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Otoacoustic emission assessment of hearing loss prevalence among Ghanaian preschoolers: A cross-sectional study

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Abstract

Background: Childhood hearing impairment is a health concern which can result in reduced ability to communicate, inability to interpret speech sounds, leading to poor language acquisition, educational disadvantage and social isolation. Early childhood screening for hearing loss enables the detection and management of the condition.

Objective: This study aimed to determine the prevalence of hearing loss among selected preschool children following screening with Distortion Product Otoacoustic Emission (DPOAE).

Methods: This study was a cross-sectional investigation of preschool children aged 3 to 5 years. Data collected included demographic information, outcome of otoscopy, and otoacoustic emission assessment (OAE). The data were analysed with IBM SPSS version 21. The Chi-Square test was used to determine the associations between outcomes of the OAE test and the demographic characteristics of participants. P-values less than 0.05 were considered statistically significant.

Results: Six hundred and eleven (611) preschool children from four schools were examined. The mean age was 3.8 ± 0.8 years. Out of the 1,222 ears examined, 89.9% passed the DPOAE test. Otoscopic exams showed 64.8% of right ears and 68.6% of left ears were normal, while 35.0% and 31.4% had impacted wax, respectively. One child had a foreign body in the right ear. For both ears, no significant sex differences were observed (p = 0.427 and 0.862). The prevalence of failed OAE tests in both ears was 4.4%. There was an association between age and outcome of OAE assessment for both right and left ears (p = 0.001 and 0.014, respectively).

Conclusion: The Prevalence of failed OAE test bilaterally of the preschool children was 4.4%. Age was associated with the outcome of the OAE assessment.

Keywords: Preschool children, otoacoustic emissions assessment, refer, prevalence, hearing loss.

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INTRODUCTION

Human initial perception of environmental noise is known to begin as early as the 20th week of gestation, during which the human ear is sufficiently developed to support hearing, and by 27 weeks, environmental sounds become apparent [1,2]. Disabling hearing loss is defined as hearing loss greater than 40 decibels (dB) in the better-hearing ear for adults and greater than 30 dB in the better-hearing ear for children [3,4]. Approximately 5.3% of the world's population lives with disabling hearing loss, of which 328 million (91%) are adults and 32 million (9%) are children [5]. Hearing loss is unequally distributed globally, with the highest prevalence observed in South Asia, the Asia Pacific, and Sub-Saharan Africa [5]. In 2011, the global prevalence of hearing loss among children aged 0 – 14 years was 1.7%, notably higher

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in developing countries [6]. In the United Kingdom, 2 out of every 1,000 children have significant hearing loss [7], while in the United States, 2 to 3 out of every 1,000 children are born with detectable hearing loss in one or both ears [8].

Population-based studies estimating the prevalence of hearing impairment in Africa are limited. A systematic review by Mulwafu et al. [9] reported a median prevalence of 6.6% among schoolchildren with hearing loss at a cut-off of 30 dB HL. In South Africa, infant hearing loss is the most common congenital sensory birth defect, with a prevalence of 4 to 6 per 1,000 live births [10]. Approximately 7.5% of schoolchildren in South Africa experience varying degrees of hearing loss [10]. In Kumasi, Ghana, the prevalence of hearing impairment among school children was reported as 6.5% [11], while in Accra, preschool hearing screenings revealed prevalence rates of 6% to 14% at frequencies ranging from 500 Hz to 6000 Hz [12]. Hearing-impaired children often face difficulties understanding speech, which impacts their attention, academic performance and socialisation and also affects emotional and language development [13].

