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# ROZPRAWA DOKTORSKA

## Analiza wyników i czynników ryzyka zaburzeń słuchu wśród dzieci w wieku szkolnym na podstawie badań przesiewowych słuchu

Analysis of the results and risk factors for hearing disorders among school-aged children based on hearing screening

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Kajetany 2022

# SPIS TREŚCI

# 1. Wykaz publikacji będących podstawą rozprawy doktorskiej

Podstawa dzieła naukowego, stanowiącego dorobek naukowy do ubiegania się o stopień doktora nauk o zdrowiu, to cykl dziesięciu oryginalnych, pełnotekstowych prac oraz jednego rozdziału w monografii naukowej, nawiązujących do tematu pt. „Analiza wyników i czynników ryzyka zaburzeń słuchu wśród dzieci w wieku szkolnym na podstawie badań przesiewowych słuchu". Prace, stanowiące cykl publikacji, uzyskały sumaryczny współczynnik oddziaływania **IF = 14,747** i liczbę punktów **MEiN = 795.** W trzech pracach kandydatka jest pierwszym autorem, w czterech – drugim i w dwóch – trzecim współautorem. W rozdziale monografii naukowej doktorantka jest trzecim współautorem.

**M-1**

Skarżyński Piotr H., Krumm Mark, Świerniak Weronika, Hatzopoulos Stavros. *Chapter 18: Hearing Screening: Teleaudiology and Its Application with Children in Africa and Europe.* [w:] Hatzopoulos Stavros, Ciorba Andrea, Krumm Mark (Eds.) *Advances in Audiology and Hearing Science.* Taylor & Francis Group, 2020: 481–494. DOI: 10.1201/9780429292590; (MEiN = 100); udział procentowy w wytworzeniu monografii: 40%.

**Publikacje w czasopismach z listy filadelfijskiej:**

**P-1**

Świerniak Weronika, Gos Elżbieta, Skarżyński Piotr H., Czajka Natalia, Skarżyński Henryk. *Personal Music Players Use and Other Noise Hazards among Children 11 to 12 Years Old.* International Journal of Environmental Research and Public Health, 2020; 22:17(18): 6934. DOI: 10.3390/ijerph17186934. (IF = 3.39, MEiN = 70); udział procentowy w wytworzeniu publikacji: 30%.

**P-2**

Świerniak Weronika, Gos Elżbieta, Skarżyński Piotr H., Czajka Natalia, Skarżyński Henryk. *The accuracy of parental suspicion of hearing loss in children.* International Journal of Pediatric Otorhinolaryngology, 2021; 11:141: 110552. DOI: 10.1016/j.ijporl.2020.110552 (IF = 1.675, MEiN = 70); udział procentowy w wytworzeniu publikacji: 30%.

**P-3**

Świerniak Weronika, Skarżyński Piotr H., Gos Elżbieta, Czajka Natalia, Matusiak Monika, Hartwich Patryk, Skarżyńska Magdalena B. *Hearing Screening among First-Grade Children in Rural Areas and Small Towns in Małopolskie Voivodeship, Poland,* Audiology Research, 2021, 11(2): 275–283; DOI: 10.3390/audiolres11020025 (MEiN = 70); udział procentowy w wytworzeniu publikacji: 30%.

**P-4**

Skarżyński Piotr H., Świerniak Weronika, Gos Elżbieta, Gocel Maria, Skarżyński Henryk. *Organization and results of a hearing screening program in first-grade children of the Mazovian region of Poland.* Language, Speech and Hearing Services in Schools, 2021: Jun 7; 1–12., DOI: 10.1044/2021_LSHSS-20-00083 (IF = 2.983, MEiN = 100); udział procentowy w wytworzeniu publikacji: 30%.

**P-5**

Skarżyński Piotr H., Świerniak Weronika, Gos Elżbieta, Pierzyńska Irina, Walkowiak Adam, Cywka Katarzyna B., Wołujewicz Kinga, Skarżyński Henryk. *Results of hearing screening of school-age children in Bishkek, Kyrgyzstan.* Primary Health Care Research & Development, 2020; 10:21: e18. DOI: 10.1017/S1463423620000183 (IF = 1.458, MEiN = 40); udział procentowy w wytworzeniu publikacji: 30%.

**P-6**

Skarżyński Piotr H., Świerniak Weronika, Gos Elżbieta, Bieńkowska Katarzyna, Adeyinka Paul, Olubi Olawale, Afolabi Simeon, Skarżyńska Magdalena B., Hatzopoulos Stavros. *Pilot hearing screening of school-age children in Lagos, Nigeria.* Journal of Health Care for the Poor and Underserved, 2021; 32(3): 1444–1460. DOI: 10.1353/hpu.2021.0143 (IF = 1.449, MNiSW = 70); udział procentowy w wytworzeniu publikacji: 25%.

**P-7**

Skarżyński Piotr H., Cyran Olivia, Świerniak Weronika, Wołujewicz Kinga, Barylyak Roman, Skarżyński Henryk. *Pilot hearing screening in schoolchildren from Armenia, Russia, Kyrgyzstan, and Azerbaijan.* Journal of Hearing Science, 2020;10(2): 35–39. DOI: 10.17430/JHS.2020.10.2.4 (MEiN = 100); udział procentowy w wytworzeniu publikacji: 25%.

**P-8**

Skarżyński Piotr H., Świerniak Weronika, Piłka Adam, Ludwikowski Maciej, Gos Elżbieta, Skarżyńska Magdalena B., Skarżyński Henryk. *Pilotażowe przesiewowe badania słuchu u dzieci w wieku szkolnym z różnych krajów w Afryce.* Nowa Audiofonologia, 2018; 7: 29–34. DOI: 10.17431/1003134 (MEiN = 5); udział procentowy w wytworzeniu publikacji: 20%.

**P-9**

Skarżyński Henryk, Gos Elżbieta, Świerniak Weronika, Skarżyński Piotr H. *Prevalence of hearing loss among Polish school-age children from rural areas – results of hearing screening program in the sample of 67 416 children.* International Journal of Pediatric Otorhinolaryngology, 2020; 128: 109676. DOI: 10.1016/j.ijporl.2019.109676 (IF = 1.675, MEiN = 70); udział procentowy w wytworzeniu publikacji: 20%.

**P-10**

Raj-Koziak Danuta, Gos Elżbieta, Świerniak Weronika, Skarżyński Henryk, Skarżyński Piotr H. *The prevalence of tinnitus in children in Warsaw, Poland. Result from the sample of 43 064 children*. International Journal of Audiology, 2020; 14: 1–7. DOI: 10.1080/14992027.2020.1849829 (IF = 2.117, MEiN = 100); udział procentowy w wytworzeniu publikacji: 15%.

# 2. Tło teoretyczne

## 2.1. Zarys problemu

Słuch, jako jeden ze zmysłów społecznych, pozwala człowiekowi odbierać bodźce akustyczne ze świata zewnętrznego, co umożliwia werbalną komunikację z otaczającym środowiskiem. Zmysł ten działa stale bez udziału woli, nawet w czasie snu. Według danych Światowej Organizacji Zdrowia (ang. *World Health Organization*, WHO) szacuje się, że około 34 miliony dzieci na całym świecie ma zaburzenia słuchu (ubytek słuchu większy niż 30 dB w lepszym uchu). W wielu krajach i rejonach świata zaburzenie słuchu jest najczęstszą niepełnosprawnością występującą w dzieciństwie [1–4], dotykającą 1 do 3 na 1000 żywych urodzeń [2]. Łagodny ubytek słuchu jest ukrytym problemem występującym u większości dzieci w wieku od 1 do 9 lat [5]. Dane z ostatniego przeglądu systematycznego i metaanalizy wykazały, że u dzieci w wieku od 0 do 18 lat częstość występowania ubytków słuchu (>15 dB HL; decybele poziomu słyszenia) została oszacowana na 13,1% (dane ze Stanów Zjednoczonych, Kanady, Australii, Holandii) [6]. Częstość występowania lekkiego ubytku słuchu u dzieci w wieku szkolnym szacuje się na 2,4% do 14,9%, w zależności od kraju, w którym przeprowadzono badania [1,7–9]. W przeglądach systematycznych oszacowano globalne i regionalne rozpowszechnienie niedosłuchu [10,11], brakuje jednak danych na temat krajowych szacunków częstości występowania tego schorzenia w wielu krajach. W związku z tym istnieje konieczność, aby każdy kraj oszacował rozpowszechnienie i opracował specjalne programy zapobiegania i leczenia zaburzeń słuchu. Dane z Wielkiej Brytanii wskazują, że występowanie niedosłuchu wzrasta z około 0,11% u dzieci w wieku 3 lat do 0,21% u dzieci w wieku 9-15 lat [12]. W grupie kanadyjskich dzieci w wieku 6-19 lat u 7,7% stwierdzono ubytek słuchu [13]. Ponadto, wśród dzieci poniżej 15. roku życia około 60% przypadków zaburzeń słuchu można ograniczyć dzięki odpowiednio stosowanej profilaktyce pierwotnej [14]. Sytuacja ta dotyczy w szczególności krajów rozwijających się, w których niedosłuch jest znaczącym problemem zdrowotnym wśród dzieci w wieku szkolnym [15]. Wskaźniki rozpowszechnienia ubytku słuchu u dzieci różnią się w zależności od regionu – najwyższe są notowane w regionach rozwijających się, takich jak Azja Południowa i Afryka Subsaharyjska [16]. Zapewnienie dzieciom dostępu do opieki medycznej w odpowiednim czasie ma kluczowe znaczenie i może zapobiec długotrwałym następstwom [17,18]. Szczególnie ważne jest to w krajach o niskich i średnich dochodach, w których występuje >80% globalnego przypadków ubytku słuchu. Wskaźniki są znacznie niższe w krajach o wyższych dochodach, głównie z powodu powszechniejszego dostępu do środków zapobiegawczych i usług medycznych [19]. Mimo to ubytek słuchu jest przedmiotem niewielkiej uwagi w porównaniu z innymi przewlekłymi schorzeniami [20]. Niewykryty niedosłuch w dzieciństwie może przyczynić się do uzyskania niższego poziomu wykształcenia i w konsekwencji skutkuje ograniczonymi możliwościami zatrudnienia, co negatywnie wpływa na jakość dorosłego życia szczególnie w krajach rozwijających się [18,21].

Dostępna literatura dotycząca etiologii niedosłuchu u dzieci w wieku szkolnym koncentruje się na sześciu głównych przyczynach, tj. postępujące wady wrodzone, wysiękowe zapalenie ucha środkowego, ototoksyczność leków, infekcje, zaleganie czopów woszczynowych i narażenie na hałas. Kluczowe jest stałe monitorowanie stanu słuchu wśród dzieci, również u tych, które pomyślnie przeszły badania przesiewowe słuchu u noworodków. U tych dzieci może zostać niewykryty postępujący ubytek słuchu lub ubytek słuchu związany z przyczynami wrodzonymi może rozwinąć się w późniejszym okresie dzieciństwa [22–24]. Ubytek słuchu o opóźnionym początku może wystąpić po infekcjach wrodzonych. Historycznie, prenatalne narażenie na organizmy z grupy TORCH (toksoplazmoza, inne, między innymi ospa wietrzna, wirus B19 czy, różyczka, CMV, wirus opryszczki) było częstą przyczyną wrodzonych ubytków słuchu. Jednakże epidemiologia tych organizmów uległa zmianie i obecnie tylko wrodzony wirus CMV jest istotną przyczyną opóźnionego początku ubytku słuchu w wielu krajach [25]. Częstość występowania wrodzonego zakażenia CMV wynosi 0,4% do 2,3% wszystkich noworodków [26]. Wśród niemowląt z potwierdzonym wrodzonym ubytkiem słuchu 6% do 7% ma wrodzone zakażenie CMV. W badaniach przeprowadzonych przez Fowlera i wsp. wykazano, że do 43% niemowląt z wrodzonym CVM otrzymuje prawidłowy wynik badania przesiewowego noworodka, ale później w okresie niemowlęcym lub dziecięcym występuje u nich odbiorczy ubytek słuchu [26]. Niektóre z niesyndromowych genów recesywnych są również związane z postępującym odbiorczym ubytkiem słuchu, a wynik badania przesiewowego noworodków będzie prawidłowy, ponieważ może występować znacznie łagodniejszy ubytek, który z czasem się pogłębia. Należą do nich GJB2 (koneksyna 26), MYO15A i STRC; autosomalne dominujące, niesyndromowe geny postępującego ubytku słuchu obejmują TMC1 i KCNQ4 [25].

Znaczna część występowania dziecięcych ubytków słuchu ma charakter nabyty, ale specyficzny udział w tej globalnej częstości występowania nie został dobrze zbadany ani udokumentowany [25]. Światowa Organizacja Zdrowia przypisuje 31% możliwych do uniknięcia przyczyn ubytków słuchu u dzieci infekcjom, 17% powikłaniom poporodowym, 4% stosowaniu leków ototoksycznych przez ciężarne matki i niemowlęta, takich jak aminoglikozydy, a 8% innym przyczynom [27]. W późniejszym okresie dzieciństwa jedną z częstszych przyczyn utraty słuchu jest zapalenie opon mózgowych, które może prowadzić do głębokiego ubytku słuchu [28]. Około jeden na tysiąc noworodków ma ubytek słuchu, a dwoje na tysiąc dzieci zaczyna doświadczać zaburzeń słuchu w ciągu pierwszych trzech latach życia. Te fakty uzasadniają wykonywanie przesiewowych badań audiologicznych u dzieci nie tylko po urodzeniu, ale również w pierwszych latach życia.

Najczęstszą przyczyną niedosłuchu w populacji dziecięcej pozostają patologie w obrębie ucha środkowego [12,28–32]. Wiele badań wskazuje, że jest to główna przyczyna przewodzeniowego ubytku słuchu u młodszych dzieci [9,33–35]. W badaniu mającym na celu określenie czynników predykcyjnych utraty słuchu wśród ubogich dzieci mieszkających w Peru stwierdzono, że nieleczona choroba ucha środkowego w kontekście ograniczonego dostępu do opieki pediatrycznej była głównym czynnikiem ryzyka utraty słuchu [36]. Podobnie w badaniach przeprowadzonych w Bangladeszu, Danii, Egipcie, Indiach, Malezji, Nigerii, Suazi i Turcji zauważono, że najczęstszą przyczyną niedosłuchu u dzieci jest zapalenie ucha środkowego, zwłaszcza z wysiękiem [10,37]. Pomimo szeroko zakrojonych badań nad leczeniem zapalenia ucha środkowego oraz redukcji wielu czynników socjoekonomicznych związanych z tą chorobą, schorzenie to nadal jest jedną z najczęstszych infekcji wśród dzieci, również w krajach rozwiniętych [32,38,39]. Zapalenie ucha środkowego jest powszechną chorobą u dzieci i może wystąpić po infekcjach wirusowych lub bakteryjnych górnych dróg oddechowych. Zwykle ostre zapalenie ucha środkowego jest powikłaniem dysfunkcji trąbki słuchowej, która wystąpiła podczas ostrej wirusowej infekcji górnych dróg oddechowych [40,41]. Wyizolowane bakterie z posiewów płynu z ucha środkowego w 50% do 90% przypadków są to: *Streptococcus pneumoniae*, *Haemophilus influenzae* (nietypowy) i *Moraxella catarrhalis* [29]. *H. influenzae* stał się najczęstszym drobnoustrojem wśród dzieci z ciężkim lub opornym na leczenie ostrym zapaleniem ucha środkowego po wprowadzeniu szczepionki koniugatowej przeciwko pneumokokom [42]. W regionach o niskich i średnich dochodach, w tym w niektórych częściach Afryki Subsaharyjskiej i Azji, infekcje bakteryjne i wirusowe zostały uznane za ważne czynniki etiologiczne trwałego ubytku słuchu z powodu dużej częstości występowania chorób zakaźnych i stosowania ogólnoustrojowych antybiotyków ototoksycznych [43].

Ponadto, zaburzenia słuchu spowodowane hałasem stały się rosnącym problem wśród nastolatków we wszystkich regionach świata, ze względu na coraz częstsze używanie odtwarzaczy muzycznych. W 2018 roku le Clercq i wsp. [44] podjęli się przeglądu systematycznego i metaanalizy dotyczącej niedosłuchu indukowanego muzyką i jego objawów u dzieci, młodzieży i młodych dorosłych. Stwierdzili, że częstość występowania ubytków słuchu spowodowanych muzyką wynosiła od 0% do 12,6% (przy ocenie średnich progów) oraz od 14,2% do 34,9% przy uwzględnieniu podwyższenia progu dla jednej lub więcej częstotliwości. Średnia ważona częstości występowania ubytków słuchu spowodowanych muzyką wynosiła 9,6%, a dla ubytków o wysokiej częstotliwości – 9,3%. Kluczową rolę w wykrywaniu zaburzeń słuchu odgrywają przesiewowe badania słuchu. Światowa Organizacja Zdrowia w dokumencie pt. *Childhood hearing loss: strategies for prevention and care* [27] wskazuje, iż najbardziej optymalnym rozwiązaniem aby poprawić zdrowie społeczeństwa jest zachowanie zdrowego stylu życia oraz wykonywanie badań przesiewowych, które umożliwiają wczesne wykrycie zaburzeń zdrowotnych. Od wielu lat w Polsce oraz w większości krajów europejskich, a także w Ameryce Północnej, realizowane są programy powszechnych badań przesiewowych słuchu u noworodków, których celem jest wykrywanie wrodzonych zaburzeń słuchu [45]. Ubytek słuchu może być pojedynczym deficytem (niesyndromowy ubytek słuchu) lub może współistnieć z zaburzeniami innych narządów (syndromowy ubytek słuchu). W około 60% przypadków wrodzony ubytek słuchu ma etiologię genetyczną, gdzie warianty chorobowe mogą zmieniać każdy element drogi słuchowej [46]. Podwalinami, na których został stworzony obecny system rutynowych badań przesiewowych słuchu w Polsce był „Program badań przesiewowych słuchu u noworodków", opracowany przez prof. Henryka Skarżyńskiego wraz z doc. Marią Góralówną, we współpracy z zespołem Ośrodka Diagnostyczno-Leczniczo-Rehabilitacyjnego „Cochlear Center". Wynikiem tych działań było rozpoczęcie w 2001 roku „Programu Powszechnych Przesiewowych Badań Słuchu u Noworodków", realizowanym w każdym ośrodku neonatologicznym na terenie kraju i obejmującym prawie wszystkich najmłodszych Polaków. Badania te wykonuje się w drugiej dobie życia dziecka. W przypadku nieprawidłowego wyniku, badanie jest powtarzane tuż przed wypisem niemowlęcia z oddziału noworodkowego. Taki schemat przeprowadzania badań istotnie zmniejsza liczbę wyników fałszywie dodatnich. Jednak nawet w krajach, w których wprowadzono programy badań przesiewowych noworodków, ubytek słuchu u dzieci w wieku szkolnym nadal pozostaje problemem zdrowia publicznego, na który nie zwraca się wystarczającej uwagi. Badania noworodków nie pozwalają na wykrycie postępujących i późno pojawiających się patologii, które mogą stanowić do 20% wszystkich przypadków upośledzenia słuchu u dzieci w wieku rozwojowym [47]. Wczesne wykrycie zaburzeń słuchu jest szczególnie ważne dla dzieci – im wcześniej zostaną zdiagnozowane, tym szybciej można dobrać odpowiednią protezę słuchową i/lub dziecko włączyć do programu wczesnej interwencji. Działania te umożliwiają specjalistom wykorzystanie krytycznego okresu, kiedy przyswajana jest mowa oraz dają rodzicom więcej czasu na podjęcie decyzji, jaki typ programu edukacyjnego wybrać dla swojego dziecka. Ponadto, szkolne programy badań przesiewowych mogą być kluczowym czynnikiem w identyfikacji ubytków słuchu u dzieci w krajach o niskim i średnim dochodzie, w których nie wykonuje się powszechnych badań przesiewowych słuchu u noworodków. W tych krajach szkolne programy przesiewowych badań słuchu, jeśli istnieją, są często przeprowadzane u dzieci w przedszkolu lub u małych dzieci w klasach szkoły podstawowej. W związku z tym szkolne programy przesiewowe dają pierwszą możliwość rozpoznania problemu ze słuchem wśród dzieci, w miejscach gdzie nie są dostępne powszechne programy badań przesiewowych słuchu u noworodków.

Monitorowanie słuchu w grupie dzieci w wieku szkolnym jest istotnym aspektem, gdyż stwarza im szansę na prawidłowy rozwój. W monografii M1 dokonano syntezy wiedzy dotyczącej wpływu ubytku słuchu na rozwój dzieci w wieku szkolnym. Stwierdzono, że zaburzenia w zakresie funkcjonowania słuchu, nawet niewielkiego stopnia, utrudniają bądź uniemożliwiają dziecku dostęp do informacji dźwiękowych oraz mogą prowadzić do opóźnionego lub zaburzonego rozwoju mowy, co z kolei ma negatywny wpływ na nabywanie przez dziecko umiejętności lingwistycznych i edukacyjnych, a także rozwój społeczny i emocjonalny [48,49]. Zaburzenia słuchu w dzieciństwie mają szkodliwy wpływ na globalny rozwój dziecka bez względu na wiek, płeć, pochodzenie etniczne czy status społeczno-ekonomiczny [50,51]. Fundamentalne znaczenie zmysł słuchu pełni, kiedy rozwija się dzięki niemu mowa werbalna, zwiększa się zasób słownictwa oraz kształtuje się wiedza poznawcza [52]. Szkoła, a w szczególności klasa lekcyjna, jest środowiskiem słuchowo-werbalnym, w którym precyzyjne nadawanie i odbieranie oraz kodowanie i dekodowanie mowy jest kluczowe dla efektywnego uczenia się. Prawidłowo funkcjonujący słuch w decydujący sposób wpływa na rozwój inteligencji i myślenia abstrakcyjnego. Typowe zachowania, które występują w przypadku ubytku słuchu to: trudności z przyswajaniem informacji mówionych lub innych informacji dźwiękowych, częste prośby o powtórzenie, zmęczenie podczas słuchania, niewłaściwe odpowiedzi na pytania, unikanie kontaktów z rówieśnikami, trudności w czytaniu i pisaniu oraz niska tolerancja na frustrację. Efekty behawioralne ubytku słuchu są często subtelne i wyglądają podobnie jak u dzieci z zaburzeniami uwagi [53]. Istnieje wiele czynników, które wpływają na przyswajanie mowy i języka, a następnie na osiągnięcia szkolne, w tym m.in. stopień i rodzaj ubytku słuchu. Progi słyszenia wyznaczone w audiometrii tonalnej nie zawsze pozwalają przewidzieć niepowodzenie lub sukces w szkole. Na przykład, dzieci z lekkim ubytkiem słuchu mogą wykazywać znaczne niepowodzenia w nauce. Dzieci z lekkim jednostronnym ubytkiem słuchu osiągają niższe wyniki w nauce i częściej powtarzają klasę, wykazują trudności w lokalizowaniu źródła dźwięku oraz zgłaszają problemy z rozumieniem mowy [54–56]. Prawdopodobnie spowodowane jest to faktem, iż rozwój poznawczy oraz rozwój umiejętności komunikacyjnych to procesy złożone, które wymagają wszechstronnej oceny rozwoju dziecka. Dlatego też każde zaburzenie słuchu, bez względu na to jak łagodne, musi być zostać poddane diagnozie, aby zidentyfikować wszelkie bariery w uczeniu się. W konsekwencji, osoby z niedosłuchem wykazują potrzebę dodatkowego wsparcia edukacyjnego w celu rozwiązania problemów edukacyjnych, psychospołecznych i behawioralnych w klasie. Zarówno odbiorcze, jak i ekspresyjne umiejętności językowe, poprawiają się wraz z wczesną identyfikacją i interwencją w przypadku wystąpienia niedosłuchu [17,57]. W związku z tym dzieci z ubytkiem słuchu mogą odnieść wiele korzyści z rozpoznania zaburzenia na wczesnym etapie życia. Negatywne skutki mogą być złagodzone dzięki wczesnej interwencji za pomocą aparatów słuchowych, implantów ślimakowych oraz różnorodnych urządzeń wspomagających słyszenie. Dodatkowo wcześnie wdrożona rehabilitacja słuchu może złagodzić szkodliwe skutki u wielu dzieci, zwłaszcza gdy niedosłuch jest rozpoznany przed lub na początku edukacji w szkole podstawowej. W związku z tym, należy jak najwcześniej postawić trafną diagnozę i wdrożyć odpowiednie działania stymulujące oraz wspomagające rozwój dziecka w obrębie zaburzeń słuchu, aby uzyskać lepsze rokowania i zwiększyć szansę na dobre funkcjonowanie pacjenta w przyszłości [25].

## 2.2. Czynniki ryzyka

W dalszej części rozprawy omówione zostaną czynniki ryzyka – parametr, który określa i przewiduje prawdopodobieństwo rozwoju choroby. Identyfikacja czynników ryzyka jest ważna, gdyż może przyczynić się do wdrażania i utrwalenia wzorców (tzw. profilaktyka wczesna) oraz wypracować mechanizmy zapobiegania występowania określonego schorzenia poprzez kontrolowanie tychże czynników (tzw. profilaktyka pierwotna). Współczesna medycyna nastawiona jest głównie na profilaktykę schorzeń, stąd szczególnego znaczenia nabiera ocena czynników ryzyka wystąpienia niedosłuchu, w tym także szumów usznych oraz zagrożenie hałasem, których identyfikacja pozwala na ocenę czynników etiologicznych i wdrożenie metod zapobiegawczych [58]. Ważnym problemem społecznym jest brak świadomości rodziców w zakresie występowania wad słuchu u ich dzieci oraz potrzebie wykonywania badań skriningowych. W krajach rozwijających się rodzice i nauczyciele często nie rozpoznają objawów ubytku słuchu we wczesnym dzieciństwie (ubytek słuchu prelingwalny), ponieważ błędnie odczytują słabą komunikację jako oznakę ogólnego opóźnienia rozwojowego [17]. Ponadto zaburzenia słuchu, które rozwinęły się po wykształceniu mowy (niedosłuch postlingwalny), mogą również pozostać niezauważone do czasu rozpoczęcia nauki w przedszkolu lub szkole podstawowej. Niejednokrotnie, nawet jeśli niedosłuch zostanie wykryty, niektóre z tych dzieci z wadą słuchu mogą być nieodpowiednio leczone (z powodu niskiego statusu socjoekonomicznego rodziców lub braku wykwalifikowanych specjalistów i placówek w niedalekiej odległości od miejsca zamieszkania) [59]. W związku z tym rozpowszechnianie wiedzy w zakresie rodzajów zaburzeń słuchu oraz budowa świadomości wśród dzieci i rodziców jak istotna jest profilaktyka powinno być stałym i obowiązkowym elementem programów badań przesiewowych. Rodzice i opiekunowie nie zawsze posiadają wiedzę na temat profilaktyki narządu słuchu oraz nie mają świadomości, że ich dziecko może mieć wadę słuchu. Ponadto poważnym zagrożeniem dla słuchu dzieci i młodych ludzi jest hałas. Szacuje się, że 12,5% (około 5,2 miliona) amerykańskich dzieci w wieku 6–19 lat ma obniżenie progu słyszenia wywołane hałasem (ang. *notch*) w jednym lub obu uszach [1]. Poważnym zagrożeniem dla słuchu dzieci jest hałas, także ten, który powoduje zbyt głośno nastawiana muzyka. Hałas jest szczególnie niebezpieczny dla dzieci i młodych ludzi, którzy od najmłodszych lat słuchają głośnej muzyki przez słuchawki. Właśnie słuchanie muzyki, zwłaszcza przez słuchawki wewnątrzuszne, jest szkodliwy dla narządu słuchu. Rodzice powinni być tego świadomi i zwracać baczniejszą uwagę na to, jak długo i w jaki sposób ich dziecko słucha muzyki. To ważne, jak bowiem wynika z danych Światowej Organizacji Zdrowia, około połowa dzieci i młodzieży jest narażona na niebezpieczny dla zdrowia poziom decybeli płynących z przenośnych urządzeń audio. Co gorsza, te statystyki stale rosną. Nadmiar decybeli może nie tylko stanowić zagrożenie dla narządu słuchu (m.in. zaburzać działanie mechanizmu chroniącego słuch przed urazami akustycznymi), lecz także obniżać poziom uwagi, powodować bezsenność, czy zmęczenie. Aby uchronić dzieci przed tymi zgubnymi skutkami słuchania głośnej muzyki, warto im tłumaczyć, dlaczego tak ważne jest, aby rzadziej sięgały po słuchawki. Według Światowej Organizacji Zdrowia nie powinno się używać słuchawek dłużej niż sześćdziesiąt minut dziennie, a dodatkowo poziom 105 decybeli – maksymalne natężenie dźwięku większości urządzeń audio – jest bezpieczny dla słuchu tylko przez cztery minuty. Warto także wspomnieć w tym miejscu o szumach usznych, zwłaszcza subiektywnych, które są często objawami uszkodzenia w uchu wewnętrznym, nierzadko spowodowanego wpływem hałasu. Identyfikacja problemu doświadczania szumów usznych przez dzieci jest szczególnie istotna ze względu na etiologię, która może być identyczne jak u dorosłych (przyczyny metaboliczne oraz naczyniowe, uraz głowy, guz nerwu VIII), lecz także z uwagi na fakt, że szumy uszne mogą negatywnie wpływać na stan psychiczny dzieci oraz być przyczyniać się do osiągania słabszych wyników w nauce [48]. Brak świadomości na temat wspomnianych zaburzeń powoduje niezwracanie uwagi na niepokojące zachowania i symptomy. Czynniki ryzyka zaburzeń słuchu wśród dzieci w wieku szkolnym zostały opisane w pracach P-1, P-2, P-7 oraz P-10. Programy badań przesiewowych przyczyniają się do zwiększenia wykrywalności zaburzeń słuchu, a poprzez to – do podjęcia działań diagnostycznych, leczniczych i rehabilitacyjnych pozwalających na zminimalizowanie negatywnych konsekwencji wykrytych wad słuchu.

## 2.3. Badania przesiewowe wśród dzieci w wieku szkolnym

W wielu krajach wprowadzono programy powszechnych badań przesiewowych słuchu u noworodków, które umożliwiają identyfikację dzieci z wrodzonym ubytkiem słuchu tuż po urodzeniu [12,60]. Wraz z wiekiem zwiększa się odsetek dzieci z różnymi problemami związanymi ze słuchem, które mogą mieć istotne znaczenie dla harmonijnego rozwoju dziecka [61]. Edukacja w szkole podstawowej koncentruje się na rozwijaniu podstawowych umiejętności czytania, pisania i liczenia, jest obowiązkowa w prawie wszystkich krajach, dzięki czemu szkoły są kluczowym punktem dostępu do zintegrowanych badań zdrowotnych, takich jak badania słuchu, co dalej zmniejsza nierówności społeczno-demograficzne w dostępie do opieki zdrowotnej [62]. Badania przesiewowe słuchu w szkołach mogą pomóc w wypełnieniu luki w opiece profilaktycznej, która pojawia się po okresie badań przesiewowych słuchu u noworodków, wykorzystując dostęp do dużej części populacji dzieci w jednym fizycznym miejscu, przy jednoczesnym wykorzystaniu zintegrowanej infrastruktury edukacyjnej, takiej jak pielęgniarki szkolne i szkolne badania kontrolne [14,33]. Bez obowiązkowego programu rutynowych badań przesiewowych w szkołach, nabyte wady słuchu mogą nie zostać zidentyfikowane w grupie dzieci w wieku szkolnym. Przyczyny tego stanu rzeczy są wieloaspektowe – wśród nich jest brak świadomości rodziców, władz szkolnych i pracowników służby zdrowia na temat negatywnych skutków nawet niewielkiego ubytku słuchu. Podczas gdy szkolne programy badań przesiewowych mogą zmniejszyć negatywne konsekwencje późnego rozpoznania wad słuchu, profilaktyka nadal nie jest uważana za sprawę pilną w polityce zdrowotnej wielu państw na świecie [63].

