

Pediatric Hearing Aid Solutions: Assessing the Impact of Microphone Directionality on Speech Perception

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ABSTRACT

Hearing loss in children presents significant challenges to their speech, language, and cognitive development. Early detection and intervention, including the use of pediatric hearing aids, are critical for improving communication outcomes. This study examines the impact of microphone directionality—specifically omnidirectional and directional microphones—on speech perception in children aged 5 to 12 years with mild to severe sensorineural hearing loss (SNHL). Using a within-subject design, 18 participants were fitted with hearing aids featuring both microphone configurations over a two-month period, with speech perception and sound localization assessed through the P.E.A.C.H. test.

The results reveal that directional microphones significantly enhance speech recognition in noisy environments by reducing background noise, making them ideal for structured settings like classrooms. Conversely, omnidirectional microphones provide better sound localization and environmental awareness, crucial for safety and incidental learning in dynamic or quiet environments. These findings emphasize the importance of a balanced approach to microphone configuration in pediatric hearing aids, suggesting that adaptive microphone technologies—capable of switching between modes based on the acoustic environment—may offer the best solution.

This study provides evidence-based recommendations for optimizing pediatric hearing aid technology to meet the diverse listening needs of children. It highlights the need for further longitudinal research to explore the long-term effects of microphone directionality on auditory development and cognitive growth. The findings also offer practical guidance for audiologists, advocating for personalized hearing aid fittings that consider both the severity of hearing loss and the environments in which the child typically communicates.

Keywords: *Hearing Aid, Pediatric Audiology, Speech perception, P.E.A.C.H., Microphone Directionality. Hearing aid technology.*

INTRODUCTION

Hearing loss in children affects critical areas of development, including speech, language, cognitive skills, and social integration. Without early identification and timely intervention, children with hearing loss often face challenges in educational and social settings. Pediatric hearing aids are essential tools that provide necessary auditory input, fostering language acquisition and cognitive growth. Among recent technological advancements in hearing aids, microphone directionality has become a critical feature influencing how children perceive and interact with their acoustic environments. These microphones can be configured to either omnidirectional mode, which captures sounds from all directions, or directional mode, which focuses on sounds from a specific direction, typically in front of the listener.

Choosing the optimal microphone setting for children presents unique challenges. Directional microphones improve speech perception in noisy environments by reducing background noise, making them suitable for structured environments like classrooms where focused communication is essential (Stiles et al., 2008; Jespersen et al., 2021; Ricketts, 2013). Conversely, omnidirectional microphones enhance spatial awareness and sound localization, which are critical for safety and incidental learning in dynamic or quiet environments (Arndt, 2011; McCreery et al., 2012). For children who navigate various acoustic environments, both configurations offer unique advantages that enhance their auditory experiences.

Building on Stiles et al.'s (2008) demonstration of improved speech perception in noisy environments through directional microphones, Jespersen et al. (2021) extended these findings, advocating for adaptive microphone technology. Adaptive microphones provide a flexible solution by automatically switching between directional and omnidirectional modes, depending on the noise level. This adaptability is essential for children with SNHL, who need both improved speech clarity in structured environments, such as classrooms, and broader spatial awareness for safe navigation in dynamic settings. This study investigates the practical outcomes of these recommendations by assessing the real-world effectiveness of adaptive microphone settings in pediatric hearing aids, thus contributing new insights into the optimal configurations for varied environments.

Globally, the prevalence of hearing loss in children varies significantly by region, with factors such as healthcare access and early screening programs impacting these rates. According to the Centers for Disease Control and Prevention (CDC, 2020), approximately 1 to 3 per 1,000 children are born with hearing loss, with additional cases acquired during childhood due to untreated infections or injuries. Early detection through neonatal screening has significantly improved outcomes by facilitating timely intervention; however, in regions lacking universal screening, undiagnosed hearing loss continues to impact children's educational and social development (World Health Organization [WHO], 2021).

Pediatric hearing aids play a critical role in mitigating these effects, as they provide essential auditory input needed for speech

and language development. Microphone directionality, specifically the omnidirectional and directional configurations, has been identified as a significant factor affecting speech perception in various environments. Directional microphones, by focusing on sounds from the front, are effective at improving speech intelligibility in noisy settings. However, this benefit can come at the cost of reduced awareness of sounds from other directions, which may impact safety and incidental learning (Arndt, 2011). Omnidirectional microphones, which capture sounds from all directions, are beneficial for maintaining environmental awareness, though they may struggle in environments with significant background noise, where speech perception becomes challenging (McCreery et al., 2012).