Currently, Ghana lacks a national policy for universal newborn and preschool hearing screening. Newborn hearing screenings were initiated at Korle-Bu Teaching Hospital in 2012 and at the Trust Specialist Hospital in 2017. To date, only one preschool hearing screening study has been conducted in a suburb in Accra, Ghana, as reported by Tumpi [12]. Recognising hearing impairment in preschool children early is crucial to ensure timely interventions. School-based hearing screening programs play a vital role in identifying children with undetected hearing loss that may have been missed during neonatal screening [12]. Early identification of hearing impairment among preschool children through screening can positively impact speech and language acquisition, cognitive development, social skills, and emotional well-being [12]. This study aimed to determine the prevalence of hearing loss among preschool children using the Distortion Product Otoacoustic Emission (DPOAE) screening method.

MATERIALS AND METHODS

This study employed a cross-sectional design to evaluate the outcomes of OAE (Otoacoustic Emission) assessments among preschool children aged 3 to 5 years in selected schools within the Korle-Bu, a suburb in Accra. The age group selection was based on Ghana's educational policy, which classifies preschool children as those aged 3 to 5 years. The study was conducted between July 2018 and January 2020 and involved four schools: Ministry of Health Basic School, Lilliput Nursery and Kindergarten School, Tilitet School, and Bright Minds Montessori School. The Ministry of Health Basic School, a public institution situated within the Korle-Bu Teaching Hospital in Accra, has an estimated total student population of 1,560, including 410 preschoolers. The preschool section comprised children aged 3 to 6 years, supported by 68 teaching and 16 non-teaching staff. Lilliput Nursery and Kindergarten School is a private institution also located within the Korle Bu Teaching Hospital. It provides early childhood education to 202 pupils aged 1 to 5 years, with 20 teaching and 10 non-teaching staff. Tilitet Nursery School, also located near the Korle-Bu Teaching Hospital (specifically at Lartebiokorshie), has a total student population of 191. The pupils, aged 9 months to 5 years, are guided by 11 teaching and 10 non-teaching staff. Bright Minds Montessori School, another private school located in Laterbiokorshie near the Korle-Bu Teaching Hospital, has an enrolment of 77 pupils aged 1 to 5 years. The school employs 7 teaching and 8 non-teaching staff. Inclusion criteria focused on preschool children from the selected schools who had normal external auditory canals and tympanic membranes as confirmed by otoscopic examination. Exclusion criteria included those unable to complete all three stages of the hearing screening procedure, and those with abnormal otoscopic findings such as otitis externa, perforated tympanic membranes due to suppurative otitis media, dull tympanic membranes indicative of otitis media with effusion, or external canal abnormalities preventing ear probe insertion. Additionally, children with active upper respiratory tract infections were excluded.

A minimum sample size of 611 preschool children was required for the study. The sample size was calculated using the Cochran sampling formula; $n = z^2p(1-p)/(d^2)$ [14]. Where "n" is the sample size, "p" is a known prevalence (14.0%) which was obtained from a study by Tumpi [12], "d" is the degree of accuracy desired, i.e., 0.05 and "z" is the confidence level, i.e., 1.96. Accounting for a non-response of 10% and a design effect of 3.0, a total of 611 preschool children were required for the study. Participants were selected using multistage sampling across the four schools, with simple random sampling (SRS) applied at all stages. At stage one, SRS was used to select schools from a sampling frame provided by the Ghana Education Service. The list of schools around the Korle-Bu area was entered into Microsoft Excel, where the RAND function was employed to generate randomised selections. The first four schools, Ministry of Health Basic School, Lilliput Nursery and Kindergarten School, Tilitet Nursery School, and Bright Minds Montessori School were chosen. In stage two, a sampling ratio was calculated by dividing the sample size by the total number of preschoolers in the four schools (n = 611/880).

