Int. Adv. Otol. 2010; 6:(3) 394-400

ORIGINAL ARTICLE

Hearing Impairment Among Preschool Children as Detected by Transient-Evoked Otoacoustic Emission Test and Tympanometry

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Objective: Hearing impairment is one of the most common disorders of childhood. The earlier children with hearing loss are identified, the better the prognosis for habilitation and remediation. For this reason many tests are being used, such as Transient Evoked Otoacoustic Emissions (TEOAE), Pure Tone Audyometry (PTA) and Auditory Brainstem Responses (ABR). This study is the first in Turkey using TEOAE and tympanometry among preschool aged population as a first-stage hearing screen.

Materials and Methods: This cross-sectional study was done in 1,096 preschool children in Sivas city of Turkey. Subjects were tested (TEOAE and tympanometry) individually in non-sound treated rooms within each school. The Chi-squared test was used to examine the association between variables. A P-value less than 0.05 were considered statistically significant.

Results: Type B tympanograms were found in 180 (16.4%); Type C tympanograms were obtained in 6 children (0.6%), whilst the remaining 887 children (80.9%) displayed type A tympanograms. TEOAE screening, 883 (80.6%) passed and required no further follow-up. A total of 180 (16.4%) "Referred" on this screening. Hearing impairment among pre-school children was 2.8%. Conductive hearing loss was found in 1.9% of children and a sensorineural hearing loss was found in 0.9% of the children screened. Hearing impairment increases with age and this increase is statistically significant by the chi-square (Linear by Linear Association) test (P = 0.036).

Conclusions: The results of this study should be valuable for planning actions in the prevention of hearing impairment and for raising awareness of the subject in the community and in government agencies.

Submitted : 06 October 2009 *Accepted : 11 July 2010*

Introduction

Hearing impairment is one of the most common disorders of childhood [1, 2]. According to data for 2001 from the World Health Organization (WHO) [3] and from the Global Burden of Hearing Loss study [4], 250 million persons worldwide have disabling hearing impairments. Although they represent only 4.2% of the world's population, two thirds of these persons live in developing countries. Furthermore, several studies indicated that prevalence of childhood (aged 4 to 11 years) hearing loss ranges from 5% to 21% [2, 5-7].

According to the recommendations of the American Academy of Pediatrics; every newborn should receive an objective hearing screen, and children are to be periodically screened through adolescence [8]. Also, universal hearing screening in the neonatal period is the preferred option for early identification of hearing impairment [8-10].

In developing countries, including Turkey, where the vast majority of children in the world live, the prevalence and surveillance of hearing impairment has been difficult to document and monitor. Routine school screening for hearing loss is still uncommon, and in any case would miss children not attending school. In addition, primary health care and public health infrastructures that can serve as referral/monitoring resources are extremely limited.

Clearly, since the effects of such impairment are serious, the earlier children with hearing loss are identified, the better the prognosis is for their habilitation and remediation [11]. Thus, the method used for hearing screening must address the need for limited subjectivity, as well as minimal judgment and decision-making on the part of the screener. Without accurate prevalence data, it is difficult to plan for services; therefore, identifying children with hearing

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loss raises awareness leading to increased availability of services and interventions [12].

The objectives of this study was (a) to determine the prevalence of hearing impairment in preschool children in the study population using TEOAE and tympanometry tests; (b) to provide the first population-based data on hearing impairment anywhere in Turkey; and (c) to offer information useful to health workers and policymakers in establishing prevention programs.

Materials and Methods

Study Design

This cross-sectional study was conducted between October 2007 and April 2008 in Sivas city of Turkey. Population density (population per one square kilometer) in Sivas city in 2000 was 26 according to Census of Population, 2000, Turkey. Annual growth rate of population was -1.54‰ between 1990 and 2000 [13]. Average size of households was 5.27. Our region's gross domestic product per capita was 1,185$ in 2000 [13].