Dane dotyczące wdrażania szkolnych programów badań przesiewowych słuchu są ograniczone. Niektóre kraje, takie jak Nowa Zelandia i Szwecja, wprowadziły programy badań przesiewowych słuchu, ale dotyczą one wyłącznie przedszkolnej grupy wiekowej [18,64]. W Wielkiej Brytanii około 10% szkół nie przeprowadza badań przesiewowych mimo zaleceń [65]. W Turcji od 2015 roku rozpoczął się ogólnokrajowy program badań przesiewowych dla uczniów klas pierwszych, wprowadzony przez Ministerstwo Zdrowia [66]. W Stanach Zjednoczonych przeprowadza się obowiązkowe badania przesiewowe słuchu, gdy uczeń rozpoczyna edukacje w szkole. Badania te są powtarzane w określonych odstępach czasu wyznaczonych przez władze danego stanu [67,68]. Pomimo narodowych zaleceń dane wskazują, że tylko 66% Stanów prowadzi obecnie jakąkolwiek formę badań przesiewowych słuchu w szkołach [69]. Badania przesiewowe słuchu są zalecane w RPA, ale są nie dostępne dane na temat liczby badań, które są przeprowadzane [70]. Kanji i wsp. [71] wykazali, że w RPA nadal istnieje wiele barier dla skutecznych badań przesiewowych słuchu. W krajach rozwijających się, takich jak Nigeria, zostały przeprowadzone jedynie pilotażowe badania przesiewowe słuchu. Ponadto ogólna świadomość na temat wad słuchu jest znikoma, natomiast liczba nigeryjskich dzieci z ubytkiem słuchu jest stosunkowo wysoka [8,72]. W Indiach nie ma prowadzonych rutynowych badań przesiewowych słuchu u dzieci [73,74]. Shinn i wsp. [75] wykazali, że na obszarach wiejskich w Kenii poziom hałasu w otoczeniu podczas badań przesiewowych słuchu był tak wysoki, że otrzymywano wiele fałszywie pozytywnych wyników. W innych krajach opublikowano niewiele danych lub nie opublikowano wcale na temat aktualnych przepisów i polityki w zakresie badań przesiewowych słuchu w szkołach [18]. Wdrażanie programów w krajach rozwijających się jest niezwykle trudne – głównym powodem jest brak funduszy na programy zdrowotne [76]. Sytuację pogarsza niedobór audiologów, brak świadomości korzyści płynących z badań przesiewowych słuchu oraz niedostępność sprzętu, takiego jak audiometry, urządzenia do badania potencjałów pnia mózgu i emisji otoakustycznej. W tej sytuacji niedrogie badania przesiewowe słuchu mogą być pierwszym pozytywnym krokiem w kierunku poprawy zdrowia w zakresie słuchu osób z ubogich obszarów. Takie rozwiązanie wymaga wykorzystania tanich i skutecznych procedur, które mogą być dostarczone do obszarów, gdzie zasoby technologiczne lub ludzkie są finansowo niedostępne [77].

W Polsce istnieje program rutynowych badań przesiewowych noworodków, ale nie ma z kolei obowiązkowej obserwacji dzieci w wieku szkolnym [78]. Jednakże od wielu lat Instytut Fizjologii i Patologii Słuchu pod kierownictwem Profesora Henryka Skarżyńskiego, podejmuje różnorodne inicjatywy, do których zaliczyć można szczególnie przesiewowe badania słuchu.

Fundamentalnym celem realizowanych programów jest wykrycie na możliwe jak najwcześniej etapie rozwoju zaburzeń słuchu, w szczególności u dzieci rozpoczynających naukę w szkole podstawowej. Te działania mają także na celu uwrażliwienie rodziców i środowiska szkolnego na problemy dzieci związane ze słyszeniem oraz promowanie zdrowego trybu życia. Realizacja i opis wyników programów badań przesiewowych wśród dzieci w wieku szkolnym wykonywanych w Polsce został opisany w publikacjach P-3, P-4 oraz P-9.

Stworzony i wykorzystywany z powodzeniem w Instytucie Fizjologii i Patologii Słuchu model organizacyjny badań przesiewowych oparty na mobilnych urządzeniach do badań (Platforma Badań Zmysłów) oraz unikalnych systemach informatycznych (System Zintegrowanej Operacji Komunikacyjnej) umożliwia realizację badań przesiewowych w sposób odpowiedzialny u dzieci w wieku szkolnym nie tylko w Polsce, ale również poza jej granicami. Programy pilotażowych badań przesiewowych słuchu są realizowane przede wszystkim w krajach rozwijających się, które mają niższy poziom rozwoju medycyny i profilaktyki oraz nie dysponują wysokospecjalistycznym sprzętem. Na przestrzeni lat zrealizowano szereg programów masowych badań przesiewowych w Polsce oraz badania pilotażowe na trzech kontynentach wśród dzieci w wieku szkolnym. Realizacja i opis wyników programów badań przesiewowych w grupach dzieci w wieku szkolnym, wykonywanych przez Instytut Fizjologii i Patologii Słuchu w różnych krajach na trzech kontynentach, został opisany w publikacjach P-5, P-6, P-7, P-8 oraz M-1. W 2014 roku Instytut Fizjologii i Patologii Słuchu powołał „Międzynarodowe Konsorcjum Badań Przesiewowych Słuchu" w celu zapewnienia jak najlepszej organizacji oraz promowania wdrażanych programów badań przesiewowych w Polsce i za granicą. Dzięki powołaniu tej organizacji z powodzeniem realizowany jest „Program wczesnego wykrywania wad słuchu w celu wyrównania szans edukacyjnych dzieci na czterech kontynentach". W skład Konsorcjum wchodzą ośrodki medyczne z takich krajów jak Armenia, Kirgistan, Mołdawia, Rumunia, Senegal, Tadżykistan, Wybrzeże Kości Słoniowej. We wszystkich tych krajach, a także w Ukrainie i zachodniej Syberii, w Azerbejdżanie, Kongo, Rwandzie, Tanzanii i Kolumbii specjaliści przeprowadzili pilotażowe badania przesiewowe słuchu w szkołach.

Potrzebę stałego monitorowania słuchu u dzieci od najwcześniejszych lat w okresie dzieciństwa podkreślało wielu badaczy i klinicystów [2,67], kładły na to nacisk także liczne organizacje, m.in. American Academy of Audiology [24], American Speech-Language-Hearing Association [79] oraz European Federation of Audiology Societies [80,81]. Na przestrzeni lat zostały zaproponowane zalecenia, zgodnie z którymi dzieci poniżej 18. roku życia powinny być poddawane badaniom przesiewowym słuchu w celu wykrycia wrodzonych i/lub nabytych zaburzeń słuchu, które mogą mieć negatywny wpływ na zdrowie, rozwój, komunikację lub osiągnięcia edukacyjne [19,82], zostały one opisane w M-1. W Polsce w Instytucie Fizjologii i Patologii Słuchu nadano priorytet badaniom przesiewowym, zgodnie z konkluzjami Rady Unii Europejskiej w sprawie rozpoznawania i terapii zaburzeń komunikacyjnych u dzieci, z wykorzystaniem narzędzi e-zdrowia i innowacyjnych rozwiązań [22,80,81]. W 2011 roku prof. Henryka Skarżyńskiego zintegrował krajowe i europejskie stowarzyszenia oraz środowisko otolaryngologów, audiologów, foniatrów i logopedów, wokół idei wyrównywania szans dzieci z zaburzeniami komunikacyjnymi. Pod przewodnictwem Pana Profesora podpisano dwa Europejskie Konsensusy Naukowe przyjęte w Warszawie 22 czerwca 2011 r. podczas X Kongresu Europejskiej Federacji Towarzystw Audiologicznych. Pierwszy z nich to „Europejski Konsensus Naukowy nt. badań przesiewowych słuchu u dzieci w wieku przedszkolnym i szkolnym", podpisany przez przedstawicieli 27 krajów, w większości reprezentantów krajowych zrzeszonych w Europejskiej Federacji Towarzystw Audiologicznych (EFAS). W gronie sygnatariuszy znalazły się następujące kraje: Austria, Białoruś, Belgia, Chorwacja, Cypr, Dania, Finlandia, Francja, Hiszpania, Holandia, Irlandia, Izrael, Niemcy, Norwegia, Polska, Portugalia, Rumunia, Rosja, Słowacja, Słowenia, Szwecja, Szwajcaria, Turcja, Ukraina, Węgry, Wielka Brytania oraz Włochy. Dokument ten stał się jednym z najważniejszych narzędzi wzmacniających realizację priorytetu polskiej prezydencji w Radzie Unii Europejskiej, a także wyrazem uznania dla dokonań, przedsiębiorczości i skuteczności polskich działań na tym polu. Powierzenie Polsce reprezentowania tych problemów na forum Unii Europejskiej było niezwykle ważnym gestem ze strony europejskich środowisk naukowych.

Drugim ważnym dokumentem jest „Konkluzja Rady UE w sprawie wczesnego wykrywania i leczenia zaburzeń komunikacyjnych u dzieci, z uwzględnieniem zastosowania narzędzi e-zdrowia i innowacyjnych rozwiązań". Obrady nad omówieniem projektu konkluzji i uzyskaniu konsensusu odbywały się pod przewodnictwem prof. Henryka Skarżyńskiego. Dokument ten został zaakceptowany przez wszystkich 27 attache ds. zdrowia i 2 grudnia 2011r. w Brukseli podczas posiedzenia Rady UE ds. Zatrudnienia, Polityki Społecznej, Zdrowia i Spraw Konsumenckich (EPSCO) została formalnie przyjęta. Konkluzja ma na celu zwrócenie uwagi społecznej na problem zaburzeń komunikacyjnych oraz ich konsekwencji dla prawidłowego rozwoju intelektualnego i emocjonalnego dzieci, co ma wpływ na ich sytuację społeczną i ekonomiczną w życiu dorosłym.

W maju 2017 roku w Genewie przyjęto rezolucję World Health Assembly (WHA) [83] w sprawie zapobiegania niedosłuchom i głuchocie. Przyjęcie tej rezolucji oznacza, iż zaburzenia w obrębie słuchu zostały uznane za problem globalny. WHA wzywa tym samym wszystkie kraje do uwzględnienia działań na rzecz profilaktyki zaburzeń słuchu w polityce ochrony zdrowia oraz wyraźnie określa ścieżkę, którą musi podążać Światowa Organizacja Zdrowia, aby wesprzeć kraje we wszystkich ich przedsięwzięciach z tym związanych. Ponadto rezolucja WHA podkreśla jak kluczowe jest kształcenie lekarzy audiologów i otolaryngologów oraz wskazuje potrzebę realizacji tanich i efektywnych programów badań przesiewowych słuchu. Podczas gdy niektóre regiony, takie jak Stany Zjednoczone i Europa, zaproponowały ujednolicone wytyczne, w większości innych obszarów brakuje danych na temat najlepszych praktyk w zakresie szkolnych badań przesiewowych słuchu [22,84,85]. W związku z tym nie ma aktualnych międzynarodowych wytycznych dotyczących szkolnych badań przesiewowych słuchu. Na całym świecie brakuje wytycznych dotyczących badań przesiewowych słuchu w szkołach, a te, które istnieją, nie są spójnie wdrażane.

Podsumowując, w przeciwieństwie do badań przesiewowych słuchu u noworodków, obecny stan badań przesiewowych słuchu w szkołach jest niespójny w różnych regionach świata, a stosowane protokoły są bardzo zróżnicowane [23,34,86]. Istnieje zatem pilna potrzeba wprowadzenia na całym świecie ujednoliconych wytycznych w zakresie szkolnych badań przesiewowych słuchu, które ułatwią dokładniejsze badania częstości występowania ubytków słuchu oraz określenie czułości i specyficzności testów przesiewowych. Z kolei kroki te zwiększą możliwości badania efektów interwencji przesiewowych i leczenia, a także pomogą w opracowaniu wytycznych dotyczących badań przesiewowych, diagnostyki i rehabilitacji, niezbędnych do zmniejszenia skutków ubytku słuchu u dzieci.

# 3. Założenia i cel pracy

Celem przedkładanego dzieła naukowego, stanowiącego spójny tematycznie cykl artykułów, opublikowanych w specjalistycznych czasopismach naukowych była analiza wyników badań przesiewowych słuchu wśród dzieci w wieku szkolnym, z uwzględnieniem zarówno przesiewowych badań audiometrycznych, jak i narzędzi samoopisowych. Dla realizacji celu głównego przyjęto następujące cele szczegółowe:

a) ocena częstości występowania zaburzeń słuchu wśród dzieci w wieku szkolnym w kraju i na świecie;
b) ocena czułości, swoistości i wartości predykcyjnej rodzicielskiego podejrzenia występowaniu niedosłuchu u ich dzieci;
c) ocena częstości występowania szumów usznych wśród dzieci w wieku szkolnym;
d) zbadanie związku pomiędzy używaniem odtwarzaczy muzycznych (ang. *personal music players*) a stanem narządu słuchu oraz zidentyfikowanie innych źródeł hałasu, na które narażone są dzieci.

# 4. Materiał

Badaniami objęto grupę 221 725 dzieci w wieku szkolnym, które wzięły udział w programach badań przesiewowych słuchu zrealizowanych w Polsce, Europie, Azji i Afryce przez Instytut Fizjologii i Patologii Słuchu. Szczegółowy opis poszczególnych grup badawczych został przedstawiony w dalszej części rozprawy. W procesie rekrutacyjnym uczestnicy badania musieli spełnić kryteria włączenia i wyłączenia poszczególnych programów. Przed rozpoczęciem badania rodzice/opiekunowie dziecka zostali poinformowani o procedurach badawczych i wyrażali pisemną zgodę na udział ich dzieci w badaniu. Opracowane narzędzia teleinformatyczne umożliwiały organizację i przeprowadzenie badań w szkołach, następnie uzyskane wyniki poddać ocenie przez lekarzy specjalistów, którzy wskazywali dzieci wymagające dalszej opieki specjalistycznej. Wszyscy uczestnicy badań otrzymywali pisemny wynik. Jeśli zaistniało podejrzenie, że u dziecka występują zaburzenia słuchu, rodzice otrzymywali informację o nieprawidłowym wyniku. Informowano też o konieczności przeprowadzenia kontrolnego badania słuchu u dziecka w placówce audiologicznej lub laryngologicznej, powiadamiając jednocześnie, że niezbędne jest wcześniejsze uzyskanie skierowania do właściwej poradni od lekarza pediatry lub lekarza podstawowej opieki zdrowotnej. Badania były przeprowadzone po uprzednio uzyskanej zgodzie Komisji Bioetycznej przy Instytucie Fizjologii i Patologii Słuchu i zgodnie z dobrą praktyką kliniczną (ang. *Good Clinical Practice*, GCP) oraz Deklaracją Helsińską.

**P-1**

Od listopada 2007 roku Instytut Fizjologii i Patologii Słuchu, na zlecenie Urzędu Miasta Stołecznego Warszawy, prowadzi badania przesiewowe słuchu w szkołach podstawowych na terenie Warszawy. W publikacji P-1 przeanalizowano retrospektywnie część danych uzyskanych w jednym roku z realizacji programu, aby dokonać oceny zagrożenia hałasem wśród dzieci kończących edukację w szkole podstawowej. Badaniem objęto 1032 uczniów klas szóstych (546 dziewczynek i 486 chłopców), w tym 265 dzieci (26%) w wieku 11 lat i 767 (74%) w wieku 12 lat. Badanie zostało zaakceptowane przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB.IFPS:28/4/2018).

**P-2**

W większości badań odnalezionych w piśmiennictwie, trafność percepcji rodzicielskiej dotyczącej zaburzeń słuchu u swoich dzieci oceniano w próbach nie przekraczających dwustu lub trzystu dzieci. Nie odnaleziono badań prowadzonych na większą skalę. Celem pracy P-2 była ocena czułości, swoistości i wartości predykcyjnej rodzicielskiego podejrzenia niedosłuchu na podstawie danych z badań przesiewowych słuchu przeprowadzanych przez Instytut Fizjologii i Patologii Słuchu. Uczestnicy byli rekrutowani w okresie od września 2016 r. do czerwca 2017 r. Początkowa próba liczyła 68 239 dzieci, ale 3489 rodziców nie odpowiedziało na pytanie o problemy ze słuchem. Próba badawcza składała się więc z 64 750 dzieci w wieku szkolnym (31 387 dziewczynek i 33 363 chłopców) w wieku od 6 do 13 lat (M = 8,67; SD = 2,55). Badanie zostało zaakceptowane przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB.IFPS:27/4/2018).

**P-3**

W 2008 roku Instytut Fizjologii i Patologii Słuchu we współpracy z Kasą Rolniczego Ubezpieczenia Społecznego oraz Stowarzyszeniem Osób Niesłyszących i Niedosłyszących „Homo-Homini" przeprowadził pierwszy etap badań przesiewowych dla dzieci uczęszczających do szkół wiejskich i w małych miastach (poniżej 5000 mieszkańców) we wschodniej Polsce, podczas którego przebadano 92 876 uczniów [87]. Następnie, w ramach tego samego partnerstwa, program rozszerzono na Polskę zachodnią [88]. W publikacji P-3 przedstawiono wyniki kolejnego etapu programu w województwie małopolskim. Badania przesiewowe słuchu przeprowadzono w 630 szkołach podstawowych zlokalizowanych na terenie 19 gmin województwa małopolskiego. Istotną trudnością w realizacji programu było duże rozproszenie szkół w regionach objętych programem. Na terenach wiejskich przeważały małe szkoły, w których w programie uczestniczyło mniej niż dwadzieścioro dzieci. Początkowa grupa badawcza składała się z 5038 uczniów. Dziewięcioro dzieci z wcześniejszą diagnozą kliniczną upośledzenia słuchu zostało wykluczonych z analizy. Ostatecznie w badaniu wzięło udział 5029 dzieci, w tym 2015 dzieci w wieku 6 lat i 3014 dzieci w wieku 7 lat. Grupa badawcza składała się z 2281 dziewczynek i 2748 chłopców. Badanie zostało zaakceptowane przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB:IFPS:27/5/2018).

**P-4**

Dwuletni program składał się z 41 projektów prowadzonych w 37 powiatach i czterech miastach województwa mazowieckiego. Objęto nimi tylko uczniów pierwszych klas szkół podstawowych. Przedszkole nie jest w Polsce obowiązkowe, dlatego badaniami zostali objęci uczniowie pierwszej klasy szkoły podstawowej, która jest pierwszym etapem obowiązkowej edukacji dla wszystkich dzieci. Cały program opierał się na czterech głównych modułach:

kampanii informacyjnej, spotkaniach edukacyjnych dla rodziców/opiekunów, seminariach dla lokalnego personelu medycznego oraz przesiewowych badaniach słuchu. Celem kampanii informacyjnej było dotarcie do populacji docelowej (tj. rodziców i opiekunów pierwszoklasistów), osiągnięcie wysokiej frekwencji oraz zachęcenie do aktywnego uczestnictwa. Mieszkańcy województwa mazowieckiego zostali poinformowani o programie za pośrednictwem lokalnych mediów, które to informowały o możliwości przystąpienia do programu, podkreślały jego cel i znaczenie. Ponadto rozdawano plakaty i ulotki oraz wysyłano pisma do władz lokalnych. Spotkania edukacyjne dla rodziców odbywały się w szkołach i były prowadzone przez laryngologa lub audiologa. Celem było poszerzenie wiedzy rodziców na temat słuchu, uświadomienie znaczenia dbania o słuch dzieci oraz zwrócenie uwagi na wpływ słabego słuchu na osiągnięcia szkolne. Równolegle odbywały się również konferencje szkoleniowe z cyklu „Badania przesiewowe słuchu u dzieci w wieku wczesnoszkolnym – teoria i praktyka" dla personelu medycznego z ośrodków podstawowej opieki zdrowotnej i personelu oświatowego, mające na celu zwiększenie umiejętności i kompetencji w zakresie wczesnego wykrywania deficytów słuchu u dzieci. Badaniami przesiewowymi słuchu w ramach ww. programu objęto łącznie 34 618 uczniów. Kolejne wyłączenia z początkowej próby badawczej spowodowały, iż analizie poddano łącznie 30 717 wyników dzieci zakwalifikowanych do programu: 14 596 dziewczynek i 16 121 chłopców w wieku 6-8 lat. Badanie zostało zaakceptowane przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB:IFPS:29/8//2018).

**P-5**

Badanie zostało przeprowadzone w dwóch publicznych szkołach podstawowych w Biszkeku, w Kirgistanie. Badaniami objęto 452 dzieci: 289 (63,9%) w wieku 7-8 lat oraz 163 (36,1%) w wieku 11-13 lat. Rodzice dzieci z nieprawidłowym wynikiem badania przesiewowego słuchu otrzymali informację o konieczności skierowania dziecka na specjalistyczną diagnostykę. Spośród 123 dzieci z dodatnimi wynikami badań, zebrano wyniki badań diagnostycznych 27 dzieci z pozytywnym wynikiem badania przesiewowego. Dzieci te zgłosiły się do lekarza pediatry lub otolaryngologa w przychodniach współpracujących z organizatorami badań przesiewowych słuchu. Badanie zostało zatwierdzone przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB:IFPS:26/12/2018).

**P-6**

Pilotażowe badania przesiewowe słuchu zostały przeprowadzone w szkole podstawowej Rose Valley School w Lagos, w Nigerii. Szkoła ta została nominowana przez władze lokalne, a dyrekcja szkoły zatwierdziła ten wybór. Badania odbyły się w okresie od czerwca do listopada 2018 roku. Uczniowie byli rodzimymi użytkownikami języka angielskiego. W programie wzięło udział 236 uczniów (120 dziewczynek, 116 chłopców) w wieku 5-11 lat (M = 7,17; SD = 1,63). Badani zostali podzieleni na dwie grupy wiekowe: 5-7 lat (132 uczniów) i 8-11 lat (104 uczniów). Badanie zostało zatwierdzone przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB:IFPS:26/16/2018).

**P-7**

Pilotażowe badania przesiewowe słuchu zostały wykonane w szkołach publicznych w czterech azjatyckich krajach: Armenii, Rosji, Kirgistanie i Azerbejdżanie. W Armenii badania odbyły się w jednej ze szkół w stolicy kraju, Erywaniu. W Rosji pilotażowe badania słuchu zostały przeprowadzone w jednej ze szkół w Krasnojarsku. W Kirgistanie natomiast w trzech szkołach w stolicy kraju, w Biszkeku. W Azerbejdżanie badania przeprowadzono w jednej ze szkół w stolicy kraju, Baku. Łącznie pilotażowe badania przesiewowe słuchu u dzieci w wieku szkolnym przeprowadzono u 1022 dzieci: 590 w wieku 6-7 lat (57,7%) i 432 w wieku 11-12 lat (42,3%). Szkoły zostały wytypowane przez władze lokalne i uzyskały akceptację dyrekcji. Szkoła została wybrana, jeśli duża część rodziców zgodziła się, by ich dzieci wzięły udział w badaniu oraz jeśli nie była to szkoła specjalna. Istotne różnice w poziomie socjoekonomicznym były powodem wykluczenia elitarnych szkół prywatnych. Badanie zostało zatwierdzone przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB:IFPS:26/1/2018).

**P-8**

Pilotażowe badania przesiewowe słuchu zostały wykonane wśród 608 uczniów w wieku od 6 do 12 lat w czterech państwach afrykańskich: Kamerunie, Nigerii, Rwandzie oraz Tanzanii. Z uwagi na występujące znaczne różnice w zamożności społeczeństwa do badań pilotażowych wybrano losowo szkoły powszechne i ogólnodostępne, rezygnując z badań w szkołach elitarnych i prywatnych. We wszystkich szkołach nauka odbywała się w języku angielskim. Badanie zostało zatwierdzone przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB:IFPS:26/2/2018).

**P-9**

Program badań przesiewowych, który został opisany w publikacji P-9, był populacyjnym badaniem epidemiologicznym. Uczestników rekrutowano ze wszystkich 16 województw Polski. W okresie od września 2016 r. do czerwca 2017 r. badania przesiewowe słuchu przeprowadzono w 4414 szkołach w 1463 powiatach wiejskich w Polsce (stanowi to 75,6% szkół zakwalifikowanych do programu). Po zastosowanych wykluczeniach próba badawcza liczyła 67 416 dzieci (32 630 dziewczynek i 34 786 chłopców) w wieku od 6 do 13 lat (M = 8,65; SD = 2,54). Uczestników podzielono na dwie grupy: 6-9 lat (n = 44323) i 10-13 lat (n = 23093). Takie kryterium wiekowe przyjęto zgodnie z polskim systemem oświaty – dzieci 10-letnie kończyły etap edukacji wczesnoszkolnej i rozpoczynały kolejny etap kształcenia. Badanie zostało zaakceptowane przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB:IFPS:27/6/2018).

**P-10**

Badanie opisane w publikacji P-10 było retrospektywną analizą odpowiedzi 43 064 dzieci w wieku szkolnym (21 917 dziewcząt i 21 147 chłopców) oraz ich rodziców, zebranych podczas programu przesiewowych badań słuchu, prowadzonych przez Instytut Fizjologii i Patologii Słuchu na terenie Warszawy. Wszystkie szkoły podstawowe w Warszawie zostały poinformowane o badaniach przesiewowych słuchu i zaproszone do wzięcia udziału w programie. Aby zapewnić wiarygodność wyników, badanie było przeprowadzane przez pięć kolejnych lat, od 2013 do 2017 roku. Dzieci były w wieku od 11 do 13 lat (27,9% z nich miało 11 lat, 67% miało 12 lat, a 5,1% miało 13 lat). Średnia wieku wynosiła 11,77 roku, a odchylenie standardowe – 0,53 roku. Liczba dzieci objętych badaniem, rok do roku, wynosiła: w 2013 r. – 8186 dzieci; w 2014 r. – 9142 dzieci; w 2015 r. – 8307 dzieci; w 2016 r. – 9582 dzieci; w 2017 r. – 7847 dzieci. Badanie zostało zaakceptowane przez Komisję Bioetyczną Instytutu Fizjologii i Patologii Słuchu (KB.IFPS:28/5/2018).

# 5. Metodologia badań

## 5.1. Protokoły badań przesiewowych stosowanych na świecie

W celu syntezy wiedzy z obszaru metodologii badań przesiewowych dokonano przeglądu piśmiennictwa. Ustalono, że obecnie nie istnieje ujednolicony protokół badań przesiewowych słuchu dla dzieci w wieku szkolnym, a liczne kryteria badań różnią się w zależności od wytycznych danego kraju. Uzyskanie precyzyjnej i obiektywnej informacji słuchowej dla pacjenta w planowaniu przyszłych strategii interwencyjnych staje się coraz ważniejsze [89]. We wszystkich regionach świata przesiewowa audiometria tonalna jest uznawana za złoty standard. Jest to badanie subiektywne, składające się z prezentacji bodźca na przewodnictwo powietrzne o określonym natężeniu i częstotliwości przez słuchawki, podczas której dziecko musi wykonać warunkową reakcję behawioralną, np. podnieść rękę. Jednakże kryteria i częstotliwości audiometryczne różnią się znacznie w poszczególnych badaniach. American Speech-Language-Hearing Association i American Academy of Audiology zalecają stosowanie automatycznej audiometrii tonalnej przy natężeniu dźwięku 20 dB dla częstotliwości 1000 Hz, 2000 Hz i 4000 Hz [24,90]. Uznaje się, że dziecko zaliczyło test, jeśli zareagowało prawidłowo dwa z trzech razy na bodziec o każdej z badanych częstotliwości. W 2003 roku Amerykańska Akademia Pediatrii (ang. *American Academy of Pediatrics*) zmodyfikowała powyższą procedurę zalecając badanie dodatkowo częstotliwości 500 Hz [91]. W badaniach, w których oceniano ubytek słuchu u starszych nastolatków, zwracano szczególną uwagę na wynik progów przewodnictwa powietrznego dla wysokich częstotliwości 6 i 8 kHz, ponieważ te częstotliwości są najczęściej zaburzone przez ekspozycję na hałas [1,44,92]. Kryteria odniesienia w prawie wszystkich badaniach obejmowały brak słyszenia na przynajmniej jednej częstotliwości w przynajmniej jednym uchu, ale granice progowe różniły się znacznie w poszczególnych badaniach. W większości badań do wykonywania testów przesiewowych używano konwencjonalnych audiometrów. W wybranych badaniach wykorzystano mobilne audiometry bez kabin akustycznych lub teleaudiometrię (zdalne badanie) do wykonywania przesiewowych badań audiometrycznych [23,77,93]. Badania te zalecane są jako alternatywna metoda, mogąca poprawić dostęp do badań przesiewowych słuchu na obszarach o niedostatecznym zasięgu, takich jak tereny wiejskie czy kraje rozwijające się [94]. Środowiskiem, w którym przeprowadzano badania, było najczęściej ciche otoczenie szkolne (np. pusta klasa). W większości krajów używano słuchawek redukujących hałas, aby zminimalizować wpływ hałasu otoczenia.

W protokołach badań przesiewowych stosuje się wiele testów uzupełniających wynik przesiewowej audiometrii tonalnej. Istnieją różnice w zalecanych badaniach dodatkowych, które powinny być włączone do protokołu przesiewowego badania słuchu w szkole, a które obejmują otoskopię, tympanometrię i OAE. Chociaż słuchowe potencjały wywołane z pnia mózgu dostarczają dokładnych informacji o progach słyszenia i nie wymagają dobrowolnej reakcji pacjenta, są one czasochłonne i dlatego nie są praktyczne w protokole badań przesiewowych. Najczęściej stosowane protokoły przesiewowe zawierają otoskopię i tympanometrię jako uzupełnienie przesiewowej audiometrii tonalnej [86,91]. Tympanometria jest zalecana jako kolejne wysoce użyteczne badanie ze względu na znaczenie oceny patologii ucha środkowego, takiej jak zapalenie ucha środkowego. Istnieją jednak pewne różnice w podejmowaniu decyzji o włączeniu jej jako badania przesiewowego lub zarezerwowaniu jako badania diagnostycznego po wstępnym badaniu przesiewowym za pomocą przesiewowej audiometrii tonalnej lub badania OAE [40,47]. Jako pojedyncza metoda przesiewowa, emisja otoakustyczna miała 100-procentową czułość w diagnozowaniu ubytku słuchu większego niż 30 dB oraz 90-procentową czułość i 64-procentową swoistość w diagnozowaniu ubytku słuchu głębszego niż 25 dB, co nie uległo poprawie po dodaniu tympanometrii do protokołu badania przesiewowego [47]. W praktyce najczęstszym poziomem kryterium skierowania jest 20 i 25 dB HL, co powoduje, że wiele dzieci spełniających kryteria łagodnego ubytku słuchu pozostaje niezdiagnozowanych [95].

Obecnie, w dobie cyfryzacji, możliwe jest również badanie słuchu u dziecka za pomocą bezpłatnych aplikacji dostępnych w Internecie. Aplikacje takie są najczęściej wyposażone w szczegółową instrukcję dla użytkownika oraz posiadają opisane kryteria interpretacji otrzymanego wyniku. Jednakże rezultaty takich badań są obarczone dużym ryzykiem błędu. Niemniej jeśli reakcje dziecka na dźwięki wydają się odbiegać od normy, konieczne jest przeprowadzenie bardziej szczegółowych badań.

## 5.2. Protokoły badań przesiewowych opracowane w Instytucie Fizjologii i Patologii Słuchu

W ciągu ostatnich dwudziestu pięciu lat, zespół Instytutu przeprowadził liczne masowe programy badań przesiewowych, na potrzeby których opracowano unikatowe urządzenia do wykonywania tych badań. Co więcej, wdrożono autorskie rozwiązania organizacyjne, pozwalające na przeprowadzenie masowych badań przesiewowych słuchu. Uzyskane w ten sposób doświadczenia i wstępne wyniki ujawniły konieczność stworzenia tanich procedur dla obszarów, w których brakuje środków na zakup zasobów technologicznych lub niewystarczające są zasoby ludzkie. Dzięki temu możliwa jest identyfikacja grup osób zagrożonych zaburzeniami słuchu na jak najwcześniejszym etapie [77]. Organizacyjna badań przesiewowych słuchu wdrożona w Instytucie Fizjologii i Patologii Słuchu opiera na mobilnych urządzeniach audiometrycznych oraz systemach informatycznych do gromadzenia danych oraz nadzorowania jakością badań. Model ten umożliwia wdrożenie badań przesiewowych u dzieci w wieku szkolnym, nie tylko w Polsce, ale również poza jej granicami. Dzięki tym działaniom istnieje szansa na poprawę wskaźnika identyfikacji dzieci, u których wcześniej nie rozpoznano zaburzeń słuchu, a w szczególności u dzieci rozpoczynających naukę w szkole podstawowej.

Protokoły wszystkich zrealizowanych programów badań przesiewowych słuchu obejmowały audiometrię tonalną, która jest określana mianem „złotego standardu" [96] w ocenie słuchu. Z biegiem lat protokół badań przesiewowych poszczególnych programów ulegał modyfikacjom. Rozszerzono go o badania otoskopowe i otoemisje akustyczne oraz narzędzia samoopisowe. Wstępne analizy wyników autorskich ankiet audiologicznych wskazały, że znaczny odsetek rodziców nie potrafił zaobserwować zaburzeń słuchu u swoich dzieci. W konsekwencji zostały wprowadzone kolejne modyfikacje protokołu. Programy badań przesiewowych słuchu rozszerzono o działania informacyjno-edukacyjne wśród rodziców, mające na celu wzrost wiedzy w zakresie profilaktyki słuchu i możliwych objawów niedosłuchu.

