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Hearing Screening around the World

Piotr Henryk Skarżyński and Maciej Ludwikowski

Additional information is available at the end of the chapter

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Abstract

Newborn hearing screening programs for congenital disorders and chronic diseases are expanding worldwide, and children are identified at the earliest possible stage. However, the practice is limited or absent in much of the developing world, such as Africa. Recent epidemiological studies show significant increase of hearing impairments in school-age children (around 20 in 100). Hearing disorders disturb the child's perception of sound, as well as the development of speech which in consequence negatively affects the child relations in society. The early detection of hearing impairments in children enables the effective implementation of medical and rehabilitation procedures or preventive treatment. According to the guidelines of the European Scientific Consensus on Hearing, the detection and treatment of hearing disorders in early school-age children are of the highest importance. That idea was one of the priorities during Polish Presidency of the Council of the European Union (the second half of 2011). The Institute team, in collaboration with numerous national centers, has laid the groundwork for screening programs and developed methods, procedures, and devices for carrying them out. In addition, the Institute was the coordinator and producer of many programs. Based on this, two screening models have been created—newborn and school-age children.

Keywords: hearing screening, hearing impairment, school-age children

1. Introduction

Nowadays, audiology and otolaryngology, which are included in preventive medicine, have many possibilities to assist patients with hearing impairment. However, in order to make full use of these opportunities, hearing disorders or damage should be detected in the early stages. Hence, screening programs for early detection of hearing defects are of great importance. In an optimal healthcare system, hearing screening should be conducted not only during the

neonatal or infancy but also in the subsequent years of the child's life. In this way, both congenital and acquired hearing defects can be detected.

Timely intervention is an important component of Early Hearing Detection and Intervention (EHDI) screening program. In Poland, neonatal screening program (NHS) is carried out. The first projects were performed over 25 years ago [1]. The result of the Polish EHDI/NHS program shows that the prevalence of congenital hearing impairment ranges from 2 to 7 per 1000 births [2]. The National Institute on Deafness and Other Communication Disorders (NIDCD) adduces that 6–7/1000 children have permanent hearing loss in addition to the 3/1000 likely to be diagnosed in short period after birth [3]. From the official database of the National Health & Nutrition Evaluation Studies (NHANES) for screened children who are 6–19 years, it is indicated that approximated 3/1000 prevalence of permanent hearing loss in infants can be expected to increase to 9–10/1000 children in the school-age population.

In years 2007–2016, the Institute of Physiology and Pathology of Hearing screened over million pupils from class I to VI primary school in Poland and approximately~ million children around the world [4]. This experience provided an opportunity to screen a significant number of school-age children and also created the international infrastructure for screening which makes it a suitable solution for place even in remote rural areas.

2. Etiology of hearing loss in school-aged children

Moderate-to-profound degrees of hearing loss are targeted in our newborn screening programs; however, lesser degrees of loss are often not identified until school age. The late age of identification of mild hearing loss may contribute to our lack of knowledge about causative factors. That is, in some cases, a delay in identification of hearing loss may limit our ability to interpret etiologic evaluations reliably or may affect parental memory of possible illnesses or injuries that could account for the loss [5].

As discussed by Ross et al. [6], newborn screening programs are designed to identify hearing losses that are of moderate degree or greater. As such, the equipment and protocols used for newborn screening (e.g., otoacoustic emission (OAE)) are dedicated to identify impairment greater than approximately 40 dB HL. Moreover, a lot of factors appear after newborn screening:

1. Genetic—connexin [7], mitochondrial [8]
2. Enlarged vestibular aqueduct (EVA) syndrome [9]
3. Sudden idiopathic [10]
4. Auditory neuropathy/dyssynchrony [11]
5. Noise induced [12]
6. Viral/bacterial—mumps [13], otitis media with effusion [13]; meningitis, measles, chicken pox, influenza, encephalitis, rubella
7. Head trauma

8. Ototoxic (damaging to the auditory system) drugs

Acquired hearing loss is a hearing loss which appears after birth, at any time in one's life, as a result of a disease, a condition, or an injury. In fact, the most common cause of hearing loss in young children is otitis media. Fluctuating conductive hearing loss nearly always occurs with all types of otitis media [14]. Symptoms, severity, frequency, and length of the condition vary. At one extreme is a single short period of thin, clear, no infected fluid without any pain or fever but with a slight decrease in hearing ability. At the other extreme are repeated bouts with infection, thick "glue-like" fluid, and possible complications such as permanent hearing loss. Therefore, a hearing screening in school-age children is very important [15].

3. The impact of hearing loss on child's development

It is recommended that hearing loss in infants be identified, and when possible treated, prior to 6 months of age. This recommendation is based on studies that have shown that children identified with hearing loss prior to 6 months of age have a better chance of developing skills equivalent to their peers by the time they enter kindergarten.

Following the guidelines for hearing screening, hearing deficits in children can interfere with normal speech and language development, communication, and the ability to learn.

Failure to identify children with congenital or acquired hearing impairment can lead to life-long consequences including deficits in speech and language abilities, cognition delays [16], poor academic performance [17], insufficient psychosocial skills, underemployment, and psychological distress [18].

Classroom is an auditory verbal environment where precise transmission and reception of speech is critical for effective learning to occur [19]. For instance, being able to hear all sounds is fundamental when learning to read. The behavioral effects of hearing impairment are frequently subtle and look similar to those of children who experience attention-deficit disorders, learning disabilities, language, and cognitive delays. Commonly cited behaviors include the following [20]: difficulty attending to spoken or other auditory information; often requests repetition; tired easily when listening; gives not suitable answer; avoids contacts with peers; difficulty with reading skills and written language; and easily frustrated. Children with mild unilateral hearing impairment can cause difficulties in sound-source location and problem with speech perception in background noise. In addition, problem associated with the loss of binaural summation and sound localization is delays in speech-language development and school achievements. Lack of binaural hearing may decrease accidental learning due to background noise interferes with overheard speech. Therefore, only such early identification results in early intervention via hearing aids, cochlear implants, and various assistive listening devices. The intervention allows for speech and language development and academic achievements to remain on target.