All of children (n=1261) who attended 22 governmental preschools were contacted. A total of 1096 subject's ages ranged from 4 to 6 years old were recruited for testing. This represented 86.9% of the children enrolled in the study.

Study Procedures

Parents of children in participating preschools were sent an information sheet detailing the screening tests, and a consent form. Parents who wanted their child to participate but had not returned the consent form were able to give verbal consent on the day of screening. The only criteria for inclusion in the screening consisted of signed parental consent for health screening and all subjects were invited to participate on a voluntary basis. There were no exclusion criteria.

A self administered questionnaire was completed by parents of participating children. Questionnaire items included family demographics, details of the child's environment from gestation to early childhood, lifestyle, health conditions and parental concerns. Parents were asked to report on whether the child had hearing loss and whether this had been doctor diagnosed. There was no child previously identified with hearing loss.

The study was approved by the Human Research Ethics Committee of the Cumhuriyet University of Turkey.

Measurement

An otoscopic investigation was carried out prior to testing. In order to ensure that the following test results were not influenced by conditions such as impacted wax or occlusion/obstruction/collapse of the external auditory canal. Than, TEOAE testing was administered first, followed by tympanometry. Both testing was conducted by two audiologists who had undertaken specific training in the testing procedures. Subjects were tested individually in non-sound treated rooms within each school, where ambient noise levels ranged from 40 to 53 dB A. Such levels compare favourably with those of McPherson's study [14] who reported a range of 38–52 dB A.

Tympanometry was performed using a MAICO MI 44 Analyzer. Aside from providing insight into the status of the middle ear system, tympanometry results also provide important information regarding the possible source of reduced or obliterated TEOAE. Failure of tympanometry was defined as any result that could be classified as a type B or C tympanogram.

TEOAE testing and analysis utilized the MAICO ERO SCAN Analyzer. Disposable ear tips were used to cover the probes and seal the ear canals snugly during testing. When a test was completed, the results were displayed on the screen as "PASS" when there was TEOAE response, and "REFER" when there was no response to a stimulus. When a "REFER" result was obtained, the screening test was repeated twice to confirm the result, as conditions such as cerumen or debris plugging the ear canals might temporarily prevent the TEOAE tone from reaching the cochlear.

Failure of tympanometry or TEOAE screening indicated failure of overall screening. All subjects with ear disease or hearing loss were offered to Cumhuriyet University Ear, Nose and Throat Clinic for follow-up diagnostic assessment.

Data analysis

Data were analysed using Statistical Package of Social Science (SPSS Inc., Chicago, IL) for Windows version 13.0. The Chi-squared test was used to examine the association between variables. A P-value less than 0.05 were considered statistically significant.

Results

Data of 1,096 children (2192 ears) were used; 52.7% (n=578) of them were boys, and 47.3% (n=518) were girls. Their average age was 5.5±0.7 years. Figure 1 shows the distribution of age-groups by gender.

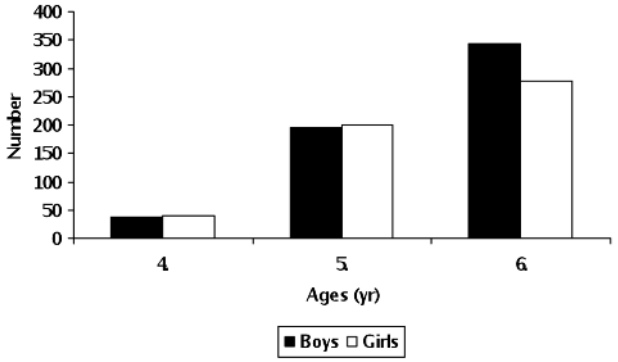

Figure 1. Distribution of age groups by gender

Regarding otoscopic results ear wax was evident in 18 children (1.6%). Twenty-one children (1.9%) displayed gross signs of possible middle ear pathology (e.g. inflammation of tympanic membrane, retraction of tympanic membrane, pain/tenderness, bubbles visible behind the tympanic membrane, etc.).

