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A Hearing Screening Program for Children in Primary Schools in Tajikistan: A Telemedicine Model

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Background: According to the guidelines of the European Scientific Consensus on Hearing (European Federation of Audiology Societies 'EFAS' Congress, June 2011, Warsaw, Poland), the detection and treatment of communication disorders in early school-age children is of the highest importance. This objective was adopted by the Polish president of the EFAS Council from the second half of 2011; as a result, pilot programs on children's hearing screening were initiated in various European countries. This paper reports data from a pilot program in Dushanbe, Tajikistan.





Material/Methods: We randomly selected 143 children from 2 primary schools. Each child was assessed by pure tone audiometry and 2 questionnaires (dedicated to parents and children). The study allowed the validation of: (i) hearing screening procedures in young children, and (ii) data collection via a telemedicine model.

Results: Hearing impairments were identified in 34 cases (23.7%) with a 50% ratio between unilateral and bilateral losses. We found a higher incidence of hearing impairment in children than that reported in previous Polish studies.

Conclusions: The data from the present study suggest that it is possible to use a telemedicine model to assess the hearing status of children and to provide a long-distance expert assistance. The latter is very important for rural areas without specialized medical services.

MeSH Keywords: **Audiometry, Pure-Tone • Hearing Loss, Sensorineural • Neonatal Screening**

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Background

Hearing is necessary for the proper development of every child. Both the psychomotor and emotional development can be significantly impaired when the child has hearing problems. Lack of information and acoustical stimuli in the first years of life restricts or even disables the development of speech [1]. Early detection of hearing loss allows the possibility of early treatment. Earlier diagnosis of hearing problems in an infant or child enhances the possibility of choosing the proper diagnostic and therapeutic path. Timely intervention is an important component of any Early Hearing Detection and Intervention (EHDI) screening program [2,3]. The first neonatal screening programs (NHS) in Poland were designed in the 1980s and subsequent studies took place in the mid-1990s [4,5]. The results of the Polish NHS/EDHI program suggest that the incidence of congenital hearing disorders ranges from 2 to 7 per 1000 births, estimates which have been verified by other studies in the literature [6–11].

A child might present a hearing loss caused by acquired hearing or genetic disorders, usually in the form progressive hearing loss [12]. Data in the literature suggest that any undetected impairment, even of a mild degree, can significantly affect the language development and social and emotional development of children, as well as their educational achievements [1–3,13]. For example, undetected mild unilateral hearing loss can cause difficulties in speech understanding and problems with sound-source location, significantly affecting the learning process. These children do not achieve the same progress in school as their peers with good hearing, and 40% of school-age children with unilateral hearing loss fail final-year exams and must repeat a class [3,14,15]. One of the most common causes of acquired hearing loss is otitis media. Otitis media with effusion is one of the most common childhood diseases. Studies in various populations show that 76–95% of all examined children had this disease at least once during early childhood [14]. There is a growing incidence of high-frequency hearing loss in young children caused by listening to loud music through headphones [16–18]. Other causes of hearing loss in school-age children include infectious diseases (e.g., mumps, measles, and meningitis), mechanical injuries, and congenital cholesteatoma [5,19,20].

In 1999, the Institute of Physiology and Pathology of Hearing (Warsaw, Poland), conducted hearing screening tests in different regions of Poland, assessing a group of more than 6200 school-age children. Data from this study suggested that 1 in every 5 children aged 6–18 years has hearing problems, with the most common locus in the middle ear [5,21].

In 2008 a team from the Institute of Physiology and Pathology (Warsaw, Poland) carried out numerous mass-screening

programs for a period of 4 years. To ensure credible results, unique devices and proprietary solutions were developed. In a period spanning 4 years, more than 300 000 school-age children were assessed. The important innovation of this program was in choosing primary schools located not in the big cities, but in small schools in urban peripheries. During this period, specific computerized tools were developed (e.g., the sense examination-platform SZOK, which is a telemedicine model) that made possible the organization and performance of hearing tests at relatively low costs. In addition, medical specialists were able to review, via the platform, “remotely collected data” and to identify children requiring additional care [5,21]. The data from this study showed that 7–14% of the assessed children had peripheral hearing loss. For 70% of those children it was the first hearing screening test in their life and for 60% of these children the families were unaware of the hearing deficit. These large-scale screening experiences called for a European Scientific Consensus agreement, which was defined and signed during the European Federation of Audiology Societies (EFAS) meeting in June 2011, at Warsaw, Poland. As a result of the consensus agreement and under the auspices of the Institute of Physiology and Pathology of Hearing, a number of pilot hearing screening programs were started in various countries [22–24], promoting hearing-loss detection and treatment of communication disorders in young school-age children.