Research increasingly supports the importance of balancing these configurations to optimize the listening experience for children with hearing loss. Adaptive microphone technology, which automatically switches between omnidirectional and directional modes depending on the acoustic environment, has emerged as a promising solution (Jespersen et al., 2021). Such adaptive systems allow children to benefit from enhanced speech perception in noisy environments while preserving spatial awareness in quieter settings, addressing both the need for communication clarity and environmental awareness.

This study systematically investigates the effects of omnidirectional and directional microphone configurations on speech perception and sound localization in children with sensorineural hearing loss (SNHL). By comparing these two settings, the research

aims to provide evidence-based recommendations for best practices in pediatric hearing aid fittings, promoting an individualized approach that aligns with children's diverse listening needs. Highlighting the potential of adaptive hearing technology, this study contributes to ongoing efforts to improve pediatric hearing aids, ultimately supporting better communication outcomes and overall development for children with hearing loss.

REVIEW OF LITERATURE

Microphone Directionality in Pediatric Hearing Aids

Microphone directionality plays a pivotal role in determining auditory experiences of children with hearing loss. Previous studies have investigated the trade-offs between omnidirectional and directional microphones in both adult and pediatric populations. While there is a consensus that directional microphones improve speech perception in noisy environments, the literature highlights the limitations of relying solely on directional settings, particularly in children who are still developing spatial hearing skills. There are two main types of microphones used in hearing aids: omnidirectional microphones, which pick up sounds from all directions equally, and directional microphones, which focus on amplifying sounds from a specific direction, typically in front of the listener. This distinction is crucial because it affects how children perceive and interact with their auditory environment (Wolfe et al., 2022).

While directional microphones improve speech perception in noisy environments by reducing background noise (Jespersen et al.,

2021), they may compromise a child's ability to localize sounds from other directions. This can be problematic for children's safety and for auditory development, as sound localization is critical for environmental awareness (Arndt, 2011; Ricketts, 2013). Conversely, omnidirectional microphones, though more effective in supporting sound localization and awareness, may struggle in noisy environments, leading to decreased speech intelligibility (McCreery et al., 2012).

Speech Perception in Noisy vs. Quiet Environments

Children with hearing loss face significant challenges in noisy environments, as they require a higher signal-to-noise ratio than adults to recognize speech effectively (Brimijoin, 2014). Research consistently shows that directional microphones can provide substantial benefits in these settings by filtering out background noise and focusing on the speaker's voice (Stiles et al., 2008). This enhancement allows children to participate more fully in conversations, particularly in structured environments like classrooms (Ricketts, 2013).

However, there is concern about over-reliance on directional microphones in children. Some studies suggest that while directional microphones improve speech recognition, they may hinder children's ability to engage in incidental learning—the process by which children absorb information from the environment without directly focusing on it (Wolfe et al., 2022). This learning is crucial for cognitive development, particularly in social settings where non-verbal cues and environmental sounds play a significant role (Arndt, 2011). Therefore, it is essential to balance the need for improved speech perception in noisy

environments with the developmental need for auditory awareness.

Omnidirectional vs. Directional Microphone Performance

The trade-offs between omnidirectional and directional microphones have been well documented, but there remains a lack of consensus regarding their optimal use in pediatric hearing aids. Omnidirectional microphones facilitate greater auditory awareness and sound localization, which are critical for safety and learning in dynamic environments (Wolfe et al., 2022). Children equipped with omnidirectional hearing aids can detect important environmental sounds, helping them better navigate their surroundings (McCreery et al., 2013). However, omnidirectional microphones are less effective in noisy environments, as they do not distinguish between speech and background noise, leading to a decline in speech perception (Chung, 2004).

In contrast, directional microphones improve speech intelligibility by focusing on sound from the front, making them particularly useful in noisy environments (Stiles et al., 2008). Research shows that children using directional microphones can achieve speech recognition levels similar to their normal-hearing peers in noisy settings like classrooms (Ricketts, 2013). Yet, the increased focus on front-facing sounds can lead to diminished awareness of peripheral sounds, potentially affecting sound localization and overall auditory development (Wolfe et al., 2022).