Table 1 displays the percentages of the total 1,096 subjects who were able to be tested using TEOAE and tympanometry, along with pass/refer rates obtained for each and combined protocol screening. Full results of tympanometry for a total of 1,096 children were obtained. Type B tympanograms were found in 180 children (16.4%). Type C tympanograms were obtained in 6 children (0.6%), whilst the remaining 887 children (80.9%) displayed type A tympanograms.

A total of 23 children (2.1%) were documented as "could not test" (CNT).

As a result of the TEOAE screening, 883 (80.6%) passed and required no further follow-up. A total of 180 (16.4%) “Referred” on this screening, while 33 (3.0%) were documented as CNT. All of CNT cases were not testable (TEOAE and tympanometry together); two-thirds were due to behavioral issues and the remaining one-third to excessive ear wax and other reasons (e.g. illness/absence during period of testing).

The combined test protocol of TEOAE and tympanometry was passed by 78.4% of 1,096 subjects. The remaining total 21.6% failed in at least one ear on either test (17.8%) or CNT (3.8%). These subjects required immediate referral, with further medical or audiological investigation recommended.

Overall, as shown in Table 2, of the 195 (17.8%) children who failed the screening and received diagnostic follow-up services, 132 were identified with a hearing loss or disorder requiring treatment or monitoring. Further analysis of these 132 cases revealed that 31 children had conductive or sensorineural hearing loss (one or two ears), 83 had otitis media, and 18 had excessive earwax or congestion. The remaining 63 of the 195 receiving follow-up were diagnosed as normal and no further treatment was recommended.

Table 1. Percentage of could-not-test (CNT) and pass/refer for testing of study population.

	TEOAE*		**Tympanometry**		**Combined**	
	n	%	n	%	n	%
CNT* (total)	33	3.0	23	2.1	42	3.8
CNT* (both ears)	19	1.7	12	1.1	27	2.4
CNT* (single ear)	14	1.3	11	1.0	15	1.4
Pass (both ears)	883	80.6	887	80.9	859	78.4
Refer (1 or 2 ears)	180	16.4	186	17.0	195	17.8
Overall	1096	100.0	1096	100.0	1096	100.0

** TEOAE: Transient evoked otoacoustic emission; **CNT: Could-not-test*

Table 2. Summary of diagnostic outcomes among 195 referred from screening

Diagnostic outcomes of children	**Number (%)**
Hearing loss or disorder requiring treatment or monitoring	132 (72.8%)
Sensorineural hearing loss (1 or 2 ears)	10
Conductive hearing loss (1 or 2 ears)	21
Otitis media (ear infection)	83
Excessive earwax or congestion	18
No treatment recommended	63 (27.2%)
Total	195 (100.0)

Table 3 contains a summary of the occurrence of case history factors, such as birth history and medical history for hearing impairment among children who referred from screening. The most common causes of hearing impairment were ear infection (42.0%).

Table 3. A summary of the occurrence of case history effects on hearing impairment among children who referred from screening

Case history feature	Number (%)
Ear infection (Otitis media)	82 (42.0)
Oxygen at birth	36 (18.5)
Head trauma	24 (12.3)
Mumps	22 (11.3)
Measles	17 (8.7)
Low birth (<1.500gr)	8 (4.1)
Ear trauma	6 (3.1)
Total	195 (100.0)

Table 4 shows the sex and age distribution of children who displayed hearing impairments. The table clearly shows that hearing impairment increases with age and this increase is statistically significant by the chi-square (Linear by Linear Association) test ($p = 0.036$). Also as showed in Table 4, there was a difference between girls and boys in the proportion of DHI; however, the difference was not statistically significant by the chi-square test ($p = 0.223$).

