implantation contributes to improved receptive vocabulary development, while delayed implantation may limit optimal language acquisition outcomes.

Table 5

*Age at Time of Implant * Peabody Picture Vocabulary Test Score*

		Peabody Picture Vocabulary Test Score				P-Value
		Moderately Low Score (70-85)	Average Score (85-115)	Moderately High Score (115-130)	Extremely High Score (130-160)	
Age at Time of Implant	.50	0	0	0	2	.022
	.00	0	0	0	2	
	.50	0	0	0	1	
	.00	0	0	1	0	
	.50	0	1	0	0	
	.00	4	2	0	0	
	.50	1	0	0	0	
	.00	1	0	0	0	
Total		5	3	1	5	

4 DISCUSSION

The present study examined speech and language outcomes in pre-lingually deaf children who received cochlear implants, with particular attention to the effect of age at implantation on receptive vocabulary and speech intelligibility. The findings provide important evidence regarding the role of early auditory access in shaping communication development, especially in children implanted at later ages.

The demographic profile of the participants showed variability in chronological age and implantation age, while hearing age remained relatively consistent. This indicates that although children had similar durations of device use, differences in age at implantation may have played a critical role in their speech and language outcomes. The

variability in implantation age (1.5 to 5.5 years) is particularly relevant, as it reflects differing exposure to auditory stimulation during the sensitive period of language development. Previous literature consistently highlights that early auditory input is essential for optimal neuroplasticity and language acquisition, which aligns with the current sample characteristics.

In relation to receptive vocabulary, a statistically significant association was observed between age at implantation and Peabody Picture Vocabulary Test (PPVT) scores ($p = 0.022$). Children who received implants at younger ages demonstrated superior receptive vocabulary skills, with a majority achieving average to extremely high scores. In contrast, those implanted at older ages, particularly after 5 years, predominantly scored in the moderately low range. These findings are consistent with earlier research emphasizing the advantages of early cochlear implantation for vocabulary development. Studies such as Svirsky *et al.* (2004) and Nixon *et al.* (2014) have similarly reported that children implanted before the critical language period show significantly better receptive language outcomes due to enhanced auditory stimulation during early brain development. The present study reinforces this evidence, highlighting that delayed implantation may limit vocabulary acquisition due to reduced exposure to structured linguistic input during early childhood.

Speech intelligibility outcomes, measured through the Speech Intelligibility Rating (SIR) scale, showed a clear but non-significant trend ($p = 0.128$) favoring earlier implantation. Children implanted at younger ages were more likely to demonstrate completely or mostly intelligible speech, whereas those implanted after 5 years were primarily rated as “understandable with effort” or “frequently unintelligible.” Although the association did not reach statistical significance, the observed pattern is consistent with established literature. Research by Geers *et al.* (2009) and Wilson *et al.* (2020) has similarly reported that earlier implantation supports clearer speech production due to improved auditory feedback mechanisms during speech development. The lack of statistical significance in the current study may be attributed to the small sample size and inter-individual variability in rehabilitation outcomes.

Overall, the findings suggest that while cochlear implantation provides benefits regardless of age, earlier implantation results in significantly better receptive vocabulary outcomes and more favorable speech intelligibility trends. The results support the theory

of a sensitive period for language acquisition, during which the brain is most responsive to auditory stimulation. Delayed implantation beyond this period may limit the full potential of language development, even with appropriate rehabilitation.

Several additional factors may also have influenced outcomes, including variability in therapy access, parental involvement, and individual developmental differences. These factors are widely recognized in the literature as contributing to variability in post-implantation performance.

In conclusion, the present study contributes to the growing body of evidence supporting early cochlear implantation as a key determinant of speech and language success. Although late-implanted children demonstrate progress, their outcomes remain comparatively limited, particularly in receptive vocabulary development. These findings emphasize the importance of early detection of hearing loss, timely cochlear implantation, and structured post-implant rehabilitation to optimize communication outcomes in pre-lingually deaf children.

5 CONCLUSION

In conclusion, the study found that age at cochlear implantation plays an important role in speech and language outcomes in pre-lingually deaf children. Earlier implantation was associated with better receptive vocabulary and improved speech intelligibility, while late implantation showed comparatively weaker outcomes. Although children implanted after 5 years demonstrated progress, results remained limited. Overall, timely cochlear implantation within the early developmental period is crucial for achieving optimal communication and language development outcomes.

6 RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed:

Early identification of hearing loss should be prioritized through universal newborn hearing screening programs to ensure timely diagnosis and intervention. Cochlear implantation should ideally be performed within the critical period of language development to maximize speech and language outcomes. For children implanted after 5

years of age, intensive and individualized speech-language therapy programs should be implemented focusing on auditory training, vocabulary development, and speech intelligibility improvement.

Parental involvement should be actively encouraged, with structured training provided to create a language-rich home environment that supports continuous auditory and verbal stimulation. A multidisciplinary approach involving speech-language pathologists, audiologists, psychologists, and educators is essential for comprehensive rehabilitation. Regular follow-up and continuous assessment should be ensured to monitor progress and modify intervention plans accordingly.

Furthermore, awareness campaigns should be strengthened to educate communities about the importance of early cochlear implantation. Accessibility to cochlear implant services and post-implant rehabilitation should be improved, particularly in underserved regions. Finally, further large-scale and longitudinal research is recommended to better understand long-term outcomes and optimize intervention strategies for children with late cochlear implantation.

7 LIMITATIONS

This study has several limitations that should be considered when interpreting the findings. The sample size was relatively small, which limits the statistical power and generalizability of the results to the broader population of pre-lingually deaf children. All participants were pre-lingually deaf and most received cochlear implants after the age of 5, which restricts comparison with early-implanted children and limits evaluation of age-related differences across a wider spectrum.

The absence of a control group of children implanted at an earlier age further limits the ability to directly compare outcomes and strengthen causal inferences regarding the effect of implantation age. Variations in post-implantation rehabilitation, including differences in therapy intensity and access to speech-language services, may also have influenced individual outcomes.

In addition, factors such as parental involvement, socioeconomic status, and educational background were not fully controlled, although they are known to significantly affect speech and language development. Finally, the follow-up duration

may not have been sufficient to capture long-term language and communication outcomes, and some assessment tools may not have been fully adapted to the participants' linguistic and cultural context.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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