***Otoskopia***

Otoskopia jest najdokładniejszą metodą wizualną badania struktury ucha zewnętrznego, która ma na celu sprawdzenie i zdiagnozowanie zmian w uchu zewnętrznym i środkowym, m.in. takich jak przewlekłe lub ostre zapalenie ucha środkowego (z wysiękiem), zakażenie grzybicze i zmiany w błonie bębenkowej, a także obecność dużej ilości woskowiny. Badanie błony bębenkowej i przewodu słuchowego zewnętrznego jest niezbędne we wszystkich ocenach zdrowia ucha i słuchu. Otoskopia w badań przesiewowych była wykonywana wyłącznie przez audiologa lub otolaryngologa. Procedura ta jest dobrze tolerowana przez dzieci, stosowana przed badaniami audiometrycznymi, aby uzyskać dokładniejsze wyniki badań przesiewowych. Badanie to jest również szczególnie przydatne w regionach o dużej częstości występowania czopów woszczynowych oraz zapalenia ucha środkowego – badaniach przeprowadzonych w Lagos, Nigerii (P-6) oraz wśród dzieci rozpoczynających naukę w szkole podstawowej (P-4).

***Otoemisje akustyczne***

Otoemisje akustyczne (TEOAEs) wykonuje się w celu oceny funkcjonowania ślimaka. Odpowiedzi TEOAE w przeprowadzonych badaniach zostały uzyskane za pomocą urządzenia Sentiero-Advanced (Path Medical, Niemcy), przy użyciu nieliniowego protokołu stymulacyjnego przy 80 dB SPL. Wyniki TEOAE uznawano za prawidłowe (PASS), gdy stosunek sygnału do szumu w trzech z czterech badanych częstotliwości (2, 3, 4, 5 kHz) wynosił ≥ 3 dB.

***Przesiewowa audiometria tonalna***

Podczas przesiewowych badań słuchu audiometria tonalna jest wykonywana przy użyciu Platformy Badań Zmysłów (PBZ), opracowanej przez Instytut Fizjologii i Patologii Słuchu oraz Instytut Narządów Zmysłów. Narzędzie to wykorzystano do realizacji badań we wszystkich krajach Europy, Azji i Afryki. Badanie audiometryczne na przewodnictwo powietrzne wykonywano w zakresie częstotliwości 500–8000 Hz z uwzględnieniem w szczególnych przypadkach częstotliwości półoktawowych 3000 i 6000 Hz. Pomiary przeprowadzono metodą zstępującą, z wartością kroku 5 dB. Za próg słyszenia przyjęto najniższe natężenie tonu, przy którym uzyskano odpowiedź zgodnie z regułą: uzyskanie dwóch lub trzech jednakowych wartości progów słyszenia dla danej częstotliwości, odpowiednio w trzech lub pięciu próbach.

W tym miejscu warto krótko scharakteryzować Platformę Badań Zmysłów. Jest to przenośny audiometr zakwalifikowany według normy PN-EN 60645-1 jako audiometr klasy IV. Urządzenie składa się z komputera typu notebook, przycisku dla pacjenta oraz słuchawek Sennheiser HDA200, które dodatkowo zapewniają skuteczną izolację akustyczną od hałasu otoczenia (na bazie ochronników słuchu Peltor™). Po wykonaniu badań wyniki zostają automatycznie przesyłane do centralnej bazy danych (za pomocą internetu, bezpośrednio z urządzenia do badań przesiewowych). W PBZ wykorzystano nowoczesne technologie gromadzenia i przesyłania danych z zachowaniem najwyższej jakości związanej z ich bezpieczeństwem, które zostaną opisane w dalszej części rozprawy. Stworzono cały system do obsługi badań przesiewowych, a jako narzędzia do wymiany danych oraz do administracji użyto specjalnych aplikacji. Używana aparatura jest przystosowana do badań słuchu w miejscach takich jak szkoła, gdzie trudno o absolutną ciszę. Przed badaniem dzieci wkładają słuchawki wyciszające, ponadto system monitoruje hałas w otoczeniu. Jeśli okazuje się on zbyt duży, system uniemożliwi wykonanie badania. Nie ma także możliwości, aby na wynik badania wpłynął błąd badacza, jego pośpiech czy po prostu zaniedbanie niedostateczną starannością – system to wychwyci i przekaże specjalistom informację, że badanie nie zostało przeprowadzone prawidłowo. Podczas badań przesiewowych uzyskuje się więc w pełni wiarygodne wyniki, których dokładność jest porównywalna z dokładnością wyników badań słuchu wykonywanych w kabinie ciszy.

***System Zintegrowanej Operacji Komunikacyjnej "SZOK"®***

Każdy program z zakresu profilaktyki prowadzony na skalę masową stanowi szansę na wczesne wykrycie zaburzeń. Aby usprawnić proces diagnostyki, Instytut Fizjologii i Patologii Słuchu zaangażował się w opracowanie Systemu Zintegrowanej Operacji Komunikacyjnej „SZOK”®. System ten służy do przesyłania, automatycznego gromadzenia wyników badań w centralnej bazie danych i ich wszechstronną analizę. Telemedyczne rozwiązania polegają na wykorzystaniu systemu do pomocy pacjentom w przebyciu zdalnej diagnostyki i przeniesieniu wyników ich badań do sektora usług zdrowotnych. Wyniki audiometrycznych badań słuchu są automatycznie gromadzone w centralnej bazie danych "SZOK"® w postaci zaszyfrowanych danych. W systemie dane są oceniane, zarówno automatycznie zgodnie ze zdefiniowanymi kryteriami, jak i przez lekarzy-specjalistów podejmujących ostateczną decyzję co do dalszego postępowania terapeutycznego. Gromadzone wyniki są oznaczane unikalnymi identyfikatorami, co gwarantuje pełną ochronę danych osobowych badanych osób zgodnie z obowiązującymi przepisami prawa. Dzięki takiemu rozwiązaniu możliwe jest dokonanie analizy epidemiologicznej na obszarach wykorzystujących urządzenia współpracujące z Platformą Badań Zmysłów.

***Narzędzia samoopisowe***

Autorskie ankiety audiologiczne stanowiły cykl ustrukturyzowanych pytań, opracowanych przez specjalistów laryngologów i audiologów pracujących w Instytucie Fizjologii i Patologii Słuchu. W opracowaniu pytań kluczową rolę odegrały doświadczenia w zakresie badań przesiewowych wśród dzieci szkolnych, które były prowadzone w Instytucie od wielu lat. Narzędzia te dostarczały cennych informacji na temat stanu słuchu dzieci oraz pozwoliły na określenie czynników ryzyka, a dzięki temu umożliwiły stałą poprawę opieki zdrowotnej świadczonej na rzecz dzieci w wieku szkolnym. Udzielone odpowiedzi przez rodziców stanowiły cenną wskazówkę przy formułowaniu informacji o wyniku badania. Ankieta audiologiczna była skierowana do rodziców/opiekunów prawnych i dzieci. Ankiety były wypełniane przez rodziców i dzieci przed badaniem audiometrycznym.

***a) zagrożenie hałasem***

Ankieta zawierała 7 pytań (6 pytań zamkniętych i 1 otwarte) dotyczących stosowania przenośnych odtwarzaczy muzycznych (PMP), narażenia na inne źródła hałasu oraz stosowania środków ochrony słuchu. Używanie PMP oceniano na podstawie 6 pytań, na które odpowiadali uczniowie: 1. Czy używasz PMP? („tak”, „nie”); 2. Jakiego rodzaju słuchawek używasz najczęściej? („słuchawki”, „słuchawki douszne”); 3. Zaznacz na linii poziom głośności, jaki zwykle ustawiasz na swoim PMP (znak został następnie przeliczony na procenty); 4. Jak często słuchasz muzyki przez PMP na określonym poziomie głośności? („codziennie”, „4-6 razy w tygodniu”, „2-3 razy w tygodniu”, „raz w tygodniu”, „rzadziej niż raz w tygodniu”, „nie słucham muzyki”); 5. Ile godzin dziennie słuchasz muzyki za pośrednictwem PMP? („powyżej 6 h”, „5-6 h”, „3-4 h”, „1-2 h”, „mniej niż 1 h”); 6. Jakie czynności wykonujesz podczas korzystania z PMP? Ostatnie pytanie dotyczyło używania środków ochrony słuchu w głośnym otoczeniu, np. na koncertach, meczach, dyskotekach, strzelnicy („nigdy”, „rzadko”, „czasami”, „często”, „zawsze”, „nie dotyczy”).

***b) szumy uszne***

Rodziców poproszono o udzielenie pisemnej odpowiedzi na następujące pytanie: „Czy Twoje dziecko skarży się na szumy w uszach/głowie, gdy jest cicho?”. Odpowiedź polegała na wybraniu jednej z możliwych odpowiedzi: bardzo często, często, rzadko lub nigdy. Dzieci także poproszono o pisemną odpowiedź na podobne pytanie – „Czy słyszysz szumy w uszach, gwizdy lub piski, gdy zasypiasz lub gdy w Twoim pokoju jest cicho?”. Wybierając odpowiedź „tak, cały czas”, „tak, okresowo i przez ponad 5 minut”, „tak, ale tylko przez bardzo krótki czas”, „nie”. Jeśli rodzice odpowiadali „bardzo często” lub „często”, a dzieci „tak, cały czas”, „tak, okresowo i przez ponad 5 minut”, uznawano to za wynik pozytywny, czyli wskazujący na obecność szumów usznych.

***c) świadomość rodziców odnośnie zaburzeń słuchu***

Rodziców poproszono o udzielenie odpowiedzi na następujące pytanie – „Czy uważa Pan(i), że Pana(i) dziecko ma jakiekolwiek problemy ze słuchem?” („tak”, „nie”).

# 6. Wyniki badań

## 6.1. Definicje

Zgodnie z klasyfikacją Światowej Organizacji Zdrowia dzieci od urodzenia do 14 roku życia, które mają ubytek słuchu powyżej 30 dB w uchu lepszym, są uznawane za osoby z niedosłuchem [97]. Klasyfikacja ta wzbudza wątpliwości wśród naukowców i klinicystów. Jednym z powodów jest uznanie progu dla normalnego słuchu wynoszącego 25 dB. Taka granica dla normalnego słyszenia nie jest zgodna z kilkoma doniesieniami literaturowymi dotyczącymi funkcjonowania osób z niewielki lub łagodnym ubytkiem słuchu (<25 dB) [41]. Drugim powodem jest stworzona definicja upośledzenia słuchu, która wyłącza osoby z lekkim obustronnym ubytkiem słuchu oraz wszystkich pacjentów z jednostronnym ubytkiem słuchu o dowolnym stopniu nasilenia, co nie jest zgodne z ICF – Międzynarodową Klasyfikacją Funkcjonowania, Niepełnosprawności i Zdrowia (ang. *International Classification of Functioning, Disability and Health*). Grupa ekspertów globalnych obciążeń chorobami ds. ubytków słuchu (ang. *Global Burden Disease* , GBD) zajęła się tymi problemami i zweryfikowała poprawność klasyfikacji WHO dotyczącej ubytków słuchu w 2008r. [10]. W konsekwencji została poprawiona klasyfikacja Światowej Organizacji Zdrowia, granicę dla normalnego słuchu obniżono do 20 dB, stworzono oddzielną kategorię dla jednostronnego ubytku słuchu, a sześć kategorii dla obustronnych zaburzeń słuchu konsekwentnie zróżnicowano w odstępach co 15 dB. W związku z powyższym w niniejszej rozprawie zdecydowano się zastosować klasyfikację ICF. Łagodny ubytek słuchu definiowano jako >20-40 dB, natomiast umiarkowane lub głębszego stopnia definiowano jako powyżej 40 dB według klasyfikacji BIAP. W przypadku obustronnego ubytku słuchu, do określenia stopnia upośledzenia słuchu przyjęto średnią w uchu gorszym.

Po przesłaniu wyników audiometrycznych do systemu „SZOK" ®, nieprawidłowe – zgodnie z przyjętymi kryteriami – wyniki testu zostały wyselekcjonowane i dokonano podziału na obu- i jednostronne uszkodzenia słuchu. Kolejnym krokiem przeprowadzonym przez specjalistów otolaryngologów i audiologów z Instytutu Fizjologii i Patologii Słuchu był podział nieprawidłowych wyników przesiewowych badań słuchu na poniższe rodzaje audiogramów (osobno dla każdego ucha):

- wskazujące na ubytek słuchu w zakresie niskich częstotliwości (LFHL), w którym próg słyszenia dla 500 i/lub 1000 Hz wynosił 25 dB HL i więcej, podczas gdy dla innych częstotliwości nie przekraczał 20 dB HL,

- wskazujące na ubytek słuchu w zakresie wysokich częstotliwości (HFHL), w którym próg słyszenia dla częstotliwości 4000 i/lub 8000 Hz wynosił 25 dB HL i więcej, podczas gdy dla innych częstotliwości nie przekraczał 20 dB HL,
- inne – inne nieprawidłowe wyniki badań przesiewowych, w których wartość progu słyszenia była większa niż 20 dB HL i występowała na co najmniej dwóch arbitralnych częstotliwościach,
- wskazujące na ubytek słuchu istotny dla mowy (FFPTA), w którym próg słyszenia dla częstotliwości 0,5, 1, 2 i 4 kHz nie przekraczał 20 dB HL.

## 6.2. Badania słuchu

**P-3**

Pozytywne wyniki przesiewowych badań słuchu uzyskano u 1032 z 5029 dzieci (tj. 1032 dzieci miało podwyższony próg słyszenia dla co najmniej jednej częstotliwości). Wskaźnik ten wyniósł 20,5% (95% CI, 19,4-21,6%). Nieprawidłowy wynik uzyskało 20,6% dziewcząt (95% CI, 19,0-22,3%) i 20,4% chłopców (95% CI, 18,9-21,9%). Jednostronny niedosłuch stwierdzono u 388 dzieci, tj. u 7,7% (95% CI, 7,0-8,5%), a obustronny u 193 dzieci, tj. u 3,8% (95% CI, 3,3-4,4%).

**P-4**

***Otoskopia***

Otoskopię przeprowadzono u 34 618 dzieci. U 3901 dzieci przewód słuchowy był całkowicie zatkany przez woskowinę lub ciało obce i z tego powodu dzieci te zostały wyłączone z dalszej analizy. Zgodnie z polskimi przepisami, wszelkie procedury medyczne (w tym usuwanie woskowiny z ucha) mogą być wykonywane tylko w placówkach medycznych. Otolaryngolodzy wykonujący otoskopię zaobserwowali następujące nieprawidłowości: zmiany w błonie bębenkowej (w tym przekrwienie, ścieńczenie, retrakcja lub bliznowacenie błony bębenkowej, płyn za błoną bębenkową), wąskie przewody słuchowe, egzostozy, zmiany skórne w przewodzie słuchowym zewnętrznym, naczyniaki oraz podejrzenie uszkodzenia kosteczek słuchowych. Wyniki badania wykazały, że najczęstszymi nieprawidłowościami w otoskopii były: wysiękowe zapalenie ucha środkowego, kieszonki retrakcyjne i tympanoskleroza. Ogółem, nieprawidłowości w otoskopii występowały u 25,1% i były nieco częstsze u dziewczynek niż u chłopców (OR = 1,11; 95% CI [1,06-1,17]; Z = 4,04; $p < .001$).

Nieprawidłowości w badaniu otoskopowym stwierdzono u 26,2% dzieci mieszkających w małych miastach i wsiach oraz u 15,3% dzieci mieszkających w dużych miastach, przy czym różnica ta była istotna statystycznie (OR = 1,97; 95% CI [1,78-2,18]; Z = 12,96; p < .001).

### *Audiometria tonalna*

Odsetek wyników nieprawidłowych wynosił 19,2%. Był on podobny u chłopców i dziewcząt (OR = 1,04; 95% CI [0,99-1,11]; Z = 1,48; p = .139) i nie różnił się istotnie między dziećmi mieszkającymi w dużych miastach a dziećmi mieszkającymi w małych miastach lub na wsi (OR = 1,08; 95% CI [0,98-1,19]; Z = 1,50; p = .135). Odsetek wyników pozytywnych u dzieci z nieprawidłowościami w otoskopii wynosił 26,9% i był istotnie wyższy niż u dzieci z prawidłowymi wynikami otoskopii – 16,6% (OR = 1,85; 95% CI [1,74-1,97]; Z = 19,74; p < .001). Częstość występowania czteroczęstotliwościowego ubytku słuchu wynosiła 6,8%. Była ona nieco wyższa u dziewcząt niż u chłopców (OR = 1,10; 95% CI [1,01-1,20]; Z = 2,09; p = .037) i podobna u dzieci mieszkających w dużych miastach oraz w małych miastach i wsiach (OR = 1,12; 95% CI [0,96-1,30]; Z = 1,40; p = .162). Wśród uczestników z nieprawidłowościami w otoskopii była ona istotnie wyższa niż u uczestników z prawidłowymi wynikami otoskopii (OR = 2,53; 95% CI [2,31-2,77]; Z = 20,15; p < .001). Częstość występowania niedosłuchu o niskiej częstotliwości (LFHL) wynosiła 8,0%. Była ona nieco wyższa u dziewczynek niż u chłopców (OR = 1,22; 95% CI [1,12-1,32]; Z = 4,69; p < .001) i podobna u dzieci mieszkających w dużych miastach oraz w małych miastach lub wsiach (OR = 1,14; 95% CI [0,98-1,31]; Z = 1,74; p = .081). Ponownie zaobserwowano istotną różnicę między dziećmi z nieprawidłowościami w otoskopii a dziećmi z prawidłowymi wynikami otoskopii (OR = 2,38; 95% CI [2,19-2,59]; Z = 20,04; p < .001). Częstość występowania niedosłuchu o wysokiej częstotliwości wynosiła 7,8%. Tym razem była ona nieco niższa u dziewczynek niż u chłopców (OR = 0,84; 95% CI [0,78-0,92]; Z = 3,94; p < .001), ale nadal podobna u dzieci mieszkających w dużych miastach i w małych miastach lub na wsi (OR = 1,13; 95% CI [0,98-1,31]; Z = 1,67; p = .095). Łagodny ubytek słuchu stwierdzono u 9,7% dzieci, natomiast częstość występowania umiarkowanego lub głębszego ubytku słuchu była niższa i wynosiła tylko 1,3% (95% CI [1,2%-1,4%]). Dla wszystkich kategorii PTA (ang. *Pure Tone Audiometry*), ubytek słuchu łagodny obserwowano częściej niż umiarkowany lub głębszy. Jednostronny ubytek słuchu (ang. *Unilateral Hearing Loss, UHL*) stwierdzono u 7,5% dzieci, natomiast obustronny ubytek słuchu (ang. *Bilateral Hearing Loss*, BHL) u 3,4% dzieci (95% CI [3,2%-3,6%]). Ubytek słuchu w jednym uchu był częstszy niż w obu uszach dla wszystkich kategorii PTA.

**P-5**

***Audiometria tonalna***

Nieprawidłowy wynik badań przesiewowych słuchu uzyskano u 123 dzieci (27,2%), natomiast u pozostałych 329 dzieci (72,8%) progi audiometryczne były poniżej kryterium 20 dB. U 80 dzieci (65% z 123 dzieci z wynikiem pozytywnym) stwierdzono jednostronne uszkodzenie słuchu, a u 43 dzieci (35%) – obustronne. Stwierdzono istotną statystycznie różnicę w częstości występowania wyników pozytywnych między dziećmi młodszymi i starszymi: $\chi 2 = 9{,}98$; $P = 0{,}002$. Wyniki nieprawidłowe były częściej stwierdzane u dzieci młodszych (32,2%) niż u dzieci starszych (18,4%). Nie było statystycznie istotnej różnicy w lateralizacji wyników nieprawidłowych pomiędzy młodszymi i starszymi dziećmi: $\chi 2 = 0{,}44$; $P = 0{,}505$. Pozytywne wyniki w jednym uchu były częstsze niż w obu uszach, niezależnie od wieku. Uwzględniając uszy, w których progi audiometryczne przekraczały kryterium 25 dB, było ich łącznie 166, w tym 78 uszu z HFHL (47%), 12 uszu z LFHL (7,2%) i 76 uszu z innym typem ubytku słuchu.

***Follow-up***

U 21 z 27 dzieci, u których wynik badania przesiewowego słuchu był nieprawidłowy, stwierdzono problemy ze słuchem (tj. wskaźnik prawdziwie pozytywnych wyników wyniósł 78%). W dziewięciu przypadkach przewód słuchowy był zatkany woskowiną. Po jej usunięciu słuch okazał się być w normie. W pięciu przypadkach rozpoznano zapalenie ucha środkowego i zastosowano odpowiednią antybiotykoterapię. U dwojga dzieci zlecono tympanoplastykę z powodu perforacji błony bębenkowej. U dwojga dzieci stwierdzono przerost migdałka gardłowego i zalecono adenotomię. Dwoje dzieci miało niedawno przebytą infekcję układu oddechowego, która mogła mieć wpływ na słuch i lekarz postanowił poczekać na całkowite wyleczenie. Jedno dziecko miało otosklerozę, która została zdiagnozowana wcześniej i nie została zgłoszona przez rodziców przed badaniem przesiewowym słuchu. U sześciu dzieci z pozytywnym wynikiem badania słuchu nie potwierdzono niedosłuchu (tj. odsetek wyników fałszywie dodatnich wyniósł 22% w grupie 27 dzieci).

**P-6**

***Otoskopia***

Otoskopię przeprowadzono u wszystkich dzieci. Stwierdzono, że u 112 dzieci (47,5%) pole otoskopowe było prawidłowe, a u 124 dzieci (52,6%) nieprawidłowe. W przypadku tych ostatnich, w 70 przypadkach (29,7%) nieprawidłowości występowały w obu uszach, w 26 przypadkach (11%) w uchu lewym, a w 28 przypadkach (11,9%) w uchu prawym.

Najczęstszymi nieprawidłowościami były: woskowina, wysiękowe zapalenie ucha środkowego, grzybicze zapalenie ucha, perforacja błony bębenkowej, tympanoskleroza i stan zapalny błony bębenkowej.

### *Audiometria tonalna*

Czterdziestu sześciu badanych uczniów (19,5%) miało nieprawidłowy wynik badania audiometrycznego. Obustronny niedosłuch stwierdzono u 22 (9,3%), a jednostronny u 24 (10,2%) uczniów. W tym ostatnim przypadku siedmioro dzieci (3%) miało ubytek słuchu w uchu lewym, a 17 dzieci (7,2%) – w prawym. Podane wartości procentowe zostały obliczone z uwzględnieniem całkowitej liczby 236 ocenianych uczniów. Pod względem płci, nieprawidłowy wynik wykryto częściej wśród dziewczynek (n = 28; 23,3%) niż chłopców (n = 18; 15,5%), ale różnica ta nie była istotna statystycznie ($\chi2$ = 2,30; p = .130). W grupie dzieci młodszych (5-7 lat) ubytek słuchu stwierdzono u 20 (15,2%) uczniów. W grupie starszej (8-11 lat) częstość występowania była nieco wyższa (n = 26; 25%), ale różnica ta nie była istotna statystycznie ($\chi2$=3,60; p = .058). Pod względem jednostronnego lub obustronnego ubytku słuchu obie grupy nie różniły się istotnie ($\chi2$=3,71; p = .157). Niedosłuchy LFHL stanowiły 48,6% , zaś niedosłuchy HFHL stanowiły 16,2%.

### *Otoemisje akustyczne*

Z przyczyn technicznych badanie TEOAE przeprowadzono u 108 dzieci: 46 dzieci (42,6%) uzyskało prawidłowy wynik TEOAE, a 62 (57,4%) nie uzyskało pozytywnej oceny. W przypadku tych ostatnich 33 (30,6%) prezentowało obustronny niedosłuch, 17 (7,2%) niedosłuch ucha lewego i 12 (5,1%) niedosłuch ucha prawego.

### *Czułość i specyficzność*

W celu oszacowania wartości specyficzności i czułości badania otoskopowego, dane porównano z danymi audiometrycznymi (uznanymi za złoty standard). Dwadzieścia siedem z 46 dzieci, które uzyskały nieprawidłowy wynik badania audiometrycznego, wykazało nieprawidłowości w badaniu otoskopowym, co dało wartość czułości 58,6%. Spośród 190 dzieci z prawidłowym wynikiem przesiewowej audiometrii tonalnej, 93 miało prawidłową otoskopię, co dało wartość specyficzności 48,9%. Ogólna dokładność otoskopii została oceniona na 51%. W celu oceny wartości specyficzności i czułości procedury otoemisji akustycznych, wyniki TEOAE porównano z danymi audiometrycznymi od 108 dzieci. Trzynaście dzieci, które uzyskały nieprawidłowy wynik przesiewowych badań audiometrycznych, prezentowały nieprawidłowe odpowiedzi TEOAE, co dało czułość TEOAE równą 100%. Spośród 95 dzieci z prawidłowym profilem audiometrycznym 46 prezentowało prawidłowe odpowiedzi TEOAE, co dało specyficzność TEOAE 48,4%.

**P-7**

Pozytywne wyniki badań przesiewowych słuchu, zgodnie z przyjętym kryterium, uzyskano u 251 dzieci (24,6%), natomiast u pozostałych 771 dzieci (75,4%) progi audiometryczne były równe lub niższe od 20 dB. Częstość występowania pozytywnych wyników badań przesiewowych słuchu wahała się od 12,5% w Rosji do 47% w Azerbejdżanie. Rozkład pozytywnych wyników był podobny w grupach wiekowych 6-7 lat i 11-12 lat. Jednostronny ubytek słuchu stwierdzono u większości dzieci z pozytywnym wynikiem przesiewowych badań słuchu (54,6%). Inaczej było tylko w Azerbejdżanie, gdzie obustronny ubytek słuchu stwierdzono u 57,4% dzieci. Pozytywne wyniki w jednym uchu były częstsze u dzieci młodszych (59,9%) niż u dzieci starszych (46,5%). Uwzględniając uszy, w których progi audiometryczne przekraczały kryterium 25 dB, LFPTA wykryto wśród 32,6% uszu, podczas gdy wskaźnik HFHL wyniósł 29,9%. Jednak w Rosji i Kirgistanie HFHL występował częściej niż LFHL. Szacowana częstość występowania typu zaburzeń słuchu była podobna wśród dzieci w wieku 6-7 lat i starszych. Częstość występowania lekkiego ubytku słuchu (>20 dB) wynosiła 7,6% i była częstsza niż umiarkowany lub głębszy stopień niedosłuchu (0,8% badanych dzieci) dla każdego progu przewodnictwa powietrznego.

**P-8**

***Otoskopia***

Analiza wyników badania otoskopowego wykazała, że 43,8% badanej grupy (253 uczniów) miało nieprawidłowy wynik badania w przynajmniej jednym uchu. Otrzymane wyniki dzieci z krajów afrykańskich wskazują, że częściej nieprawidłowości dotyczyły obojga uszu (62,4%). Najczęściej obserwowane zmiany to: korki woszczynowe, przewlekłe zapalenie ucha środkowego z wyciekiem, perforacja błony bębenkowej, tympanoskleroza, kieszonki retrakcyjne, wada wrodzona ucha zewnętrznego, wyciek ropny, zrosty.

***Audiometria tonalna***

Analiza wyników przesiewowej audiometrii tonalnej wykazała, że pozytywny wynik audiometrii tonalnej, zgodnie z przyjętym kryterium powyżej 25 dB, stwierdzono u 188 dzieci (22,4% badanej populacji). W grupie wiekowej 6-9 lat odsetek nieprawidłowych wyników wynosił 20,8% (tj. 98 uczniów), natomiast wśród dzieci w wieku 10-12 lat pozytywny wynik badania przesiewowego uzyskano u 90 uczniów (tj. 24,5% grupy badanej). Jeśli chodzi o uszy, w których stwierdzono ubytki słuchu, całkowita liczba wynosiła 224. Najczęściej obserwowano ubytki obejmujące wszystkie badane częstotliwości – 58,9% (132 uszu), u 30,4% (68 uszu) stwierdzono ubytek słuchu o niskiej częstotliwości (LFHL), u 10,7% (24 uszu) ubytek słuchu o wysokiej częstotliwości (LFHL).

**P-9**

Odsetek pozytywnych wyników badań przesiewowych słuchu wynosił 16,4% (95% CI, 16,1%-16,6%). Był on prawie równy u chłopców i dziewcząt (OR, 1,03, 95% CI, 0,99-1,07; Z = 1,37, P = 0,17), ale był istotnie wyższy u młodszych dzieci niż u starszych (OR, 2,05, 95% CI, 1,95-2,15; Z = 29,24; P < 0,001). Wyniki tego badania wskazują, że 9,4% (95% CI, 9,18%-9,62%) dzieci w wieku od 6 do 13 lat i mieszkających na obszarach wiejskich miało ubytek słuchu w jednym lub obu uszach, na podstawie jednej lub więcej średnich wartości: FFPTA i/lub HFPTA i/lub LFPTA. Częstość występowania zaburzeń słuchu była taka sama wśród chłopców i dziewcząt (OR,1,00, 95% CI, 0,95-1,05; Z = 0,06, P = 0,95). Wśród uczestników w wieku 6-9 lat częstość występowania nieprawidłowych wyników była istotnie wyższa niż u badanych uczniów w wieku 10-13 lat (OR, 2,21, 95% CI, 2,07-2,35; Z = 24,40; P < 0,001). Częstość występowania czteroczęstotliwościowego ubytku słuchu została oszacowana na 5,6% (95% CI, 5,5%-5,8%). Współczynniki wśród chłopców i dziewcząt były prawie równe (OR,0,94, 95% CI, 0,88-1,01; Z = 1,78, P = 0,08). Ponownie zaobserwowano istotną różnicę między grupami wiekowymi (OR,2,28, 95% CI, 2,10-2,48; Z = 19,62, P < 0,001). Częstość występowania LFPTA HL oceniono na 6,2% (95% CI, 6,1%-6,4%), przy czym współczynniki wśród chłopców i dziewcząt były prawie takie same (OR, 0,96, 95% CI, 0,90-1,02; Z = 1,36, P = 0,17). Grupy wiekowe nadal różniły się istotnie (OR,2,28, 95% CI, 2,11-2,47; Z = 20,63, P < 0,001). Częstość występowania HFPTA HL oceniono na 7,4% (95% CI, 7,2%-7,6%). Współczynniki wśród chłopców i dziewcząt nie różniły się istotnie (OR, 1,06, 95% CI, 1,0-1,12; Z = 1,03, P = 0,05). Ponownie zaobserwowano znaczącą różnicę między grupami wiekowymi (OR, 2,21, 95% CI, 2,06-2,38; Z = 21,84, P < 0,001). Częstość występowania łagodnego ubytku słuchu (>20 dB) wynosiła 5% (95% CI, 4,8%-5,1%) dla FFPTA, 5,5% (95% CI, 5,4%-5,7%) dla LFPTA i 6,3% (95% CI, 6,3%-6,5%) dla HFPTA i była częstsza niż umiarkowany lub głębszy ubytek słuchu. U dzieci częściej występowało jednostronne niż obustronne zaburzenie słuchu. Częstość występowania jednostronnego ubytku była najwyższa dla HFPTA i wynosiła 5,2% (95% CI, 5,1%-5,2%), niższa dla LFPTA (4,2%; 95% CI, 4,1%-4,4%) i dla FFPTA (3,9%; 95% CI, 3,7%-4%).

## 6.3. Narzędzia samoopisowe

- ***Zagrożenie hałasem***

**P-1**

Spośród 1032 uczestników badania, 82% (n = 849) miało przenośny odtwarzacz muzyki (PMP), a 183 dzieci (18%) nie miało. Spośród dzieci posiadających PMP, 48% (n = 411) twierdziło, że używa słuchawek nausznych, podczas gdy 52% (n = 438) używało słuchawek dousznych. Uczestnicy badania oszacowali poziom głośności ustawiony przez nich w PMP na średnio 50,8% (SD = 21,2; mediana 45,3%; n = 438). Częstotliwość korzystania z PMP była następująca: 86 dzieci (10,1%) podało, że słucha muzyki codziennie; 58 (6,8%) 4-6 razy w tygodniu; 187 (22%) 2-3 razy w tygodniu; 119 (14%) raz w tygodniu; 126 (14,8%) rzadziej niż raz w tygodniu; a 273 (32,2%) zgłosiło, że nie słucha muzyki. Czas słuchania PMP wynosił: 3 dzieci (0,3%) podało, że słucha muzyki 5 lub więcej godzin dziennie, 23 (2,7%) 3-4 godziny dziennie, 101 (11,9%) 1-2 godziny dziennie oraz 449 (52,9%) mniej niż 1 godzinę dziennie. Najczęstsze sytuacje, w których korzystano z PMP to: podróż samochodem (31,6%, n = 268) lub transportem publicznym (29,3%, n = 249); granie w gry komputerowe (27,1%, n = 230); granie na telefonie (19,7%, n = 167); spacerowanie (19,1%, n = 162); odrabianie lekcji (13%, n = 110); uprawianie sportu (11,5%, n = 98); spanie (9,7%, n = 82); i czytanie (3,9%, n = 33). Progi słyszenia u użytkowników i osób nie korzystających z PMP były podobne, z wyjątkiem 3 kHz w lewym uchu oraz 4 i 6 kHz w prawym uchu. Zaobserwowano wyższe średnie progi słyszenia dla wyżej wymienionych częstotliwościach w grupie użytkujących PMP, jednak różnice były mniejsze niż 2 dB.