Discussion

The preschool years are characterized by rapid speech, language, social, emotional, and preacademic growth. Normal hearing during these years is essential for development. Early childhood represents a critical opportunity to identify children with hearing impairments. As hearing disorders in early childhood can have a significant negative impact on the acquisition of language and speech, academic performance and social–emotional development, it is vital to determine the hearing status of all children in order to permit effective habilitation [9, 15-19]. Preschool children, as well as children of low socioeconomic status are at increased risk for otitis media (OM), the most common cause of hearing loss in young children[20, 21]. Given that hearing screening is not routinely performed in preschool and that at-risk populations for low SES have decreased access to care and may have an increased risk of the adverse effects of a late diagnosis of hearing loss [22]. Thus, detection of hearing impairment at younger ages is important for successful interventions and therapies.

Many preschool children are not properly screened or evaluated until they reach kindergarten. In a recent study of hearing screening with the use of pure tone audiometry during well-child visits for children aged 3–19 years, found that 3-year-olds were 33 times more likely than older children to be recorded as CNT [23]. The ability to participate in testing only 30% of the 3-year-olds in the study population. Thus, the current practice of pure tone screening in the preschool populations poses some concern. TEOAE may provide a viable alternative to pure tone audiometry. TEOAE are the sounds emitted by the cochlea in response to a specific acoustic stimulus of short duration. This device can be recorded in the ear canals of normal hearing individuals but are absent in the ear canals of individuals with significant hearing loss (>30 dBHL). Early investigators found TEOAE, a rapid, non-behavioral procedure that may be administered by trained volunteers, has been proposed as a more objective and efficient device for young children [24, 25]. More recent studies found no significant difference in the pass/refer rates between TEOAE and traditional pure tone screen in children 2–5 years old [26, 27]. Because of this unique property, TEOAE provide a useful, objective measure that is quick, affordable, and well tolerated for screening difficult-to-test populations.

This study is the first in Turkey using TEOAE test and tympanometry among preschool aged population as a first-stage hearing screen. In our study, abnormal findings from the otoscopic investigation of the 4-6 year old group were noted to be higher than those reported by Driscoll et al. [28] in their study of 6 years

Table 4. Distribution of the children who displayed hearing impairments by sex and age groups

	Disabling hearing impairments		
Age (yr)	Girls Number (%)	Boys Number (%)	Overall* Number (%)
4	6 (6.8)	4 (3.7)	10 (5.1)
5	40 (45.5)	36 (33.6)	76 (39.0)
6	42 (47.7)	67 (62.6)	109 (55.9)
Overall	88 (100.0)	107 (100.0)	195 (100.0)

**p=0.036, by the chi-square for trend test*

old children (1.6% versus 1%). It is possible that the difference between the ages of the two groups contributed to this finding.

In the current study, tymoanometry and TEOAE testing presented as a feasible tool for hearing screening of preschool children. Using those techniques, 78% of the current subjects could be tested. Although CNT rate of the TEOAE testing in current study was higher than that reported by Driscoll et al. [28] in the 6 years old group (3.8% vs. <1%, respectively), it compares favorably with other reported CNT rates of TEOAE-such as those described by Berg et al. [29] 2-5 years old group (8%). It is likely that this disparity is reflective of differences in subject groups.

Regarding tympanometry results, failure rates were similar to Driscoll et al[28]. 6-year-old group (17.0% vs. 17.9%, respectively). As noted by Haggard and Hughes [29], children aged 4–6 years are particularly at risk of middle ear dysfunction. Furthermore, a large proportion of testing for the current study was conducted during the winter and spring seasons, when the frequency of middle ear pathology (Table 3) is higher than in the warmer months.

For the TEOAE plus tympanometry protocol of the present study, the 17.8% failure rate is detected similar to in Berg's study [30], 17% among children 2-5 years age, however it was lover than that reported in Driscoll's study [28], 20.3% among 6 years age group. The variable rates may be owing to the fact that hearing impairment may be acquired later in life, resulting in increased prevalence with age (Table 4) [31, 32]. Formal testing of children who failed the screening in this study would likely decrease the true prevalence of hearing loss suggested by the number of abnormal screening tests. Each of these factors is likely to have contributed to the different findings among these studies.