What is important, there are many factors that affect the speech and language acquisition, academic achievements of each child. Level of hearing loss (mild, moderate, severe, or

profound) based on the pure-tone threshold does not predict handicap or success in school. Some children have severe hearing loss; however, their speech is comprehensible and they get good grades. But on the other hand, other children with mild hearing loss and lack of family support exhibit considerable academic failure. Therefore, any hearing impairment, no matter how mild, needs to be assessed in order to assert confidently attention to any barrier of learning.

Children with unilateral hearing loss (UHL) appear to have an increased rate of grade failures, need for additional educational assistance, and perceived behavioral issues in the classroom. Possible risk factors include lower cognitive ability, right-ear hearing loss, and severe-to-profound hearing loss. Speech and language development may be delayed in some children with UHL, but it is unclear if children “catch up” as they grow older.

4. Screening methods around the world

As part of a hearing evaluation, child’s healthcare provider will do a complete medical history and physical exam. In addition, there are many different types of hearing tests. Some of them may be used on all ages, while others are used based on child’s age and level of understanding. Moreover, a variety of objective tools have been developed for screening tools. Hearing screening test should be conducted in a quiet area where visual and auditory distractions are minimal.

4.1. Questionnaires

Newton et al. [21] developed an eight-item questionnaire for hearing screening of children in Kenya. This tool is based on typical behavioral reaction to sound and communication ability. The main aim of this questionnaires was to identify children who may have bilateral hearing loss of a moderate degree or greater. It was designed for children of 3–8 years old and completed by teachers, parents, or community nurses, but authors recommended this tool for use only when administered by community health nurses. This questionnaire showed a high sensitivity of 100% but lower specificity of 75%. In addition, all young patients were invited to have an evaluation by ear-nose-throat physician and to have pure-tone audiometry completed.

Olusanya [22] created a questionnaire to screen children at school entry in Nigeria, Lagos. In this study was compared audiometry to results of questionnaires, otoscopy, and also tympanometry for each child. First step was a full physical exam on the children and then the parents were interviewed using a structured questionnaire that explored past medical/developmental history and family history of hearing loss. The parent questionnaire showed high specificity of 94% but low sensitivity of only 10%. The author noted that given limited resources in developing countries there is a need for a low-cost method that requires minimal training and that a questionnaire is a feasible approach. Moreover, the authors recommended the use of the questionnaire for mass screening when administered by trained teachers.

Samelli et al. [23] developed a 14-item questionnaire to identify children at risk for screening in Sao Paulo in Brazil. This tool is dedicated to children of 2–10 years old. In this study, a parent-completed questionnaire was compared with the results of an audiological assessment.

Conduction analyses show that this questionnaire from all of the children identified only with permanent severe-to-profound hearing loss. This tool showed low sensitivity of 44% and specificity of 87%. Researchers recommended the questionnaire for use in healthcare settings.

To conclude, all questionnaires were designed as a tool to identify children with hearing problems so that appropriate treatment and/or intervention could be provided; there were differences in the extent of hearing loss being targeted by the questionnaire. The purpose of population-based hearing screening is to identify those who need further testing from those who do not, with a minimum of false positives (failing the questionnaire when hearing is normal) and false negatives (passing the questionnaire when hearing loss exists).

4.2. Evoked otoacoustic emission

Physiologic test specifically measures outer hair cell response to presentation of a click stimulus (transient evoked OAEs). The test is that acoustic signals generated from within the cochlea travel in a reverse direction through the middle-ear space and tympanic membrane out of the ear. OAEs use a tiny, flexible plug that is inserted into the baby's ear. Sounds are sent through the plug. A microphone in the plug records the otoacoustic emissions (responses) of the normal ear in reaction to the sounds. There are no emissions in a baby with hearing loss. This test is painless and usually takes just a few minutes, while the baby sleeps.

1. **Advantages:** quick time test; ear-specific results; not dependent on whether patient is asleep or awake
2. **Limitations:** infant or child must be relatively inactive during the test; not a comprehensive test of hearing, because it does not assess cortical processing of sound; OAEs are very sensitive to middle-ear effusions and cerumen or vernix in the ear canal
3. **Average time:** 10-min test

4.3. Automated auditory brainstem response

Auditory brainstem responses (ABR) are measures of electrical events generated within the auditory brainstem pathway. These ABRs are used to assess brainstem function at different levels of the auditory pathway and are typically evoked by rapid multi-frequency clicks or chirps. Small metal discs with thin electrodes (wires) are placed on the baby's scalp, and then send signals to a computer to record the results. One objective physiologic means of screening hearing is the automated ABR. This instrument measures cochlear response in the 1- to 4-kHz range with a broadband click stimulus in the ear. While the baby sleeps, clicking sounds are made through tiny earphones in the baby's ears. As in OAEs, this test is painless.