The resulting ratio (0.694) was then multiplied by the preschool population in each school to determine the number of participants to be sampled. Stage three involved proportional allocation, where the total number of children in each class was divided by the total number of children in the school, and the outcome was multiplied by the number sampled from the school to determine the number selected from each class. Stage four utilised SRS to select individual participants from class registers. Names were assigned numbers, entered into an Excel worksheet, and randomised

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using the RAND function. Names appearing first were selected sequentially until the required number for each class was met. A total of 285 children were sampled from the Ministry of Health Basic School, 140 from Lilliput Nursery and Kindergarten School, 133 from Tilitet Nursery School, and 53 from Bright Minds Montessori School. Preliminary otoscopic assessments were conducted on all 611 participants to identify and exclude those with otitis externa or abnormal tympanic membranes. No participants presented with these conditions. Twelve children (2.0%) with impacted wax or foreign bodies were referred to the ENT unit at Korle-Bu Teaching Hospital for ear washing and were recruited one week later upon passing repeat otoscopic assessments.

The study was conducted in three parts.

1. Demographic Data Collection: Information on age, sex, parents' or guardians' education levels, whether children had undergone hearing screening within the first four weeks of life, and whether parents noticed changes in their children's hearing was collected using structured questionnaires.
2. Physical Examination: Otoscopic assessments were conducted using a YNR Mini–Fibre Optic Otoscope (CE Approved). External ear canals and tympanic membranes were examined for obstructions such as impacted wax, foreign bodies, infections (otitis externa or otitis media), or any alterations (e.g., perforations or dullness from otitis media with effusion).
3. Otoacoustic Emission Assessment: Hearing sensitivity was evaluated using a calibrated portable OAE machine (Interacoustics OtoRead™; Serial No. SN IA3002508; IEC 60645) from Interacoustics, Denmark. DPOAE testing was conducted in a noiseless environment, utilising miniature speakers and a microphone-equipped probe inserted into the external auditory canal. Stimuli were generated by the speakers, while the microphone recorded the resulting emissions, indicating cochlear outer hair cell functionality. Hearing sensitivity was assessed using an automated pass or refer/fail criterion.

Testing protocol

DPOAEs were measured at frequencies ranging from 2000 Hz to 5000 Hz, with intensity levels set at 65 dB SPL (L2) and 55 dB SPL (L1). The frequency ratio (F2:F1) and signal-to-noise ratio were set to 1.2 and 6 dB, respectively. Three valid responses from the four frequencies presented constituted a "pass," while fewer than three constituted a "fail/refer."

Data analysis

Statistical analysis was conducted using IBM SPSS Statistics (version 21.0). Demographic data, including age, sex, and year level, were analysed using descriptive statistics, including percentages, means, and standard deviations. The prevalence of OAE fail/refer rates among preschool children was presented as a percentage. Associations between OAE outcomes and demographic characteristics, such as age and gender, were assessed using Chi-square tests. A p-value < 0.05 was considered statistically significant.

RESULTS

Six hundred and eleven (n = 611) preschool children from four schools participated in the study. Most (46.6%, n = 285) were recruited from the Ministry of Health Basic Schools. Three hundred and twenty-four (53.0%) were males. The mean age was 3.8 years (SD 0.8) with a modal age of 3 years. Most (30.1%, n = 184) were in Nursery 2. Eleven (1.8%, n = 11) parents/guardians indicated that their children had previously been diagnosed with hearing loss, and 20.0% (n = 122) mentioned their children were screened for hearing loss (HL) during the first four weeks of life. Out of the 122 previously screened for HL, 16.0% (n = 98) were screened at the KBTH. Most (39.8%, n = 243) of the parents/guardians had a Senior High School education. The average age of the parent/guardian was 34.3 years (SD 4.5) (Table 1).

Observation of change in the child's hearing ability by parents/guardians and outcome of OAE assessment

Sixty-nine (11.3%, n = 69) and 9.0% (n = 55) of the children failed the OAE test in the right and left ear, respectively. Those who passed the OAE test were 88.7% (n = 542) and 91.0% (n = 556) for the right and left ear, respectively. Of the children whose parents/guardians indicated they had observed a change in their child's hearing ability, 0.7% (n = 4) failed the OAE test for the right ear, and 1.2% (n = 7) failed the OAE test for the left ear.