It is important to remember that a failed screening does not equate with hearing loss. The failure rate observed in this study is higher than the estimated prevalence of hearing loss among preschool children. Findings of the current investigation revealed that hearing impairment among pre-school children in Sivas city was 2.8%. Conductive hearing loss was found in 1.9% of children and a sensorineural hearing loss was found in 0.9% of the children screened. These findings are consistent with rates found in a population-based cross-sectional survey of the prevalence of hearing impairment among in primary school children in Zimbabwe [33]. In that study, the children tested for hearing loss were found as 2.4%.

As there are various infectious causes of hearing impairment such as measles, mumps, and rubella, immunisation is an important preventative measure available to the population. Almost one-third of children with hearing impairment identified in this study were believed on history to most likely have an infectious cause for their impairment. While history taking from parents of young children is not a reliable way to assess causality, these findings are consistent with known preventable causes of hearing impairment identified in other studies in developing countries [33]. Also, as mentioned above, this study was performed in winter and spring seasons, when hearing impairment due to infections and/or serous otitis media might be higher than at other times of the year.

Among the limitations of the study, the estimated prevalence of hearing loss may be an underestimation of the true prevalence of hearing loss in Sivas. The current study gained access to children through the preschool environment. Thus, those children not currently attending preschool were not available for possible enrolment in the study, and therefore, not subject to testing. If these children are not attending because of hearing impairment a greater proportion of the total child population in Sivas city may suffer from hearing impairment than actually measured in our study.

Conclusion

The results of this study should be valuable for planning actions in the prevention of hearing impairment and for raising awareness of the subject in the community and in government agencies.

References

1. G.W. Mauk and T.R. Beherens, Historical, political, and technological context associated with early identification of hearing loss. In: K.R. White and T.R. Beherens, Editors, The Rhode Island Hearing Assessment Project: Implications for Universal Newborn Hearing Screening, Seminars in Hearing 1993; 8:1–17.

2. Centers for Disease Control and Prevention, Serious hearing impairment among children aged 3–10 years. Atlanta, Georgia, 1991–1993, Morb Mortal Wkly Rev 1997; 46:1073–76.

3. World Health Organization. WHO calls on private sector to provide affordable hearing aids in developing world? Available from: http://www.who.int/inf-pr-2001/ en/pr2001-34.html. (Accessed on Aug 30, 2007).

4. Mathers C, Smith A Concha M. Global burden of hearing loss in the year 2000. Available from:http://www3.who.int/whosis/burden/gbd2000docs/Hearing%20loss.zip?path=evidence,burden,burden_gbd2000docs,burden_gbd2000docs_hearingloss&language=english. (Accessed on Mar 18,2007).

5. Bess FH, Dodd-Murphy J Parker RA. Children with minimal sensorineural hearing loss: prevalence, educational performance, and functional status. Ear Hear 1998;19:339–54.

6. Connor LE. Determining the prevalence of hearing impaired children. Except Children 1961; 27:337–44.

7. Eiserman WD, Hartel DM, Shisler L, Buhrmann J, White KR, Foust T. Using otoacoustic emissions to screen for hearing loss in early childhood care settings. Int J Pediatr Otorhinolaryngol 2008; 72:475-82.

8. American Academy of Pediatrics, Committee on Practice and Ambulatory Medicine. Recommendations for preventive pediatric health care. Pediatric. 2000; 105:645.

9. Joint Committee on Infant Hearing, Year 2007 position statement: principles and guidelines for early hearing detection and intervention programs. Pediatrics 2007; 120:898–921.

10. European Consensus Statement, European consensus statement on neonatal hearing screening. Scand Audiol 1998; 27:259–60.

11. Yoshinaga-Itano C, Sedey AL, Coulter DK Mehl AL. Language of early- and later-identified children with hearing loss. Pediatrics, 1998; 102:1161–71.

12. Berg AL, Spivak LG. Universal newborn hearing screening: should we leap before we look? Pediatrics 1999; 104:351–52.

13. State Institute of Statistics Prime Ministry Republic of Turkey. 2000 Census of Population. Social and Economic Characteristics of Population. Ankara, March, 2003.