Challenges and Opportunities in Microphone Directionality

The adaptive technologies that blend both omnidirectional and directional modes hold

promise for addressing these challenges. (Jespersen et al., 2021) suggest that hybrid systems, which adjust microphone settings based on the acoustic environment, could provide an optimal balance between speech perception and environmental awareness. These adaptive systems have shown improvements in listening comfort and overall speech understanding in children with hearing loss, especially in complex environments (Petersen, 2022).

However, despite these advancements, there are still significant gaps in the research, particularly concerning the long-term developmental effects of using directional versus omnidirectional microphones in pediatric populations. Most studies have focused on short-term outcomes, such as immediate improvements in speech perception, but there is little evidence regarding how these technologies influence auditory development over time (Walker et al., 2013). This gap in knowledge suggests a need for further longitudinal studies to understand the full impact of microphone directionality on children's auditory and cognitive development.

Implications for Clinical Practice

The current body of research underscores the importance of adopting a flexible approach to microphone configuration in pediatric hearing aids. Audiologists must consider the individual needs of each child, as well as the specific listening environments they encounter daily. While directional microphones may offer significant benefits in structured, noisy settings, omnidirectional microphones remain critical for promoting sound localization and environmental awareness, particularly in unstructured,

dynamic settings where safety is a concern (McCreery et al., 2012).

The clinical implications are clear: an adaptive strategy that transitions seamlessly between omnidirectional and directional settings may be the best solution for pediatric patients. As technology continues to evolve, further research is needed to determine the best practices for optimizing hearing aid configurations, ensuring that children with hearing loss can achieve both improved speech perception and full auditory development (Ricketts, 2013).

Need of the study

Despite advancements in hearing aid technology, there remains a lack of consensus regarding the optimal microphone configuration for pediatric populations with hearing loss. Specifically, the effectiveness of directional versus omnidirectional microphone systems in improving speech perception outcomes in children aged 6 to 12 years has not been comprehensively evaluated. This gap in evidence-based decision-making poses challenges for audiologists when fitting hearing aids for pediatric patients, often leading to suboptimal outcomes and delayed speech development.

Addressing this gap through systematic research is essential for advancing clinical practice and improving communication outcomes for pediatric hearing aid users. By investigating the impact of microphone directionality on speech perception, this study aims to provide crucial insights that can optimize hearing aid technology for children. The findings of this research will inform audiological practices and contribute

to better auditory development for children with hearing loss.

METHOD

Aim of the study

The study aimed to compare the effectiveness of omnidirectional and directional microphones in pediatric hearing aids. The rationale for this research is to highlight the importance of optimizing hearing aid technology for pediatric populations, thereby improving their auditory experiences and overall quality of life.

Inclusion criteria

This study utilized a within-subjects design to compare the effectiveness of omnidirectional and directional microphones in pediatric hearing aids on speech perception. The research was conducted over a two-month period, during which each participant used their pediatric hearing aids with both omnidirectional and directional microphone configurations for one full month each. The sequence in which participants were exposed to the two microphone types was randomly assigned to minimize bias and ensure the validity of the results.

Participants included 18 children aged 6 to 12 years with mild, moderate, or severe sensorineural hearing loss (SNHL). All participants had staple hearing aids fitting and normal cognitive function, attended regular schools with normal-hearing peers, and were capable of complying with study procedures.

This study's choice of microphone settings aligns with children's developmental needs by examining directional settings in structured environments like classrooms, where focused communication is vital, and omnidirectional settings in dynamic or open spaces, promoting spatial awareness and safety. By focusing on these varied environments, the study aimed to assess each microphone configuration's impact on both speech perception and sound localization, aligning technology use with everyday developmental needs.

Procedure

Participants were recruited through local audiology clinics. The small sample size was justified by the exploratory nature of the study, through a larger sample would provide more generalizable results.

Participant were fitted with hearing aids from two leading brands- Phonak and Oticon pediatric hearing aids that offer both omnidirectional and directional microphone settings. The intervention was divided into two phases. During the first month, participants used hearing aids set to either omnidirectional or directional microphone settings, and during the second month, the microphone mode was switched. This ensured exposure to similar environments—home, school, and outdoor settings—during each phase, thus controlling for environmental factors and eliminating bias towards a specific microphone configuration.