Outcomes of initial otoscopic examination of the preschool children before recruitment

For the right ear, 64.8% (n = 396) were normal, 35.0% (n = 214) had impacted wax, and only 0.2% (n = 1) of preschool children had an impacted foreign body. There was no significant difference between males and females in the outcome of otoscopic examination for the right ear (p-value = 0.427) (Table 2). For the left ear, 68.6% (n = 419) were normal, while 31.4% (n = 192) had impacted wax. There was no significant difference between males and females in the outcome of otoscopic examination for the left ear (p-value = 0.862) (Table 2). For the right ear, 35.2% (n = 215) of males had normal otoscopic findings, 17.6% (n = 108) had impacted wax, and 0.2% (n = 1) had an impacted foreign body. For females, 29.6% (n = 181) had normal otoscopic findings, and 17.4% (n = 106) had impacted wax (Table 2). For the left ear, 36.2% (n = 221) of males had normal otoscopic findings, and 16.8% (n = 103) had impacted wax. For females, 32.4% (n = 198) had normal otoscopic findings, and 14.6% (n = 89) had impacted wax (Table 2).

Outcome of otoacoustic emissions (OAE) assessment among preschool children

A total of 1,222 ears from 611 preschool children were screened. The total number of ears that passed the DPOAE test was 89.9% (n = 1,098), and 10.1% (n = 124) failed.

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Table 1. Demographic characteristics of the preschool children

Demographic characteristics	n (%)
Age of children	
3	260 (42.6)
4	226 (37.0)
5	125 (20.4)
Gender of children:	
Male	324 (53.0)
Female	287 (47.0)
Total	611 (100.0)
Year level at school:	
Year level at school:	
Nursery 1	132 (21.6)
Nursery 2	184 (30.1)
KG 1	175 (28.6)
KG 2	120 (19.7)
Schools:	
MOH	285 (46.6)
Lilliput	140 (22.9)
Tilitet	133 (21.8)
Bright Minds Montessori	53 (8.7)
Child had been diagnosed with hearing loss	11 (1.8)
Child's hearing screened during the first 4 weeks of life	122 (20.0)
Place of screening for child's hearing	
Korle Bu Teaching Hospital	98 (16.0)
The Trust Specialist Hospital	24 (3.9)

Most (39.8%, n = 243) of the parents/guardians had a Senior High School education. The average age of the parent/guardian was 34.3 years (SD 4.5). Mean age of preschool children = 3.8 years (SD ± 0.8); modal age = 3years; minimum age = 3 years; maximum age = 5 years. KG = Kindergarten; MOH = Ministry of Health Basic School

Association between outcomes of otoacoustic emissions (OAE) assessment, gender, and age of preschool children

A total of 88.7% (n = 542) of the preschool children passed the OAE assessment of the right ear. Out of this, 46.5% (n = 284) were males. Of the 69 preschool children who failed the test for the right ear, 6.5% (n = 40) were males and 4.8% (n = 29) were females. There was no statistically significant association between outcomes of OAE assessment and gender of preschool children for the right ear (p = 0.443) (Table 3). A total of 91.0% (n = 556) passed the examination for the left ear. The number of males who passed the OAE examination for the left ear was 48.1% (n = 294). Out of the 55 preschool children who failed the test for the left ear, 4.9% (n = 30) were males and 4.1% (n = 25) were females. The outcome of the assessment on the left ear between males and females did not show any significant difference (p = 0.463) (Table 3). Two hundred and eleven (81.2%, n = 211) preschool children out of the total of 260 aged 3 years passed the assessment for the right ear, and 18.8% (n = 49) failed. For preschool children aged 4 years, a total of 226 were examined, with 92.5% (n = 209) passing the test in the right ear and 7.5% (n = 17) failing. For those aged 5 years, a total of 125 were examined for the right ear, with 97.6% (n = 122) passing the test and 2.4% (n = 3) failing. There was a significant association between the ages of the preschool children and the outcome of OAE assessment (p = 0.001) for the right ear (Table 3).

