NEONATAL HEARING LOSS: THE INFLUENCE OF LOW BIRTH WEIGHT AND PREMATURITY ON OTOACOUSTIC EMISSION (OAE) RESULTS

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ABSTRACT

Background: *Congenital hearing loss is a common disorder in neonates, with a higher risk in infants with low birth weight (LBW) and prematurity. Otoacoustic Emission (OAE) screening is recommended as an initial examination, but studies regarding its relationship with LBW and prematurity in Indonesia are still limited.* ***Objective:*** *To determine the relationship between LBW and prematurity on OAE hearing screening results in neonates at Dr. Hasan Sadikin General Hospital, Bandung.* ***Methods:*** *An analytic observational study with a cross-sectional design using secondary data from the medical records of neonates who underwent OAE examinations from November 2024 to October 2026. Bivariate analysis was performed using the Chi-Square test with a significance level of* $p<0.05$. ***Results:*** *The study involved 1,007 subjects, with 31.4% having LBW and 29.7% being premature. A total of 93.1% of subjects passed and 6.8% referred. Hearing loss was higher in the LBW group compared to normal birth weight (10.2% vs 5.2%;* $p=0.004$*) and in the premature group compared to term (9.7% vs 5.5%;* $p=0.016$*).* ***Conclusion:*** *LBW and prematurity have a significant relationship with hearing loss based on OAE screening results in neonates at Dr. Hasan Sadikin General Hospital, Bandung.*

Keywords: *Hearing Loss, Low Birth Weight, Neonates, Otoacoustic Emission, Premature*

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INTRODUCTION

Congenital hearing loss in neonates is the most common disorder with a global prevalence reaching 1 to 3 per 1,000 live births. In Southeast Asia, the average prevalence of hearing loss is 2 per 1,000 births, whereas in high-risk populations (neonates treated in the intensive care unit), the incidence can increase significantly to 1% to 7.5%.[1–3]

Furthermore, the Centers for Disease Control and Prevention (CDC) estimates that about 25% of all childhood hearing loss cases are associated with a history of birth weight below 2,500 grams. Low birth weight (LBW) and prematurity are associated as risk factors affecting the auditory system. Infants with a history of LBW and prematurity generally have immature cochlear structures, especially in the stria vascularis area. This congenital condition makes the outer hair cells in the organ of Corti highly susceptible to damage from medical exposure in the intensive care unit. This damage is typically triggered by oxygen deprivation (asphyxia), severe respiratory distress, or the cumulative effects of ototoxic drugs like aminoglycoside antibiotics. These various factors damage the mechanical function of outer hair cells in responding to sound and trigger a decline in sensorineural hearing function.[3–5]

If this disorder is not detected and intervened before the age of 6 months, the sensory deficit will cause permanent delays in speech, language, and cognitive development. This condition also has the potential to reduce the quality of psychosocial interactions and the child's daily functional abilities until they reach adulthood. In addition, this disorder also triggers an economic burden for the healthcare system and families, such as treatment costs, prescriptions, and hospitalization fees. Therefore, early detection and intervention are needed to minimize lifelong disabilities.[1,4]

The Joint Committee on Infant Hearing (JCIH) recommends early hearing detection and intervention to detect and manage hearing loss. Otoacoustic Emission (OAE) is recommended as the initial screening modality because it is objective, non-invasive, and has a quick examination time. OAE works by detecting and recording the reflection of retrograde acoustic energy emitted by intact outer hair cells in the cochlea. Although OAE is frequently used in hospitals as an initial screening for hearing loss, studies analyzing the relationship between LBW and prematurity on the final results of OAE screening are still limited, especially in Indonesia. This study aims to determine the relationship between LBW and prematurity on OAE hearing screening results in the neonatal population at Dr. Hasan Sadikin General Hospital, Bandung.[6,7]

METHODS

A. Study Design and Population

This study used an analytic observational method with a cross-sectional design aimed at analyzing the relationship between low birth weight (LBW) and prematurity with Otoacoustic Emission (OAE) hearing screening results. The study population included all neonates (age <29 days) who underwent OAE examinations at Dr. Hasan Sadikin General Hospital, Bandung from November 1, 2024, to October 31, 2026, and met the inclusion criteria.