1. **Advantages:** ear-specific results; responses not dependent on patient cooperation
2. **Limitations:** infant or child must remain quiet during the test (sedation is often required); not a comprehensive test of hearing, because it does not assess cortical processing of sound
3. **Average time:** 15-min test

4.4. Play audiometry

Behavioral test of auditory thresholds in response to speech and frequency-specific stimuli is presented through earphones and/or bone vibrator. This test is dedicated to children of 2–4 years old. A test that uses a special audiometer which is able to transmit sounds at different volumes and pitches into child's ears. This test is modified slightly in the toddler age group and made into a game. The toddler is asked to do something with a toy (such as touch or move a toy) every time when a sound is heard through earphones. Air-conduction hearing threshold levels of greater than 20 dB at any of these frequencies indicate possible hearing impairment. This test relies on the cooperation of the child, which may not always be given.

1. **Advantages:** ear-specific results; assesses auditory perception of child
2. **Limitations:** attention span of child may limit the amount of information obtained
3. **Average time:** 15–30 min test

4.5. Pure-tone audiometry

Behavioral test measuring auditory thresholds in response to frequency-specific stimuli is presented through earphones for children of 4 years and older. A test that uses a audiometer which is able to produces sounds at different frequently and intensity into child's ears. The child usually wears some type of earphones. Each ear should be tested at 500, 1000, 2000, and 4000 Hz. Results greater than 20 dB at any frequencies indicate possible hearing loss. In this age group, the child is simply asked to respond in some way when the tone is heard in the earphone. In that test, the most important is the cooperation of the child.

1. **Advantages:** ear-specific results; assesses auditory perception of child
2. **Limitations:** depends on the level of understanding and cooperation of the child
3. **Average time:** 15- to 30-min test

5. Hearing screening programs around the world

The major aim of hearing screening program is to detect a disease at a stage when treatment can be effective in reducing long-term complications [24]. According to the estimates provided by the World Health Organization (WHO), nearly 7.5 million children suffer from hearing loss [25]. Around 80% of them live in low- to middle-income countries [26].

In the absence of a systematic effort to screen infants with hearing loss, the average age of detection is well over 2 years, and detection may be as late as 6 years in sub-Saharan Africa [27]. In Kenya, many children with hearing impairment are not identified until 5–7 years old due to stigma, while some are hidden and are never diagnosed [28].

India launched the National Programme for Prevention and Control of Deafness. Under this program, the following two-part protocol for infant hearing screening is being complemented: institution- and community-based screening. First, screen every baby born in a hospital or

admitted there soon after birth using OAE and second, screen babies who are not born in a hospital; screening is carried out using a brief questionnaire and behavioral testing.

In 2011, 97.9% of babies born in the United States had their hearing screened in the first few weeks of life according to Centers for Disease Control and Prevention (CDC) [29].

In Europe and England, two models are used: first, in hospital before discharge, if discharge takes place before the test is completed, a letter is sent asking the mother to attend an appointment for the screening test and second, in some areas, the test is done at home by a health visitor nurse.

Although newborn hearing screening programs have greatly improved outcomes for those diagnosed with hearing loss in the immediate newborn period, there is no objective universal screening protocol in place during the critical early development years [28]. Unfortunately, school-age children are rarely screened for hearing loss during routine clinical examination, and health authorities pay little attention to audiometric evaluation particularly in primary schools.

5.1. Comprehensive approach to hearing screening in Poland

One of the priority activities of the Institute of Physiology and Pathology of Hearing in Kajetany is a screening program for children of all ages. The Institute team, in collaboration with numerous national centers, has laid the groundwork for screening programs and developed methods, procedures, and devices for carrying out them. He was the coordinator and producer of many programs. Based on this, two screening models have been created—newborn and school-age children.

5.1.1. Newborn hearing screening

The foundation on which the modern screening system was based was a research program for 150,000 newborns with funds in 15 neonatal and infants' centers in Warsaw. It was realized in 1992–1994 under the direction of Professor Maria Góralowna, and we cooperate with the team Diagnostic-Therapeutic and Rehabilitation Center “Cochlear Center” headed by Professor H. Skarżyński.

In the years 1995–1998, under the direction of Professor H. Skarżyński, a grant awarded to the Minister of Health, “Development of a unified screening program for neonates with hearing defects” was implemented. As part of the program, methods and procedures for screening hearing in newborns were developed, as well as their models - universal and intended for newborns at risk. At the end of the project, a draft of the Minister of Health was prepared for hearing screening in neonates.

In 1998, the grants were awarded the team award of the Minister of Health first degree. Another important initiative was implemented in 1996–1998, when the Institute of Physiology and Pathology of Hearing participated in the European program “European Concerted Action AHEAD (*Advancement of Hearing Assessment Methods and Devices*)”. This program aimed to develop a common European position on hearing screening for newborns.

In 1998, in Milan, a consensus on universal screening of hearing in newborns in Europe was signed. The signature on the Polish side was by Professor H. Skarżyński.

In the years 1998–2001, in the framework of the Government Action Plan for Disability Achievement, in which several dozen centers participated, hearing screening were disseminated and enriched. Alternative diagnostic, therapeutic, and rehabilitation facilities have been created for future screening programs. In 70 centers, more than 60,000 newborns and infants were examined.

5.1.2. *School-aged children hearing screening*

In 1999, the team of the Institute of Physiology and Pathology of Hearing collaborated with Brigham Young University of the United States and University of Michigan. M. Curie-Skłodowska from Lublin conducted pioneering screening of hearing in various regions of the country in a group of about 6000 children and adolescents in school age. Studies have shown that every 5 children aged 6–18 have hearing problems.

As part of the implementation of various programs (e.g., the Ministry of Health—the “Program for the Care of Persons with Hearing Loss in Poland”—the Mazovian Regional Health Service, the Ministry of National Education and Sport) conducted by the Institute of Physiology and Hearing Pathology in the years 2000–2006 in cooperation with the dozens of centers around the country, modern multimedia tools are developed for hearing screening. To use the program “I hear ...” has trained over 3500 people and screened many centers. In cooperation with the Gdansk University of Technology, highly specialized systems such as “I can hear...,” “I can see...,” and “I can speak...” have been developed. About 16 million people from 62 countries have used the Internet.