One of the start-up screening programs was implemented in Dushanbe, Tajikistan. The medical community was exposed to information regarding the screening equipment developed in Poland and various organizational solutions (SZOK) that allow data collection on a larger scale. The project was organized in cooperation with the MZ-RT National Medical Center (Dushanbe, Tajikistan), the Trade and Investment Promotion Section of the Polish Embassy in Tashkent, and the Department of Otolaryngology of Abuali Ibni Sino Tajik State Medical University in Dushanbe.

The objectives of this pilot project were: (i) To perform audiometry screening tests in schools and to classify the results via a telemedicine model; (ii) To provide, if possible, medical consultation; and (iii) To raise awareness, among both medical specialists and parents in Tajikistan, about the potential causes of hearing loss and the possibilities for prophylaxis, diagnosis, treatment, and rehabilitation. The present article describes the results obtained during the first year of this project.

Material and Methods

The hearing assessment took place in 2 elementary schools in the Dushanbe area. Due to significant differences in the socioeconomic levels, these 2 public schools were randomly chosen,

excluding elite private schools. In one of the schools the teaching language was Tajik and in the other Russian. The pilot study assessed a total of 143 (286 ears) students aged 7–8 years. Testing was conducted by a team from the Institute and from the Abuali Ibni Sino Tajik State Medical University (medical doctors and other specialists). The final results were given to the directors of the schools, who contacted the parents of the children who did not pass the screening, for further clinical assessments and information on the observed hearing deficits.

Audiometric hearing tests were performed using a telemedicine model (SZOK) described previously [5]. The model used remote client devices and software developed during the 2008 Polish screening program. Additional details on the model/platform are presented in sections A2 and A3 in the Appendix. Tests were conducted in quiet rooms in order to determine hearing threshold in the 500–8000 Hz range (see additional details in section A1 of the Appendix), with the same paradigms as in a previous study [25]. According to already published criteria [26,27], cases presenting threshold levels >25 dB at 1 or more frequencies or in 1 ear were marked with a hearing loss status.

Prior to testing, the children's parents were informed of the testing procedures and provided their written consent. They had the option to receive additional information by completing a questionnaire with data on the potential causes of the child's hearing problems, medical history, possible presence of tinnitus, and any presence of learning difficulties. In total, 100 questionnaires were collected (69.9% of the parents collaborated).

The results of the individual tests (pure tone averages and questionnaires) were sent via an Internet connection to the "SZOK" platform via encrypted lines. Test results presenting a hearing loss status were divided into 2 classes: subjects with unilateral or bilateral hearing losses. The subjects in each class were further assigned into 3 groups according to the pattern of their corresponding audiograms:

- *Low-frequency hearing loss (LFHL)* – The value of the hearing threshold for the frequencies of 500 and/or 1000 Hz was at least 25 dB HL, while the hearing threshold for the frequencies of 2000, 4000, and 8000 Hz did not exceed 20 dB HL;
- *High-frequency hearing loss (HFHL)* – The value of the hearing threshold for the frequencies of 4000 and/or 8000 Hz was at least 25 dB HL, and for the frequencies of 500, 1000, and 2000 Hz it did not exceed 20 dB HL;
- *Other* – The hearing threshold exceeded 20 dB HL for at least 2 non-adjacent frequencies. This category was initially called mixed (i.e., low- and high-frequency losses), but the name improperly suggested the existence of a specific middle and inner ear pathology and it was abandoned for a more generic term.

Based on the hearing test results and the questionnaire outcomes, and in accordance with the screening criteria developed during the programs implemented in Poland, medical specialists from the Institute of Physiology and Pathology of Hearing (IFPS) classified children with hearing losses into 2 groups: (i) a group requiring further clinical care; and (ii) a group requiring continuous monitoring over time, according to standard hearing prophylaxis procedures. The parents of the latter group obtained additional information on hearing disorders and the various factors causing the deterioration of hearing.