B. Data Collection and Statistical Analysis

Secondary data obtained from medical records were extracted and processed digitally using statistical software. Then, univariate analysis was conducted for demographic characteristics, and bivariate analysis using the Chi-Square test was used to evaluate the association of variables with a significance level of $p<0.05$. All analysis results are presented in narrative form and frequency distribution tables.

RESULTS

A. Characteristics of Study Subjects

This study involved 1,007 study subjects who met the inclusion and exclusion criteria. Demographic characteristics based on gender showed the proportion of female neonates was more dominant, with 570 subjects (56.6%), compared to male neonates with 435 subjects (43.2%). Most of the study subjects were born with a normal birth weight, amounting to 691 subjects (68.6%). Meanwhile, the proportion of infants with Low Birth Weight (LBW) was 31.4% (316 subjects). For the gestational age variable, 70.3% or 708 neonates were born full-term, while the prematurity rate in this study population was 29.7% (299 subjects). Evaluation of hearing function using the OAE screening instrument showed 938 subjects (93.1%) obtained a Pass result. Conversely, 68 subjects (6.8%) showed a Refer result, indicating a suspicion of early hearing loss. The characteristics of the study subjects are presented in Table 1.

Table 1. Study Subject Characteristics

Characteristic	Frequency (n)	Percentage (%)
Gender		
Male	435	43.2
Female	570	56.6
Birth Weight		
Normal	691	68.6
LBW	316	31.4
Prematurity		
Preterm	299	29.7
Term	708	70.3
OAE Results		
Pass	938	93.1
Refer	68	6.8

LBW = low birth weight (<2,500 grams); OAE = otoacoustic emission.

B. Relationship between Birth Weight and Hearing Loss

Table 2 presents the results of the analysis of the relationship between birth weight status and hearing loss. In the normal birth weight group, 94.8% did not experience hearing loss, and only 5.2% showed indications of hearing loss (refer OAE results in both ears). In the LBW group, the percentage of hearing loss incidence was higher, reaching 10.2% compared to 89.8% who did not experience hearing loss. Additionally, the statistical test results using Chi-Square showed a significant *p*-value ($p=0.004$). This indicates that there is a statistically significant relationship between LBW and hearing loss based on OAE screening results in neonates.

Table 2. The Relationship between Birth Weight and Hearing Loss

Birth Weight	Hearing Loss		p^a
	Pass	Refer	
Normal	655 (94.8%)	36 (5.2%)	0.004
LBW	288 (89.8%)	32 (10.2%)	

[a]*p* value obtained using the Chi-Square test.
LBW = low birth weight (<2,500 grams).

C. Relationship between Prematurity and Hearing Loss

Table 3 presents the analysis between prematurity status and hearing loss. In the premature infant group, 9.7% experienced hearing loss, while 90.3% did not. Then, in the term infant group, the incidence of hearing loss was found to be lower (5.5%) and the remaining 94.5% were declared normal (pass during OAE screening). After the Chi-Square statistical test, a *p*-

value of 0.016 was obtained, indicating that statistically, there is also a significant relationship between premature birth and the final hearing screening results in this study population. The proportions of refer results according to birth-weight and gestational-age status are illustrated in Figure 1.

Table 3. The Relationship between Prematurity and Hearing Loss

Prematurity	Hearing Loss		p^a
	Pass	Refer	
Premature	270 (90.3%)	29 (9.7%)	0.016
Term	668 (94.5%)	39 (5.5%)	

[a]*p* value obtained using the Chi-Square test.