- **Szumy uszne**

**P-1**

Stwierdzono istotną różnicę pomiędzy użytkownikami i osobami niekorzystającymi z PMP w zakresie odczuwania szumów usznych: $\chi 2(4) = 16,87$; $p = 0,002$. Około 76% osób niekorzystających z PMP nigdy nie doświadczyło szumów usznych, natomiast wśród użytkowników PMP odsetek ten był niższy (61,6%). Jednocześnie odsetek osób doświadczających szumów usznych zawsze lub często był wyższy wśród użytkowników PMP (3,2%) w porównaniu do osób niekorzystających z PMP (1%).

**P-7**

Analiza danych wykazała, że 12,2% rodziców stwierdziło, że ich dzieci mają szumy uszne. Nie stwierdzono istotnej statystycznie zależności między niedosłuchem a odczuwaniem szumów usznych ($\chi2 = 1,55$; $p = 0,213$)

**P-10**

W latach 2013-2017 1,4% rodziców stwierdziło, że ich dziecko często lub bardzo często skarżyło się na szumy uszne. Wskaźnik ten był prawie taki sam, zarówno dla chłopców, jak i dziewczynek (OR = 0,86; $p > 0,05$). Nieco ponad 12% rodziców stwierdziło, że ich dziecko sporadycznie skarżyło się na szumy uszne, przy czym ponownie różnica pomiędzy odpowiedziami rodziców chłopców i dziewczynek była niewielka. Większość rodziców (86,2%) stwierdziła, że ich dziecko nigdy nie skarżyło się na szumy uszne, a różnica między rodzicami chłopców i dziewczynek była nadal nieznaczna. Rodzice dzieci z zaburzeniem słuchu częściej zauważali szumy uszne (4,1%) w porównaniu z rodzicami dzieci z normą słuchową (1,4%). Częstość występowania ciągłych szumów usznych zgłaszanych przez dzieci była stabilna i wynosiła 0,6-0,8%, jednakowa dla obu płci. W sumie 0,7% dzieci zgłaszało szumy uszne trwające cały czas, a 2,4% dzieci twierdziło, że doświadczało ich okresowo i że trwały one dłużej niż pięć minut. Odsetek ten był podobny u chłopców i dziewczynek (OR = 0,93; $p > 0,05$). Około 28% dzieci zgłaszało szumy uszne, które zdarzały się rzadko i trwały przez bardzo krótki czas. Szumów usznych nie odczuwało 69,1% dzieci, podobnie u chłopców i dziewczynek.

- **Świadomość rodziców odnośnie zaburzeń słuchu**

**P-2**

Większość rodziców (92,5%; n = 59 876) nie dostrzegała żadnych problemów ze słuchem u swoich dzieci, natomiast 7,5% rodziców (n = 4874) stwierdziło, że ich dziecko ma problemy ze słuchem. Pozytywne wyniki badań przesiewowych słuchu (tj. powyżej 20 dB na jednej lub więcej częstotliwościach w jednym lub obu uszach) uzyskano u 16,3% dzieci (n = 10 573). Czułość rodzicielskiego podejrzenia niedosłuchu wynosiła 17,8%, a jego dodatnia wartość predykcyjna 22%. Swoistość i ujemna wartość predykcyjna były wyższe – odpowiednio 93,5% i 91,7%. Czułość postrzegania niedosłuchów przez rodziców wynosiła aż 22% (najwyższa dla

FFPTA). Pozytywna wartość predykcyjna była podobna lub nieco niższa niż czułość. Wysoka swoistość i ujemna wartość predykcyjna wynikają z dużej liczby prawdziwych ujemnych wyników, natomiast wykrycie prawdziwych dodatnich wyników jest znaczące. Stopień ubytku słuchu był istotnym czynnikiem wpływającym na czułość podejrzeń rodziców co do występowania zaburzenia słuchu u ich dzieci. Czułość wynosiła od 16,9% do 19,7% dla łagodnego ubytku słuchu i była wyższa, od 31,6% do 36,1 dla umiarkowanego lub cięższego niedosłuchu.

**P-4**

W ciągu 2 lat trwania programu 19 783 rodziców uczniów klas pierwszych wzięło udział w 1600 spotkaniach edukacyjnych. Trzy miesiące po zakończeniu programu rodzice odpowiadali na pytania dotyczące ich wiedzy na temat słuchu. W odpowiedzi na pierwsze pytanie: „Czy dzięki udziałowi w spotkaniu zyskałeś lub poszerzyłeś swoją wiedzę na temat dbania o słuch?", 78,3% rodziców odpowiedziało „tak", 1,1% – „nie", a 20,6% –„nie wiem/trudno powiedzieć". W odpowiedzi na drugie pytanie: „Czy wykorzystuje Pan/Pani wiedzę o tym, jak dbać o słuch w życiu codziennym?", 67,4% rodziców odpowiedziało „tak", 2,2% – „nie", a 30,4% – „nie wiem/trudno powiedzieć". W odpowiedzi na trzecie pytanie: „Jak wykorzystuje Pan(i) wiedzę o tym, jak dbać o słuch w życiu codziennym?" (pytanie wielokrotnego wyboru), 75,8% odpowiedziało, że jestem świadomy, że w przyszłości należy powtórzyć badania słuchu, 38,7% odpowiedziało „dzielę się informacjami z rodziną i przyjaciółmi", 22,6% – „rzadziej słucham głośnej muzyki", a 6,5% „w inny sposób" (np. unikając głośnych miejsc, przestając czyścić uszy wacikami).

W czasie trwania programu zorganizowano osiem seminariów dla lokalnego personelu medycznego. Wzięło w nich udział 57 lekarzy i pielęgniarek podstawowej opieki zdrowotnej.

# 7. Wnioski

Analiza wyników badań przesiewowych słuchu wśród dzieci w wieku szkolnym dokonana na podstawie narzędzi samoopisowych i badań audiometrycznych pozwoliła wysnuć cztery główne wnioski, mające dalsze przełożenie praktyczne:

a) W krajach afrykańskich częstość występowania nieprawidłowego wyniku badania przesiewowego wynosi od 18% do 34%, natomiast w krajach azjatyckich – od 15,9% do 24,1%. Dane uzyskane z badań przeprowadzonych w Polsce wskazują, że od 11% do 16,4% dzieci uzyskało nieprawidłowy wynik badania przesiewowego słuchu. Ponadto częstość występowania ubytków słuchu u dzieci w krajach rozwiniętych jest zwykle niższa niż w krajach rozwijających się. Potrzebna jest zatem intensyfikacja w zakresie wdrażania programów profilaktyki i wczesnego wykrywania zaburzeń słuchu.

b) Stopień ubytku słuchu był istotnym czynnikiem wpływającym na czułość wykrywania zaburzeń słuch u dzieci przez rodziców. Czułość wykrywania ubytku słuchu przez rodziców wynosiła około 20% dla lekkiego stopnia i ponad 31% dla umiarkowanego lub głębszego ubytku słuchu. Niezwykle istotnym praktycznym wnioskiem z badań omówionych w niniejszej rozprawie jest wyraźna potrzeba edukowania rodziców i opiekunów w zakresie objawów niedosłuchu i znaczenia jego wczesnego wykrywania. Priorytetową kwestią wydaje się więc konieczność organizowania działań edukacyjno-informacyjnych dotyczących zaburzeń słuchu.

c) Dzieci rzadko spontanicznie skarżą się na szumy uszne, a ich rodzice nie są świadomi, że ich dzieci doświadczają tej dolegliwości. Wyniki badania wskazują, że istnieje potrzeba wprowadzenia rutynowego pytania o odczuwanie szumów usznych podczas badań pediatrycznych. Szczególną uwagę należy zwrócić na dzieci z wadami słuchu, ponieważ istnieje u nich większe ryzyko współwystępowania szumów usznych. Częstsze zgłaszanie szumów usznych przez rodziców dzieci z ubytkiem słuchu może wynikać z większej obawy, że ich dziecko może mieć inne schorzenie związane z ubytkiem słuchu. Ponadto, uzyskane wyniki sugerują, że szumy uszne mogą być wczesnym objawem NIHL wśród młodzieży szkolnej.

d) Narażenie na hałas jest powszechnym problemem wśród dzieci. Nie ma jednoznacznych dowodów na istnienie związku między narażeniem na hałas w czasie wolnym a obniżeniem progów słyszenia u dzieci w wieku szkolnym. Najczęstszym źródłem hałasu w czasie wolnym, innym niż korzystanie z PMP, było granie w gry komputerowe. Tylko 11,5% dzieci kiedykolwiek używało środków ochrony słuchu podczas przebywaniu w głośnym otoczeniu. Istnieje potrzeba przeprowadzenia w przyszłości badań mających na celu obiektywne określenie narażenia na hałas u dzieci w tym wieku. Szczególną uwagę należy zwrócić na profilaktykę NIHL wśród małych dzieci.

Opublikowane w czasopismach naukowych wyniki stanowią bazę i przyczynek do dalszych badań nad programami przesiewowymi słuchu wśród dzieci w wieku szkolnym w Polsce i zagranicą. Kolejne doniesienia naukowe są w trakcie recenzji oraz w przygotowaniach do druku.

# 8. Streszczenie

## Wstęp

Według danych Światowej Organizacji Zdrowia (WHO) szacuje się, że około 34 miliony dzieci na całym świecie ma zaburzenia słuchu. Ponadto wśród dzieci poniżej 15. roku życia około 60% przypadków zaburzeń słuchu można ograniczyć dzięki odpowiednio stosowanej profilaktyce pierwotnej. Konkluzja Rady Unii Europejskiej z 2011roku w sprawie wczesnego wykrywania i leczenia zaburzeń komunikacyjnych u dzieci, w tym korzystania z narzędzi e-zdrowia i innowacyjnych rozwiązań wskazuje, jak ważne jest wczesne rozpoznawanie dzieci z zaburzeniami słuchu, ich diagnostyka oraz wdrażanie odpowiedniego leczenia i rehabilitacji. Istotnym aspektem jest ocena czynników ryzyka wystąpienia niedosłuchu, w tym również szumów usznych oraz zagrożenia hałasem, których identyfikacja pozwala na ocenę czynników etiologicznych i wypracowanie procedur postępowania zapobiegawczego. Rodzice i opiekunowie nie zawsze mają wiedzę na temat profilaktyki narządu słuchu oraz nie mają świadomości, że ich dziecko może mieć wadę słuchu. Budowanie świadomości wśród dzieci i rodziców, jak ważna jest profilaktyka, powinno być stałym elementem programów badań przesiewowych. Brak świadomości na temat wad słuchu powoduje niezwracanie uwagi i ignorowanie niepokojących symptomów. Celem przedkładanego dzieła naukowego, stanowiącego spójny tematycznie cykl artykułów, opublikowanych w czasopismach naukowych, była analiza wyników badań przesiewowych słuchu wśród dzieci w wieku szkolnym, z uwzględnieniem zarówno przesiewowych badań audiometrycznych, jak i narzędzi samoopisowych.

## Materiał i metody

Badaniami objęto grupę 221 725 dzieci wieku szkolnym, które wzięły udział w programach badań przesiewowych słuchu, zrealizowanych przez Instytut Fizjologii i Patologii Słuchu w Polsce oraz w Europie, Azji i Afryce.

W ciągu ostatnich dwudziestu lat zespół Instytutu przeprowadził liczne masowe programy badań przesiewowych, na potrzeby których opracowano unikatowe urządzenia do wykonywania tych badań oraz wdrożono autorskie rozwiązania organizacyjne, pozwalające na przeprowadzenie masowych badań przesiewowych słuchu. Uzyskane w ten sposób doświadczenia i wstępne wyniki ujawniły konieczność stworzenia tanich procedur dla obszarów, w których brakuje środków na zakup zasobów technologicznych lub zasoby ludzkie są niewystarczające. Dzięki temu możliwa jest identyfikacja grup osób zagrożonych zaburzeniami słuchu na jak najwcześniejszym etapie. Protokoły wszystkich zrealizowanych programów badań przesiewowych słuchu obejmowały audiometrię tonalną, która jest określana mianem „złotego standardu" w ocenie słuchu. Audiometria tonalna była wykonywana przy użyciu Platformy Badań Zmysłów (PBZ) podczas badań przesiewowych we wszystkich krajach Europy, Azji i Afryki. PBZ została opracowana przez Instytut Fizjologii i Patologii Słuchu oraz Instytut Narządów Zmysłów. W centralnej bazie danych "SZOK"® były gromadzone oraz oceniane wyniki badań przesiewowych. Z biegiem lat protokół badań przesiewowych poszczególnych programów ulegał modyfikacjom. Rozszerzono go o badania otoskopowe i otoemisje akustyczne oraz narzędzia samoopisowe.

**Wyniki**

Odsetek wyników nieprawidłowych w grupie dzieci szkolnych wynosi ok. 22%, co pozwala wysnuć wniosek, iż problemy ze słuchem występują u co 5. dziecka rozpoczynającego naukę w szkole podstawowej. Wskaźniki rozpowszechnienia ubytku słuchu u dzieci różnią się w zależności od regionu – znacznie niższe są w krajach o wyższych dochodach, głównie z powodu powszechniejszego dostępu do środków zapobiegawczych i usług medycznych. U dzieci z zaburzeniami słuchu istnieje większe ryzyko współwystępowania szumów usznych. Uzyskane wyniki potwierdzają, iż świadomość rodziców dotycząca zaburzeń słuchu u ich dzieci jest niska. Odsetek rodziców, którzy nie zauważają problemów ze słuchem u swoich dzieci, pozostaje bardzo wysoki. Dane te uzasadniają konieczność i celowość wykonywania badań przesiewowych ukierunkowanych na wykrywanie zaburzeń słuchu u dzieci rozpoczynających naukę w szkole. Ponadto zagrożeniem dla słuchu dzieci jest hałas, który jest generowany przez odtwarzacze muzyki.

**Wnioski**

Opracowanie protokołów badawczych, walidacja metod pomiarowych, skonstruowanie specjalistycznej aparatury i systemu informatycznego na cele badań przesiewowych słuchu pozwoliło objąć szybkimi i rzetelnymi badaniami słuchu dzieci w Polsce i na świecie. Zaproponowany i wdrożony protokół oraz Platforma Badań Zmysłów, stosowane przez Instytut Fizjologii i Patologii Słuchu, są efektywnymi i bezpiecznymi narzędziami, wydają się zatem skuteczne w identyfikacji przypadków poporodowego ubytku słuchu, co umożliwia wczesną interwencję. Dzięki tym działaniom istnieje szansa na poprawę wskaźnika identyfikacji dzieci, u których wcześniej nie rozpoznano zaburzeń słuchu, a w szczególności u dzieci rozpoczynających naukę w szkole podstawowej.

# 9. Summary


### Introduction

According to the World Health Organization (WHO), an estimated 34 million children worldwide suffer from a hearing impairment. In addition, among children under 15 years of age, approximately 60% of hearing impairment may be reduced by properly administered primary prevention. Conclusions of the Council of the European Union in 2011 on early detection and treatment of communication disorders in children, including the use of e-Health tools and innovative solutions indicate the importance of early identification of children with hearing disorders, their diagnosis, and implementation of appropriate treatment and rehabilitation. An important aspect is an assessment of risk factors for hearing loss, including tinnitus and noise environment, the identification of which allows to assess etiological factors and develop preventive procedures. Parents and caregivers are not always knowledgeable about hearing loss prevention and are not aware that their child may have a hearing loss. Building awareness among children and parents of the importance of prevention should be an ongoing component of screening programs. Lack of awareness about hearing defects results in unnoticed symptoms. Screening programs contribute to increased detection of hearing defects and, through this, to prompt diagnostic, treatment, and therapeutic interventions to increase the detection rate and minimize the consequences of detected hearing disorders. The aim of the scientific work, which consists of thematically consistent series of articles published in the scientific journals was to analyze the results of hearing screening examinations among school-aged children, taking into account both audiometric screening tests and self-report assessment tools.

### Material and methods

The study involved a group of 221,725 school-age children who participated in hearing screening programs implemented by the Institute of Physiology and Pathology of Hearing in Poland and also in Europe, Asia, and Africa.

Over the past twenty years, the Institute's team has conducted numerous mass screening programs for which unique screening devices have been developed and proprietary organizational solutions have been implemented to enable mass hearing screening. The resulting experience and preliminary results have revealed the need for low-cost procedures for areas that lack the resources to purchase technological or human resources. This makes it possible to identify groups of people at risk for hearing disorders at the earliest possible stage.

The protocols for all of the hearing screening programs implemented included pure-tone audiometry, which is referred to as the ‘gold standard’ in hearing assessment. Screening pure-tone audiometry was performed using the Senses Examination Platform in all countries in Europe, Asia, and Africa, which was developed by the Institute of Physiology and Pathology of Hearing and the Institute of Sensory Organs. In the central database ‘SZOK’® the screening results were collected and evaluated. Over the years the screening protocol of each program was modified. It was expanded to include otoscopy, otoacoustic emission, and self-report assessment tools.

**Results**

The percentage of abnormal results in the group of school children is about 22%, i.e. hearing problems are present in every 5$^{th}$ child beginning elementary school. The prevalence rates of hearing loss in children vary depending on the region, and are much lower in higher-income countries, mainly due to more widespread access to preventive measures and medical services. Children with hearing impairment have a higher risk of tinnitus comorbidity. The obtained results confirm that parents' awareness of hearing disorders in their children is low. The percentage of parents who do not notice hearing problems in their children remains very high. These data justify the necessity and expediency of screening tests aimed at detecting hearing disorders in children starting school. In addition, noise from music players is a threat to children's hearing.

**Conclusions**

Development of research protocols, validation of measurement methods, construction of specialized equipment, and IT system for hearing screening purposes allowed to cover children in Poland and in the world with effective and reliable hearing tests. This proposed and implemented protocol and the Senses Examination Platform used by the Institute of Physiology and Pathology of Hearing are effective and safe tools and therefore seem to be efficient in identifying cases of postnatal hearing loss, which enables early intervention. Thanks to these activities, there is a chance to improve the identification rate of children with previously undiagnosed hearing disorders, especially in children beginning elementary school.

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# 11. Wykaz skrótów

| Skrót | Pełna nazwa angielska | Pełna nazwa polska |
|---|---|---|
| BHL | Bilateral hearing loss | Obustronny ubytek słuchu |
| CMV | Cytomegalovirus | Cytomegalia |
| dB HL | Decibels Hearing Level | Zero audiometryczne (średni poziom słyszenia dla każdej częstotliwości dla normalnej młodej osoby dorosłej) |
| FFPTA | Four-frequency pure-tone average at 0.5, 1, 2, and 4 kHz | Średnia czystych tonów dla czterech częstotliwości 0,5, 1, 2 i 4 kHz |
| HFHL | High frequency hearing loss | Ubytek słuchu na wysokich częstotliwościach |
| LFHL | Low frequency hearing loss | Ubytek słuchu na niskich częstotliwościach |
| NIHL | Noise-induced hearing loss | Uszkodzenie słuchu wywołane hałasem |
| OAE | Otoacoustic Emissions | Otoemisja akustyczna |
| PBZ | Senses Examination Platform | Platforma Badań Zmysłów |
| PMP | Pesonal Music Players | Przenośny odtwarzacza muzyczny |
| PTA | Pure-tone average | Średni próg słyszenia (dla czystych tonów) |
| TEOAE | Transient Evoked Otoacoustic Emissions | Otoemisja akustyczna wywołana trzaskiem |
| UHL | Unilateral hearing loss | Jednostronny ubytek słuchu |
| WHA | World Health Assembly | Światowe Zgromadzenie Zdrowia |
| WHO | World Health Organization | Światowa Organizacja Zdrowia |

# 12. Załączniki

1) Monografia oraz publikacje z cyklu stanowiące osiągnięcie naukowe:

M-1 Skarżyński Piotr H., Krumm Mark, Świerniak Weronika, Hatzopoulos Stavros. Chapter 18: Hearing Screening: Teleaudiology and Its Application with Children in Africa and Europe [w:] Hatzopoulos Stavros, Ciorba Andrea, Krumm Mark (red.) *Advances in Audiology and Hearing Science*. Taylor & Francis Group, 2020; 481–494. DOI: 10.1201/9780429292590.

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## CHAPTER 18

# Hearing Screening: Teleaudiology and Its Application with Children in Africa and Europe

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### ABSTRACT

The World Hearing Center in Poland has a long history with teleaudiology, cochlear implants, and, more recently, hearing, vision, and speech testing. The efforts of multinational European working groups have resulted in a number of consensus statements providing a catalyst for hearing screening in children of all ages. These statements have also emphasized the use of modern technologies including teleaudiology as a means to provide the best access of hearing healthcare for children with hearing deficits. The World Hearing Center in Warsaw has developed the System of Integrated Communication Operations telehealth platform (for hearing, speech, and vision testing) and has used this platform to screen more than 1,000,000 children to date.

## 18.1 INTRODUCTION

Contemporary audiology and otolaryngology practices typically include both early identification and preventive measures to assist patients experiencing hearing impairment. The desired outcome with these practices is that hearing disorders are detected and treated in their early stages. Teleaudiology technology provides a means to identify and monitor hearing loss in many groups (including children) where hearing healthcare is not easily accessible. Even with minimal Internet connectivity, teleaudiology services can be used to provide mass pediatric screenings and examinations. Therefore, teleaudiology (used in conjunction with other telemedicine strategies) can be employed in alignment with national health policies and to increase accessibility while decreasing costs of hearing healthcare. The Institute of Physiology and Pathology of Hearing located at the World Hearing Center in Kejatany, Poland, has a history of innovative programs utilizing telemedicine and teleaudiology. One of the priority activities developed by this institute is a screening program for children of all ages in collaboration with numerous national centers in Europe.

In response to the obvious need to address hearing loss in children worldwide, the International Society for Telemedicine and eHealth (www.isfteh.org/) formed a working group and developed methods, procedures, and devices for administering hearing healthcare programs for children in different countries. Members of this working group were affiliated with the World Hearing Center Institute team, in collaboration with numerous other national centers. It is notable that following the development of teleaudiology guidelines, hearing screenings were provided directly in a number of countries by the teleaudiology working group committee members and chairs to validate the guidelines.

## 18.2 DEVELOPMENT OF THE PLATFORM FOR SENSE ORGANS SCREENING (PSOS)

In 2008, the Institute of Physiology and Hearing Pathology (IPHP) and the Institute of Sensory Organs (ISO) were located at the World Hearing Center in Kajetany, Poland. The IPHP and ISO prototyped a new PC system for teleaudiology applications in hearing screening. This system came to be known as the PSOS and is still in use today (see Fig. 18.1).

The PSOS platform is built around an internet network solution, interfacing a central computer system and a series of portable computers equipped with audiometric headphones and a response–button interface. The portable computers are equipped for telehealth services capable of doing the following protocols:

**FIGURE 18.1** The platform for Sense Organs Hearing Screening (PSOS).

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. **Dichotic digits test (DDT)**: The DDT utilizes dichotic digits to assess central auditory processing function. During the administration of this procedure, digits are presented to each ear simultaneously and the client is instructed to repeat what they heard in one or both ears. This provides an overall profile of central auditory function and can be used to refer individuals for further central auditory processing evaluation.
3. **Frequency patterns test (FPT)**: Specifically, the FPT test items are sequences of three tone bursts that are presented to one or both ears. In each of these sequences, two of the tone bursts are the same frequency, while the third tone is of a different frequency. There are only two different frequencies used in this test: a high-frequency sound and a low-frequency tone which are played in different sequences. Given this procedure is not difficult, problems with the FPT suggests need for further auditory processing evaluation.

4. **Duration patterns test (DPT)**: The DPT consists of sequences of three tones, one of which differs from the other two in the sequences by being either longer or shorter. The inability to distinguish between durations is suggestive of an auditory processing disorder and warrants further evaluation.
5. **Gaps in noise test (GINT)**: This test allows assessment of the potential of perception of gaps in noise. During the test, the noise is presented with various lengths of gaps which can be distinguished by the normal ear. However, failure to have sufficient gap detection is suggestive of peripheral or auditory processing issues. Consequently, the client should be evaluated further.

## 18.3 SYSTEM OF INTEGRATED COMMUNICATION OPERATIONS: "SZOK"®

Every large-scale project involving children or adults provides a significant opportunity for early detection of congenital or acquired disorders. In response to social needs related to the early detection of birth and acquired disorders, IPHP implemented a project named System of Integrated Communication Operations "SZOK"® (see Fig. 18.2). The IPHP was chosen for this program because this program has a well-documented history of success with past telehealth projects.

The project utilized a system to first assess patients using remote computing technology. These results were subsequently transferred to physicians for interpretation at the IPHP at the World Hearing Center in Kajetany. It was hypothesized by the project directors that the evaluation of patient data using the SZOK system in a telehealth paradigm would shorten patient waiting times for visits to IPHP (or other specialized partner facilities). In addition, it would provide more access for patients as the barriers commonly associated with distance would be reduced or completed avoided. One aspect unique to this project is the approach for teleaudiology integrating both remote testing and e-health solutions.

## 18.4 HEARING SCREENING IN SCHOOL-AGE CHILDREN AROUND THE WORLD CONDUCT BY IPHP

In the time period from 2007 to 2016, the Institute of Physiology and Pathology of Hearing screened over one million young students from the first to the six grade, attending primary schools in Poland (Skaryżyński et al., 2011) and almost 500,000 children around the world (Skarżyński, Piłka, Ludwikowski, and Skarżyńska, 2015). This experience provided an opportunity to validate the efficacy of SZOK using a significant large number of school aged children. In addition, the outcome of the SZOK project created the international infrastructure for teleaudiology screening which provides an effective solution to even remote rural areas.

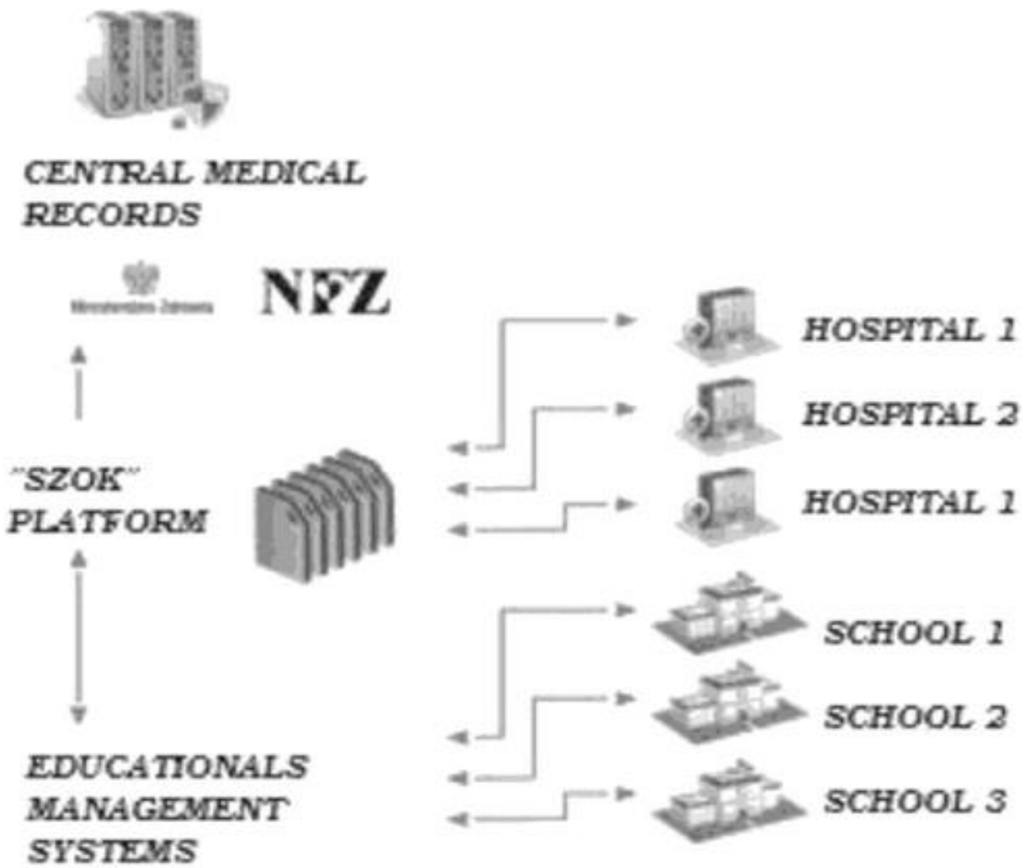


**FIGURE 18.2** The Telemedicine System of Integrated Communication Operations and it's components.

The results from the SZOK hearing screening program were ultimately used for a European Scientific Consensus agreement, which was developed during the 2016 European Federation of Audiology Societies (EFAS) meeting. As an immediate result, a number of pilot hearing screening programs were started in various countries (Skarżyński et al., 2016). Table 18.1 shows the countries in which teams from the Institute of Physiology and Pathology of Hearing in Kajetany have conducted (and still conduct) hearing screening programs.

**TABLE 18.1** Overview of Hearing Screening around the World Conducted by the Institute Physiology and Pathology of Hearing.

| Country in which IFPS conducted hearing screening | Children'sage (y) | Number of testedchildren | 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 somedistricts |
| **Congo** | 6–8 | 200 | no screening program |
| **Ghana** | 6–12 | 170 | no screening program |
| **IvoryCoast** | 6–8 | 130 | no screening program |
| **Kazakhstan** | 7–8 | 250 | no screening program |
| **Kyrgyzstan** | 6–7 | 300 | no screening program |
| **Moldova** | 6–7 | 179 | no information |
| **Nigeria** | 4–12 | 350 | 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 | 400 | no screening program |
| **Tajikistan** | 7–8 | 143 | no screening program |
| **Tanzania** | 6–11 | 200 | no screening program |
| **Turmenistan** | 6–8 | 200 | no screening program |
| **Ukraine** | 6–11 | 384 | no screening program |
| **Uzbekistan** | 6–8 | 200 | no screening program |

Some of these countries have partnered with the National Network of Teleaudiology (NNT), a system of international medical centers which cooperate with each other. For this purpose, information technology (IT) procedures and storage solutions are shared among partners. The primary center of the NNT in Kajetany coordinates four centers outside Poland: Odessa (Ukraine), Brest (Belarus), Bishkek (Kyrgyzstan), and Lutsk (Ukraine). Each of these centers has the capacity to remotely adjust the speech processor of a patient's cochlear implant system. In addition, these centers are enabled to remotely perform objective hearing tests (Brainstem Stem responses and Otoacoustic Emissions) and rehabilitation for people with hearing and other communication disorders.

## 18.5 THE IMPACT OF HEARING LOSS ON A CHILD'S DEVELOPMENT

The major aim of hearing screening programs is to detect a disorder at a stage when treatment can be effective in reducing various long-term complications (Herman et al., 2002). According to the World Health Organization (WHO), nearly 7.5 million of children presenting hearing complications live in low to middle income countries (Ravi et al., 2016).

School screening programs may be a key factor for identifying hearing loss in children in low to middle income countries. In these countries, school hearing screening programs, if they exist, are often administered to children in kindergarten or at young children in primary school grades. Consequently, school screening programs offer the first opportunity to identify hearing loss in young children when universal newborn hearing screening programs are not available.

The rationale for school screening programs is almost obvious. The classroom is an auditory verbal environment where precise transmission and reception of speech is critical for effective learning to occur (Davis et al., 1986). Stated differently, 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 (Skarżyński et al., 2013). Common behaviors which occur with hearing loss include: difficulty attending to spoken or other auditory information; frequent requests for repetition; fatigue when listening; inappropriate answers to questions; avoidance of contacts with peers; difficulty with reading skills and written language; and a low tolerance for frustration (Johnson and Seaton, 2011). Children with mild unilateral hearing loss (UHL) exhibit difficulties in sound-source location and problems with speech understanding and these factors can significantly affect in long-term educational outcomes (Lewis et al., 2015). Such negative outcomes can be ameliorated with early identification of hearing loss and intervention via hearing aids, cochlear implants, various assistive listening devices, and aural rehabilitation. These interventions facilitate student speech and language, cognitive and social development, and consequently academic achievement is more likely to remain on target.

Certainly there are many factors that affect the speech and language acquisition and subsequent academic achievement of each child include the configuration, degree, and type of hearing loss. Interestingly, pure tone thresholds do not always predict handicap or success in school. For example, children exhibiting mild hearing loss may exhibit considerable academic failure (National Academies of Sciences, 2016). Such an outcome is not normally expected but reflects the inadequate metrics of pure tone thresholds to predict communication skills in children. This is likely due to the fact that communication skills development is a complex process and requires measurements of several different domains to be clearly understood. Therefore, any hearing impairment, no matter how mild, needs to be properly assessed in order to *assert attention to any barrier of learning* (Sangen et al., 2017).