Analyses of variance (ANOVA) was conducted with SPSS version 16.0 at a significance level of $p \leq 0.05$. The testing variables were defined as follows: school ID/language; gender; screening outcome (Pass/Fail); unilateral hearing impairment; bilateral hearing impairment; and lateralization (right/left impaired ear). The age variable was not tested because it was found to be homogenous in the assessed sample (i.e., the children had the same age).

Results

The use of the remote client devices (PCs) and the transmission of data via the SZOK platform did not present any particular technical complications. On occasion, due to poor Internet connections (transmission rates below 40 KB/s), the transmission of data took twice the time necessary, but no corrupted data were reported.

The ANOVA analyses suggested that the language (i.e., the site of assessment) was a significant factor in every tested variable, but this was caused by the asymmetric sample sizes taken from the 2 schools (see numbers of participants in Table 1). No gender effects were observed on the screening outcome or on the incidence of unilateral/bilateral hearing impairment.

In terms of screening, 109 children passed the set criteria, while 34 children (24%) presented audiometric levels above the 25-dB criterion and were considered as Refer cases. In both schools, the proportion of bilateral to unilateral hearing impairment was found to be very similar, at close to 1:1. Based on the screening results of the 34 Refer cases and the data gathered from the questionnaires, audiologists and otolaryngologists from the IFPS referred 24 students to further specialist care. The parents of the remaining 10 students were provided with information on hearing loss prophylactic procedures. The data are summarized in Table 1.

In terms of ears presenting hearing losses, the total number was 51, derived from 17 unilateral and 17 bilateral cases. Among these, 31.4% (16 ears) presented low-frequency hearing loss (LFHL), 25.5% (13 ears) high-frequency hearing loss

Table 1. The total number of students with hearing loss and incidence of unilateral and bilateral hearing loss to schools.

Language and School ID	Number of students taking part in the study	Cases with a hearing deficit		
		TOTAL Cases with a deficit	Unilateral hearing loss	Bilateral hearing loss
Tajik (#2)	110	9 (27.3%)	4 (44.4%)	5 (55.6%)
Russian (#15)	33	25 (22.7%)	13 (52.0%)	12 (48.0%)
Total cases	143	34 (23.8%)	17 (50.0%)	17 (50.0%)
Total ears	286	51 (17.8%)	17 (33.3%)	34 (66.6%)

The third column (hearing loss in general) is divided further in two additional columns named unilateral and bilateral hearing loss, respectively. The numbers in the third column are the sums of the corresponding values in the fourth and fifth columns.

Table 2. The number and incidence of different types of audiograms among the 51 ears with abnormal hearing screening results.

Type of hearing loss	Number of ears/incidence
Only low frequency hearing loss– LFHL	16 (31.4%)
Only high frequency hearing loss– HFHL	13 (25.5%)
Others – other types of hearing loss	22 (43.1%)

(HFHL), and the remaining 43.1% (22 ears) presented hearing losses involving all tested frequencies. For the low and high-frequency loss-groups, ANOVA analyses showed a significant lateralization effect favoring the right ear. Similarly, for the cases classified in the “other” category, ANOVA analyses showed a lateralization effect favoring the left ear. Due to the small numbers of ears in these groups, these observations may be slightly biased. The analytical data are presented in Table 2.

The questionnaires showed that only 9 (37%) of the 24 children needing additional health care had previously undergone hearing tests. Children with Refer screening results had experienced otitis media twice as often as the other normal children and had a runny nose during the hearing tests at school. The occurrence of tinnitus in the Pass and Refer screening groups was similar. The analytical questionnaire outcomes are presented in Table 3.

Discussion

The objective of this pilot hearing screening program in Tajikistan was to validate a telemedicine model with methods and procedures already tested in other programs, in a region where hearing screening is rare. Data were collected from first-graders and the hearing screening outcomes were enriched with additional information from questionnaires. The latter proved to be an adequate tool in assessing non-specific information related to screening, such as otitis incidence, tinnitus incidence, and runny nose incidence. Unfortunately,

Table 3. The percentage of responses to each survey question with regard to the positive hearing screening test results in children. For each question two possible outcomes were received: a “Yes” (affirmative response) or a “No”.