For the left ear, a total of 260 children aged 3 years were examined. Out of this, 90.0% (n = 234) passed, and 10.0% (n = 26) failed. Among those aged 4 years, 226 were examined, and 89.4% (n = 202) passed, while 10.6% (n = 24) failed. Among those aged 5 years, 125 were examined,

Table 2: Outcomes of otoscopic examination of pre-school children for both ears

Outcome	Gender			P-value
	Male N (%)	Female N (%)	Total N (%)	
Right ear				
Normal	215(35.2)	181(29.6)	396(64.8)	
Impacted wax	108(17.6)	106(17.4)	214(35.0)	
Impacted foreign body	1(0.2)	-	1(0.2)	
Total	324(53.0)	287(47.0)	611(100.0)	0.427
Left ear:				
Normal	221(36.2)	198(32.4)	419(68.6)	
Impacted wax	103(16.8)	89(14.6)	192(31.4)	
Impacted foreign body	-	-	-	
Total	324(53.0)	287(47.0)	611(100.0)	0.862

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Table 3. Association between outcomes of otoacoustic emissions (OAE) assessment and gender and age of preschool children for the right ear

Characteristics	OAE outcome			P-value
	Pass N (%)	Fail N (%)	Total N (%)	
Sex				
Right ear				
Male	284(46.5)	258 (42.2)	542 (88.7)	
Female	40 (6.5)	29 (4.8)	69 (11.3)	
Total	324(53.0)	287 (47.0)	611 (100.0)	0.443
Left ear:				
Male	294 (48.1)	262 (42.9)	556 (91.0)	
Female	30 (4.9)	25 (4.1)	55 (9.0)	
Total	324 (53.0)	287 (47.0)	611 (100.0)	0.463
Age				
Right ear				
3	211 (81.2)	49 (18.8)	260 (100.0)	
4	209 (92.5)	17 (7.5)	226 (100.0)	
5	122 (97.6)	3 (2.4)	125 (100.0)	0.001
Left ear	234 (90.0)	26 (10.0)	260 (100.0)	
3				
4	202 (89.4)	24 (10.6)	226 (100.0)	
5	120 (96.0)	5 (4.0)	125 (100.0)	0.038

Table 4. Prevalence of unilateral and bilateral fail/refer OAE assessment among preschool children

Characteristics	Unilateral			P-value
	Pass N (%)	Prev. Failed OAE N(%)	Total N (%)	
Gender				
Male	297(91.7)	27(8.3)	324 (100.0)	
Female	272(94.8)	15(5.2)	287 (100.0)	
Total	569 (93.1)	42(6.9)	611 (100.0)	0.08
Age				
3	231 (88.8)	29(11.2)	260 (100.0)	
4	217 (96.0)	9(4.0)	226 (100.0)	
5	121 (96.8)	4(3.2)	125 (100.0)	
Total	569 (93.1)	42(6.9)	611 (100.0)	0.001
	Both ears			
Gender				
Male	309(95.4)	15(4.6)	324 (100.0)	
Female	275(95.8)	12(4.2)	287 (100.0)	
Total	584(95.6)	27(4.4)	611 (100.0)	0.545
Age range				
3	245(94.1)	15(5.9)	260 (100.0)	
4	216(95.6)	10(4.4)	226 (100.0)	
5	123(98.4)	2(1.6)	125 (100.0)	
Total	584(95.6)	27(4.4)	611 (100.0)	0.001

and 96.0% (n = 120) passed, while 4.0% (n = 5) failed. A significant association was found between the ages of the preschool children and the outcome of the OAE assessment (p-value = 0.038) for the left ear (Table 3).