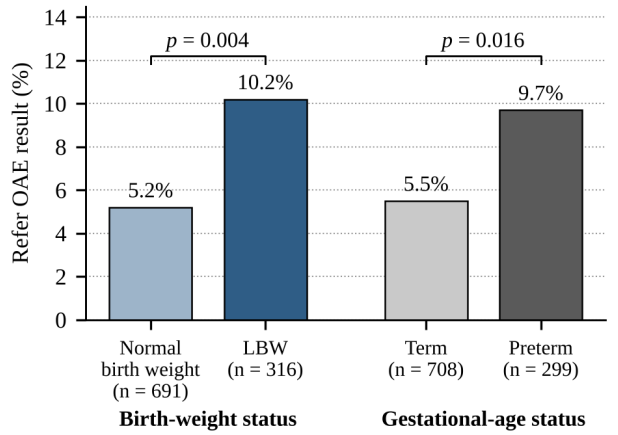

Figure 1: Proportion of refer OAE results according to birth-weight status (normal birth weight vs LBW) and gestational-age status (term vs preterm). Values are derived from Tables 2 and 3; p *values were obtained using the Chi-Square test.*

DISCUSSION

A. Refer Rate and Interpretation of OAE Results

The results of this study showed that most subjects passed the screening, while only 6.8% of neonates received a refer result in both ears. This finding is higher than reported by Liemiyah et al. in Semarang, which was refer in 3% of newborns, and relatively comparable to the findings of Megantara et al. at Santosa Hospital Bandung Central, which recorded refers in 7% of 972 examined ears. The difference in rates between studies can likely be explained by population composition. This study was conducted in a tertiary hospital that includes many at-risk infants, whereas studies with lower refer rates included more infants without risk factors.[6,8]

Furthermore, a refer result on OAE needs to be distinguished from actual hearing loss. OAE records the response of outer hair cells, but the signal is also influenced by the condition of the ear canal and middle ear. Residual vernix, fluid in the middle ear, and testing too early can cause a refer result in infants with normal cochleae. Kaveh et al. found that all infants with bilateral refers on the first-day screening actually had normal ABR results, and factors increasing the risk of this false positive were cesarean section delivery and male gender. Thus, hearing loss based on OAE screening needs to be confirmed with rescreening and ABR.[7,9]

B. Low Birth Weight and OAE Refer Results

In this study, refer results were found to be more dominant in neonates with LBW and showed a significant relationship. This finding aligns with a study in Bandung that found low birth weight was significantly associated with OAE refer results (p=0.029), and in a regression model, LBW infants were at about twice the risk of experiencing a refer result (OR 2.0; p=0.032). A study in Egypt involving 250 neonates screened upon discharge from the NICU also reported LBW as a factor contributing to hearing loss (p=0.003). Additionally, Salvago et al. showed that the relationship between birth weight and sensorineural hearing loss was mainly seen in the extremely low birth weight group (<1,000 g), whereas in the 1,000–1,499 g group, the proportion was actually lower in deaf infants.[8,10,11]

The cochlea of LBW infants is not yet fully mature. Blood vessels and the stria vascularis, which maintain the endocochlear potential to drive the outer hair cells, are still immature, as is the myelination of the auditory nerve and brainstem pathways. Outer hair cells require a large supply of oxygen and energy, making them highly vulnerable to hypoxia, ischemia, and metabolic disorders. Low birth weight also often reflects fetal growth restriction due to placental insufficiency and chronic hypoxia in the womb, a condition associated with impaired maturation of auditory pathways. After birth, LBW infants more frequently experience asphyxia, respiratory distress requiring ventilation, hyperbilirubinemia, severe infections, and exposure to ototoxic drugs like aminoglycosides and loop diuretics. This damage can be understood as a double-hit mechanism, where the inner ear—already vulnerable due to immaturity, hypoxia, infection, or metabolic disorders—is subsequently exposed to ototoxic drugs, such as aminoglycosides and loop diuretics, causing oxidative stress, mitochondrial dysfunction, and hair cell death. Because neonates with LBW undergo intensive care and are exposed to these drugs more frequently, this outer hair cell damage can be reflected as a refer result on OAE.[3,5,12,13]