Survey questions (affirmative responses)	Results of the screening test		
	Normal hearing	Recommended prophylaxis	Referred to control hearing tests
The child had undergone hearing tests before	25%	32%	37%
The child had been treated for otitis	16%	23%	34%
The child can hear a teacher standing at the blackboard	97%	86%	74%
The child hears squealing/whistling noise when put to sleep or when the room is quiet	9%	10%	14%
The child had a runny nose during the tests	23%	42%	53%
The child’s school performance is poor or very poor	12%	14%	29%

questionnaires require time and smooth collaboration between parents and the Audiology staff and these factors in many instances prevent the proper collection of information.

The data suggest that almost 1 in 4 students (i.e., 34/143=23.7%) has a hearing impairment. Data from previous hearing screening tests conducted by the Institute of Physiology and Pathology of Hearing in 1999 (5, 15) showed a lower incidence, suggesting that 1 in 5 (20%) students has a hearing problem. Although these studies assessed different sample sizes and children of different ages, the hearing deficit estimates successfully describe the variability that commonly characterizes hearing screening outcomes in school-age children.

Thirty-four percent of the tested children in Tajikistan were diagnosed with a low-frequency hearing loss. Similar data have been reported in a study in Nigeria, where 167 out of 500 examined children (33.4%) presented LFHL in their right ear and 39 in their left ear [26]. Very different data were reported from an American population, where the percentage of children with LFHL was reported as 7.1% [27]. The differences in the results between prior studies and the Tajikistan data may be caused by the fact that the research in Tajikistan was carried out in the autumn, when there is an increased incidence of upper respiratory tract infections (URTI). Research conducted at the Pediatric Clinic of Otolaryngology, Audiology, and Phoniatrics of the Medical University of Lodz, Poland showed a correlation between URTI and hearing loss. It was observed that children often suffering from URTI have temporary conductive hearing loss [28].

The data from the Tajikistan project showed that the low- and high-frequency hearing loss occurs more likely in the right ear than in the left. Similar results were observed in studies in Nigeria [26], where there is a higher incidence of hearing loss involving high frequencies in the right ear. In these tests, high-frequency hearing loss occurred almost 3 times more often in the right ear as in the left. Data from this study suggest that for subjects presenting hearing losses at multiple frequencies, there is a strong lateralization effect towards the left ear. These findings confirm the data trends found in a previous study by the same authors in a pilot study in Poland [25]. Nevertheless, the findings in both studies refer to a finite sample size; therefore, data from a larger pool of subjects should be considered prior to forming any definite conclusions.

According to Kuppler [30], the most common hearing disorder is the unilateral hearing loss, which is found in approximately 3% of school-aged children. Sektar et al. [31] reported values of unilateral hearing loss incidence as high as 88% (59/67) in a group of 296 assessed children, of which 67 presented hearing deficits. Niskar et al. [32] conducted screening tests in

6166 American children aged 6–19 years; almost 15% of the children presented a low- or high-frequency hearing loss with 82% unilateral losses. Data from an Iranian children population [29] report an incidence of unilateral hearing loss of 75% of all reported hearing losses. In the present study the incidence of unilateral hearing disorders was 50% (17/34 cases), an estimate which is much lower than the estimates reported in the above-mentioned studies. A number of hypotheses (or their combinations) might explain this outcome, such as: (i) The population of Dushanbe has this particular characteristic; (ii) The assessed sample of 143 students did not accurately represent the characteristics of the general population; and (iii) Previous studies considered a wider age interval, which could have led to different unilateral/bilateral hearing deficit ratios. The findings of the present study suggest that many factors play important roles in the data reported from child screening programs. The age-range and the sample size of the assessed population are important, but one has to also consider other factors such as the hearing assessment protocols and the instrumentation errors during the data assessment.

The proposed screening procedures allow the detection not only of children with hearing loss, but also those with other hearing disorders, such as tinnitus. According to data in the literature, the incidence of tinnitus in school-age children is approximately 13–37.7% [33,34]. Data from the current study show that 9% of the normal hearing group who passed the screening has tinnitus. For the cases classified to a group requiring further clinical care, the incidence of tinnitus was found to be 14%. Additional data from screening in Poland have reported an even larger percentage, showing that nearly 32% of children with normal hearing have tinnitus [32–34].