Speech perception and sound localization abilities were assessed using the Parent's Evaluation of Aural/Oral Performance of Children (P.E.A.C.H.) test (Appendix A). The P.E.A.C.H. test is designed to evaluate a

child’s auditory performance in both quiet and noisy environments, providing a comprehensive assessment of their speech recognition capabilities. The reliability of the P.E.A.C.H. test has been well-established through various studies, showing strong correlations with other established measures of speech perception, such as the Early Speech Perception Test (ESPT) and the Listening Comprehension Test (LCT).

Data were collected at the end of each month, and the results were recorded and analysed for each participant using appropriate statistical methods.

Ethical Considerations

The study followed strict ethical guidelines, with informed consent obtained from parents or legal guardians and assent obtained from participating children (Appendix B). The study protocol was reviewed and approved by the institutional ethics committee to ensure compliance with ethical standards. This study was approved by ethics committee of School of Advanced Education, Research and Accreditation S.L (Spain).

RESULTS

Descriptive Statistics of the Participants

A total of 18 children aged 6 to 12 years participated in the study. The Parent’s Evaluation of Aural/Oral Performance of Children (P.E.A.C.H.) test was used to assess the participants' speech perception in both quiet and noisy environments under two microphone settings: omnidirectional and directional. The results reveal distinct performance patterns based on the microphone setting used, with directional

microphones enhancing speech recognition in noisy environments, while omnidirectional microphones supported better sound localization in quieter settings. Table 1 provides an overview of the participant characteristics, showing the distribution of gender, hearing aid brand used, and the degree of hearing loss among the children in this study. This distribution offers insight into the variety of factors potentially impacting speech perception performance.

Table 1.

Participant Characteristics

Variable	Category	Count
Gender	Female	11
	Male	7
Hearing Aid Brand	Phonak	10
	Oticon	8
Degree of Hearing Loss	Mild	1
	Moderate	7
	Severe	10

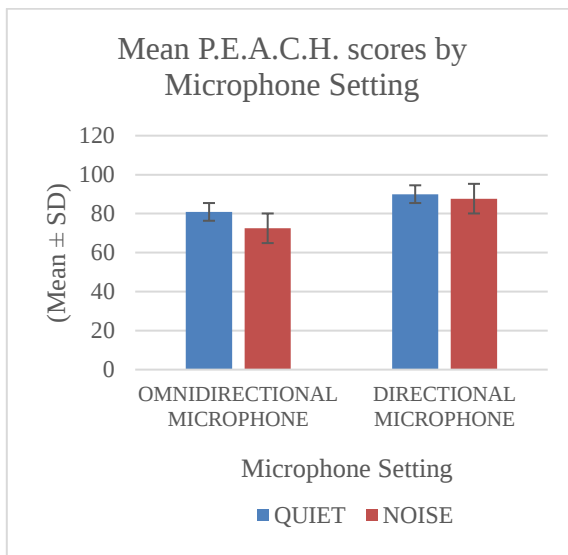
P.E.A.C.H. Test Results: Omnidirectional vs. Directional Microphones

The P.E.A.C.H. test measured speech perception performance in both quiet and noisy environments with omnidirectional and directional microphones. A clear performance distinction emerged between the two settings. Figure 1 below displays the mean P.E.A.C.H. scores, indicating that directional microphones significantly outperformed omnidirectional microphones in both quiet and noisy environments. This

improvement was particularly notable in noisy settings, where directional microphones achieved a mean score of 87.7 compared to 72.5 for omnidirectional microphones, reflecting the directional setting's ability to focus on speech and reduce background noise.

Figure 1.

Mean P.E.A.C.H. Scores by Microphone Setting



From the results, it is evident that directional microphones significantly outperformed omnidirectional microphones in both quiet and noisy environments. The overall mean scores for directional microphones were higher, with a notable difference in noisy environments (87.7 for directional microphones versus 72.5 for omnidirectional).