Children with unilateral hearing loss exhibit an increased rate of failing and repeating a grade level. Consequently, these individuals exhibit a need for additional educational support for addressing educational, psychosocial, and behavioral issues in the classroom. Possible risk factors include with these children lower cognitive ability, right ear hearing loss, social isolation, and educational failure (Anne, Lieu, and Cohen, 2017). Speech and language development may be delayed in some children with UHL, but it is unclear if children "catch up" as they grow older (Anderson, 2011).

## 18.6 THE HEARING SCREENING PROTOCOL FOR SCHOOL-AGE CHILDREN

This section describes preliminary work of the Institute of Physiology and Pathology of Hearing from 2007 to 2017. 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, a medical history, the possible presence of tinnitus, and concerns of learning difficulties.

Hearing assessment protocols:

- Video otoscopy: This test was administered by audiologists or otolaryngologists to provide examiners a visual method to examine the outer ear and tympanic membrane. This examination was used to diagnose pathology such as earwax, acute or chronic otitis media (with effusion), fungal infection and pathology affecting the tympanic membrane. Consequently, video otoscopy was considered an essential tool in teleaudiology assessment in children. Digital still images and videos were recorded while testing the child at school and transmitted to the Institute of Physiology and Pathology of Hearing for assessment by specialists. Live video consultations were provided via telehealth services and a reduction in waiting times for specialist services were observed. Following diagnosis by practitioners at the Institute of Physiology and Pathology of Hearing, treatment recommendations were carried out by primary care clinicians (trained for this purpose) at the client location.

- Otoacoustic emissions (OAE): OAEs offer a method of assessing the peripheral hearing system. Although not technically a test of hearing, OAEs can provide an objective measure of inner ear function. Hence, one significant advantage of OAEs is that this procedure can be used across cultures with different languages as behavioral responses are unnecessary. This is an important aspect related to OAEs as the Institute of Physiology and Pathology of Hearing provided hearing screening to other nations and OAEs results were not significantly affected by language and cultural differences in those instances.
- Pure tone audiometry (PTA): Hearing screening is usually the backbone of hearing screening programs. The PSOS was utilized for this project to provide an inexpensive and universal screening program for a large population of children using teleaudiology procedures. In the event, individuals being screened by OAEs did not pass, pure tone testing was provided. For these individuals, thresholds for air conduction were obtained in the frequency range of 500–8000 Hz. Thresholds greater than 20 dB at any frequencies indicate possible hearing loss in children and these individuals were referred for further testing and management in their communities.

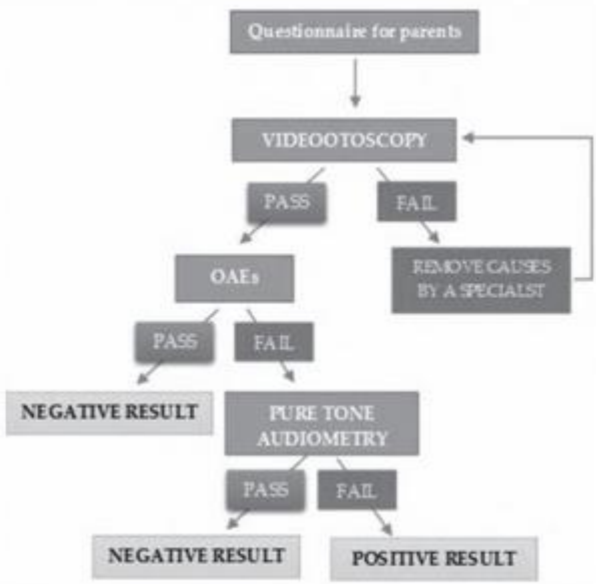


**FIGURE 18.3** Schema of hearing screening protocol in school-age children used in the Institute Physiology and Pathology of Hearing.

It is of interest that the hearing screening procedures used by Institute of Physiology and Pathology of Hearing allow the detection not only of children with hearing loss, but also those with other hearing disorders including tinnitus. Tinnitus is not an insignificant issue in children, according to the data of Raj-Koziak et al. Their data show that the incidence of tinnitus in school-age children is approximately from 13 to 37.7% (Raj-Koziak et al., 2011). As tinnitus can have significant psychological consequences, diagnosis of tinnitus in children should be incorporated as a facet of screening so that counseling services or tinnitus therapy can be provided as necessary.

## 18.7 MOBILE HEARING CENTER

The Institute of Physiology and Pathology of Hearing also has a mobile unit to provide audiology services for a rural hearing health study. This vehicle, called the "Mobile Hearing Center" is shown in Figure 18.4. Inside, the mobile unit functions as a regular audiology clinic, only on a much smaller scale. This vehicle has two booths and the larger of the two booths has a typical audiology setup with video otoscopy. The larger of the two booths has been designed to assess for middle ear disease. 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, the mobile unit is used only for hearing screening. However, in the future, the Mobile Hearing Center will be configured with internet so that remote evaluations can be conducted for teleaudiology purposes when difficult cases arise, requiring an audiologist or otolaryngologist to conduct more advanced procedures remotely (e.g., video otoscopy or audiometry). Of course, telemedicine would be ideal for most mobile units providing the level of expertise required for virtually any client need. Although the Mobile Hearing Center is not presently equipped with telemedicine capabilities, it is nevertheless a completely self-contained mobile audiology clinic, delivering the same level of service expected in a standard clinic. This service modality is a practical method to provide necessary and timely delivered hearing healthcare to rural communities which may otherwise be underserved by traditional medical models.

## 18.8 SUMMARY

By planning and setting public health priorities, representatives of the Institute of Physiology and Hearing Pathology have attempted to mobilize


**FIGURE 18.4** Mobile Hearing Center.

as a group of European audiologists, phoniatrists, otolaryngologists, speech therapists, and ophthalmologists (including both national and international experts). The goal of this effort was to provide children with communication disorders to have access to the most modern forms of intervention possible (Skarżyński et al., 2011). The international of experts, led by Prof. Henryk Skarżyński of the World Hearing Center, resulted in two European Scientific consensus statements adopted in Warsaw on June 22, 2011, during the 10th Congress of the European Federation of Audiovisual Societies. The first is the "European Consensus in Screening in Pre-school and School Children" signed by representatives of 27 countries, most of whom are national members of the European Federation of Audiovisual Societies. The signatories were: Austria, Belarus, Belgium, Croatia, Cyprus, Denmark, Finland, France, Germany, Hungary, Ireland, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Spain, Sweden, Switzerland, Turkey, Ukraine, and the United Kingdom. On the same day, Dr. Ewa Kopacz, Minister of Health, received and signed the "European Consensus on Screening for Hearing, Visual and Speech in Pre-school and School Children." Among the signatories were Prof. Linda Luxon (the President of the European Federation of Audiological Societies); Prof. Antoinette am Zehnhoff-Dinnesen (President of the European Phoniatrics

Group); Michèle Kaufmann-Meyer (Vice-President of the Committee for Speech/Speech Therapists in the European Union); Prof. Jerzy Szaflik National Consultant in Ophthalmology (representing the environment of European ophthalmologists); and Prof. Henryk Skarżyński whose key leadership led to the development of the "European Consensus on Screening for Hearing, Visual and Speech in Pre-school and School Children." This consensus statement (see Appendix) provides the rationale for European audiologists, phoniatrists, speech therapists, and ophthalmologists to identify and treat childhood communication disorders. This statement also describes the need for normal hearing, vision, speech, and language skills for the proper intellectual and emotional development of children. This consensus statement has become one of the most important tools to strengthen the implementation of the Presidency's priority in Poland, as well as recognition of the achievements, entrepreneurship, and effectiveness of Polish activities in this field.

*Additional Links:*

http://skrining.ifps.org.pl/-hearing screening program in Warsaw
http://www.sponin.org.pl/-hearing screening program in rural areas
https://przesiewy-mazowsze.ifps.org.pl/-hearing screening program in Mazovia

## APPENDIX: EU EARLY DETECTION OF COMMUNICATION DISORDERS AND THE USE OF E-HEALTH

One of the main objectives of the Presidency's Public Health Task Force in Poland was to prepare and adopt the EU Council Conclusions on the Early Detection and Treatment of Communication Disorders in Children, taking into account the use of e-Health tools and innovative solutions. The discussion on the conclusions took place at the meetings of the Working Group on Public Health in Brussels. This group, attended by health attaches from 27 EU Member States, representatives of the Council, and the European Commission, was chaired by a representative of the Polish Presidency, supported by representatives of the Institute of Physiology and Pathology of Hearing—the coordinator of the issue. Following a detailed discussion of the draft conclusions and consensus, the document received the approval of all 27 health attachés and was submitted to formal adoption in accordance with the procedure. On December 2, 2011, a meeting of the EU Council on Employment, Social Policy, Health and Consumer Affairs (EPSCO) was held in Brussels. Participants in the meeting were the health ministers of the Member States and the high representatives of EU countries. At that time, a consensus statement was developed which embraced telehealth as a means to addressing hearing loss in children. This statement was entitled "EU Council Conclusions on Early Detection and Treatment of Communication Disorders in Children, Including the Use of eHealth Tools and Innovative Solutions" (Council of the European Union, 2011).

The aim of this statement was to bring social attention to the problem of communication disorders in children and how these disorders affect their developmental, social, and economic outcomes even into adulthood. The document is intended to encourage government representatives in EU Member States and relevant institutions to identify and treat children with hearing, vision, and speech disorders through effective and economically justified screening programs including modern e-health technologies and tools. Included in this plan is the prevention, monitoring, and active involvement of parents, careers, and teachers who are also an integral part of children's health.

## KEYWORDS

- **hearing loss**
- **hearing screening**
- **pure tone audiometry**
- **school-age children**
- **neonatal screening**
- **prevalence**
- **public health**
- **school health services**

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International Journal of
*Environmental Research and Public Health*

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# Personal Music Players Use and Other Noise Hazards among Children 11 to 12 Years Old

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Received: 21 August 2020; Accepted: 19 September 2020; Published: 22 September 2020

**Abstract:** Exposure to loud music—due to widespread personal music players (PMPs) and noisy leisure activities—are major risk factors for noise induced hearing loss (NIHL) in adolescents. However, there is little evidence of the impact of noise on the hearing of younger children. This study aimed to explore an association between PMP use and hearing, and to identify other sources of noise among children. The study sample consisted of 1032 children aged 11–12 years old. Hearing thresholds were determined from 0.5 to 8 kHz. PMP use and other noise exposures were evaluated using a survey. We found that 82% of the children had a PMP, and 78% were exposed to noise when playing computer games. An audiometric notch was documented in 1.3% of the children. Only 11.5% of the children ever used hearing protection while engaged in noisy activities. We found no convincing evidence of an association between PMP use and hearing thresholds, although our results suggest that tinnitus may be an early sign of NIHL in young children. The study shows a need to provide children, their parents, and educators with knowledge of how to take care of hearing, including how to avoid and minimize noise exposure.

**Keywords:** noise; noise induced hearing loss; personal music players; children

## 1. Introduction

Noise exposure is a common component of life which negatively affects human health. There are many studies that have described the effects of environmental noise and its association with health problems such as annoyance [1,2], sleep disturbance [3], hypertension and ischemic heart disease [4,5], and learning impairment in children [6,7]. Some people are exposed to constant but lower noise, not high enough to have a direct effect, but inducing various health problems [8,9].

Noise exposure is particularly detrimental to hearing. Noise-induced hearing loss (NIHL) can result from both a single sudden noise (acoustic trauma) or from long-term steady noise [10]. It can injure the eardrum or middle-ear ossicles, damage hair cells in the cochlea [11–13], and affect the auditory nerve and its myelin sheath [14]. NIHL is typically revealed by a notch in the audiogram at 4 kHz [15], which can spread to nearby frequencies at 3 and 6 kHz but with some hearing recovery at 8 kHz [16,17]. A genetic susceptibility to NIHL is being investigated [13,18], but most researchers focus their attention on environmental factors. For adults, occupational noise is the main consideration [19], but for children the impact of noisy leisure activities and use of personal music players (PMPs) is the primary aspect [20].

Many studies have shown that the prevalence of NIHL is considerable among young people. Data from a large-scale American study (1988–1994) indicated that 15.9% of children aged 12 to 19 years had hearing deficits attributable to noise exposure [21]. More recent data (2005–2006) from young Americans were quite similar, the rate being 16.8% [22]. In the Netherlands it has been found that 14.2% of a large cohort showed that children aged 9 to 11 years had hearing impairment possibly correlated with NIHL [23]. In Poland, 11.5% of 643 youths aged 13 to 18 years showed a notched hearing loss at 4 or 6 kHz, and it was significantly higher in those with heavy exposure to loud music (16.3%) compared to those with mild exposure (10.7%) [24].

Many children, adolescents, and young adults engage in noisy recreational activities (e.g., attending concerts, matches, discos, playing with noisy toys, and listening to loud music). As documented by Henderson et al. [22], exposure to loud noise or listening to music over headphones is an upward trend among young people—which is not surprising, given the widespread use of PMPs, such as MP3 players, iPods, and mobile phones. In 2016, le Clercq et al. [20] undertook a systematic review and meta-analysis of music-induced hearing loss and its symptoms in young people, although most of the 33 articles concerned adolescents and young adults. It was concluded that most studies reported no significant association between exposure to loud music and pure-tone air thresholds, although some studies showed a higher prevalence of tinnitus and decreased otoacoustic emissions in participants more exposed to music. Significantly poorer hearing thresholds were documented for PMP users than for non-users, and le Clercq et al. [20] finally conclude that the accumulated data suggest an association between music exposure and hearing loss in children.

Generally, there are few studies related to NIHL in younger children, and their conclusions are not strong [23,25,26]. There is no clear-cut evidence for association between recreational noise exposure and hearing loss in younger children. The aim of this study was to explore an association between personal music player use and hearing, and to identify other sources of noise among children.

## 2. Materials and Methods

### 2.1. Study Design

Since November 2007, the Institute of Physiology and Pathology of Hearing, commissioned by Warsaw City Hall, has conducted hearing screening in primary schools in Warsaw. The goal of the program is to increase the detection of hearing disorders, improve early diagnosis, and give equal opportunities to children by reducing or eliminating the adverse consequences of hearing impairment [27,28]. The main objective of the hearing screening program is to assess the hearing of the studied population. For the purposes of the present article we retrospectively analyzed a portion of the data obtained in one year of the program to assess the noise hazard among sixth-grade children who were due to complete their primary education.

Prior to testing, the children's parents were informed of the testing procedure and were asked to give written consent for their children to participate in the hearing examinations. The study was conducted following the Declaration of Helsinki and was approved by the Research Ethics Committee (KB.IFPS:28/4/2018).

### 2.2. Audiometric Testing

Screening pure tone audiometry was conducted in a quiet room allocated by the school headmaster. The examination was performed on the Platform for Sensory Organs Examination [27,29,30] connected to the "SZOK"® central database [31]. The system is based on a powerful central computer with multiple portable computers communicating with it via the Internet. Each portable device is equipped with software that allows it to perform pure-tone audiometry. The platform includes a response button and is set up with Sennheiser HDA300 audiometric headphones which provide effective acoustic isolation from background noise. The platform is shown in Figure 1.


**Figure 1.** Platform for Sensory Organs Examination.

For each ear separately, air conduction thresholds at conventional octave frequencies from 0.5 to 8 kHz were determined with the same paradigms as in a previous study [27,29,32] as well as at half-octave frequencies of 3 and 6 kHz. Measurements at 125 and 250 Hz were omitted as being less useful and vulnerable to noise disturbance [33].

Presence of a Notched Audiogram

Children were studied for the presence of a high-frequency notch. According to Niskar et al. [21], a notch was considered to be present when three conditions were met: (i) thresholds at 0.5 and 1 kHz were lower (better) than 15 dB; (ii) thresholds at 3, 4, or 6 kHz were 15 dB or higher (poorer) than the poorest threshold at 0.5 or 1 kHz; and (iii) the threshold at 8 kHz was at least 10 dB lower (better) than the poorest threshold at 3, 4, or 6 kHz.

### *2.3. Survey*

A brief survey used was developed by an ENT specialist and audiologists working in Institute of Physiology and Pathology of Hearing in Poland. Developing it we based on our experience on screening examination among school children which we have been conducted for many years. The survey contained 8 questions (6 closed-ended and 2 open-ended questions) concerned PMP use, exposure to other sources of noise, tinnitus experience, and use of hearing protection.

The survey was completed by the children before audiometric testing. PMP use was assessed on the basis of 6 items reported by the participants: 1. Do you use PMP? (yes, no). 2. Which kind of headphones do you use the most frequently? (headphones, earphones). 3. Mark on the line the volume level you normally set on your PMP (the mark was then converted into percent). 4. How often do you listen to music through PMP on a specified level? (every day, 4–6 times a week, 2–3 times a week, once a week, less than once a week, I do not to listen music). 5. How many hours a day do you listen to music through the PMP? (above 6 h, 5–6 h, 3–4 h, 1–2 h, less than 1 h). 6. What are your activities when you use your PMP?

Exposure to other sources of noise was evaluated by questioning how often the children participated in various noisy activities (listed in Table 1). A question about tinnitus was: Do you hear tinnitus, whistles, squeaks or other sounds when in quiet? (never, rarely, sometimes, often, always). The last question concerned use of hearing protection in noisy environments, e.g., concerts, matches, disco, shooting range (never, rarely, sometimes, often, always, not applicable).

**Table 1.** Frequency of noisy leisure activities.

| Activity | Every Day | 4–5 Times a Week | 2–3 Times a Week | Once a Week | Once a Month | Several Times a Year | No; Not Applicable |
|---|---|---|---|---|---|---|---|
| Practising musical instruments | 10 (1.0) | 3 (0.3) | 10 (1.0) | 20 (1.9) | 6 (0.6) | 21 (2.0) | 962 (93.2) |
| Hunting, shooting | - | - | 3 (0.3) | 5 (0.5) | 8 (0.8) | 30 (2.9) | 986 (95.5) |
| Noisy power tools (e.g., chain saw, electric drill) | 1 (0.1) | 1 (0.1) | 2 (0.2) | 9 (0.9) | 10 (1.0) | 49 (4.7) | 960 (93.0) |
| Concerts, music events | - | - | 1 (0.1) | 2 (0.2) | 24 (2.3) | 258 (25.0) | 747 (72.4) |
| Computer games (Playstation, X-Box, Nintendo) | 116 (11.2) | 114 (11.0) | 246 (23.8) | 156 (15.1) | 101 (9.2) | 74 (7.2) | 225 (21.8) |
| Using caps, fireworks, firecrackers | - | - | 4 (0.4) | 1 (0.1) | 8 (0.8) | 262 (25.4) | 757 (73.4) |
| Grass-cutting with lawnmower | - | - | - | 14 (1.4) | 53 (5.1) | 132 (12.8) | 833 (80.7) |
| Playing slot machines | - | - | 2 (0.2) | 2 (0.2) | 12 (1.2) | 55 (5.3) | 961 (93.1) |
| Matches, sporting events | 4 (0.4) | 3 (0.3) | 22 (2.1) | 52 (5.0) | 96 (9.3) | 237 (23.0) | 618 (59.9) |
| Disco | - | - | - | 5 (0.5) | 41 (4.0) | 554 (53.7) | 432 (41.9) |

Children playing computer games were divided into two groups: Those who played 2–3 times a week or more often ($n$ = 476), and those who played at most once a week or not at all ($n$ = 556). Their hearing thresholds did not differ significantly.

### 2.4. Participants

There were 1032 children (546 girls and 486 boys), made up of 265 children (26%) aged 11 years and 767 (74%) aged 12 years.

### 2.5. Statistical Analysis

Hearing thresholds between PMP users and non-users were compared using a $t$-test for independent samples. A chi-square test for independence was made to determine if there was a significant association between tinnitus and PMP use. Statistical significance was set at a $p$-value of 0.05. Analysis was conducted using IBM SPSS Statistics v. 24 (IBM Corp., Armonk, NY, USA).

## 3. Results

### 3.1. Personal Music Player Use

Of 1032 participants, 82% ($n$ = 849) had a PMP, while 183 children (18%) did not. Of children having a PMP, 48% ($n$ = 411) said they used headphones, while 52% ($n$ = 438) used earphones.

The participants estimated the volume level normally set by them on their PMP as 50.8% on average (SD = 21.2, median 45.3%). The frequency of PMP use was as follows: 86 children (10.1%) reported they listened to music every day; 58 (6.8%) 4–6 times a week; 187 (22%) 2–3 times a week; 119 (14%) once a week; 126 (14.8%) less than once a week; and 273 (32.2%) reported they did not listen to music. The PMP listening time was: 3 children (0.3%) reported they listened to music 5 or more hours a day; 23 (2.7%) 3–4 h a day, 101 (11.9%) 1–2 h a day; and 449 (52.9%) less than 1 h a day.

The most common situations when using a PMP were: Traveling by car (31.6%, $n$ = 268) or public transport (29.3%, $n$ = 249); playing computer games (27.1%, $n$ = 230); playing on a phone (19.7%, $n$ = 167); walking (19.1%, $n$ = 162); doing homework (13%, $n$ = 110); playing sport (11.5%, $n$ = 98); sleeping (9.7%, $n$ = 82); and reading (3.9%, $n$ = 33).

Comparisons of hearing thresholds across all tested frequencies for PMP users and non-users are shown in Table 2.

Hearing thresholds in the PMP users and non-users were generally similar, except at 3 kHz in the left ear and 4 and 6 kHz in the right ear. Poorer average hearing thresholds at above mentioned frequencies were observed in the non-user group, however the differences were less than 2 dB.

**Table 2.** Hearing thresholds (dB HL) in personal music player (PMP) users and non-users.

| | | PMP Users ($n$ = 849) | | PMP Non-Users ($n$ = 183) | | $t$ | $p$ |
|---|---|---|---|---|---|---|---|
| | **kHz** | **M** | **SD** | **M** | **SD** | | |
| LE | 0.5 | 11.18 | 5.55 | 11.72 | 6.01 | 1.17 | 0.242 |
| | 1 | 8.43 | 5.75 | 9.07 | 6.46 | 1.33 | 0.184 |
| | 2 | 7.39 | 6.62 | 7.68 | 6.87 | 0.53 | 0.598 |
| | 3 | 7.72 | 7.16 | 9.04 | 8.24 | 2.21 | 0.028 |
| | 4 | 6.02 | 6.88 | 7.16 | 8.09 | 1.96 | 0.051 |
| | 6 | 7.70 | 7.16 | 8.61 | 8.08 | 1.52 | 0.128 |
| | 8 | 9.13 | 8.27 | 9.81 | 8.95 | 0.99 | 0.320 |
| RE | 0.5 | 11.31 | 5.08 | 11.17 | 5.43 | 0.33 | 0.741 |
| | 1 | 9.09 | 5.39 | 9.26 | 5.71 | 0.39 | 0.693 |
| | 2 | 7.20 | 5.99 | 7.73 | 5.95 | 1.10 | 0.272 |
| | 3 | 6.90 | 6.27 | 7.57 | 5.79 | 1.33 | 0.183 |
| | 4 | 5.23 | 6.36 | 6.39 | 7.82 | 2.15 | 0.032 |
| | 6 | 7.00 | 6.32 | 8.61 | 9.02 | 2.87 | 0.004 |
| | 8 | 8.23 | 7.91 | 8.69 | 9.07 | 0.69 | 0.492 |

LE, left ear; RE, right ear; M, mean; and SD, standard deviation.

### 3.2. Tinnitus

There was a significant difference between the PMP users and non-users in terms of experiencing tinnitus: $\chi^2(4) = 16.87$; $p = 0.002$. Some 76% of PMP non-users never experienced tinnitus, but among the PMP users the rate was lower (61.6%). At the same time, the rate of experiencing tinnitus often or always was higher in PMP users (3.2%) in comparison to PMP non-users (1%). The data are shown in Table 3.

**Table 3.** Prevalence of tinnitus in PMP users and non-users.

| | Never | Rarely | Sometimes | Often | Always |
|---|---|---|---|---|---|
| PMP users ($n$ = 849) | 523 (61.6) | 168 (19.8) | 131 (15.4) | 20 (2.4) | 7 (0.8) |
| PMP non-users ($n$ = 189) | 139 (76.0) | 30 (16.4) | 12 (6.6) | 1 (0.5) | 1 (0.5) |

### 3.3. Other Sources of Leisure Noise

Table 1 shows how often the children undertook or participated in various noisy leisure activities. As can be seen, the most common source of leisure noise, other than PMP use, was playing computer games. Attending musical and sporting events was much rarer, and other activities were very rare.

### 3.4. Hearing Protection Use

Of 1032 participants, 701 (67.9%) reported they never used hearing protection in noisy environments (e.g., concerts, matches, disco, and shooting range); 59 (5.7%) used them rarely; 45 (4.4%) sometimes; 9 (0.9%) often; 6 (0.6%) always; and 212 (20.5%) not applicable. That means that only 119 of the 1032 children (11.5%) ever used any hearing protection.

### 3.5. Audiometric Notches

Audiometric notches were observed in 13 (1.3%) of the children (7 in the left ear, 2 in the right ear, and 4 bilaterally). Notched audiograms were found in 6 girls and 7 boys. Of the 13, 8 used a PMP and 5 did not; 4 wore headphones and 4 wore earphones. Generally, we did not observe any specific noisy leisure time activity among the 13 children with audiometric notches. As in the whole study group, the most common noisy activity was playing computer games. The 13 children with audiometric notches did not stand out from the other children.

## 4. Discussion

The aim of the present study was to determine the impact of PMP use on children's hearing and to identify other problematic sources of noise. We used data collected during hearing screening of children aged 11–12 years old who were completing the last grade of primary school in Warsaw. We found that 82% of the children had a PMP, and 78% of the children were exposed to noise when playing computer games. We therefore assume that exposure to noise is a common problem among children.

In 2016 le Clercq et al. [20] undertook a systematic review and meta-analysis of music-induced hearing loss and its symptoms in children, adolescents, and young adults. The authors examined 33 articles which met strict inclusion criteria and had sufficient methodological quality. They reported a prevalence of music-induced hearing loss of 0% to 12.6% (when evaluating average thresholds) and 14.2% to 34.9% when considering an increase in threshold at one frequency or more. The weighted average of the prevalence of music-induced hearing loss was 9.6% and for high frequency hearing loss 9.3%. The authors concluded that on the one hand, most studies reported no significant association between exposure to loud music and pure-tone air thresholds, but on the other hand they showed in the meta-analysis that PMP users had significantly poorer hearing thresholds than non-users at high frequencies (4, 6, 8, 10, 12.5, and 16 kHz).

Our findings do not confirm the harmful effect of PMP use on hearing. Pure tone hearing thresholds were not significantly elevated in PMP users in comparison to PMP non-users. In both groups hearing thresholds were generally similar, however slightly poorer hearing (about 2 dB) at three frequencies was observed in children who did not use a PMP. We must admit we did not expect such a result, even though no consensus exists regarding the risk associated with personal listening devices in causing NIHL. Mostafapour et al. [34] state that the majority of young PMP users are at low risk of NIHL, but point out that NIHL is an additive process and even slight effects of continued exposure to noise may accumulate over many years. Le Clercq et al. [23] also showed no association between PMP use and notched audiograms in a large cohort of children aged 9–11 years, but they did find an association between PMP use and high-frequency hearing loss (average threshold at 3, 4, 6, and 8 kHz). Similarly inconclusive are the results of a study conducted by Båsjö et al. [25] concerning listening habits in 415 nine-year-old children. The study showed that hearing thresholds for children who often listen to music with headphones were significantly poorer in comparison with children who did not listen with headphones, but only in the right ear.

Cone et al.'s study [26] which examined 6581 children aged 7–11 years showed that exposure to recreational noise (e.g., noisy toys, firecrackers, referee whistles, lawn mowers, and power tools) was slightly higher in children with mild sensorineural hearing loss (18%) than in children with normal hearing (10.2%). Use of personal stereos was also a significant risk factor for mild sensorineural hearing loss with an odds ratio of 1.7 (although it should be noted that the 95% confidence interval was from 1.0 to 3.0). In summary, the results are equivocal.

Our children were 11–12 years old. We think they had not been using a PMP for a long time and had not yet developed a habit of listening for long periods. Over half of the participants listened to music through their PMP for less than 1 h a day, and only 10% listened to music every day. They did not seem to have used their PMP long enough to impair their hearing thresholds. Furthermore, PMP users reported that the volume level they used was on average about 50%, so the noise level was probably insufficient to cause damage to hearing over a short time.

A quite similar view was presented by You et al. [35] after a study of 1009 Korean college students who used personal listening devices. Harrison [36] supposed that, in the short term, the impact of noise exposure may not be apparent and not manifest immediately, but the accumulated effects may eventually lead to serious hearing deficits later on. This opinion sounds plausible.

Our study showed that PMP users more often experienced tinnitus than PMP non-users. The link between tinnitus and noise has been documented by many researchers. Mazurek et al. [37] revealed that 83% of adult tinnitus patients had high-frequency hearing loss corresponding to the pattern found with NIHL. Similar evidence has been given by other researchers [38–41] but all these studies were done in adult subjects. Knowledge of noise-induced tinnitus in children remains limited to only a few studies [42]. Holgers et al. [43], Juul et al. [44], and Nemholt et al. [45] investigated noise-induced tinnitus in children, but only after listening to loud music or other loud sounds, so their results refer to temporary threshold shift (TTS) rather than to NIHL. More interesting are the findings of Coelho et al. [46] who investigated children aged 5 to 12 years old. They conclude that a history of noise exposure was a risk factor for tinnitus (an odds ratio of 1.8) and for troublesome tinnitus (an odds ratio of 2.8); however, it was unclear how a history of noise exposure was defined. Our findings suggest that tinnitus may precede full-blown NIHL and be an early sign of hearing impairment following later. This hypothesis is worth verifying, preferably in a longitudinal study.

In our study we asked children about several activities described in the literature as being noisy and a risk factor for NIHL. The main finding was that children often play computer games—78% engaged in this activity at various levels. Among the harmful effects that computer games may have on children's health, research has pointed to aggressive behavior and thoughts, emotional problems, hyperactivity, and inattention [47,48]. The potential effect of playing computer games on hearing has not been widely discussed, but Iannace et al. [49] showed that game users are highly exposed to noise and potential damage to hearing depends on a game's sound intensity and exposure time. Our study revealed that other leisure activities (e.g., attending music or sporting events) were not frequently undertaken by the children, which seems understandable taking into account the young age of our cohort.

We found that only 11.5% of the children ever used hearing protection while engaged in noisy activities. Bogoch et al. [50] found that only about 20% of attendees of rock concerts ever wore hearing protection at such events. Similar data was given by Olsen–Widen et al. [51] who found that about 30% of adolescents used hearing protection at concerts. We think that, for younger children, the parents' attitude and health education play key roles. Nowadays, children routinely use bike helmets, seat belts, or car seats to prevent possible injury, and we think that hearing protection devices should also be promoted. Teachers and parents need to teach children health-oriented behaviors of how to avoid and minimize the harmful effects of noise.

We found notched audiograms in only 1.3% of the children. This rate is lower than in other studies—4.5% by le Clercq et al. [23] in a study sample of 3116 children 9–11 years old and the 16.8% figure found by Henderson et al. [22] in a sample of 4310 adolescents 12–19 years old. However, Twardella et al. [52] found that only 2.3% of 2143 adolescents displayed a notched audiogram. This inconsistency, especially with the le Clercq et al. [23] results obtained in younger children, shows that there is a need to accumulate evidence about noise exposure and its impact on children's hearing from various countries.

Our study has certain limitations. We gathered data during a hearing screening conducted in primary schools in Warsaw, the capital of Poland. The aim of the screening was to detect possible hearing impairment and refer pupils with positive results for further diagnostic testing. Audiological testing consisted only of pure tone audiometry, which is considered the gold standard for evaluating hearing levels [53,54], but otoacoustic emissions might be a more sensitive way of detecting hearing impairment related to noise exposure. Although our study sample was rather large, it is not representative of the whole population of Polish children aged 11–12 years; it only comprised children living in the biggest Polish city. Another limitation is a reliance on self-reporting by the children of their exposure to noise. Our study was observational, not an experiment, and we were not able to precisely define the frequency, duration, and loudness of exposure to loud music and other sources of noise. Some scalar quantity of noise would be beneficial to the study. Despite these drawbacks, this study is noteworthy because the evidence of the effects of noise exposure in younger children is currently scarce. Accumulating a range of results from different settings will help create guidelines of how to determine NIHL in children and how to prevent it.