Since 2007, a hearing screening program has been launched in Warsaw for children in class VI. Since 2011, the program also includes children in first grades. In total, these programs have covered up to now more than 56,000 children in Warsaw.

In the years 2008–2011, the programs were conducted by the Institute of Physiology and Pathology of Hearing in cooperation with the Contribution Fund of Social Insurance of Farmers and the Agricultural Insurance Fund Social screening in rural centers and small towns. Within these programs, nearly 300,000 children were studied.

In 2008, new multimedia tool—Platform for Sense Examination—used in screening was developed by the Institute of Physiology and Hearing Pathology in cooperation with the Institute of Sensory Organs. In addition, local screening programs were implemented, within the Ministry of National Education, which involved around 500 psychological and pedagogical clinics throughout the country.

In June 2007, the Institute team organized an exhibition at the European Parliament in Brussels. “HEAR-VISION-SPEAK” is the basis of communication and integration of the young generation of Europe. The exhibit was accompanied by a series of lectures, and numerous audiophiles and audiologists were examined by MEPs. The abovementioned actions aimed to draw Europeans’ attention to the major social problem of communication disorders.

The exhibition was an introduction to further European activity. More than 3 years of negotiations and preparations resulted in the signing of the European Consensus on Audiology, Vision and Speech Screening in preschool and school children on June 22, 2011. There was great support during the Polish Presidency and an important argument for the adoption of the

“EU Council Conclusions on Early Detection and Treatment of Communication Disorders in Children, including the use of eHealth tools and innovative solutions”.

Thanks to all these activities, Poland is currently at the forefront of countries that perform hearing screening in children of all ages.

5.1.3. System of integrated communication operations “SZOK”[®]

Every large-scale project involving children or adults is a great opportunity for early detection of congenital or acquired defects. In response to social needs related to the early detection of birth defects and acquired by detection and prevention, the Institute of Physiology and Hearing Pathology was involved in the implementation of the project, which was named System of Integrated Communication Operations “SZOK”[®].

The project’s innovation is the use of a system to assist patients with remote diagnosis and to transfer the results of their research to the health services sector. Integrating patient data into the “SZOK”[®] system will allow for quick service and thus shorten patient waiting times for visits to IFPS or other specialized facilities and as a comprehensive patient medical base. The system can also be successfully used in other healthcare and other medical fields. It is a unique solution in the field of telemedicine and e-health and is an excellent starting point for the Center for Screening.

Moreover, a standard for the transmission of audiological screening results has been implemented in the “SZOK”[®] system, which is developed within the Institute’s project, so that it is adapted to obtain research results from other institutions and collect them in one place (Figure 1).

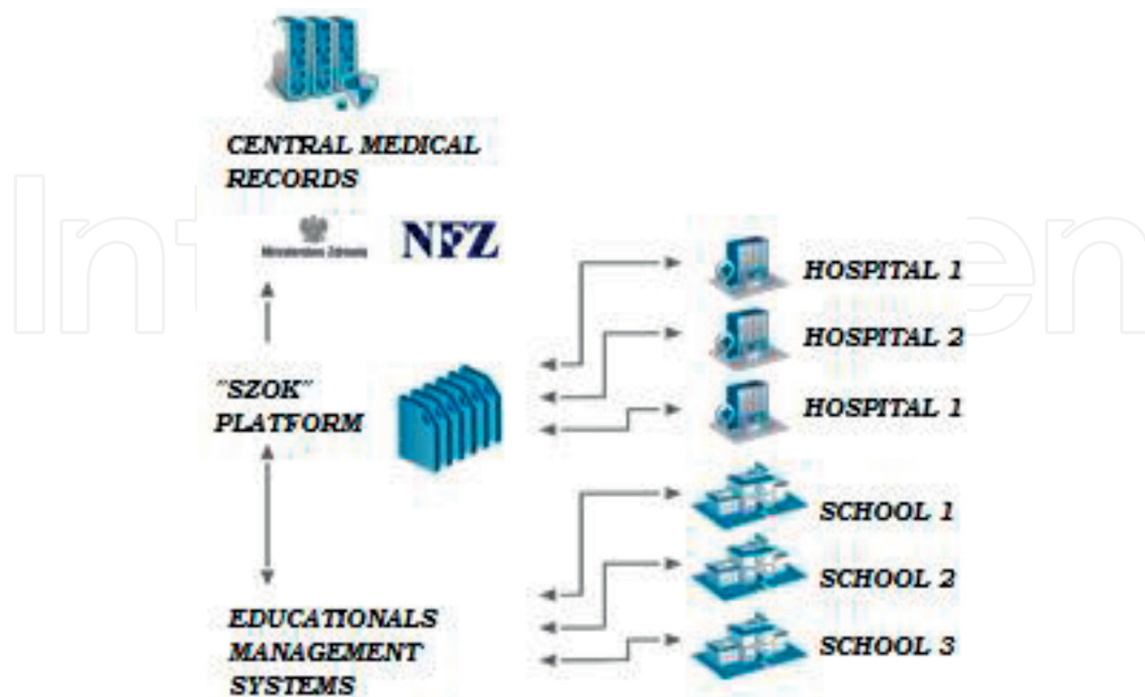


Figure 1. System of integrated communication operations “SZOK”[®].

5.1.4. Platform for sense organ examination

In 2008, new multimedia tool used in screening—Platform for Sense Organs Screening—was developed by the Institute of Physiology and Hearing Pathology in cooperation with the Institute of Sensory Organs(**Figure 2**).