Prevalence of failed/referred OAE assessment among preschool children

For the gender-specific prevalence of unilateral fail/refer OAE assessment, males had a prevalence of 8.3% (n = 51), and females had a prevalence of 5.2% (n = 34). The age-specific prevalence of unilateral fail/refer OAE assessments was 11.2% (n = 29) for children aged 3 years, 4.0% (n = 9) for those aged 4 years, and 3.2% (n = 4) for those aged 5 years (Table 4). The gender-specific overall prevalence of preschool children who failed DPOAE in both ears was as follows: males 4.6% (n = 15) and females 4.2% (n = 14) (p = 0.545). The age-specific overall prevalence of those who failed DPOAE in both ears was 5.9% (n = 15) at age 3 years,

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4.4% (n = 10) at age 4 years, and 1.6% (n = 2) at age 5 years. There was a significant difference in the overall prevalence of those who failed DPOAE among the age groups (p = 0.001) (Table 4).

DISCUSSION

The children screened in this study were predominantly males (53.0%), aligning with findings by Tumpi [12] and Kreisman et al. [15], who also reported a higher proportion of males. Conversely, studies by Azaglo [13] and Adegbiji et al. [16] observed a female majority in their populations. The male preponderance observed in our study remains unexplained. However, a study has revealed that a mother's level of education significantly influences girls' school enrolment rates, while an increase in fathers' educational attainment boosts school enrolment for both boys and girls [17]. Domestic responsibilities have also been strongly associated with limiting the education of girls but not boys [17]. Slightly more parents or guardians in this study (243, 39.8%) had completed senior high school education. Although this study did not explore the relationship between parental educational level and gender, it is important to note that most of the parents who participated were female. The average age of the preschool children screened was 3.8 years (SD = 0.8), close to the typical age of 4 years for children in Nursery 2 and Kindergarten 1. The majority of the children were within the 3-4-year age range, consistent with findings from studies by Tumpi [12] and Adegbiji et al. [16], which also reported that most preschoolers fell within the 3-year age bracket.

This study identified an overall prevalence of hearing loss of 4.4%, which is lower than the 6.5% reported among schoolchildren in Kumasi, Ghana [11], and the 6–14% observed in preschool hearing screenings in Accra [12]. However, it is slightly higher than findings from Antwi's study, which reported a prevalence of 4% [18]. Our prevalence was also lower than the 6.6% reported in a systematic review of hearing loss among schoolchildren in Africa by Mulwafu et al. [9] and the 7.5% observed in South Africa [10]. Nevertheless, it exceeded the global prevalence rate of 1.7% among children aged 0 – 14 years [6]. These variations might be attributed to factors such as limited screening infrastructure, increased susceptibility to risk factors (e.g., Otitis media, genetic conditions), unequal access to screening services, and etiological factors such as infections and the prevalence of consanguinity in the region [5,6]. Middle ear dysfunctions, such as otitis media, which are often transient, can compromise otoacoustic emission production in children. Factors such as an immature Eustachian tube and a higher likelihood of upper respiratory infections in this age group can exacerbate conductive pathologies, potentially affecting Distortion Product Otoacoustic Emission (DPOAE) measurements [19,20]. As children grow, cochlear function and test reliability improve [21,22], underscoring the need for age-specific screening criteria and consideration of repeat screenings in younger children, where transient conditions may resolve over time. Children aged 3 and 4 years demonstrated higher prevalences of fail/refer outcomes (5.9% and 4.4%) in OAE assessments than older children. Similar trends were reported in a study by Adegbiji et al. [16], which found the highest prevalence (37.6%) at the age of 3. Other studies, including Abdel-Hamid et al. [23] and Hamid et al. [24], also reported high prevalence rates of 22.4% and 22.3%, respectively, in this age range. Children between 6 months and 4 years are particularly vulnerable to Otitis media due to frequent upper respiratory infections, as well as Otitis media with effusion caused by Eustachian tube dysfunction [25,26].