The successful use of the SZOK software platform in a population with a different language is a positive step towards a model of telemedicine/telehealth [35–37] serving rural areas where specialist medical care is not available. The proposed platform can be used not only for screening children but also for starting EDHI programs. The platform was not evaluated in terms of quality of data or transmission efficiency because these tasks were performed in previous studies [5,21]. Despite INTERNET connection issues, no data corruption was reported. A novel aspect of using this telemedicine model in the future could be the education of professionals and families on issues of hearing deficits and intervention policies.

Conclusions

The results of this pilot study confirm that, even in developed countries, the awareness of hearing disorders is low. Many school-age children have hearing loss, but often the problem stays unnoticed by parents and teachers.

The data from the present study suggest that:

1. It is possible to apply a telemedicine model to assess the hearing status of children and to provide long-distance expert assistance. The latter is important for rural areas which do not have specialized medical services.
2. The reported data suggest that in Dushanbe, Tajikistan, 1 in every 4 young children has a hearing deficit.
3. The incidence of unilateral hearing loss was very similar to the incidence of bilateral losses. This estimate is much lower than the figures presented in previous reports in the literature. A number of factors (e.g., age, sample size, and protocol used), can significantly influence these values; therefore, direct comparison of screening outcomes from various studies can be difficult.

Appendix

A1: Pure tone audiometry testing in free field

Audiometry testing was conducted during lecture hours in quiet rooms (noise level=45–50 dB A). The testing audiometers could also measure ambient noise and testing was stopped when the noise level before and during testing exceeded 50 dB A.

In a free-field audiometry testing, it is very difficult to obtain low frequency (125 and 250 Hz) threshold estimates without many repetitions. The latter significantly increases the total session time. To avoid this, the low audiometric frequencies were excluded from the Tajikistan testing protocol. Since the main deliverable of the project was to identify the pros and cons of future screening guidelines, this procedural compromise was considered acceptable.

A2. Description of the SZOK Platform

The Sense Examination Platform (SZOK) is a telemedicine model for screening and testing: (i) hearing and sight; and (ii) speech in children, young adults, and, in general, of those with special needs.

The system was developed by the Institute of Sensory Organs in collaboration with the Institute of Physiology and Pathology of Hearing (Warsaw, Poland). The Sense Examination Platform is equipped with a variety of screening tests enabling it to

detect a number of dysfunctions in the field of hearing, sight, and speech. In addition, the platform was designed to collect data for surveys and general epidemiological research. The type of data and the form of the survey are totally adaptable.

A3. Design and testing protocols

The platform is built around an INTERNET network solution, interfacing a central computer system and a series of portable computers (remote client devices) equipped with audiometric headphones and a response-button interface. The platform allows the user to conduct the following tests:

1. Audiometric testing (module Audiogram 2009): This feature allows the user to perform air conduction audiometric testing for each ear separately, in a tone frequency range from 250 to 8000 Hz and for hearing threshold levels not exceeding 80 dB HL.
2. Hearing screening test (module I can hear 2009): This feature enables the implementation of hearing screening tests for tones at the frequencies 1000, 2000, and 4000 Hz (in various stimulus intensities) and the assessment of speech intelligibility in noise.
3. Speech screening test (module I can speak 2009): The speech test is carried out to obtain reliable information on: (i) the quality of verbal behavior of the child and (ii) the degree of speech development (or of any potential delays) and any pathological linguistic phenomena occurring in the speech of the child.
4. Sight screening test (module I can see 2009): The sight screening test is based on the contrast differentiation test, the color vision test, and the stereoscopic vision test.
5. Audiological survey (module Survey 2009): This module allows the user to conduct a general survey regarding the hearing, sight, and speech of a patient. The surveys were developed by specialists based on years of experience in specific areas and they provide reliable information on the tested person.
6. Test module DDT 2009: This is a dichotic listening test. During the test, pairs of sounds are presented to each ear and the task of the tested subjects is to repeat what they heard in one or both ears.
7. Test module GDT 2009: This test allows assessment of the potential of perception of gaps in noise. During the test, the noise is presented with constantly emerging gaps of varying lengths.

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