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:** 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. **Speech screening:** The speech test is carried out to obtain reliable information on: (1) the quality of verbal behavior of the child and (2) the degree of speech development (or of any potential delays) and any pathological linguistic phenomena occurring in the speech of the child.
3. **Audiological survey:** 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.
4. **Test module DDT:** 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.
5. **Test module FPT:** This is a frequency pattern test. The test items are sequences of three tone bursts that are presented to one or both ears. In each of the sequences, two tone bursts



Figure 2. Platform for sense organs examinations.

are of the same frequency, while the third tone is of a different frequency. There are just two different frequencies used in this test: one is a high-frequency sound and the other a low-frequency sound pattern test.

6. **Test module DPT:** This is a duration pattern test. Test consists of sequences of three tones, one of which differs from the other two in the sequences by being either longer or shorter.
7. **Test module GIN:** 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.

5.2. Protocol used in the hearing screening in school-age children around the world conducted by world hearing Centre in Kajetany, Poland

Large-scale hearing screening experience called for a European Scientific Consensus agreement, which was defined and signed during the European Federation of Audiology Societies (EFAS) meeting in 2011 under auspices of the Institute of Physiology and Pathology of Hearing. As a result of this, a number of pilot hearing screening programs were started in various countries. Countries in which the team from the Institute of Physiology and Pathology of Hearing in Kajetany conducted hearing screening were presented in the **Table 1**.

Country in which IFPS conducted hearing screening	Children's age	Number of tested children	Universal Newborn Hearing Screening in this country
Armenia	6–9	200	No information
Azerbaijan	6–8	200	No screening program
Cameroon	5–15	220	No screening program
Columbia	6–8	150	In some district
Congo	6–8	200	No screening program
Ivory Coast	6–8	130	No screening program
Kazakhstan	7–8	212	No screening program
Kyrgyzstan	6–7	300	No screening program
Moldova	6–7	179	No information
Nigeria	4–7	200	Pilot project
Romania	6–7	130	No screening program
Russia	6–12	166	No screening program
Rwanda	6–15	195	No screening program
Senegal	6–10	200	No screening program
Tajikistan	7–8	143	No screening program
Tanzania	6–11	200	No screening program
Ukraine	6–11	184	No screening program

Table 1. Overview of hearing screening around the world conducted by the Institute Physiology and Pathology of Hearing.

School-entry hearing screening is especially important. That screening may actually be the first point of access to detect childhood hearing impairment.

Prior to testing, the children's parents were informed of the testing procedures and provided their written consent. The results of the audiometric tests were supplemented by the results of the questionnaire completed by the parents. This questionnaire included questions concerning data on the potential causes of the child's hearing problems, medical history, possible presence of tinnitus, and any presence of learning difficulties.

A hearing screening protocol used by a team from the Institute of Physiology and Pathology of Hearing in Kajetany, while screening in different countries includes three steps (**Figure 3**).

The first step is video-otoscopy. In this test, the specialist otolaryngologist views the middle ear on the monitor. This is the most accurate visual cure repair method and structure of the outer ear. This examination allows the diagnose change in the outer and middle ear such as excessive earwax, acute or chronic otitis media, fungal infection and changes in the tympanic membrane.

Second step is otoacoustic emission (OAE). It is an objective method of assessment—technically not a test of hearing but rather a reflection of inner ear mechanism. OAEs are sounds detected in the external ear canal that are generated by the outer hair cells within the cochlea. If the otoacoustic emission is absent, then we perform the third step—pure-tone audiometry.

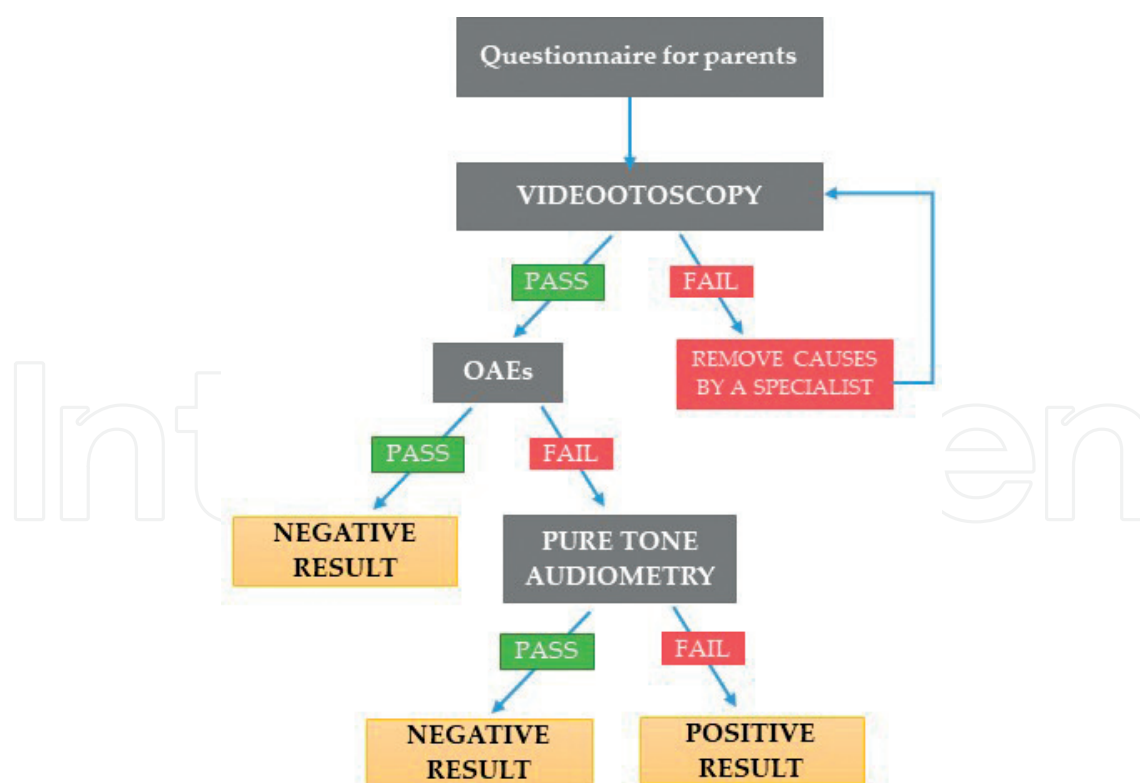


Figure 3. Schema of hearing screening protocol in school-age children used in the institute physiology and pathology of hearing.