Impact of Microphone Directionality on Speech Perception

The data reveals distinct advantages in using directional microphone modes for enhancing speech perception, especially in noisy

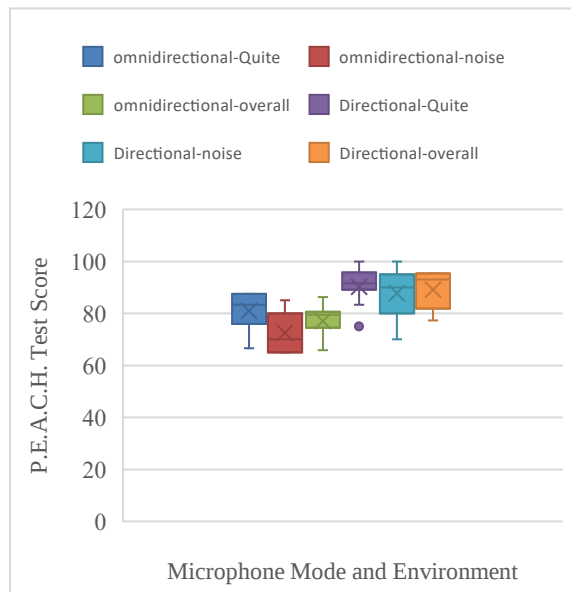
environments. Subjects generally scored higher on the P.E.A.C.H. test when utilizing directional microphones in both quiet and noisy conditions, suggesting that this mode helps focus on relevant auditory signals while filtering background sounds.

In quiet environments, the directional mode provided slightly better P.E.A.C.H. test results compared to the omnidirectional mode, indicating that directional microphones can enhance speech clarity even without significant noise interference. This supports the use of directional settings for general clarity and focus on speech as shown in Figure 2.

In contrast, the omnidirectional microphone mode, which captures sounds from all directions, was less effective in noisy environments, as indicated by lower P.E.A.C.H. test scores. This suggests that omnidirectional microphones may be more suited to environments where awareness of all sounds is beneficial rather than selective focus on speech.

Figure 2.

Comparison of P.E.A.C.H Test Scores by Microphone Mode and Environment



Impact of Hearing Loss Severity

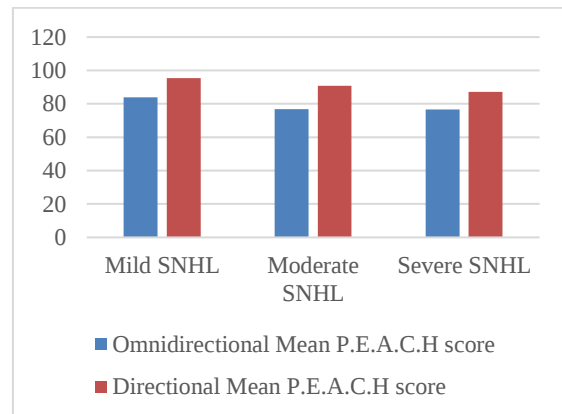
The severity of hearing loss influenced P.E.A.C.H. test outcomes, with children experiencing milder hearing loss generally scoring higher across both omnidirectional and directional settings. Figure 3 illustrates the relationship between hearing loss severity and P.E.A.C.H. test scores.

In the omnidirectional setting, children with milder hearing loss showed consistently better performance, while variability increased among children with severe hearing loss. However, the directional microphone setting appeared to mitigate some of these challenges, leading to more stable and higher scores even among those with greater hearing loss. This finding suggests that directional microphones can compensate for some difficulties faced by

children with severe hearing loss in noisy environments.

Figure 3.

P.E.A.C.H. Scores by Degree of Hearing Loss



Summary of Findings

Overall, directional microphones significantly enhance speech perception in both quiet and noisy environments, particularly benefiting children who struggle the most in challenging auditory settings. While children with milder hearing loss benefited more from omnidirectional settings, directional microphones helped mitigate performance challenges for those with severe hearing loss, supporting a more stable listening experience. This analysis underscores the need for careful consideration of both microphone settings and hearing aid brands during the fitting process for pediatric patients, tailoring choices to the child's specific degree of hearing loss and listening environments.

DISCUSSION

Microphone modes in pediatric hearing aids do more than enhance speech perception; they also play a vital role in supporting

broader developmental milestones. Directional settings improve speech intelligibility by focusing on the primary speaker, making them particularly effective in structured, noisy environments like classrooms. This focused listening experience fosters language acquisition and cognitive participation. In contrast, omnidirectional modes promote spatial awareness and incidental learning by capturing sounds from all directions, which is essential for children's safety, social engagement, and cognitive growth. Together, these findings suggest that microphone settings serve not just as auditory adjustments but as developmental tools that align with children's diverse listening needs.