C. Prematurity and OAE Refer Results

In this study, the premature group was also found to have more OAE refer screening results compared to term neonates. Prematurity in this study was also proven to be significantly associated with OAE screening results. This finding is in line with several previous studies. Megantara et al. reported prematurity as a highly significant factor (p<0.001), with a refer risk 7.1 times greater than term infants. ElGindy et al. also found a significant relationship between prematurity and hearing loss (p=0.001) in a neonatal population treated in the NICU. Liemiyah et al. noted refers in 4.1% of premature infants, which was higher than the overall refer rate in that study (3%). Meanwhile, varying risk findings were found by a study in Italy that divided prematurity into three groups (extremely preterm/EPT, ≤27 weeks; very preterm/VPT, 28–31 weeks; and moderate-to-late preterm/MLPT, 32–37 weeks). The study found that EPT infants were much more prevalent in the sensorineural hearing loss group (22.5%) compared to the normal hearing group (8.3%). Conversely, MLPT infants had almost the same proportions in both groups (25% and 29%). This illustrates that the relationship between prematurity and hearing loss mainly stems from infants born very early.[6,8,10,11]

Premature infants are born before their hearing organs have finished maturing. The development of the peripheral part of the auditory system, including the cochlea, is essentially completed by mid-pregnancy. However, the maturation of blood vessels, the stria vascularis, myelination of the auditory nerve, and brainstem pathways continues into the neonatal period and even up to around two years of age. Furthermore, in premature infants, the immature blood-brain barrier also allows bilirubin to more easily damage the hearing pathways, making premature infants less likely to recover from disorders caused by hyperbilirubinemia. Then, the middle ear of premature infants is more often filled with fluid, and this can cause a refer result on OAE even though the cochlea functions normally. It should be noted that OAE only assesses outer hair cell function. Disorders at the synapse and auditory nerve, such as auditory neuropathy, are not detected, so the risk in premature infants is likely greater than what is caught by OAE screening.[11,12]

D. Study Limitations

This study has a cross-sectional design, so it only shows associations and cannot conclude causal relationships. This study used secondary data from medical records in one hospital, so the quality of recording can vary, including the possibility of incomplete or inaccurate data. Refer results have not been confirmed by rescreening or ABR, so some of them might be false positives and cases of auditory neuropathy went undetected. Bivariate analysis did not control for confounding factors such as hyperbilirubinemia, asphyxia, mechanical ventilation, ototoxic drug exposure, cesarean delivery, length of NICU stay, and age at screening.

CONCLUSION

Based on the present study, it can be concluded that low birth weight (LBW) and prematurity have a significant relationship with hearing loss based on otoacoustic emission (OAE) screening results in the neonatal population at Dr. Hasan Sadikin General Hospital, Bandung.

RECOMMENDATIONS

Based on this study, several recommendations can be given which are expected to be useful for all parties involved in the research. These recommendations are as follows.

1. LBW and premature infants need special attention in hearing screening programs. Infants with a refer result should undergo rescreening and ABR examination to confirm the presence or absence of hearing loss.
2. Future studies should use a prospective design with long-term monitoring, which will also help assess hearing loss that appears later. LBW and premature infants should continue to be monitored after discharge, including those who pass the screening.
3. Future studies should use multivariate analysis with logistic regression so that the effects of LBW and prematurity can be separated from other factors such as hyperbilirubinemia, asphyxia, mechanical ventilation, ototoxic drug exposure, and length of stay in the NICU.
4. Future studies should assess the relationship based on the degree of LBW (normal, low birth weight/LBW, very low birth weight/VLBW, extremely low birth weight/ELBW) and gestational age group (term, moderate to late preterm, very preterm, and extremely preterm).

DECLARATIONS

Ethics approval and consent to participate: Name of the Health Research Ethics Committee, approval number and date,

and the statement on waiver of informed consent for the use of de-identified medical-record data are to be completed by the authors.

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Data availability: The de-identified data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to institutional approval and patient-confidentiality regulations.

Author contributions: SM: …; W: …; APP: …; NAY: … (to be completed by the authors). All authors read and approved the final version of the manuscript.

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