Pure-tone audiometry (PTA) was performed using the modern platform elaborated by the Institute of Sense Organs and is fundamental for the inexpensive and universal screening in large populations of children—a platform for sense organs' screening. In addition, PTA was performed using SZOK described previously. The threshold for air conduction in the frequency range of 500–8000 Hz was determined. For abnormal test results, a hearing threshold value of 25 dB and above was used for at least one frequency in at least one ear.

The proposed screening procedure allows the detection not only of children with hearing loss but also of those with other hearing disorders, such as tinnitus. According to data study conducted by the team, led by Professor H. Skarżyńskiego, the incidence of tinnitus in school-age children is approximately 13–37.7% [30].

Moreover, the Institute of Physiology and Pathology of Hearing has their own truck that they are currently using for running a rural hearing health study—called Mobile Hearing Center. Inside, the truck functions as a regular audiology clinic, only on a much smaller scale. The larger of the two booths has a typical audiology setup with video-otoscopy. They were able to conduct assessment of the external and middle ears. The smaller booth is strictly used for testing adults. It may appear to be a small space; however, it is relatively spacious inside for the patient. Currently, we conduct only hearing screening, but in future, they hope to have Internet on the truck, so when they encounter a situation (e.g., with video otoscopy), they can evaluate the patient remotely. In that case, it would be a combination of two delivery types. Right now, it is a completely contained mobile audiology clinic, delivering the same level of service as you would expect in a brick-and-mortar clinic, except that they are able to bring hearing care services to the local community.

6. Summary

The positive impact of early identification and intervention for children with hearing loss is well established, and the primary care provider plays a vital role in screening children who require such services. Without prompt intervention, hearing loss in early childhood can cause significant delays in speech development, socioemotional growth, and school achievement.

Index of technical terms

Acute Otitis Media—painful type of ear infection. It occurs when the area behind the eardrum called the middle ear is inflamed and infected.

Auditory Brainstem Response (ABR)—neurologic test which gives information about the inner ear and brain pathways for hearing. The ABR is performed by pasting electrodes on the head—similar to electrodes placed around the heart when an electrocardiogram is run—and recording brain wave activity in response to sound.

Auditory Neuropathy/Dyssynchrony—hearing disorder in which sound enters the inner ear normally but the transmission of signals from the inner ear to the brain is impaired. People with auditory neuropathy may have normal hearing, or hearing loss ranges from mild to severe but they always have poor speech-perception abilities.

Behavioral Test—test investigates propensities toward certain kinds of behavior and styles of interaction with others.

Cerumen (Earwax)—brown, gray, or yellowish waxy substance secreted in the ear canal. It protects the skin of the human ear canal, assists in cleaning and lubrication, and also provides some protection against bacteria, fungi, insects, and water.

Chickenpox (Varicella)—a virus infection, commonly of children, caused by the varicella zoster virus and characterized by mild headache and fever, malaise, and eruption of blisters on the skin and mucous membranes.

Chronic Otitis Media—a long-standing, persistently draining perforation of the eardrum.

Cochlea—the auditory portion of the inner ear situated in the temporal bone. The cochlea interacts with the middle ear via two holes that are closed by membranes: the oval window, which is located at the base of the scala vestibuli and which undergoes pressure from the stapes, and the round window, which seals the base of the tympanic membrane and is used to relieve pressure. The cochlea is filled with a watery liquid, the perilymph, which moves in response to the vibrations coming from the middle ear via the oval window.

Cochlear Implant—a device that provides direct electrical stimulation to the auditory (hearing) nerve in the inner ear. Children and adults with a severe-to-profound sensorineural hearing loss who cannot be helped with hearing aids may be helped with cochlear implants. Cochlear implants have external (outside) parts and internal (surgically implanted) parts that work together to allow the user to perceive sound.

Congenital Hearing Impairment—it means that the hearing impairment is present at birth. Congenital hearing loss can be caused by genetic or nongenetic factors.

Connexin—structurally related transmembrane proteins that assemble to form vertebrate gap junctions.

Dichotic Listening Test—a psychological test commonly used to investigate selective attention within the auditory. Specifically, it is used as a behavioral test for hemispheric lateralization of speech sound perception. During a standard dichotic listening test, a participant is presented with two different auditory stimuli simultaneously (usually speech). The different stimuli are directed into different ears over headphones.

Duration Pattern Test—standard version is an auditory processing disorder test for ages 11 and over using nonverbal stimuli. The duration patterns are composed of three 1000-Hz tones and two 300-ms intertone intervals.

Ear Canal—it is a tube running from the outer ear to the middle ear. The adult human ear canal extends from the pinna to the eardrum and is about 2.5 cm (1 in) in length and 0.7 cm (0.3 in) in diameter.

Encephalitis—inflammation of the brain tissue. The most common cause is viral infections. In rare cases, it can be caused by bacteria or even fungi. Symptoms may include headache, fever, confusion, a stiff neck, and vomiting.