14. McPherson B, Smyth V. Hearing screening for school children with otitis media using otoacoustic emission measures. Asia Pac J Sp Lang Hear 1997; 2:69–82.

15. Bess FH, Tharpe AM. Unilateral hearing impairment in children. Pediatrics 1984; 74:206–16.

16. Prior MR, Glazner EA, Sanson A, Debelle G. Temperament and behavioural adjustment in hearing impaired children. J Child Psychol Psychiatr 1988; 29:206–16.

17. Sharma A, Dorman MF. Central auditory development in children with cochlear implants: clinical implications. Adv Otorhinolaryngol 2006; 64:66-88.

18. Lieu JE. Speech-language and educational consequences of unilateral hearing loss in children. Arch Otolaryngol Head Neck Surg 2004; 130: 524–30.

19. Yoshinaga-Itano C. Language, speech and social emotional development of children who are deaf and hard of hearing: the early years Volta. Rev. Monogr 2000; 100:213–27.

20. Baldwin RL. Effects of otitis media on child development. Am J Otol 1993; 14:601–604.

21. Roush J. Screening school-age children. In: Bess FH and Hall JW III, Editors, Screening Children for Auditory Function, Bill Wilkerson Center Press;1992. pp. 297–313.

22. Calderon R. Parental involvement in deaf children's education programs as a predictor of child's language, early reading, and social-emotional development. J Deaf Stud Deaf Educ 2000; 5:140-55.

23. Halloran DR, Wall TC, Evans HH, Hardin JM, Woolley AL. Hearing screening at well-child visits. Arch Pediatr Adolesc Med 2005; 159: 949-55.

24. Glattke TJ, Pafitis IA, Cummiskey C, Herer GR. Identification of hearing loss in children and young adults using measures of transient otoacoustic emission reproducibility. Am J Audiol 1994; 4:71–76.

25. Spektor Z, Leonard G, Kim D, Jung MD, Smurzynski J. Otoacoustic emissions in normal and hearing-impaired children and normal adults. Laryngoscope 1991; 101:965-76.

26. Yin L, Bottrell C, Clarke N, Shacks J Poulsen MK. Otoacoustic emissions: a valid, efficient first-line hearing screen for preschool children. J Sch Health 2009; 79:147-52.

27. Sideris I, Glattke TJ. A comparison of two methods of hearing screening in the preschool population. J Commun Disord 2006; 39:391-401.

28. Driscoll C, Kei J, McPherson B. Transient evoked otoacoustic emissions in 6-year-old school children: A comparison with pure tone screening and tympanometry. Int J Pediatr Otorhinolaryngol 2001; 57:67-76.

29. Haggard M, Hughes E. Screening children's hearing: a review of the literature and implications of otitis media, HMSO, London 1991.

30. Berg AL, Papri H, Ferdous S, Khan NZ, Durkin MS. Screening methods for childhood hearing impairment in rural Bangladesh. Int J Pediatr Otorhinolaryngol 2006; 70:107-14.

31. Niskar AS, Kieszak SM, Holmes AE, Esteban E, Rubin C, Brody DJ. Estimated prevalence of noise-induced hearing threshold shifts among children 6 to 19 years of age: the Third National Health and Nutrition Examination Survey, 1988-1994, United States. Pediatric 2001; 108:40-43.

32. Fortnum HM, Summerfiled AQ, Marshall DH, Davis AC, Bamford JM. Prevalence of permanent childhood hearing impairment in the United Kingdom and implications for universal neonatal hearing screening: questionnaire-based ascertainment study. BMJ 2001; 323:536-40.

33. Westerberg BD, Skowronski DM, Stewart IF, Stewart L, Bernauer M, Mudarikwa L. Prevalence of hearing loss in primary school children in Zimbabwe. Int J Pediatr Otorhinolaryngol 2005;69: 517-525