## 5. Conclusions

Our findings show that children aged 11–12 years are exposed to leisure noise and PMP use is its considerable source. However, only 10% of the children reported using PMP every day, and 53% of the PMP users listened to music less than hour a day. The volume level normally set by the children was on average 50.8%. We did not find a convincing association between pure-tone hearing thresholds and PMP use, and notched audiograms were documented in only 1.3% of the children. However, the results suggest that tinnitus, which was slightly more frequent in PMP users, might be an early sign of NIHL. The most common source of leisure noise, other than PMP use, was playing computer games (78% of the children). Only 11.5% of the children ever used hearing protection while engaged in noisy activities. There is a need for future research to objectively quantify noise exposure in children of this age. Particular attention should be paid to prevention of NIHL among young children.

**Author Contributions:** Conceptualization, P.H.S., H.S., W.S., E.G., N.C.; methodology, W.S., E.G., N.C.; formal analysis, E.G.; data curation: W.S., E.G.; writing—original draft preparation, W.S., E.G.; writing—review and editing, E.G., W.S., P.H.S., N.C.; project administration: P.H.S., N.C.; funding acquisition: H.S., P.H.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** The authors received no specific funding for this work.

**Acknowledgments:** We acknowledge Andrew Bell for proofreading the manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

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International Journal of Pediatric Otorhinolaryngology 141 (2021) 110552

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

# The accuracy of parental suspicion of hearing loss in children

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ARTICLE INFO

*Keywords:*
Hearing
Hearing screening
Children

ABSTRACT

*Objectives:* Parental suspicion of hearing impairment in their children is generally inaccurate. Parents tend to underestimate hearing problems in their children. The aim of the study was to assess the accuracy of parental suspicion of hearing loss in their children.
*Methods:* This was a population-based, epidemiological study conducted in elementary schools in villages and small towns in Poland. The study sample was 64,750 children aged 6–13 years old. The children underwent hearing screening with pure-tone audiometry. The parents answered a question about hearing problems in their children.
The outcome parameters were sensitivity, specificity, and predictive value of parental perception of hearing problems in their children. Parental suspicion of hearing problems was assessed by a questionnaire. Pure-tone air-conduction hearing thresholds were obtained from 0.5 to 8 kHz. Hearing loss was defined as a pure-tone average higher than 20 dB in one or both ears in at least one of the three following pure-tone averages: four-frequency pure-tone average, high-frequency pure-tone average, and low-frequency pure-tone average.
*Results:* Positive results of hearing screening were obtained in 16.3% of children. Hearing loss was detected in 6025 children (9.3%), of whom 1074 (17.8%) were correctly perceived by parents as having hearing problems. The degree of hearing loss was a significant factor which influenced the sensitivity of parental suspicion of HL in their children. Sensitivity of detecting hearing loss by parents reached about 20% for mild hearing loss and above 31% for moderate or worse hearing loss.
*Conclusions:* Parents underestimate hearing problems in their children, but they are more able to accurately detect hearing loss if it involves speech-related frequencies and is at least a moderate hearing loss or bilateral loss.

## 1. Introduction

In Poland exist newborn routine screening program but there is no mandatory follow-up in school-age children [1,2]. Hearing screening among school-age children should be an integral tool for identifying children with hearing impairment who have not been identified at birth or who have developed hearing disorders later. The effect of Institute's work and negotiations conducted during the Polish Presidency has been the adoption of the EU Council Conclusions on Early detection and Treatment of Communication Disorders in Children, including the Use of e-Health Tools and Innovative Solutions [3]. It is the guidelines how to identify and treat children with sense disorders through screening programs including modern e-health technologies. As a result of the consensus agreement a number of hearing screening programs were started in Poland [3]. Approximately a million children have been included in these programs up to 2018. The rate of positive results (i.e. audiometric levels >20 dB at one frequency or more) was 13.9%–23.9% depending on age group [4]. In 2008 a screening program for school-children from rural areas and small towns was also implemented [5,6]. Moreover, in 2017 the Institute Psychology and Pathology of Hearing started hearing screening programs, involving the entire Mazovia region. It was the first in Poland region where hearing screening

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https://doi.org/10.1016/j.ijporl.2020.110552
Received 1 September 2020; Received in revised form 9 December 2020; Accepted 9 December 2020
Available online 11 December 2020

encompasses the whole population of children beginning school education [2]. Despite of some local programs, hearing screening programs at primary schools is not standard in Poland. The reasons for this are multifaceted; among them is a lack of awareness from parents, school authorities, and healthcare providers about the adverse effects of even mild hearing loss [7].

Parents are sometimes called "health agents", because they are the most significant persons in their children's lives, are able to create a healthy environment, and can form protective behaviors at an early stage. It is the parents who decide whether to provide the child with medical care, not only in case of obvious disease but also if there is a suspicion concerning the child's health. The parents' income, socio-economic status, level of education, and their own health are important factors affecting their children's health [8]. In addition, where they live is an important factor, since access to medical care is still more limited in rural areas than in urban ones [9]. So in rural areas in particular, identification of childhood hearing impairment remains very dependent on parental suspicion.

Hearing loss (HL) is the most common sensory impairment [10]. The prevalence of HL among children is estimated between 7.7% and 15.5%, depending on the criteria applied [11,12]. Undetected HL, even mild or unilateral, in the early stages of education is a major problem because of the significant negative impact on a child's development. HL impairs the ability to listen and understand auditory information, language development, correct pronunciation, and the child's behavior in general [13].

There is some evidence that parents are not always able to appropriately evaluate the health status of their child and provide them with prompt medical care. Even in the case of obesity, which is visible to the naked eye, the majority of parents fail to recognize that their child is overweight [14].

Symptoms of hearing impairment in children can manifest in different ways and in some cases can remain unnoticed. A child with unilateral or mild HL can learn to compensate for the limitation of audible signals, by being more sensitive to other signals (e.g. visual signs, vibrations of objects). So despite hearing impairment, the child's responses and behavior may seem adequate to the situation [15].

Nearly 30 years ago Watkin et al. [16] noticed that parental suspicion of hearing loss is inaccurate. The difficulty parents have in identifying hearing loss was also pointed out by Stewart et al. [17]. Brody et al. [18] stated that parents are not able to detect mild hearing loss in their children. The low accuracy of parental suspicion of hearing loss in children with otitis media was also documented by Lo et al. [19].

In most of the above mentioned studies, the accuracy of parental perception was evaluated in samples not exceeding two or three hundred children. On a larger scale, there is simply a lack of research. However, the possibility exists for widespread hearing screening in a population of children.

The aim of the present study is to assess the sensitivity, specificity, and predictive value of parental suspicion of HL on the basis of the hearing screening data collected in 2016–17. The study has been approved by a local ethical committee (KB:IFPS: June 27, 2018) and conforms to the stipulations of the Declaration of Helsinki.

## 2. Material and methods

### 2.1. Participants

The participants were recruited between September 2016 and June 2017. Hearing screening was conducted in 4414 schools in 1463 rural districts (below 5.000 inhabitants) in Poland. Prior to testing, the children's parents were informed of the testing procedures and signed a consent form for their children to participate in a hearing screening examination. If the parents gave written consent, their child was examined. The initial sample was 68,239 children, but 3489 parents did not answer the question about hearing problems. The study sample therefore comprised 64,750 school-age children (31,387 girls and 33,363 boys) from 6 to 13 years old ($M = 8.67$; $SD = 2.55$).

### 2.2. Audiometric measurement

Protocol hearing screening included pure tone audiometry using the Platform for Sense Organs Screening [5,20]. The platform is equipped with Sennheiser HDA200 headphones, which provide effective acoustic isolation of the ear from background noise (based on Peltor™ Ear Defenders). Tests were conducted in quiet rooms in order to determine hearing threshold over the range 500–8000 Hz with the possibility of applying 3000 and 6000 Hz half-octave interval in frequencies in specific cases. The Hughson and Westlake procedure of threshold measurement was used, i.e. two out of three responses at threshold are required [21]. The results of audiometric hearing tests were automatically collected in the „SZOK"® central database [22]. The hearing thresholds were transmitted to the central data base at the Institute of Physiology and Pathology of Hearing in Warsaw, Poland. There, within a short period of time, analyses can be performed and the results can be evaluated by ENT specialists.

According to already published criteria [20,23], cases presenting threshold levels >20 dB at one or more frequencies in at least one ear were considered positive results. Results of pure tone audiometry were assigned to one of three groups:

- speech relevant hearing loss having a four frequency pure-tone average (FFPTA) at 0.5, 1, 2, and 4 kHz of >20 dB;
- high frequency pure-tone average (HFPTA) having a pure-tone average above 2 kHz (i.e., 4 and 8 kHz) of >20 dB;
- low frequency pure-tone average (LFPTA) at 0.5, 1, and 2 kHz of >20 dB.

Mild HL was defined as >20–40 dB, whereas moderate or worse HL was defined as above 40 dB according to the BIAP classification [24]. For bilateral HL, the average in the worse ear was used to define the degree of hearing impairment.

### 2.3. Parental perception measurement

The outcome parameters were sensitivity, specificity, and predictive value of parental perception of their child's hearing problems. The parents were asked to complete a questionnaire in which they had to answer the question, *Do you think your child has any problems with hearing?* by choosing one of two responses, *yes* or *no*.

### 2.4. Statistical analysis

The frequencies of the binary parental responses were tabulated according to the results of PTA (occurrence of hearing loss) in the form of 2 × 2 contingency tables. Similarly, contingency tables were created for the parental responses according to the degree of hearing loss and unilateral *vs* bilateral hearing loss.

Sensitivity, specificity, positive predictive value, and negative predictive value were used as measures of accuracy. The definitions and calculation methods followed the guidelines of Altman and Bland [25,26].

## 3. Results

The majority of parents (92.5%; $n = 59{,}876$) did not perceive any hearing problems in their children, whereas 7.5% of parents ($n = 4874$) stated that their child had hearing problems.

Positive results of hearing screening (i.e. above 20 dB at one frequency or more in one or both ears) were obtained in 16.3% of children ($n = 10{,}573$). FFPTA HL and/or LFPTA HL and/or HFPTA HL was detected in 9.3% of children ($n = 6025$) was revealed.

The prevalence of FFPTA HL was 5.6% ($n = 3599$), while prevalence of LFPTA HL was slightly higher (6.2%, $n = 3991$) as well as prevalence of HFPTA HL, which was 7.4% ($n = 4772$).

The sensitivity of parental suspicion of HL was 17.8% and its positive predictive value was 22%. The specificity and negative predictive value were higher – 93.5% and 91.7%, respectively. These data, and data concerning the three types of HL (FFPTA, LFPTA, and HFPTA), are shown in Table 1.

According to the data in Table 1, the sensitivity of parental perception of HL was as high as 22% (the highest being for FFPTA). The positive predictive value was similar or slightly lower than the sensitivity; the highest was for overall HL. High specificity and negative predictive value are due to the high number of true negatives, whereas the detection of true positives is signify.

The degree of HL was a significant factor which influenced the sensitivity of parental suspicion of HL in their children. The sensitivity was between 16.9% and 19.7% for mild HL and it was higher, between 31.6% and 36.1 for moderate or worse HL. The data are shown in Table 2.

The sensitivity of parental suspicion of HL in their children was different for unilateral and bilateral HL. The sensitivity was between 16% and 19.1% for unilateral HL and it was higher, between 25.3% and 27.3 for bilateral HL. The data are shown in Table 2.

## 4. Discussion

Our study results show that on average 20% of parents accurately recognize that there's a problem with their child's hearing. Sensitivity (correct perception of hearing problems) was higher for specific types of HL, ranging from 19.1% (for HFPTA) to 21.6% (FFPTA). Specificity (correct perception of normal hearing) for all types of hearing loss was similar and was about 93%. Positive predictive value indicated that, based on the audiometric results, only about 16% of the positive parental suspicions were correct.

These findings are in line with Lo et al.'s results [19]. That study was conducted among parents of children with otitis media with effusion, and parental suspicions had very low sensitivity: only 12% for predicting positive audiometric results. Although otitis media with effusion is prevalent and increases the risk of hearing impairment, only about 1 in 8 of parents in Lo at al.'s study suspected a hearing deficit in their child.

Watkin et al. showed that in a group of 171 children with permanent hearing loss, 60% of them were identified by screening, 25% were identified thanks by parental suspicion, and 15% were identified by persons other than the parents [27]. Although the sensitivity was higher than in our study, it needs to be recognized that the Watkin study was retrospective, it covered a period of 16 years, and concerned children of all ages (from infancy to 11–12 years old). The difference in results is probably due to the fact that it is an easier task to recognize hearing problems in the first years of a child's life, because a delay in language development is promptly noticed and is very worrying for parents [28, 29].

In our study we obtained pure tone averages for following hearing loss: four-frequency, low frequency, and high frequency. Sensitivity was highest for four-frequency HL and lowest for high frequency HL. The frequencies 500–4000 Hz are most important for speech recognition [30] and our study showed that this type of HL is better recognized by parents.

It is not surprising that sensitivity of parental suspicion is lower for mild HL and higher for moderate or greater HL. However, mild HL should not be ignored. There are several studies showing negative impacts of even mild HL on a child's educational outcomes, language development, verbal abilities, and reasoning skills [31,32].

Bilateral HL was better identified by parents than unilateral HL. Sensitivity of parental suspicion for unilateral HL was 16–19%, while for bilateral HL it was 25–27%. Unilateral HL may remain unnoticed by parents because it is compensated by the child, e.g. by using visual information, acquired habits, or turning the healthy ear towards the sound

**Table 1**
Parental responses versus results of Pure Tone Audiometry.

| Results of hearing screening | HL[a] (n = 6025) | without HL (n = 58,725) | | FFPTA HL (n = 3599) | without FFPTA HL (n = 61,151) | | LFPTA HL (n = 3991) | without LFPTA HL (n = 60,759) | | HFPTA HL (n = 4772) | without HFPTA HL (n = 59,978) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parental suspicion of HL (n = 4874) | 1074 | 3800 | **PPV 22.0%** | 780 | 4094 | **PPV 16.0%** | 803 | 4071 | **PPV 16.4%** | 915 | 3959 | **PPV 18.7%** |
| Parental perception of no HL (n = 59,876) | 4951 | 54,925 | **NPV 91.7%** | 2819 | 57,057 | **NPV 95.2%** | 3188 | 56,688 | **NPV 94.6%** | 3857 | 56,019 | **NPV 93.5%** |
| | **Sensitivity 17.8%** | **Specificity 93.5%** | | **Sensitivity 21.6%** | **Specificity 93.3%** | | **Sensitivity 20.1%** | **Specificity 93.2%** | | **Sensitivity 19.1%** | **Specificity 93.5%** | |

FFPTA HL - four frequency pure-tone average hearing loss; HFPTA HL - high frequency pure-tone average hearing loss; LFPTA - low frequency pure-tone average hearing loss.
[a] FFPTA and/or LFPTA and/or HFPTA HL.

**Table 2**
Parental responses versus degree and laterality of hearing loss.

| | | Parental suspicion of HL | Parental perception of no HL | Sensitivity |
|---|---|---|---|---|
| **FFPTA HL** | **mild** | 629 | 2552 | **19.7%** |
| | **moderate or worse** | 151 | 267 | **36.1%** |
| **LFPTA HL** | **mild** | 651 | 2917 | **18.2%** |
| | **moderate or worse** | 152 | 271 | **35.9%** |
| **HFPTA HL** | **mild** | 686 | 3363 | **16.9%** |
| | **moderate or worse** | 229 | 494 | **31.6%** |
| **FFPTA HL** | **unilateral** | 481 | 2025 | **19.1%** |
| | **bilateral** | 299 | 794 | **27.3%** |
| **LFPTA HL** | **unilateral** | 482 | 2245 | **17.6%** |
| | **bilateral** | 321 | 943 | **25.3%** |
| **HFPTA HL** | **unilateral** | 549 | 2863 | **16.0%** |
| | **bilateral** | 366 | 994 | **26.9%** |

FFPTA HL - four frequency pure-tone average hearing loss; HFPTA HL - high frequency pure-tone average hearing loss; LFPTA - low frequency pure-tone average hearing loss.

source. Nevertheless, children with unilateral HL have difficulties in understanding speech in noisy environments as well as in correct localization of a sound source [33].

As with the study of Watkin et al. our study has demonstrated that parents have a low level of sensitivity to hearing problems in their children. However, why this is so remains an open question. It may be due to lack of awareness about hearing impairment and its consequences. It could also be due to objective difficulties: detection of mild or unilateral HL is a difficult task for parents, who are not equipped with either specialist knowledge or precise instrumentation for detecting HL. Psychological factors may also be important; for example, parents want to have a healthy child and so they tend to discount any worrying symptoms. Further research is required to gain a better understanding of this phenomenon.

However, the practical conclusion of our study is there is a definite need to educate parents and caregivers about the symptoms of HL and the importance of detecting it early. Primary care practitioners should be aware that they cannot rely on parental perception to decide about audiology referral, since parents cannot accurately recognize HL, especially if it is mild or unilateral.

All positive screening results should always be confirmed by further testing. In rural areas where there are not specialized medical services, it is possible to apply a telemedicine model to provide long-distance expert assistance and to transfer some parts of the procedure to smaller, cooperating centers spread around the country. Solution to address the mentioned problem is the use of National Network of Teleaudiology has been proposed [34].

Our study has a number of limitations. The first concerns the survey question. A yes/no response to the question, *Do you think your child has any problems with hearing?* facilitates the calculation of sensitivity and specificity, but it does not allow a parent to express doubts. This could be a potential source of bias, and in order to reduce it a broader set of answers should be provided. It would also be worth clarifying what kind of hearing problems parents suspect in their children. Problems other than HL (e.g. tinnitus, auditory processing disorder, hyperacusis occur in pediatric populations, so even though parents may notice them they do not appear in pure tone audiometry testing.

Another limitation of this study is that it cannot be generalized to all Polish children. The hearing screening described here was conducted only in rural areas. It would be worth comparing these results with data obtained in urban areas, where the parents' socioeconomic status, and level of education is higher and access to health care is easier.

## 5. Conclusions

Summarizing, one cannot rely on parental perception alone in detecting HL. In addition, parents should be more involved in health education and health promotion and made aware of how they can improve their children's health and school achievements. Educational meetings for parents and teachers should be included in the screening programs in school. The goal would be broaden parents' knowledge about hearing, raise awareness of the importance of looking after children's hearing as well as prophylaxis and the general principles of how to prevent hearing disorders. As a factor in reducing the burden of hearing disorders, school screening programs may reduce the consequences of late diagnosis of hearing impairment in childhood [35].

This study underlines the importance of hearing screening in early elementary school. Especially in rural areas where access to pediatric audiology services is limited, hearing screening allows hearing impairment to be identified, allowing appropriate intervention to be undertaken. This can improve not only a child's hearing, but also their quality of life.

## 6. Authors declare

No conflict of interest.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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*audiology research*

MDPI

*Article*

# Hearing Screening among First-Grade Children in Rural Areas and Small Towns in Małopolskie Voivodeship, Poland

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**Abstract:** Undiagnosed hearing deficits hamper a child's ability to learn. Hearing screening in school aged children helps detect educationally significant hearing loss and prevents negative impacts on academic achievement. The main purpose of this study was to improve early detection and assess the incidence of hearing disorders in first-graders from rural areas and small towns in the Małopolskie Voivodeship of Poland. There were 5029 children aged 6–7 years. Hearing thresholds were measured over the frequency range 0.5–8 kHz. A result was considered positive (abnormal) if the hearing threshold was worse than 20 dB HL at one or more frequencies. The prevalence of hearing loss was estimated in terms of four-frequency hearing loss, high-frequency hearing loss, and low-frequency hearing loss. Parents filled in a brief audiological questionnaire. The analysis was performed using IBM SPSS Statistics, version 24. Of all the children, 20.5% returned a positive result and were referred for further audiological diagnoses. The estimated prevalence of hearing loss was 11.6%, made up of 6.5% with FFHL, 7.6% with HFHL, and 8.2% with LFHL. This study showed that large numbers of children in the district had hearing problems. Adoption of hearing screening in primary schools is recommended as a routine procedure within preventive pediatric health care.

**Keywords:** hearing screening; hearing loss; prevalence; school screening; pure tone audiometry



**Citation:** Swierniak, W.; Skarzynski, P.H.; Gos, E.; Czajka, N.; Matusiak, M.; Hartwich, P.; Skarzynska, M.B. Hearing Screening among First-Grade Children in Rural Areas and Small Towns in Małopolskie Voivodeship, Poland. *Audiol. Res.* **2021**, *11*, 275–283. https://doi.org/10.3390/audiolres11020025

Academic Editor: Luca Oscar Redaelli de Zinis

Received: 14 April 2021
Accepted: 10 June 2021
Published: 15 June 2021



## 1. Introduction

Hearing loss has been classified as one of the most common causes of disorders among conditions arising in chronic disease and trauma. This dysfunction has been ranked higher than many other chronic diseases such as diabetes, dementia, and chronic obstructive pulmonary disease [1]. The ability to hear is essential, particularly during children's education in primary school. Listening skills are important when learning to read and write, and have a relevant impact on the development of social skills [2]. Hearing disorders are amenable to intervention; therefore, a screening program has value when the child is beginning school. School-based hearing screening programs provide an opportunity to minimize the inequities between children caused by hearing loss. However, even in countries where routine newborn screening is conducted, childhood hearing loss is an under-recognized public health problem [3–5]. Newborn screening does not detect hearing disorders that occur later in childhood, such as drug-related ototoxicity, infection, and otitis media with effusion [6–8]. One of the most common disorders in childhood, especially in low and middle-income countries and rural areas is otitis media [9–13]. Approximately 80% of school aged children have had an episode of temporary hearing loss due to otitis media [13]. However, temporary hearing disorders, such as conductive hearing loss, are often overlooked by parents or caregivers. Thus, hearing screening programs in schools may help to identify children with hearing disorders that occur after birth [14]. That solution could help to fill the gap in preventative care occurring after the period of newborn hearing screening through access to the whole population of children in one place while utilizing the integrated educational infrastructure and school nurses [15].

The European Consensus on hearing, vision, and speech screenings in preschool and school aged children encouraged the implementation of the preschool hearing screening program [7,16]. However, despite the recommendations of professional organizations, currently there is no known standardized hearing screening program for school aged children in Poland, there are only local programs. Furthermore, as opposed to newborn hearing screening, the protocols used in school hearing screening programs vary widely [17–19].

In 2008, the Institute of Physiology and Pathology of Hearing in collaboration with the Polish Agricultural Social Insurance Fund and the Association of the Deaf and Hearing Impaired 'Homo-Homini' performed the first stage of screening examinations for children attending rural schools and small towns (below 5000 inhabitants) in eastern Poland, during which 92,876 pupils were examined [20]. Afterwards, in the same partnership, the program was extended to western Poland [18]. This study presents the results of the next stage of the program in the Małopolskie Voivodeship.

The main goal of the program was to increase early detection and assess the number of hearing disorders in first grade primary school children from rural areas and small towns from the Małopolskie Voivodeship. The second goal was to increase the knowledge in the participants of the program about the potential causes of hearing disorders and the possibilities of prevention, diagnosis, treatment, and rehabilitation when it occurs. Information materials about the program, along with a prevention booklet and consent forms for the examination, were distributed to schools through local government units (municipalities). The teachers distributed the materials among parents during regular meetings. Cooperation between regional councils and local authorities with the school helped to increase the school attendance in the program.

## 2. Materials and Methods

### *2.1. Participants*

Hearing screening was performed in 630 primary schools located in 19 communities in the Małopolskie Voivodeship. Significant difficulties in program implementation were the high dispersion of schools in the regions covered by the program. The rural regions were predominantly small schools with less than twenty children participating in the program. The initial study sample consisted of 5038 students. Nine children with a prior clinical diagnosis of any hearing impairment were excluded from the analysis. Finally, there were 5029 children, including 2015 children aged 6 years and 3014 children aged 7 years. The study sample consisted of 2281 girls and 2748 boys.

### *2.2. Measurements*

The examination was performed using the Sensory Organs Examination Platform, which was developed by the Institute of Physiology and Pathology of Hearing and the Institute of Sensory Organs [21,22]. The platform is equipped with Sennheiser HDA200 headphones, which provide effective acoustic insulation for the ear against environmental noise. The platform allows the user to conduct screening based on pure tone audiometry. The feature allows the technician to perform an air conduction audiometric test for each ear separately over the frequency range 0.5–8 kHz and for levels not exceeding 80 dB HL. Screening pure tone audiometry was conducted by certified technicians in quiet classrooms in accordance with the modified Hughson and Westlake procedure [17,23]. Only the air conduction threshold was measured. Hearing thresholds were determined for the right and left ear of each patient at frequencies of 0.5–8 kHz. According to previously established criteria, an audiometric test was considered abnormal (positive), if the hearing threshold was above 20 dB HL at one or more frequencies in at least one ear [21,24]. The results of the audiometric hearing tests were automatically collected in the "SZOK"® central database, through which it is possible to perform a statistical analysis and transfer collected data to the Institute Physiology and Pathology, where they can be evaluated by a specialist audiologist or ENT. The collected results were marked with a unique identifier, which guarantees full protection of personal data of persons under examination in accordance with applicable law.

Audiometric hearing tests were supplemented by the results of a questionnaire filled in by parents or legal caregivers. The questionnaire included five questions: Do you think your child has any problems with his/her hearing? Does your child complain of tinnitus in their ears/head when in quiet? Does your child often listen to loud music? Has your child been treated for otitis media? Does your child complain about noise at school? The response format was yes or no.

### *2.3. Data Analysis*

A result of the screening was regarded as positive (refer) if a hearing threshold was above 20 dB at one or more frequencies in at least one ear. Hearing loss was defined as a pure-tone average higher than 20 dB in at least one of the following pure-tone averages: four-frequency pure-tone average (FFPTA), high-frequency pure-tone average (HFPTA), and low-frequency pure-tone average (LFPTA). Firstly, speech relevant hearing loss was defined as the four-frequency pure-tone average (FFPTA) at 0.5, 1, 2, and 4 kHz at a value for a threshold of >20 dB [25,26]. HFPTA were defined as a pure-tone average above 2 kHz (4 and 8 kHz) [22,27] and LFPTA at 0.5, 1, 2 kHz [24,28] at a value for a threshold of >20 dB HL. Unilateral hearing loss was diagnosed when there was normal hearing in one ear and hearing loss in the other [26].

The prevalence of hearing loss in children was estimated by dividing the number of cases by the total number of individuals. Additionally, 95% confidence intervals (95% CIs) were calculated to indicate uncertainty of estimates. A chi-square test for independence was conducted to assess the relationship between the child's hearing status and the parental questionnaire. Statistical significance was established as a $p$-value of <0.05. The analysis was performed using IBM SPSS Statistics, version 24.

## 3. Results

### *3.1. Positive Results of Hearing Screening*

Positive results of the hearing screening were obtained in 1032 out of 5029 children (i.e., 1032 children had an elevated threshold for at least one frequency). This rate was 20.5% (95% CI, 19.4–21.6%). There were 20.6% of the girls (95% CI, 19.0–22.3%) and 20.4% of the boys (95% CI, 18.9–21.9%) with a positive outcome.

### *3.2. Prevalence of Hearing Loss*

There were 581 children with hearing loss, i.e., having FFPTA HL, and/or LFPTA HL, and/or HFPTA HL in at least one ear. The estimated prevalence of HL was 11.6% (95% CI, 10.7–12.4%). The prevalence of the three types of hearing loss was estimated in all children, and in girls and boys separately, and is shown in Table 1.

**Table 1.** Prevalence of hearing loss in children aged 6–7 years of the Małopolskie Voivodeship.

| | FFPTA and/or LFPTA and/or HFPTA HL | | | | FFPTA HL | | | LFPTA HL | | | HFPTA HL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | *n* | % | 95% CI | *n* | % | 95% CI | *n* | % | 95% CI | *n* | % | 95% CI |
| Total | 5029 | **581** | **11.6** | 10.7–12.4 | **328** | **6.5** | 5.8–7.2 | **410** | **8.2** | 7.4–8.9 | **384** | **7.6** | 6.9–8.4 |
| Girls | 2281 | **257** | **11.3** | 10.0–12.6 | **163** | **7.1** | 6.1–8.2 | **200** | **8.8** | 7.6–9.9 | **157** | **6.9** | 5.8–7.9 |
| Boys | 2784 | **324** | **11.8** | 10.6–13.0 | **165** | **6.0** | 5.1–6.9 | **210** | **7.6** | 6.6–8.6 | **227** | **8.3** | 7.2–9.3 |

FFPTA, four-frequency pure-tone average; HFPTA, high-frequency pure-tone average; LFPTA, low-frequency pure-tone average; HL, hearing loss; N, study sample size; n, number of participants with positive result; CI, confidence interval.

Unilateral hearing loss was found in 388 children, 7.7% (95% CI, 7.0–8.5%), and bilateral hearing loss was found in 193 children, 3.8% (95% CI, 3.3–4.4%).

### 3.3. Questionnaire Results

The parents' answers were compared to their children's hearing status (normal hearing vs. hearing loss). It was found that parents of children with hearing loss more often suspected problems with hearing in their children (12.5%; $n = 66$) in comparison to parents of the children with normal hearing (5.6%; $n = 227$). The relationship was statistically significant, $\chi^2 = 36.74$; $p < 0.001$.

Our study also showed that, in the parents' opinion, children with hearing loss more often listened to loud music (13.8%; $n = 73$) than children with normal hearing (9.9%; $n = 401$), $\chi^2 = 7.59$; $p = 0.006$. We did not find any statistically significant relationship between the children's hearing status and tinnitus ($\chi^2 = 1.55$; $p = 0.213$), otitis media ($\chi^2 = 0.03$; $p = 0.954$), or complaining about school noise ($\chi^2 = 0.04$; $p = 0.948$). The questionnaire was completed by 4564 parents. Their answers are shown in Figure 1.

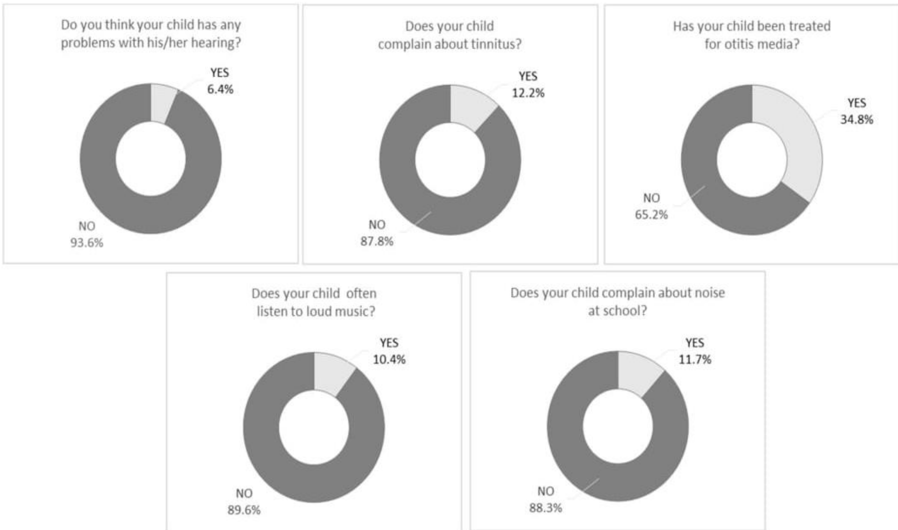


**Figure 1.** Results of the questionnaire.

## 4. Discussion

Our study revealed that 20.5% (1032 children) had a positive result. All children with a positive result were referred for a further diagnosis to an audiologist or ENT specialist. In comparison, the prevalence of hearing loss children attending rural schools and small towns throughout Poland has been estimated as 16.4% [22]. Data from pilot hearing screening projects, conducted by the Institute of Physiology and Pathology of Hearing in various African countries, have shown the prevalence of hearing loss (18–34%) [29], and in Asian countries the prevalence is 15.9–24.1% [21,26]. For comparison, the percentage of children in India with hearing loss was found to be 11.9% (more than 1 in 8 children) [30], and in Iran it was found that 10% of children aged 7–8 years old may have a hearing problem [31]. Govender and Mars [32] assessed 146 ears of learners at a school from South Africa and found that 23 ears of 20 children (16%) presented with hearing loss. The prevalence of four-frequency hearing loss in the present study was 6.5%, slightly higher than the 5.6% in the study by Skarzynski et al. [22]. Additionally, the results presented in this study are also higher than those (4.7%) obtained by Feder et al. [25]. Differences in prevalence may be due to different sample sizes, different assessment protocols [33], and by the various ages of the children. In addition, the prevalence of hearing loss in children in developed countries is typically lower than in developing countries [34]. Fortnum et al. [4] suggested that the lack of hearing screening programs, lack of education about hearing disorders, and limited access to health care in underserved areas are the reasons for these differences.