Enlarged Vestibular Aqueduct (EVA) Syndrome—a syndromic form of hearing loss, caused by the enlargement of the vestibular aqueduct in the inner ear. It is one of the most common inner ear deformities, which results in hearing loss during childhood.

Evoked Otoacoustic Emission (OAE)—sounds of cochlear origin, which can be recorded by a microphone fitted into the ear canal. They are caused by the motion of the cochlea's sensory hair cells as they energetically respond to auditory stimulation.

Frequency Pattern Test—an auditory processing disorder test for ages 8 and over using nonverbal stimuli. The frequency pattern test consists of 880 Hz (low) and 1122 Hz (high) tones that are 200 ms in duration and have an interstimulus interval of 150 ms and a 10-ms rise fall time.

Fungal infection—fungal infections occur when an invading fungus takes over an area of the body and is too much for the immune system to handle.

Gaps in noise—test auditory processing disorder test for ages 7 and older using nonverbal stimuli. It is designed to measure temporal resolution which resolution refers to the ability to detect changes in either the duration of an auditory stimulus and/or the time intervals or gaps of silence embedded within an auditory stimulus. The ability to detect small silent intervals is an important factor in speech perception.

Head trauma—any injury that results in trauma to the skull or brain.

Hearing aid—a device designed to improve hearing. Hearing aids are incapable of truly correcting a hearing loss; they are an aid to make sounds more accessible.

Hearing deficits—it is a partial or total inability to hear.

Influenza—an infectious disease caused by an influenza virus. It is characterized by a sudden onset of fever, cough (usually dry), headache, muscle and joint pain, severe malaise (feeling unwell), sore throat, and a runny nose. The cough can be severe and can last 2 or more weeks.

Measles—a highly contagious infection caused by the measles virus. Initial signs and symptoms typically include fever, often greater than 40°C (104.0°F), cough, runny nose, and inflamed eyes. Two or three days after the start of symptoms, small white spots may form inside the mouth. A red, flat rash which usually starts on the face and then spreads to the rest of the body typically begins 3–5 days after the start of symptoms.

Medical History—information gained by a physician by asking specific questions, either of the patient or of other people who know the person and can give suitable information with the aim of obtaining information useful in formulating a diagnosis and providing medical care to the patient. The medically relevant complaints reported by the patient or others familiar with the patient are referred to as symptoms, in contrast with clinical signs, which are ascertained by direct examination on the part of medical personnel.

Meningitis—an acute inflammation of the protective membranes covering the brain and spinal cord, collectively known as the meninges. The most common symptoms are fever,

headache, and neck stiffness. The inflammation may be caused by infection with viruses, bacteria, or other microorganisms, and less commonly by certain drugs.

Middle Ear—the portion of the ear internal to the eardrum, and external to the oval window of the inner ear. The mammalian middle ear contains three ossicles, which transfer the vibrations of the eardrum into waves in the fluid and membranes of the inner ear. It joins the tympanic cavity with the nasal cavity, allowing pressure to equalize between the middle ear and throat. The hollow space of the middle ear is also known as the tympanic cavity. The primary function of the middle ear is to efficiently transfer acoustic energy from compression waves in air to fluid-membrane waves within the cochlea.

Mitochondrial Hearing Loss—nonsyndromic deafness caused by mutations in both nuclear and mitochondrial genes. Nonsyndromic mitochondrial hearing loss is characterized by moderate to profound hearing loss, and a maternally inherited mutation in either the *MTRNR1* or *MTTS1* gene.

Mumps—a viral disease caused by the mumps virus. Initial signs and symptoms often include fever, muscle pain, headache, and feeling tired. This is then usually followed by painful swelling of one or both parotid salivary glands. Symptoms typically occur 16–18 days after exposure and resolve after 7–10 days. Symptoms in adults are often more severe than those in children. Complications may include meningitis, pancreatitis, permanent deafness, and testicular inflammation, which uncommonly results in infertility.

Noise-induced Hearing Loss—hearing impairment resulting from exposure to loud sound. People may have a loss of perception of a narrow range of frequencies, impaired cognitive perception of sound, or other impairment, including sensitivity to sound or ringing in the ears. Hearing may deteriorate gradually from chronic and repeated noise exposure or suddenly from a short high intensity noise. In both types, loud sound overstimulates delicate hearing cells, leading to the permanent injury or death of the cells.

Otitis Media with Effusion—when there is thick or sticky fluid behind the eardrum in the middle ear, but there is no ear infection. Normally, the Eustachian tube drains fluid from your ears to the back of your throat. If it clogs, otitis media with effusion (OME) can occur. This condition most often affects children. Muffled hearing is a common symptom.

Ototoxic Drugs—medications which can damage the ear, resulting in hearing loss, ringing in the ear, or balance disorders. The effects of ototoxicity can be reversible and temporary, or irreversible and permanent. Ototoxic drugs include, for example, antibiotics (gentamicin), loop diuretics (furosemide), and platinum-based chemotherapy (cisplatin). Outer hair cells.

Outer Hair Cells—called acoustical preamplifiers. In mammalian outer hair cells, the receptor potential triggers active vibrations of the cell body. This mechanical response to electrical signals is termed somatic electromotility and drives oscillations in the cell's length, which occur at the frequency of the incoming sound and provide mechanical feedback amplification. They also improve frequency selectivity.

Platform for Sense Examination—a portable device for screening hearing, sight and speech and hearing and speech rehabilitation in children (also with special educational needs),

adolescents and adults. The device is built on the basis of an advanced central computer system and a portable computer equipped with additional accessories enabling the test.