The study's findings underscore the importance of matching microphone settings to the listening environments that children commonly encounter. Directional microphones are ideal for structured environments, such as classrooms, where focused communication enhances learning. Conversely, omnidirectional microphones support dynamic or open settings like playgrounds, where sound awareness from multiple directions is crucial for safety and engagement in incidental learning. This alignment not only improves auditory outcomes but also supports key developmental milestones in real-world contexts.

Consistent with findings from Stiles et al. (2008), the enhanced speech intelligibility provided by directional microphones in noisy settings validates their effectiveness in environments like classrooms. However, our findings extend these benefits to adaptive technologies that switch modes

automatically based on environmental noise, as advocated by Jespersen et al. (2021). By adapting to different auditory environments, adaptive microphone settings provide a balanced auditory experience, contributing to both communication clarity and spatial awareness. These results strengthen the case for hybrid systems, suggesting that they may offer a comprehensive solution for optimizing children's developmental outcomes in varied settings.

Furthermore, the study's results showed that children with milder hearing loss performed better across both settings, but directional microphones were especially beneficial for those with severe hearing loss, helping mitigate the additional challenges of noisy environments.

These findings advocate for a personalized approach in pediatric audiology. Audiologists are encouraged to consider the individual needs of each child, including the environments they frequently encounter, to determine the optimal microphone configuration. An adaptive strategy that switches between omnidirectional and directional settings based on environmental demands may provide the most balanced solution for enhancing both speech perception and environmental awareness in children with hearing loss.

Recommendations

Based on these findings, audiologists should consider using adaptive microphone technologies that can switch between omnidirectional and directional modes. This would allow children to benefit from improved speech perception in noisy environments and maintain sound localization and environmental awareness in

quieter or more dynamic settings. Audiologists should also tailor hearing aid configurations to the specific needs and environments of each child, ensuring a personalized approach to hearing care.

Limitations

One limitation of this study is the relatively short duration of two months, which may not fully capture the long-term effects of microphone directionality on auditory development. Additionally, the sample size of 18 participants, though adequate for a preliminary analysis, limits the generalizability of the findings. Larger, more diverse studies are needed to validate these results.

Future Research

Future research should focus on the long-term developmental impact of using different microphone configurations in pediatric hearing aids. Longitudinal studies are required to assess how directional and omnidirectional microphones affect not only speech perception but also cognitive and social development over time. Moreover, further exploration of adaptive microphone technologies is necessary to determine the optimal configurations for various environments and listening needs.

CONCLUSION

This study examined the impact of microphone directionality on speech perception in children aged 6 to 12 years with mild to severe sensorineural hearing loss. The findings indicate that directional microphones significantly improve speech perception in noisy environments by reducing background noise. This

improvement is crucial for structured environments like classrooms, where focused communication is vital. On the other hand, omnidirectional microphones offer better sound localization, enhancing environmental awareness and safety, which is essential in dynamic settings.

The results emphasize the need for adaptive microphone technologies that can switch between directional and omnidirectional settings based on environmental demands. This dual-mode adaptability could provide children with the benefits of both enhanced speech perception in structured settings and full environmental awareness in dynamic spaces, thus better supporting their cognitive and social development. Tailoring hearing aid configurations to each child's unique needs, environments, and degree of hearing loss can optimize developmental outcomes and improve daily communication experiences for children with hearing loss.

CONFLICTS OF INTEREST

The author declares no conflicts of interest related to this study.

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APPENDIX

Appendix A: P.E.A.C.H. Test

The Parent's Evaluation of Aural/Oral Performance of Children (P.E.A.C.H. test) is a standardized assessment tool designed to evaluate children's auditory performance in both quiet and noisy environments. The test assesses various aspects of speech perception and localization, providing insights into how well children can understand spoken language in different auditory settings.

In this study, the P.E.A.C.H. test was administered to each participant at the end of each month during the two-month intervention period. The results were used to compare the effectiveness of omnidirectional and directional microphones in pediatric hearing aids.

Appendix B: Consent Form

The Consent Form is a document provided to parents or legal guardians of participants. It outlines the purpose of the study, the procedures involved, potential risks and benefits, and the rights of participants. The form ensures that guardians are fully

informed before giving consent for their child's participation in the research.

In this study, informed consent was obtained from all parents or legal guardians prior to the enrollment of their children. The consent form was reviewed with each guardian to address any questions or concerns they may have had about the study.