Low-frequency hearing losses were identified in 8.2% of the tested children in the Małopolskie Voivodeship. The data reported in another study conducted in Poland indicated the rate of low-frequency HL was estimated to be 6.2% [22]. For comparison, data from a study of an American population indicated a higher incidence of LFHL of 7.1% [35], and in Kyrgyzstan, results of the hearing screening indicated such an incidence in 7.2% of children [26]. In some cases, a low-frequency hearing loss may be temporary [36] and, depending on the specifics of the individual case, pharmacological or surgical intervention may be effective. The most common reasons for this kind of hearing loss are cerumen, perforation of the ear drum, tympanosclerosis, and otitis media with effusion [37]. These conditions make the child more tired in the classroom because of the increased effort needed to listen. The child may have difficulty with speech understanding in certain situations, such as understanding faint or distant speech, and can seem inattentive or distracted in the classroom [38].

High-frequency hearing losses were identified in 7.6% of the tested children in the Małopolskie Voivodeship. Our result is in line with results reported in the study conducted by Johnson et al. [27] on 2867 children in the United States which also found a 7.6% rate of HFHL. Causes of high-frequency hearing loss in children can be noise, diseases, ototoxicity, infections, or it may also be caused by genetic factors [39]. Children with HFHL may appear inattentive or distractible due to difficulties understanding speech in the noise. Recess can be very noisy, which can lead to social problems if a child is unable to hear or misinterprets information during those situations. In HFHL, speech disorders and articulation problems can arise. It is important that children with HFHL should be permanently supported in school and in their home environment [40].

Our findings showed that unilateral hearing loss (UHL) was more frequent (7.7%), than bilateral hearing loss (BHL) (3.8%), which is in line with results reported by a previous study in Poland [22]. In the USA, 3–6% of school aged children have some degree of UHL [41]. Binaural hearing offers the listener several important advantages over monophonic hearing. It has been established that binaural hearing provides better speech perception, better sound localization, increased loudness perception through binaural summation, and an overall improvement in hearing in both noisy and quiet environments [42].

Results of the hearing screening obtained due to audiometric testing were supplemented with information from the questionnaire completed by parents. We found that 6.4% of the parents suspected some problems with their child's hearing. This figure was not high, and in fact it was lower than the estimated prevalence of hearing loss in the children. Moreover, the parents' opinions were not accurate. Admittedly, in the group of hearing loss, parents suspected that there was a problem with their child's hearing (12.5%) significantly more often than in the group with normal hearing (5.6%); however, parental perception was still not appropriate. These results are in line with other researchers' findings [43–45] and has shown that parents have low levels of sensitivity to hearing problems in their children. However, the reason for this remains an open question. One hypothesis may be a lack of knowledge about hearing disorders and their associated consequences. It is also likely to be due to objective difficulties: identifying mild or single-sided hearing impairment is a challenging task for parents who have neither the expertise nor the precise instruments to detect hearing impairment. Psychological factors may also be important, for example, parents want to have a healthy child and therefore tend to underestimate any worrisome symptoms. Further research is needed to better understand this phenomenon. However, the practical conclusion of our study is that there is a great need to educate parents about the symptoms of hearing disorders and early detection.

Our study revealed that 12.2% of the parents indicated that their children have tinnitus. In the recent systematic review undertaken by Rosing et al. [46] it was stated that the estimated prevalence of tinnitus was from 4.7% to 46% in the general pediatric population, so the figures vary widely. Raj-Koziak et al. [47] emphasized that children rarely complain spontaneously of tinnitus and their parents are unaware of the condition. Tinnitus may be an independent symptom, but also it may precede full-blown hearing loss, so attention should be paid to tinnitus during routine pediatric check-ups.

Our screened children were first-graders, and they were 6–7 years old. Even so, 10.4% of their parents reported that the children often listen to loud music. Leisure time noise and loud music are a known risk factor for noise-induced hearing loss [48–51]. Our study confirms these reports: we found that significantly more children with hearing loss were exposed to loud music (13.8%) than children with normal hearing (9.9%). It should also be noticed that school noise is a real problem for first-graders. We found that 11.7% of the parents said that their children often complained about noise at school. As was demonstrated by Jamieson et al. [52] the youngest school aged children are highly susceptible to the noise in a classroom, which has a serious negative effect on their school performance. Our study shows a need to reduce noise levels in home, recreational, and school settings.

A study conducted by Harmes et al. [53] reported that an estimated 80% of the pediatric population have at least one episode of acute otitis media (AOM), and approximately 80% to 90% will have at least one incident of otitis media with effusion (OME) before reaching school age. In the current study, 34.8% of parents indicated that their child was treated for otitis media. Although most infections are a result of bacterial invasion, AOM is a consequence of Eustachian tube dysfunction that develops from an acute viral infection of the upper respiratory paths [54]. The middle ear inflammation is one of the most common reasons for temporary hearing loss [55]. During this period, preventive measures should be taken to maximize the hearing ability of affected children at home and at school. These include advising teachers to let children sit nearer the front of the classroom, and giving advice to their parents and educators to talk to their students face to face. Parents need to understand that because their child has fluid in the middle ear, they will not hear well, and behavioral problems may be due to frustration [56]. Therefore, an important task is to find the best ways to educate parents and teachers about the symptoms of hearing impairment in their children [17].

This study has revealed that hearing problems are common among first-grade students at primary schools in rural areas. There are many factors that prevent children from receiving medical care. Such obstacles involve a lack of available transportation to medical centers, the parents' inability to both take time off from their jobs, and the family's lack of financial resources. Thus, there is a need to consider whether participation in hearing screening for first-graders should be mandatory, or at least strongly recommended by central or local education authorities. The first step is to appoint a project coordinator at a a local authorites -level. It should be a local person who can collaborate with the community and coordinate information, resources, and program services. For large schools it would also be useful to establish a school coordinator (e.g., school nurse, speech pathologist, school counselor) who is able to get in touch with children and their parents.

Inexpensive hearing screening examinations could improve the hearing health of children from rural areas. With appropriate screening equipment and protocols, and in close collaboration with well-trained personnel at the school (for example, school nurses), it is feasible to conduct hearing screening among school aged children. The proposed protocol and the Sensory Organs Examination Platform used in the current study are cost-effective and safe tools and appear to be a successful method for identifying children with postnatal hearing disorders, allowing the provision of early intervention services in a timely manner.

*Limitations*

This was a cross-sectional study; therefore, it was not feasible to distinguish between congenital and acquired HL to identify if any of the cases had developed or progressed to HL. A prospective study would be needed to establish this, but such a study would be difficult due to the technical and infrastructure difficulties. This project would require repeated hearing tests for toddlers, and preschool children to identify those children who acquire losses (Wake et al., 2006). Moreover, methods used in the program did not differentiate between permanent and periodic hearing disorders. In addition, future research should consider a teacher questionnaire regarding noticing the prevalence of hearing problems among students.

## 5. Conclusions

Routine hearing screening among school aged children is still not part of public health policy in Poland. Hearing screening is an important element of health education and should be aimed not only at children, but also at parents and teachers. There is still a need to improve early detection of hearing impairment in children starting their school education. It is recommended that conditions for screening school aged children be established in terms of study population, methodology, criteria used to determine which children should be referred, and the staff and equipment needed.

**Author Contributions:** Conceptualization, P.H.S., P.H., M.B.S., W.S., E.G., N.C.; methodology, W.S., E.G., N.C.; formal analysis, E.G.; data curation: W.S., E.G.; writing—original draft preparation, W.S., E.G., M.M.; project administration, P.H.S., N.C.; funding acquisition, M.B.S., P.H.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the System of Integrated Communication Operation—"SZOK", concerning the maintenance of scientific and research apparatus/research stations, subsidized on the basis of decision number 8/E-523/SPUB-I/SN/2020 by the Ministry of Science and Higher Education.

**Institutional Review Board Statement:** The study was approved by the Ethics Committee of the Institute of Physiology and Pathology of Hearing (KB.IFPS:27/5/2018) and conforms to the Declaration of Helsinki.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study. Prior to testing, the child's parents or legal guardian were informed of the testing procedures and signed a written consent form before the child entered the study.

**Data Availability Statement:** Data available upon request.

**Acknowledgments:** We acknowledge Andrew Bell for proofreading the manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

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LSHSS

Research Article

# Organizational Aspects and Outcomes of a Hearing Screening Program Among First-Grade Children in the Mazovian Region of Poland

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**Purpose:** The purpose of this study is to describe and assess a hearing screening program of first-grade children in Poland. The program aimed to detect hearing disorders and increase awareness among parents of hearing problems.
**Method:** A hearing screening program was conducted in all elementary schools of the biggest region in Poland. A total of 34,618 first-graders were screened. The hearing screening protocol included video otoscopy and pure-tone audiometry. The program also included an information campaign directed to the local community and educational meetings between parents and medical staff.
**Results:** The estimated prevalence of hearing loss was 11%. Unilateral hearing loss was more common than bilateral hearing loss. Mild hearing loss was more frequent than moderate (or worse) hearing loss. In otoscopy, the most common positive result was otitis media with effusion. Parents and medical staff took part in 1,608 educational meetings, broadening the parents' knowledge of how to care for hearing.
**Conclusions:** A hearing screening program not only provides data on the prevalence of childhood hearing problems but is also an avenue for providing the local community with valuable knowledge about how to care for hearing. This study demonstrated the importance for systematic monitoring of children's hearing status and of increasing awareness among parents and teachers of the significance of hearing loss. The hearing screening of children starting school should become a standard part of school health care programs.

When undertaken in childhood, prevention and early clinical intervention programs offer the opportunity to improve children's health. Arguably, they provide net greater benefits than what might be derived from later interventions needed to restore hearing in adulthood. In 2019, the World Health Organization (2019) estimated that around 34 million children worldwide had hearing disorders, and in the developing world in particular, hearing loss is a significant health problem among school children (Olusanya & Adeosun, 2004). Monitoring auditory function in childhood is essential because it can forestall the possible negative consequences caused by acute or chronic ear disease, since hearing loss can have an impact on a child's social and emotional development and academic performance (Raj-Koziak et al., 2019; Warner-Czyz et al., 2015).

A range of research findings show how important it is to identify children with hearing disorders and implement appropriate treatment and rehabilitation early on (Olusanya, 2011). Newborn hearing screening, which is presently undertaken in many countries, makes it possible to identify children with congenital hearing loss at birth, although other hearing impairments may not then be evident or may be acquired later on in childhood (Włodarczyk et al., 2019). Hearing screening of school-age children should be the prime tool for identifying hearing impairment that was not identified at birth or which developed later. Without mandatory routine hearing screening programs in schools, students with acquired hearing disorders may not be identified. However, in many countries, there is a lack of diagnostic follow-up,

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Editor-in-Chief: Holly L. Storkel
Editor: Dawna E. Lewis
Received June 26, 2020
Revision received December 7, 2020
Accepted March 12, 2021
https://doi.org/10.1044/2021_LSHSS-20-00083

*Disclosure: The authors have declared that no competing interests existed at the time of publication.*

making continuous care difficult (Govender et al., 2015). The reasons for this are multifaceted: Among them is a lack of awareness from parents, school authorities, and health care providers about the adverse effects of even mild hearing loss. In addition, prevention is still not considered an urgent matter, especially in the health policies of low-income countries. In Poland, a routine newborn screening program exists, but there is no mandatory follow-up of school-age children (H. Skarżyński et al., 2019). In India and Kyrgyzstan, there is no routine hearing screening test for children (Ramkumar, 2017; P. H. Skarżyński, 2020). In Brazil and Kenya, such tests are not yet routine in most schools (Shinn et al., 2019; Tamanini et al., 2015). In developing countries, the high cost of equipment, the poor availability of hearing services, long distances, and a shortage of professionals inevitably lead to shortfalls in hearing health care (Sandström et al., 2020). A major factor is a basic lack of funding for health programs (Thomas et al., 2014). Some recommendations have already been framed that children under 18 years of age should receive hearing screening to detect congenital and/or acquired hearing impairments that could well interfere with health, development, communication, or educational achievements (Jedrzejczak et al., 2020; Swanepoel et al., 2009). In Turkey, the Ministry of Health instituted a nationwide screening program for first-grade students in 2015 (Kaplama & Ak, 2020). Hearing screening is a mandated school health service in the United States, and it is performed when the child first enters school, or as soon as practicable thereafter, and at regular intervals specified by the district governing body (American Speech-Language-Hearing Association, 2020; Dodd-Murphy et al., 2014).

School screening programs can improve overall educational outcomes and reduce the unwanted consequences of a late diagnosis of hearing impairment. They are an essential public health service that improves equity, a factor underpinning a number of initiatives for reducing the global burden of disease (Cloete et al., 2015). In Poland, the Institute of Physiology and Pathology of Hearing has prioritized child care, especially screening tests, in line with the "EU Council Conclusions on Early Detection and Treatment of Communication Disorders in Children, Including the Use of eHealth Tools and Innovative Solutions" (H. Skarżyński & Piotrowska, 2012a, 2012b). One effort to reach this target was the implementation in 2017–2018 and 2018–2019 of a Program of Hearing Screening for First Grade Pupils in Primary Schools in the Mazovian Region.

## *Organization of the Hearing Screening Program*

The 2-year program consisted of 41 projects conducted in 37 districts and four towns in the Mazovian region. Only first-grade primary school students were included. Kindergarten is not compulsory in Poland. That is why in the study, we included pupils of the first grade of primary school, which is the first stage of obligatory education for all children. The main goal was to increase early detection and assess the incidence of hearing disorders in first graders from the region. The whole program was based on four main modules: an information campaign, educational meetings for parent/caregivers, seminars for local medical staff, and hearing screening examinations.

### Information Campaign

The goal of the information campaign was to reach out to the target population (i.e., parents and caregivers of first graders), achieve a high attendance, and encourage active participation. Residents of the Mazovian region were informed about the program through local and regional media. Local media provided information about how to join the program, and highlighted its purpose and importance. In addition, posters and leaflets were distributed and letters were sent to local authorities. The letters contained basic information about the program and also emphasized the importance of hearing screening for preventing future hearing loss among children. Information packs together with a letter of invitation were sent to each school and distributed to parents of all first-grade children.

### Educational Meetings for Parents

Educational meetings for parents or caregivers were given in the schools and were led by an ear, nose, and throat (ENT) specialist or audiologist. The goals were to broaden the parents' knowledge about hearing, raise awareness of the importance of looking after children's hearing, and highlight the impact of poor hearing on school achievements. The meetings emphasized the important role that hearing plays in learning, and described types of hearing disorders and methods of overcoming them. In addition, the general principles of how to prevent hearing disorders were given, and all attendees were given educational materials. An educational brochure, addressed to parents and children, gave specific recommendations for diagnosis, treatment, and rehabilitation of hearing disorders, as well as guidelines for preventing hearing loss, in particular, avoiding loud noises whatever the source.

Medical personnel (licensed and certified audiologists) checked with the parents that they had a full set of information, explained the consent form and all the hearing screening procedures, and answered any questions. It was emphasized that participation was voluntary and consent for the child's participation could be withdrawn at any time without penalty or affecting the quality or quantity of the child's future medical care. The consent form was signed and dated by the parent or legal guardian, as well as the researcher, before the child entered the study.

The professionals who led the educational meetings for parents were from the Institute of Physiology and Pathology of Hearing. All of them had received the same training on how to educate parents and caregivers of first-grade students. The educational materials and meeting agendas covered how the hearing screening was done, the incidence of hearing impairment in children, warning signs of possible hearing loss, and general principles for reducing the risk of hearing impairment. The educational curriculum was different for parents/caregivers and for medical staff.

Three months after the end of the entire screening program, computer-assisted telephone interviewing was conducted among the parents. The interviewer called randomly selected parents and asked questions about the program, seeking knowledge about hearing care acquired from the educational meetings. The questions were:

- Have you gained or expanded your knowledge of how to care for hearing due to participation in the meeting?
- Do you use knowledge of how to care for hearing in everyday life?
- How do you use the knowledge of how to care for hearing in everyday life?

If the interviewee answered "no" to the second question, then the last question was omitted.

### Educational Events for Medical Staff

The fourth module of the program comprised educational meetings (seminars) for medical staff from the Mazovian region. Invitations were sent to ambulatory care services and other health care facilities, offering free seminars for primary care physicians and nurses. The seminars were led by experts and medical specialists: an ENT specialist, audiologist, and speech therapist. The goal was to improve the skills and competencies of local medical staff in the early detection of hearing impairment in young patients. The seminars were held in the Institute of Physiology and Pathology of Hearing in Kajetany. If any of the medical staff was unable to get to the seminars, access to livestreaming was available.

### Hearing Screening Examination

The basic formal criterion for including a child in the program was for them to be a first-grade student at a primary school in the Mazovian region in the school years 2017–2018 or 2018–2019. The inclusion criteria for participation in the program was agreement of the school management, the parent's/guardian's consent for the child's participation, and the ability of the child to have the test done on the set date. Carrying out screening at the school during lessons, or at another agreed place and time, ensured good examination conditions and high attendance. Hearing screenings were performed by 43 specialists from the Institute of Physiology and Pathology of Hearing over the 2 years, all of whom underwent the same training. The screening assessment consisted of video otoscopy and pure-tone audiometry.

Video otoscopy was done to identify any abnormalities in the external auditory canal, tympanic membrane, or middle ear that might affect the results of pure-tone audiometry and that may require a medical referral. This procedure was performed by an ENT specialist.

Screening pure-tone audiometry was performed using the Sensory Organs Examination Platform (P. H. Skarżyński et al., 2016), which was developed by the Institute of Physiology and Pathology of Hearing and the Institute of Sensory Organs. The examination was conducted by an audiologist in quiet classrooms or other rooms adapted for the purpose. The platform is equipped with Sennheiser HDA200 headphones, which provide effective acoustic isolation of the ear from background noise (based on Peltor ear defenders; Margolis & Madsen, 2015). However, in this study, it was not possible to measure ambient noise levels in the school. The school principal was asked to nominate the quietest room in the school, where the technician conducted the screening. The platform allows the performance of air-conduction audiometry tests for each ear separately over frequencies of 500, 1000, 2000, 4000, and 8000 Hz, with the option of testing 3000 and 6000 Hz in specific cases. The Hughson–Westlake procedure of threshold measurement was used, that is, two out of three responses at threshold were required (Yantis et al., 2002), and steps of 5 dB were used. In line with criteria used in other mass hearing tests (Feder et al., 2017; H. Skarżyński et al., 2019; Su & Chan, 2017), an audiometric test was considered abnormal (positive) if the hearing threshold was above 20 dB HL at one or more frequencies in at least one ear. The results of audiometric testing were automatically collected in the "SZOK" central database (P. H. Skarżyński et al., 2016), with hearing levels and otoscopy outcomes transmitted to a database at the Institute of Physiology and Pathology of Hearing in Warsaw. There, analyses can be quickly performed and the results evaluated by ENT specialists. Parents of children with positive results of hearing screening were told that their child needed to be referred for specialist examination. Early specialist diagnosis can lead to appropriate rehabilitation and thus minimize or eliminate negative impacts on the child's cognitive, language, social, emotional, and communication skills.

## Materials and Method

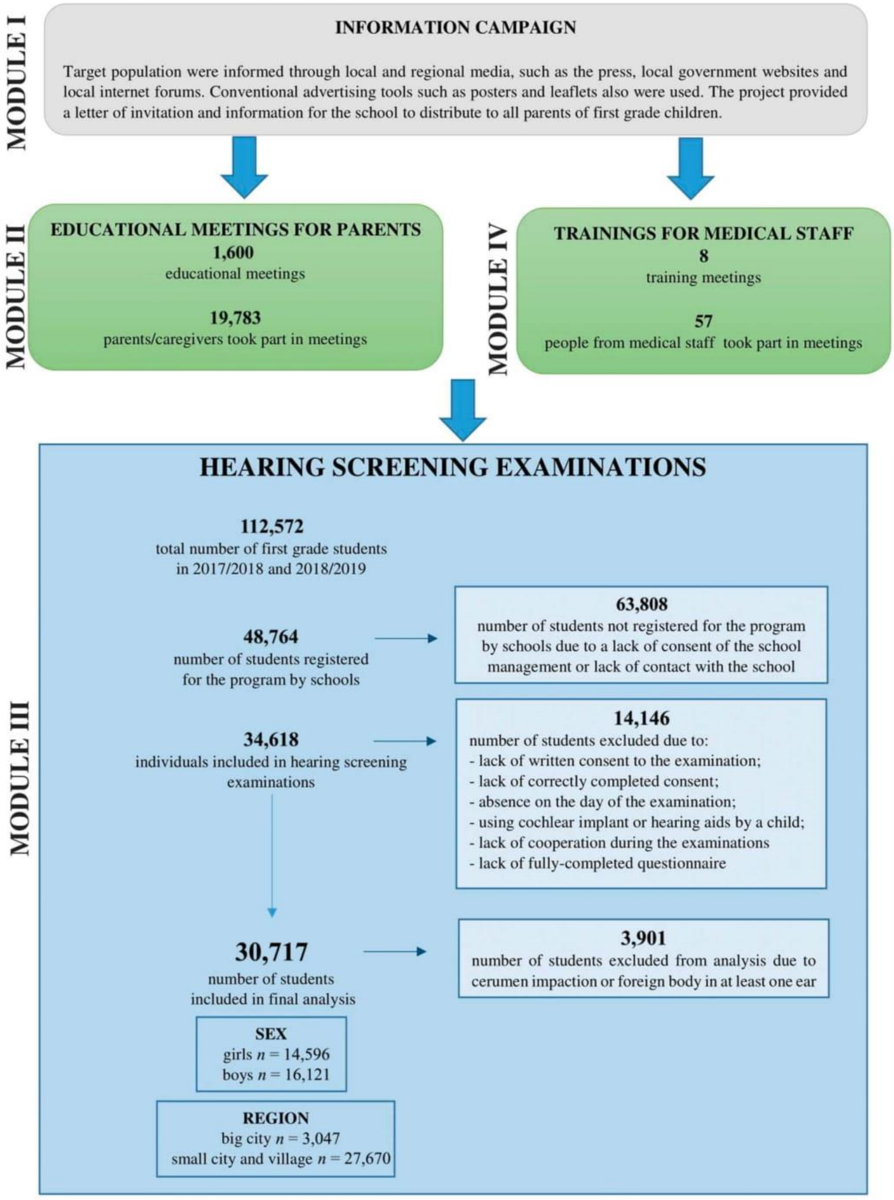
### *Participants*

Consecutive exclusions from the initial study sample and the stages of data collection are shown in Figure 1. A total of 30,717 children were screened for hearing impairment: 14,596 girls and 16,121 boys. All children were first-graders aged 6–8 years.

### *Statistical Analysis*

A positive (i.e., refer) test result was taken to be an air-conduction threshold value higher than 20 dB HL at one or more frequencies in at least one ear (Niskar et al., 1998; H. Skarżyński et al., 2019). Data on abnormal audiometric patterns was assigned to three categories: pure-tone average (PTA) of 0.5, 1, 2, and 4 kHz (Bess et al., 1998; Feder et al., 2017; Johnson et al., 2016); PTA of 0.5, 1, and 2 kHz (Feder et al., 2017; Su & Chan, 2017); and PTA of 4 and 8 kHz (Aazh et al., 2016; Bess et al., 1998). Averaging of thresholds was calculated per individual ear. The prevalence of abnormalities in otoscopy, positive hearing screening outcomes, and hearing loss were estimated as percentages by dividing the number of outcome events by the total number of individuals. Precision of estimated values was provided as standard errors and 95% confidence intervals (CIs). Odds ratios (*OR*s) were calculated to enable comparisons between groups. Statistical analysis was performed using SPSS IBM

**Figure 1.** Consecutive exclusions from initial study sample and stages of data collection.




Statistics v. 24 and MedCalc. A $p$ value below .05 was considered statistically significant.

## Results

### *Results of Educational Meetings for Parents and Medical Staff*

During the 2-year program, 19,783 parents of first-grade students took part in 1,600 educational meetings. Three months after the end of the program, the parents answered questions about their knowledge of hearing care.

In an answer to the first question, *Have you gained or expanded your knowledge of how to care for hearing due to participation in the meeting?,* 78.3% of the parents said *yes*, 1.1% said *no*, and 20.6% said *I don't know/difficult to say.* In answer to the second question, *Do you use the knowledge of how to care for hearing in everyday life?,* 67.4% of parents said *yes*, 2.2.% *no*, and 30.4% said *I don't know/difficult to* *say*. In an answer to the third question, *How do you use the knowledge of how to care for hearing in everyday life?* (a multiple-choice question), 75.8% responded with *I am aware that hearing tests need to be repeated in the future*, 38.7% responded with *I share information with family and friends*, 22.6% responded with *I listen to loud music less often*, and 6.5% with *In a different way* (e.g., avoiding loud places, stop cleaning ears with cotton buds).

During the program, eight seminars for local medical staff were organized. There were 57 primary care physicians and nurses who took part.

## Results of Video Otoscopy

Otoscopy was carried out on 34,618 children. The ear canal was completely blocked by earwax or foreign body in 3,901 children, and they were excluded from further analysis (see Table 1). According to Polish regulations, any medical procedure (including removal of ear wax) can only be performed in a medical facility. The specific findings of otoscopy in the remaining 30,717 children are listed in Figure 2.

ENT specialists performing video otoscopy observed the following abnormalities: changes in the tympanic membrane (including hyperemia, thinning, retraction, or scarring of the tympanic membrane, fluid behind the eardrum), narrow auditory meatuses, exostoses, skin lesions in the external auditory meatuses, angiomas, and suspected damage to the ossicles. The outcomes of this study showed that the most common abnormalities under otoscopy were otitis media with effusion, retraction pockets, and tympanosclerosis. Based on the otoscopy findings, the children were divided into two groups. The first group were 23,013 children with normal results of otoscopy in both ears: The tympanic membranes were normal, and there was only little occlusion by cerumen (the presence of bone growths was also allowed if they did not block the ear canal). The second group consisted of 7,704 children with abnormalities in otoscopy (in one or both ears).

The prevalence of abnormalities in otoscopy in the different groups is set out in Figure 1. Overall, there was abnormal otoscopy in 25.1% and was slightly higher in girls than in boys ($OR$ = 1.11; 95% CI [1.06–1.17]; $Z$ = 4.04; $p$ < .001). Abnormalities in otoscopy were found in 26.2%

**Table 1.** Abnormalities in otoscopy.

| Variable | *N* | *n* | % | *SE* | 95% CI |
|---|---|---|---|---|---|
| Total | 30,717 | 7,704 | 25.1 | 0.247 | 24.6–25.6 |
| Sex | | | | | |
| Girls | 14,596 | 3,814 | 26.1 | 0.364 | 25.4–26.8 |
| #Boys | 16,121 | 3,890 | 24.1 | 0.337 | 23.5–24.8 |
| Place of residence | | | | | |
| #Large towns | 3,047 | 465 | 15.3 | 0.651 | 14.0–16.5 |
| Small towns and rural areas | 27,670 | 7,239 | 26.2 | 0.264 | 25.6–26.7 |

*Note.* *N* = study sample size; *n* = number of participants with abnormalities in otoscopy; *SE* = standard error; CI = confidence interval; # = reference category.

of children living in small towns and villages and in 15.3% of children living in large towns, the difference being statistically significant ($OR$ = 1.97; 95% CI [1.78–2.18]; $Z$ = 12.96; $p$ < .001).

## Results of Hearing Screening

A total of 30,717 children were screened for hearing impairment, and their results are given in Table 2. The rate of positive (failed) results was 19.2%, according to hearing threshold above 20 dB HL at one or more frequencies in at least one ear. It was similar in boys and girls ($OR$ = 1.04; 95% CI [0.99–1.11]; $Z$ = 1.48; $p$ = .139) and did not differ significantly between children living in large cities and children living in small cities or villages ($OR$ = 1.08; 95% CI [0.98–1.19]; $Z$ = 1.50; $p$ = .135). The rate of positive results in children with abnormalities in otoscopy was 26.9%, which was significantly higher than in children with normal otoscopy findings, 16.6% ($OR$ = 1.85; 95% CI [1.74–1.97]; $Z$ = 19.74; $p$ < .001).

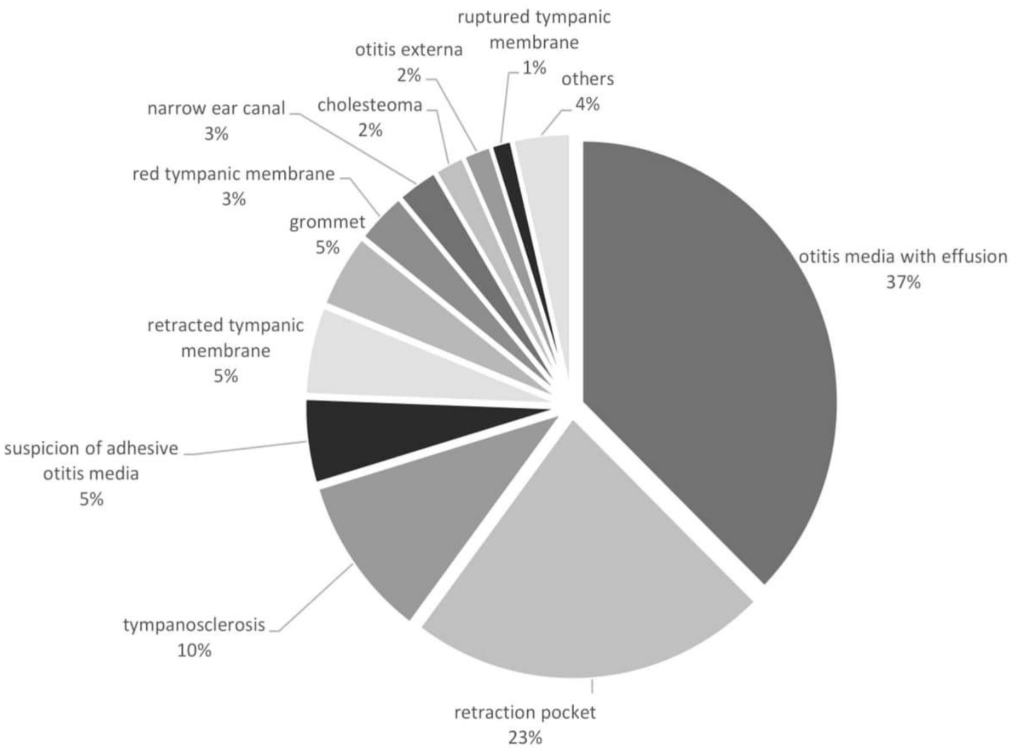
The results in terms of prevalence of hearing loss are given in Table 3. Hearing loss was defined as a PTA higher than 20 dB in at least one of the following PTAs: four-frequency PTA, high-frequency PTA, and low-frequency PTA. The overall prevalence of hearing loss was estimated to be 11%. It was similar in boys and girls ($OR$ = 1.02; 95% CI [0.95–1.10]; $Z$ = 0.61; $p$ = .545) and in children living in large towns or in small towns or villages ($OR$ = 1.08; 95% CI [0.95–1.22]; $Z$ = 1.22; $p$ = .224). The prevalence of hearing loss in children with abnormalities in otoscopy was 17.8%, and it was significantly higher than in children with normal otoscopy findings, 8.7% ($OR$ = 2.29; 95% CI [2.12–2.46]; $Z$ = 21.84; $p$ < .001).

The prevalence of four-frequency hearing loss was 6.8%. It was slightly higher in girls than in boys ($OR$ = 1.10; 95% CI [1.01–1.20]; $Z$ = 2.09; $p$ = .037) and similar in children living in large towns or in small towns or villages ($OR$ = 1.12; 95% CI [0.96–1.30]; $Z$ = 1.40; $p$ = .162). Among participants with abnormalities in otoscopy, it was significantly higher than in participants with normal otoscopy findings ($OR$ = 2.53; 95% CI [2.31–2.77]; $Z$ = 20.15; $p$ < .001).

The prevalence of low-frequency hearing loss (LFHL) was 8.0%. It was slightly higher in girls than in boys ($OR$ = 1.22; 95% CI [1.12–1.32]; $Z$ = 4.69; $p$ < .001) and was similar in children living in large towns and in small towns or villages ($OR$ = 1.14; 95% CI [0.98–1.31]; $Z$ = 1.74; $p$ = .081). Again, a significant difference was observed between children with abnormalities in otoscopy and children with normal otoscopy findings ($OR$ = 2.38; 95% CI [2.19–2.59]; $Z$ = 20.04; $p$ < .001).

The prevalence of high-frequency hearing loss was 7.8%. This time it was slightly lower in girls than in boys ($OR$ = 0.84; 95% CI [0.78–0.92]; $Z$ = 3.94; $p$ < .001), but still similar in children living in large towns and in small towns or villages ($OR$ = 1.13; 95% CI [0.98–1.31]; $Z$ = 1.67; $p$ = .095). The otoscopy finding again differed significantly ($OR$ = 2.57; 95% CI [2.36–2.80]; $Z$ = 21.67; $p$ < .001).

Figure 2. Abnormal results of otoscopy.




Hearing losses were divided into unilateral or bilateral and into mild or moderate or worse. The findings are presented in Table 4.