Play Audiometry—it allows an audiologist to test the hearing of very young toddlers and preschoolers. CPA uses behavioral conditioning to get kids to respond to sounds. It is designed for children usually between 2 and 5 years of age. It measures hearing sensitivity to determine both a child's type and degree of hearing loss, if any. The audiologist can then refer parents to another specialist, if necessary.

Pure Tone Audiometry (PTA)—the key hearing test used to identify hearing threshold levels of an individual, enabling determination of the degree, type and configuration of a hearing loss, thus providing the basis for diagnosis and management. PTA is a subjective, behavioral measurement of hearing threshold, as it relies on patient response to pure tone stimuli. Therefore, PTA is used on adults and children old enough to cooperate with the test procedure.

Questionnaire—a research instrument consisting of a series of questions (or other types of prompts) for the purpose of gathering information from respondents. Although questionnaires are often designed for statistical analysis of the responses, this is not always the case.

Rubella—is an infection caused by the rubella virus. This disease is often mild with half of people not realizing that they are sick. A rash may start around 2 weeks after exposure and last for 3 days. Complications may include bleeding problems, testicular swelling, and inflammation of nerves. Infection during early pregnancy may result in a child born with congenital rubella syndrome (CRS) or miscarriage.

Sensitivity—the ability of an organism or organ to respond to external stimuli. For example, auditory hypersensitivity occurs when a person has a collapsed tolerance to normal environmental sound. The term commonly used to describe this condition is "hyperacusis."

Sound-source location—a listener's ability to identify the location or origin of a detected sound in direction and distance. The auditory system uses several cues for sound source localization, including time and level differences (or intensity-difference) between both ears, spectral information, timing analysis, correlation analysis, and pattern matching.

Specificity—In medicine, it means the extent to which a diagnostic test is specific for a particular condition, trait, and so on.

Sudden Idiopathic Hearing Loss—defined as greater than 30 dB hearing reduction, over at least three contiguous frequencies, occurring over a period of 72 h or less. Some patients describe that the hearing loss was noticed instantaneously in the morning, and others report that it rapidly developed over a period of hours or days. Only one ear is usually affected. About half of people recover some or all of their hearing spontaneously, and some people need a treatment from an otolaryngologist.

System of Integrated Communication Operations "SZOK"[®]—a world-class solution—is a revolution in the creation of IT infrastructure and data management. The project's innovativeness is based on the use of a system supporting patient diagnosis at a distance and the transfer of research results to the health services sector. Integrating patient data into the

system platform will allow for better and faster service and will reduce patient waiting times for visits to an institute.

Teleaudiology—it is the utilization of telehealth to provide audiological services and may include the full scope of audiological practice. The innovation that is currently being developed broadens teleaudiology and hearing care practice to virtual care modalities such as clinical video telehealth, store-and-forward telehealth, home telehealth, mobile health applications, secure messaging, and electronic consults.

Telemedicine—the use of telecommunication and information technology to provide clinical healthcare from a distance. It has been used to overcome distance barriers and to improve access to medical services that would often not be consistently available in distant rural communities. It is also used to save lives in critical care and emergency situations.

Tinnitus—the hearing of sound when no external sound is present. While often described as a ringing, it may also sound like a clicking, hiss, or roaring. Rarely, unclear voices or music are heard. The sound may be soft or loud, low pitched or high pitched and appear to be coming from one ear or both. Most of the time, it comes on gradually. In some people, the sound causes depression or anxiety and can interfere with concentration.

Tympanic Membrane—a thin, cone-shaped membrane that separates the external ear from the middle ear. Its function is to transmit sound from the air to the ossicles inside the middle ear and then to the oval window in the fluid-filled cochlea. Hence, it ultimately converts and amplifies vibration in air to vibration in fluid. Rupture or perforation of the eardrum can lead to conductive hearing loss.

Unilateral Hearing Loss (UHL)—a type of hearing impairment where there is normal hearing in one ear and impaired hearing in the other ear. Patients with unilateral hearing loss have difficulty in hearing conversation on their impaired side, localizing sound, understanding speech in the presence of background noise, interpersonal and social relations. Using for example CROS hearing aids or BAHA implant can help to resist better hearing functioning.

Universal Screening Protocol—it is the largest preventive health program in Poland. Its primary goal is to examine each newborn baby to except possible hearing impairment and to analyze risk factors that predispose to hearing loss.

Vernix—the waxy or cheese-like white substance found coating the skin of newborn human babies. It is produced by dedicated cells and is thought to have some protective roles during fetal development and for a few hours after birth. Vernix is theorized to serve several purposes, including moisturizing the infant's skin, and facilitating passage through the bacteria. It serves to conserve heat and protect the delicate newborn skin from environmental stress.

Video-otoscopy—video-otoscopy is the use of an otoscope (this is an instrument used to look in the ears) that has a very tiny video camera that transmits images to a television screen. These scopes use fiber optics to transmit a very bright light that illuminates the ear canal. The video otoscope allows the doctor to see in the ear much better than a traditional handheld otoscope. With the irrigating function, debris can be cleaned deep within the ear that would be impossible to remove any other way.

Author details

Piotr Henryk Skarżyński^{1,2,3,4*} and Maciej Ludwikowski¹

*Address all correspondence to: p.skarzynski@medincus.pl

1 World Hearing Center, Institute of Physiology and Pathology of Hearing, Department of Teleaudiology, Kajetany/Warsaw, Poland

2 Institute of Sensory Organs, Kajetany, Poland

3 Heart Failure and Cardiac Rehabilitation, Department of the Medical University of Warsaw, Poland

4 Center of Hearing and Speech, MEDINCUS, Kajetany, Poland

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