This study focused on children with normal external auditory canals and tympanic membranes, excluding those with suppurative otitis media and Otitis externa. However, due to the absence of Tympanometry for middle ear function assessment, it is possible that some preschool children with normal-looking tympanic membranes had undetected otitis media with effusion. Such conditions and cochlear abnormalities might have contributed to the failed OAE tests. The lower prevalence of hearing loss among older preschool children in this study is likely due to a reduced incidence of otitis media with effusion, one of the most common causes of acquired hearing loss in this age group in our environment. However, Sallavaci et al. [27] reported the lowest prevalence of hearing loss among children aged five years in Albania and further explained that some parents who potentially identify hearing loss at this age may withdraw their children from mainstream education and either enrol them in special schools or discontinue their formal education altogether as a result of societal stigmatisation. This study found a higher prevalence of hearing loss among male preschool children (4.6%) compared to their female counterparts (4.2%). This observation aligns with the study by Lindau et al. [28], which reported a higher prevalence of hearing loss among males aged 4–5 years, though the difference was not statistically significant.

Conversely, Obukowho et al. [29] observed that females had a significantly higher prevalence of hearing loss (34.0%) compared to males (24.9%). That finding challenged the common notion that males are more vulnerable to hearing impairment. The investigators attributed their finding to females having shorter, stiffer cochleae, which offer more sensitive frequency responses [29]. In the present study, the predominance of hearing loss among male children may be due to the larger proportion of males in the recruited population. Children aged 3–4 years had the highest prevalence of hearing loss compared to those aged 5 years. Acquah [10] reported a higher prevalence of fail/refer OAE assessments among children aged 0.5 – 2.5 years. This finding was attributed to a positive correlation between age and hearing loss in pediatric populations during the first five years of life [30]. It is therefore crucial to conduct regular hearing screenings for children aged 3 – 4 years, as this age group demonstrates a significant prevalence of fail/refer outcomes in OAE tests

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[31]. This also highlights the importance of implementing hearing screening programs for children in Ghana, particularly for those aged 3 – 4 years. The significant prevalence of failed/referred OAE rates may partly be attributed to the limited number of newborn hearing screening centres in the country. Additionally, it suggests that children may require follow-up health checks, including medical and audiological interventions.

This study found no statistically significant relationship between the gender of preschool children and OAE test outcomes, indicating that gender does not influence OAE results. This observation aligns with findings from Vasconcelos et al. [32], who also reported no significant gender differences in OAE outcomes. However, it contrasts with Keogh et al. [31], who found that girls consistently exhibit stronger DPOAEs than boys at frequencies of 3.8 kHz and above. Keogh et al. [31] further noted that the absence of this gender effect at lower frequencies might be due to environmental noise interference or noise generated by the test subject (e.g., breathing or jaw movements) during DPOAE recording. This study revealed a statistically significant association between OAE outcomes and the age of preschool children, consistent with findings from other studies [33,34]. This finding may result from factors such as developmental anatomy, age-specific diseases, and environmental exposures [33]. Understanding these factors can aid in the appropriate interpretation of OAE outcomes and guide age-specific treatments. The variability in hearing screening outcomes by age highlights the need for tailored screening procedures and follow-up care in pediatric audiology. This is especially vital in resource-limited settings like Ghana, where infections and restricted healthcare access exacerbate age-related disparities.

This study employed DPOAEs for hearing screening; it is preferred to other audiological tests, such as Tympanometry, Auditory Brainstem Response (ABR), and Pure-tone audiometry, for preschool-aged children due to its rapid, non-invasive nature and objective evaluation of cochlear function [15]. This test assesses the function of cochlear outer hair cells, enabling early detection of Sensorineural hearing loss, which is crucial for identifying acquired hearing loss after neonatal screenings [15]. DPOAE test is also practical and cost-effective, as it does not require anaesthesia, patient stillness, or soundproof booths, unlike pure-tone tests [15]. It serves as a first-line screening tool for identifying children who need additional diagnostic testing. Using OAE as a second-tier screening tool in school screening campaigns and community programs may also reduce needless referrals, increase follow-up rates, and reduce testability inequalities among children with language or developmental problems [15]. Although DPOAE tests are highly accurate, efficient, and suitable for routine preschool screening, they cannot evaluate middle ear function or auditory neural pathways [15]. While our study highlighted the importance of preschool hearing screenings for identifying children with hearing loss, it also had some limitations. Firstly, we employed OAE test protocol, which does not quantify the degree of hearing loss or determine the hearing threshold level. We were therefore unable to assess the severity of impairment in individuals who fail the test. Although participants who did not pass the initial screening were referred for further evaluation using diagnostic protocols at the Korle-Bu Teaching Hospital, follow-up data on confirmatory assessments, such as ABR or Tympanometry, were not collected due to the cross-sectional study design.

Also, our study did not explore environmental noise exposure, child movement, test administrator bias, Ototoxic drug use, or recurrent infections, which may influence OAE results. Additionally, the OAE test does not evaluate the integrity of neural sound transmission from the auditory nerve to the brainstem, making it incapable of detecting Auditory neuropathy or other neurological abnormalities. Such conditions can produce normal OAE test results while yielding abnormal outcomes in ABR tests. Furthermore, the OAE test is not definitive for diagnosing hearing loss but rather evaluates the inner ear's integrity by testing the function of the cochlear outer hair cells. Therefore, any diagnosis of hearing loss based on OAE results is provisional and must be confirmed with diagnostic tests such as pure-tone audiometry, Tympanometry, or ABR audiometry. To address these challenges, testing should be conducted in quiet rooms with noise-rejection algorithms, shorter test durations, and engaging distractions for children. This research underscores the need for systematic routine hearing screenings within preschool health programs in Ghana.

Given the high rate of DPOAE screening failures, especially among younger children, it is imperative to adopt a national policy to ensure early auditory screening. Such policies would allow for early identification of at-risk children and facilitate timely interventions, minimising negative developmental outcomes. Programmes incorporating objective assessment tools, such as DPOAE, can aid early referrals for further diagnostics, including Tympanometry and ABR testing. The findings from this study should prompt policymakers to reevaluate the current status of pediatric hearing health in Ghana. Establishing nationwide hearing screening programmes for preschoolers would advance early detection and intervention efforts. These initiatives could reduce long-term complications, including language delays, academic struggles, and social isolation. Moreover, implementing such programmes would align Ghana with global recommendations from organisations such as the World Health Organisation (WHO) and the Joint Committee on Infant Hearing (JCIH), thereby ensuring compliance with international standards in pediatric hearing care.

Conclusion

The study recorded a 4.4% prevalence of failed/referred OAE assessments in both ears among preschool children, indicating potential bilateral hearing loss. There was a

significant association between OAE assessment outcomes and the ages of the preschool children for both right and left ears.

DECLARATIONS

Ethical consideration

Ethical approval for the study was obtained from the Institutional Review Board (IRB) of the College of Health Sciences, University of Ghana, with Protocol Identification Number: CHS-Et/M.4-P5.5.8/2018-2019. Permission was sought from all heads of the involved schools. Written informed consent was obtained from parents/ guardians of participating preschool children.

Consent to publish

All authors agreed on the content of the final paper.

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None

Competing Interest

The authors declare no conflict of interest

Author contribution

SMY conceived and designed the study. SMY and BA curated the data. BA performed the formal analysis. SMY acquired funding, conducted the investigation, and administered the project. SMY, KKB, AAJ, EDK, and BA developed the methodology. KKB, AAJ, and EDK supervised the project. SMY drafted the original manuscript. SMY, KKB, AAJ, EDK, and BA critically reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Availability of data

Data is available upon request to the corresponding author.

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