Mild hearing loss was found in 9.7% of children, while the prevalence of moderate or worse hearing loss was lower, only 1.3% (95% CI [1.2%–1.4%]). For all PTA categories, mild hearing loss was observed more frequently than moderate or worse.

Unilateral hearing loss (UHL) was found in 7.5% of children, while bilateral hearing loss (BHL) was found in 3.4% of children (95% CI [3.2%–3.6%]). Hearing loss in one ear was more common than in both ears for all PTA categories.

## Discussion

The prevalence and magnitude of hearing impairment among school-age children is a health issue that has been widely reported (Olusanya et al., 2011; H. Skarżyński et al., 2019). The introduction of universal newborn hearing screening programs has meant that the vast majority of children born with hearing loss are now identified. However, newborn screening does not detect hearing disorders that occur later in childhood (Collins et al., 2019; H. Skarżyński & Piotrowska, 2012b). The findings of Fortnum et al. (2001) indicate that the prevalence of permanent bilateral moderate or greater hearing impairment increases through the first decade of childhood. The ability to hear is essential, particularly during a child's primary school education. Listening skills are important when learning to read and write, and also have an impact on the development of social skills (Schick et al., 2013). Hearing disorders are amenable to intervention, and therefore, it is valuable to have a screening program in place when the child begins school (Kuppler et al., 2013). School hearing screening programs represent a unique opportunity to reduce the health and economic burden of childhood hearing loss. Without screening between the newborn period and school entry, identification of hearing impairment in children is only achieved if there is parental and professional awareness. Thus, the screening program discussed here should improve the identification rate of children starting school who have a previously unrecognized hearing disorder (Śliwa et al., 2011).

The goal of the information campaign was not fully reached. Although numerous avenues were used (regional media, posters, leaflets, local authorities, schools), we did not achieve high attendance. Of the 112,572 first-grade students in the Mazovian region, only 43.3% were registered for the program by their schools. The barrier appeared to be school authorities, who, for various reasons, failed to join up to the hearing screening program. Initially, some of them were afraid of the cost, but in the information campaign, it was clearly stated that the hearing screening would

**Table 2.** Rate of positive (failed) hearing screening outcomes.

| Variable | *N* | *n* | % | *SE* | 95% CI |
|---|---|---|---|---|---|
| Total | 30,717 | 5,886 | 19.2 | 0.225 | 18.7–19.6 |
| Sex | | | | | |
| #Girls | 14,596 | 2,746 | 18.8 | 0.323 | 18.2–19.4 |
| Boys | 16,121 | 3,140 | 19.5 | 0.312 | 18.9–20.1 |
| Place of residence | | | | | |
| #Large towns | 3,047 | 553 | 18.1 | 0.698 | 16.8–19.5 |
| Small towns and rural areas | 27,670 | 5,333 | 19.3 | 0,237 | 16.8–19.7 |
| Otoscopy | | | | | |
| #Normal | 23,013 | 3,814 | 16.6 | 0.245 | 16.1–17.1 |
| Abnormal | 7,704 | 2,072 | 26.9 | 0.505 | 25.9–27.9 |

*Note.* *N* = study sample size; *n* = number of participants with positive result; *SE* = standard error; CI = confidence interval; # = reference category.

be free, so it was unlikely that cost was the factor limiting attendance. We think the main reason was organizational (i.e., the need to access a quiet classroom for hearing testing, meetings with parents in the afternoon, and difficulty contacting small schools in remote rural areas).

To reduce the above problems, we propose two possible solutions. The first is to appoint a project coordinator at a district level. It should be a local person who can collaborate with the community and coordinate information, resources, and program services. For large schools, it would also be useful to establish a school coordinator (e.g., school nurse, speech pathologist, school counselor) who can get in touch with children and their parents. The second proposed solution is to include hearing screening in other health programs instituted by, or at least recommended by, central or local education authorities. Presently, two such programs concerned with promoting healthy eating are already carried out in Polish schools at the national level. Moreover, at a regional level, there are also various school health programs concerned with hearing (P. H. Skarżyński et al., 2011; Sulkowski et al., 2018). It might be worthwhile considering whether participation in hearing screening for first graders should be mandatory, or at least strongly recommended, by education authorities.

However, it must be said that no obligation or recommendation will help if parents are not aware of the importance of good hearing for their children and lack motivation to participate in hearing screening (by attending educational meetings, giving consent for testing, encouraging their children, and making sure they get tested). Nonattendance is a significant problem and a major limitation to the effectiveness of many health programs (Baker et al., 2010; Plumb et al., 2016; Webb et al., 2004).

During this program, we found that a number of parents misunderstood what school hearing screening was about and considered it unnecessary. In Poland, universal newborn hearing screening was implemented in 2002, and so some parents might think that if their child did have a hearing impairment, it would have been diagnosed in infancy. Low awareness of the importance of a follow-up

**Table 3.** Prevalence of hearing loss.

| Variable | *N* | Hearing loss *n* | Hearing loss % | Hearing loss *SE* | Hearing loss 95% CI | FFPTA HL *n* | FFPTA HL % | FFPTA HL *SE* | FFPTA HL 95% CI | LFPTA HL *n* | LFPTA HL % | LFPTA HL *SE* | LFPTA HL 95% CI | HFPTA HL *n* | HFPTA HL % | HFPTA HL *SE* | HFPTA HL 95% CI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 30,717 | 3,366 | 11.0 | 0.178 | 10.6–11.3 | 2,102 | 6.8 | 0.144 | 6.6–7.1 | 2,447 | 8.0 | 0.154 | 7.7–8.3 | 2,383 | 7.8 | 0.153 | 7.5–8.1 |
| Sex | | | | | | | | | | | | | | | | | |
| Girls | 14,596 | 1,616 | 11.1 | 0.260 | 10.6–11.6 | 1,045 | 7.2 | 0.213 | 6.7–7.6 | 1,274 | 8.7 | 0.234 | 8.3–9.2 | 1,040 | 7.1 | 0.213 | 6.7–7.5 |
| #Boys | 16,121 | 1,750 | 10.9 | 0.245 | 10.4–11.3 | 1,057 | 6.6 | 0.195 | 6.2–6.9 | 1,173 | 7.3 | 0.205 | 6.9–7.7 | 1,343 | 8.3 | 0.218 | 7.9–8.8 |
| Place of residence | | | | | | | | | | | | | | | | | |
| #Large towns | 3,047 | 314 | 10.3 | 0.551 | 9.2–11.4 | 190 | 6.2 | 0.438 | 5.4–7.1 | 218 | 7.2 | 0.467 | 6.2–8.1 | 213 | 7.0 | 0.462 | 6.1–7.9 |
| Small towns and rural areas | 27,670 | 3,052 | 11.0 | 0.188 | 10.7–11.4 | 1,912 | 6.9 | 0.152 | 6.6–7.2 | 2,229 | 8.1 | 0.167 | 7.7–8.4 | 2,170 | 7.8 | 0.162 | 7.5–8.2 |
| Otoscopy | | | | | | | | | | | | | | | | | |
| #Normal | 23,013 | 1,993 | 8.7 | 0.185 | 8.3–9.0 | 1,177 | 5.1 | 0.145 | 4.8–5.4 | 1,411 | 6.1 | 0.158 | 5.8–6.4 | 1,332 | 5.8 | 0.154 | 5.5–6.1 |
| Abnormal | 7,704 | 1,373 | 17.8 | 0.436 | 17.0–18.7 | 925 | 12.0 | 0.370 | 11.3–12.7 | 1,036 | 13.4 | 0.389 | 12.7–14.2 | 1,051 | 13.6 | 0.391 | 12.9–14.4 |

*Note.* Hearing loss = FFPTA HL and/or LFPTA HL and/or HFPTA HL; FFPTA = four-frequency pure-tone average; HL = hearing loss; LFPTA = low-frequency pure-tone average; HFPTA = high-frequency pure-tone average; *N* = study sample size; *n* = number of participants with positive result; *SE* = standard error; CI = confidence interval; # = reference category.

**Table 4.** Degree and side of hearing loss.

| | Degree of hearing loss | | | | | | | | Side/laterality of hearing loss | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mild > 20 to 40 dB | | | | Moderate or worse > 40 dB | | | | Unilateral hearing loss | | | | Bilateral hearing loss | | | |
| | *n* | % | *SE* | 95% CI | *n* | % | *SE* | 95% CI | *n* | % | *SE* | 95% CI | *n* | % | *SE* | 95% CI |
| Hearing loss | 2,967 | 9.7 | 0.169 | 9.3–10.0 | 399 | 1.3 | 0.07 | 1.2–1.4 | 2,313 | 7.5 | 0.151 | 7.2–7.8 | 1,053 | 3.4 | 0.104 | 3.2–3.6 |
| FFPTA HL | 1,883 | 6.1 | 0.137 | 5.9–6.4 | 219 | 0.7 | 0.05 | 0.6–0.8 | 1,485 | 4.8 | 0.122 | 4.6–5.1 | 617 | 2.0 | 0.08 | 1.9–2.2 |
| LFPTA HL | 2,228 | 7.3 | 0.148 | 7.0–7.5 | 219 | 0.7 | 0.05 | 0.6–0.8 | 1,725 | 5.6 | 0.131 | 5.4–5.9 | 722 | 2.4 | 0.09 | 2.2–2.5 |
| HFPTA HL | 2,036 | 6.7 | 0.142 | 6.4–6.9 | 347 | 1.1. | 0.06 | 1.0–1.2 | 1,715 | 5.6 | 0.131 | 5.3–5.8 | 668 | 2.2 | 0.08 | 2.0–2.3 |

*Note.* *n* = number of participants with positive result; *SE* = standard error; CI = confidence interval; FFPTA = four-frequency pure-tone average; HL = hearing loss; LFPTA = low-frequency pure-tone average; HFPTA = high-frequency pure-tone average.

examination at school age might be a reason for nonparticipation in hearing screening.

Our experience was that those parents who did attend an educational meeting often agreed to their child being tested. As we found in computer-assisted telephone interviewing 3 months after the end of the program, many of them acquired or broadened their knowledge of hearing care and used it in everyday life. We also noticed that the lowest rate of consent for testing was in schools where the parents' attendance at educational meetings was low. It remains a challenge for how to provide alternative ways for communicating with parents (e.g., off-site or online) instead of through meetings held at the school.

Another problem is the general attitude toward hearing impairment. Hearing loss in children, especially if it is unilateral and mild to moderate, is not easily noticed. Vision impairment may be more easily recognized by parents due to obvious symptoms that the child can readily report, such as blurred vision, headache, or eye pain. Moreover, a child with hearing impairment can often compensate for their disability by making greater use of available visual cues. Some researchers have reported much higher uptake rates for preschool or school vision screening programs than our hearing study achieved (Bruce & Outhwaite, 2012; Toufeeq & Oram, 2014). The truth is that hearing loss is still much of a stigma (Schick et al., 2013; Shohet & Bent, 1998) and wearing a hearing prosthesis (hearing aid or implant) is less acceptable than eyeglasses (Mueller & Jorgensen, 2019). Psychological factors may therefore be important: If parents want to have a healthy child, they tend to discount any worrying symptoms or even deny that a problem exists. Such an outlook may have contributed to the low attendance rates.

To sum up, the important task is threefold: to find the best ways to involve parents in school health, educate them about the symptoms of hearing impairment in their children (and the importance of detecting it early), and inform them of what services and treatment options are available. Parents' involvement and participation is essential for the successful implementation of hearing screening in schools.

Another goal of the program was to estimate the prevalence of hearing disorders in children from the first grade in the Mazovian region. The testing included middle ear assessment by otoscopy and detection of hearing thresholds by screening pure-tone audiometry.

Impacted cerumen is a common pathology identified during school hearing programs (Brkic, 2010; Govender et al., 2015). We found impacted earwax in 11.3% of tested children. These children were excluded from further analysis and were provided with information to take home to their parents about earwax and the need to clean the ear before a proper examination can be conducted. This is a specific weakness of the hearing screening program, and this problem needs to be solved during an examination at school. In a study conducted in Bosnia and Herzegovina, cerumen impaction was twice as common as in Poland and was found in 24.4% of examined children (Brkic, 2010). In the literature, it seems that, among first-grade children, cerumen is seen in 11.9% of them, while it occurs in 14% of children in the second year of schooling (Fairey et al., 1985; Prescott & Kibel, 1991).

Otitis media is one of the most common infections among children in developed countries and may result in temporary conductive hearing loss, especially if accompanied by middle ear effusion. Otitis media can occur after viral or bacterial infections of the upper respiratory tract (Tesfa et al., 2020). High rates of prevalence of otitis media, especially with effusion, have been found to be the most common cause of hearing loss in children in a multination study conducted on 5,776 children in Germany, Italy, Spain, Sweden, and the United Kingdom (Liese et al., 2014). The incidence of acute otitis media was 256/1000 person–years in the prospective study period. The incidence was lowest in Italy (195, 95% CI [171–222]) and highest in Spain (328, 95% CI [296–363]). In the current study, otitis media with effusion was found in 37% of the children who had abnormal otoscopy.

Middle ear pathology continues to remain a concern as a common risk factor for hearing loss in the school-age population (Govender et al., 2015). In the children here with normal otoscopy, pure-tone audiometry showed increased hearing threshold in 16.6% of them (3,814/23,013). In those with abnormal otoscopy, increased hearing threshold was found in about 27% (2,072/7,704). So it is clear that increased hearing thresholds are closely related to abnormalities in otoscopy. It can be concluded that middle ear pathology remains a risk factor for hearing loss in the pediatric population (Graydon et al., 2019).

In our study, the prevalence of hearing loss was 11% and it was almost equal among boys and girls. In addition, there were no large differences between rural and urban areas. These results are comparable with hearing screening results from preschool and elementary school children (Hurley et al., 2020), where referral rates were 10.9% for distortion product otoacoustic emission and 11.4% for pure-tone audiometry and tympanometry (an overall refer rate of 11%). Pilot screening undertaken in two European countries (Moldova and Romania) gave a similar percentage of positive results as the examinations carried out in Poland (P. H. Skarżyński et al., 2014). The prevalence of four-frequency hearing loss in this study was 6.8%, slightly higher than the 5.6% of H. Skarżyński et al. (2019). Additionally, the results presented in this study are also higher than those (4.7%) obtained by Feder et al. (2017). Considering that the four frequencies (0.5, 1, 2, and 4 kHz) are necessary for proper speech perception and communication development, it is concerning that hearing disorders occurring at these frequencies affect such a high percentage of primary school children.

LFHL was detected in 8% of children in this study, again a slightly higher figure than the 6.2% found by H. Skarżyński et al. (2019). On the other hand, the outcomes of hearing screening carried out in four African countries (Cameroon, Nigeria, Rwanda, and Tanzania; P. H. Skarżyński et al., 2018) indicated an LFHL of 48.6%. The most common reasons for these kinds of hearing loss are cerumen, perforation of the ear drum, tympanosclerosis, and otitis media with effusion (Minovi & Dazert, 2014). High-frequency hearing loss was found in 7.8% of the children, which is in line with results reported in a study conducted by Johnson et al. (2016).

The hearing impairment among school-age children in the current study was predominantly mild (9.7%). In a study of Hispanic children, it was reported that mild hearing loss (16–40 dB) may affect as many as 3%–15% of primary school children (Lee et al., 1996). It should be noted that mild hearing loss is not so easy to detect because it is more associated with receptive rather than expressive linguistic skills (Thompson & Thompson, 1991). When mild hearing loss is stable, it can remain undetected, especially if it only affects a few frequencies. Increasingly, however, research interest into milder hearing losses (including unilateral loss) is growing, and Fitzpatrick et al. (2016) estimate that 10%–15% of students have the condition, producing a significant negative impact on school performance and social interaction. A study by Doković et al. (2014) confirmed that children with mild bilateral sensorineural hearing loss have poorer phonological discrimination and short-term phonological memory than children with normal hearing. Moreover, children with mild HL show depressed language levels (e.g., in morphosyntax abilities) in comparison with their peers with normal hearing (Moeller & Tomblin, 2015).

Our findings showed that UHL was more frequent (2,313/3,366; 68.7%) than BHL, which is in line with results reported by a previous study in Poland (H. Skarżyński et al., 2019). Sekhar et al. (2011) reported one-sided hearing loss in 88% (59/67) of a group of 67 children with hearing impairment in Pennsylvania. Studies conducted by Lieu et al. (2010, 2013) looked at the effect of UHL on children's speech and language scores. The study involved children with UHL and compared speech and language results with their siblings. Children with unilateral hearing impairment scored worse than their siblings in language comprehension, oral expression, and an oral composite score. Another study among children with UHL was conducted by Borton et al. (2010) about quality of life. They found that children with UHL scored more poorly on all primary quality-of-life scales (total, psychosocial, and physical) than those with normal hearing or BHL. Parents' reports were similar to those of the children, except for better psychosocial functioning compared to BHL. Generally, children with UHL demonstrated lower quality-of-life scores, and over a wider range, compared to their normal-hearing peers or peers with BHL.

### *Limitations*

This was a cross-sectional study, and so it was not possible to separate congenital from acquired HL, or determine whether any cases were new or were older cases that had progressed. A prospective study would be needed to establish this, but such a study would be difficult due to technical and infrastructural difficulties. The project would require repeated hearing tests beginning with toddlers and on to preschool children to identify acquired losses. Moreover, the methods could not differentiate between permanent and periodic hearing disorders.

Since screening only has the ability to identify individuals likely to have a hearing disorder, we were only able to suggest that positive cases be referred for audiological assessment. However, in the Mazovian region, there are many specialized clinics and health centers where diagnostic tests are done, and parents could choose to go to any one of them. Thus, we were unable to track the outcomes of the referral and include results of the follow-up visit. Nevertheless, we think that follow-up visits for children with positive results should be part of any screening program. In the future, one might consider including follow-ups in hearing screening test protocols, because lack of follow-through makes appropriate care difficult (Govender et al., 2015).

## Conclusions

The outstanding value of the hearing screening program described here was that there are many important issues that need to be considered before a wide-scale screening program of detecting hearing problems in children can be implemented. With appropriate screening equipment and protocols, and in close collaboration with schools and pediatric ENT specialists, our study shows it is feasible for a medical team to conduct and monitor hearing screening among school-age children. This protocol appears to be effective in identifying cases of early hearing loss and allowing timely delivery of early intervention services. A child's maturity when starting school is a complex mix of emotional, social, intellectual, and physical factors. One important physical factor is normal hearing, since a child starting school faces many new requirements and expectations, and these are difficult to cope with when there is undetected hearing loss. We conclude that hearing screening should be a routine element of health care programs, and it should involve not only children but their parents as well.

## Ethical Standards

The study was approved by the Ethics Committee of the Institute of Physiology and Pathology of Hearing (KB. IFPS:29/8/2018) and conforms to the Declaration of Helsinki. Prior to testing, the child's parents were informed of the testing procedures and gave written consent for their children to participate.

## Acknowledgments

This research received no specific grant from any funding agency, or from any commercial or not-for-profit sector. We thank all the children and their parents for participation. We acknowledge Andrew Bell for proofreading the article.

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## Development

**Cite this article:** Skarżyński PH, Świerniak W, Gos E, Pierzyńska I, Walkowiak A, Cywka KB, Wołujewicz K, Skarżyński H. (2020) Results of hearing screening of school-age children in Bishkek, Kyrgyzstan. *Primary Health Care Research & Development* **21**(e18): 1–6. doi: 10.1017/S1463423620000183

Received: 30 September 2019
Revised: 30 March 2020
Accepted: 16 April 2020

**Key words:**
hearing loss; hearing screening; prevalence; pure-tone audiometry; school screening

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# Results of hearing screening of school-age children in Bishkek, Kyrgyzstan

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**Abstract**

*Aim:* To gauge the prevalence of hearing loss in school children in Bishkek, Kyrgyzstan, and refer pupils with positive results for further diagnostic testing. *Background:* According to WHO data, hearing disorders are common in school-age children. Screening for hearing loss is an important preventative tool, helping to avoid further complications. Expenditure that supports early child development can reduce future outlay on health care and social services; it can eliminate disability problems, education deficits, and social maladaptation in later adult life. *Methods:* Pure-tone air-conduction hearing thresholds were obtained at 0.5–8 kHz. The results of the hearing screening examination were regarded as positive if pure-tone thresholds were higher than 20 dB HL in one or both ears at one or more of the test frequencies. Data were also obtained from follow-up visits of children who failed the initial screening. *Findings:* This study included 452 children aged 7–13 years old. Based on audiograms, screening showed that 123 (27.2%) of the children had hearing impairment. The study has important implications for clinical practice and health policy. There is a need for systematic monitoring of hearing status among children of this age, and parents and educators need to be made aware of the significance of hearing loss.

## Introduction

Around 466 million people worldwide have disabling hearing disorders, and 34 million of these are children (World Health Organization, 2019). It is well known that late detection, and hence delayed therapy and rehabilitation of hearing disorders, has negative consequences in terms of language and speech development, emotional and cognitive development, and learning at all levels (Skarżyński and Ludwikowski, 2018). For these reasons, universal newborn hearing screening programs have been introduced in many countries to allow early identification of hearing loss (Fortnum *et al.*, 2001; Skarżyński *et al.*, 2014).

To devise suitable intervention strategies for a patient, an important aspect is obtaining precise objective auditory data (Ciorba *et al.*, 2013). In many countries, however, there is a lack of diagnostic follow-up, making continuous care difficult (Govender *et al.*, 2015). Although there is increasing awareness of hearing loss and its sequelae, prevention and treatment are still not regarded as urgent, especially in the lowest income countries. In India, there is no routine hearing screening test for children (Vaidyanath and Yathiraj, 2014; Ramkumar, 2017). Kanji *et al.* (2018) showed that in South Africa, there are still many barriers to efficient infant hearing screening. Shinn *et al.* (2019) reported that in rural areas of Kenya, ambient noise levels during hearing screening were so high that there were many false-positive referrals. In developing countries, the high cost of equipment, poor availability of hearing services, long distances, and shortage of professionals inevitably lead to shortfalls in hearing health care (Sandström *et al.*, 2020).

There is a significant difference in the prevalence of ear diseases between developed and developing countries (Jacob *et al.*, 1997). In both, the most frequent causes of hearing loss are conductive and treatable. According to WHO (2019), 60% of hearing loss in children is due to preventable causes. Epidemiological data from regions with low gross national income show that the prevalence of hearing impairment in children and adults is twice that as in high-income countries (Harris and Dodson, 2017). Poverty and unemployment make matters worse. We conclude that hearing screening and early intervention should be widely promoted in developing countries; such an effort should be rewarded with better educational outcomes.

In developing countries like Kyrgyzstan, hearing screening programs do not exist. Implementing them is extremely challenging due to long-standing health disparity issues. A major one is a basic lack of funding for health programs (Thomas *et al.*, 2014). This is aggravated by a shortage of audiologists, lack of awareness of the benefits of hearing screening, and the unavailability of equipment such as audiometers, auditory brainstem response machines, and otoacoustic emission equipment. In this situation, a low-cost hearing screening test could be a positive first step in improving the hearing health of people from impoverished areas. Such an approach requires low-cost procedures that can be supplied to areas where technological or human resources are financially out of reach. If groups at risk of hearing disorders can be identified at the earliest possible stage, then that would help reduce health inequalities (Botasso *et al.*, 2015).

A way to solve the problem is to use teleaudiology technology to perform routine screening tests at low cost. Teleaudiology has the potential to improve health services in developing countries by connecting hearing specialists, such as audiologists or laryngologists, with hearing-impaired patients in remote locations. Without teleaudiology, these patients would face impossible geographical and economic barriers (Bush *et al.*, 2016). Services for remote areas can include hearing screening and also later follow-up care.

Generally, two methods can be used for teleaudiology: on-site and remote. There is evidence that remote hearing screening gives comparable results with on-site screening. The two methods were compared in American children. Testing was done on the same children twice: once by on-site screening and again by telemedicine. For pure-tone audiometry, no statistically significant differences were found (Lancaster *et al.*, 2008). Choi *et al.* (2007) compared on-site audiometry using a personal computer (PC)-based audiometer with remote testing over the Internet on 12 adult subjects with normal hearing. Comparison between face-to-face audiometry with a PC-based system and on a conventional audiometer showed that 96.3% of the results did not differ by more than 5 dB. Givens and Elangovan (2003) compared pure-tone air thresholds (0.25–8 kHz) determined through remote synchronous audiometry on 45 subjects. Statistically, there was no significant difference between the remote test results and the face-to-face tests. The results of the study are in line with the studies by Lancaster *et al.* (2008) and Ciccia *et al.* (2011) who reported no differences between in-person and tele-pure tone audiometry in school children. A study conducted by Śliwa *et al.* (2011) indicated that systematic hearing screening of school-age children is essential and as important as those for newborns. In this way, children with hearing disorders can be identified in a timely manner.

In this study, audiometric hearing screening was performed using the Platform for Sensory Organs Examination. This tool is based on the asynchronous telemedicine model which allows screening tests to be performed and comprehensively analyzed. The system uses the System of Integrated Communication Operations (SZOK), which has been implemented in many European, African, and Asian countries (Skarżyński *et al.*, 2014: 2016). This screening model allows tests to be conducted by a trained assistant, with the results later evaluated by an audiologist or otolaryngologist at a central location. The present study was designed to detect hearing disorders in children in Kyrgyzstan using these teleaudiology tools. Any pupils with positive results were referred for diagnostic tests.

## Methods

### Participants

The study was conducted in two public primary schools in Bishkek, Kyrgyzstan. The schools were nominated by local authorities and approval from school management was obtained. Prior to testing, the children's parents were informed of the testing procedures and signed a consent form for their children to participate in a hearing screening examination. If the parents gave written consent, their child was invited to be examined; all children willingly participated. Testing involved 452 children: 289 (63.9%) aged 7–8 years old and 163 (36.1%) aged 11–13 years.

### Audiometric measurement

Pure-tone audiometric testing was conducted using the Platform for Sensory Organs Examination. Pure-tone audiometry is the gold standard for hearing screening programs for school-age children (Honeth *et al.*, 2010; Masalski *et al.*, 2018). The platform was developed by the Institute of Sensory Organs in collaboration with the Institute Physiology and Pathology of Hearing. The system is based on a powerful central computer and many portable computers communicating with it via the Internet. Each portable device is equipped with software that allows it to perform pure-tone audiometry. The platform carries Sennheiser HDA200 headphones which provide effective acoustic isolation of the ear from background noise.

The platform allows air conduction audiometry testing to be performed for each ear separately over a frequency range of 0.5–8 kHz. It is limited to hearing thresholds below 80 dB HL. The Hughson and Westlake procedure of threshold measurement is used (i.e., two out of three responses at threshold are required; Yantis, 2002). The platform has been found to be an effective and accurate tool for testing hearing (Śliwa *et al.*, 2011) and has been validated as part of a telemedicine model (Skarzynski *et al.*, 2016). The equipment was calibrated according to PN-EN ISO 389-1:2002. Testing was performed by three experienced audiologists.

The results of audiometric hearing tests were automatically collected in a central database 'SZOK'®. The collected results were marked with a unique identifier, which is guaranteed to fully protect a subject's personal data in accordance with applicable law. Audiometry testing was conducted during school hours in a quiet room and was stopped when pupils had a break. The test environment was controlled according to PN-EN ISO 8253-1/2005.

### Analysis criteria

A positive (i.e., refer) test result was taken to be an air conduction threshold value higher than 20 dB HL at one or more frequencies in at least one ear (Clark, 1981; Bess, 1985; Niskar *et al.*, 1998). Unilateral hearing loss was recognized when there was normal hearing in one ear and hearing loss in the other ear with a threshold higher than 20 dB HL at one or more frequencies. Thresholds in both ears higher than 20 dB HL at one or more frequencies were defined as bilateral hearing loss. Each audiogram with a positive result was divided into one of three types (Skarżyński *et al.*, 2014: 2016):

- *Low-frequency hearing loss* (LFHL), in which the hearing threshold for 500 and/or 1000 Hz was above 20 dB HL, while the threshold for other frequencies did not exceed 20 dB HL.
- *High-frequency hearing loss* (HFHL), in which the hearing threshold for 4000 and/or 8000 Hz was above 20 dB HL, while the hearing threshold for other frequencies did not exceed 20 dB HL.
- *Other*: abnormal screening results in which the hearing threshold was greater than 20 dB HL at two or more frequencies.

**Table 1.** Numbers (and percent) of positive results of hearing screening

| | Number of children | Positive results | Unilateral | Bilateral |
|---|---|---|---|---|
| 7–8 years | 289 | 93 (32.2%) | 62 (66.7%) | 31 (33.3%) |
| 11–13 years | 163 | 30 (18.4%) | 18 (60.0%) | 12 (40.0%) |
| Total | 452 | 123 (27.2%) | 80 (65.0%) | 43 (35.0%) |

**Table 2.** Frequency of different types of audiograms among 166 ears with a positive hearing screening result

| | Ears with positive result | LFHL | HFHL | Other |
|---|---|---|---|---|
| 7–8 years | 124 | 6 (4.8%) | 64 (51.6%) | 54 (43.6%) |
| 11–13 years | 42 | 6 (14.3%) | 14 (33.3%) | 22 (52.4%) |
| Total | 166 | 12 (7.2%) | 78 (47.0%) | 76 (45.8%) |

LFHL = low-frequency hearing loss; HFHL = high-frequency hearing loss

### *Statistical analysis*

A chi-square test for independence was conducted to determine if there was a significant association between age and the results of hearing screening. A *z*-test for the equality of two proportions was made to compare rates of various types of hearing loss. Statistical significance was specified as a *P*-value less than 0.05. Analysis was conducted using IBM SPSS Statistics v. 24.

## Results

Positive results of hearing screening were obtained in 123 children (27.2%), while the other 329 children (72.8%) had audiometric thresholds below the 20 dB criterion. There were 80 children (65% of 123 children with positive outcome) who had unilateral impairment and 43 children (35%) who had bilateral impairment. The data divided into age groups are presented in Table 1.

There was a statistically significant difference in the frequency of positive results between the younger and older children: $\chi^2 = 9.98$; $P = 0.002$. Positive results were found more often in the younger children (32.2%) than in the older children (18.4%).

There was no statistically significant difference in the laterality of positive results between the younger and older children: $\chi^2 = 0.44$; $P = 0.505$. Positive results in one ear were more frequent than in both ears, regardless of age.

Considering ears which had hearing thresholds above the 25 dB criterion, there were 166 in total, including 78 ears with HFHL (47%), 12 ears with LFHL (7.2%), and 76 ears with other type of hearing loss (HL). The data divided into age groups are presented in Table 2.

HFHL was more frequent than LFHL both in the younger group ($P < 0.001$) and in the older group ($P = 0.041$). The rate of HFHL was significantly higher in younger children than in older children ($P = 0.040$). The rate of LFHL was significantly higher in the older children than in the younger group ($P = 0.039$). The ratios of other types of HL were similar in both age groups ($P = 0.323$).

### *Follow-up*

Parents of children with positive results of hearing screening were provided with information that the child should be referred for specialist diagnostics. Information on how many of the 123 children with positive results received follow-up testing and intervention services was not available, but we did manage to collect follow-up data from 27 children with positive results. These children came to a pediatrician or otolaryngologist in medical clinics cooperating with the hearing screening organizers.

In 21 of the 27 children with positive outcome of hearing screening, some hearing problem was found (i.e., the true positive rate was 78%). In nine cases, the ear canal was blocked with ear wax. After removing it, hearing was found normal. In five cases, otitis media was diagnosed and appropriate antibiotic treatment was implemented. Tympanoplasty was ordered in two children due to perforation of eardrum. In two children, hyperplasia of the pharyngeal tonsil was found and adenotomy was recommended. Two children had a recent infection of the respiratory system which could have affected hearing and the doctor decided to wait for a complete recovery. One child had otosclerosis which had been diagnosed earlier and was not declared by the parents before hearing screening. Hearing impairment was not confirmed in six children with positive outcome of hearing screening (i.e., there was a false-positive rate of 22% in the group of 27 children).

Three selected audiograms of children with follow-up data are presented below. The first child was diagnosed with an eardrum perforation in the left ear. The ENT specialist ordered a laboratory test to identify any bacterial infection, antibiotic drops were prescribed, and tonal audiometry was ordered. A second visit took place one month later. There was no bacterial infection in the left ear, but the eardrum was still perforated. Tympanoplasty in the left ear was ordered (Figure 1A). The second audiogram shows the audiogram of a child with earwax in both ears. There was decreased hearing in the right ear, probably because of more severe blockage in this ear. Excess wax was removed by a doctor, an audiological examination was performed, and hearing was found to be normal (Figure 1B). The third audiogram comes from a child diagnosed with chronic suppurative otitis media. It was treated with antibiotic drops. Otoscopy and tonal audiometry were performed after treatment, and hearing was found to be normal. The ENT specialist recommended monitoring and regular hearing tests (Figure 1C).

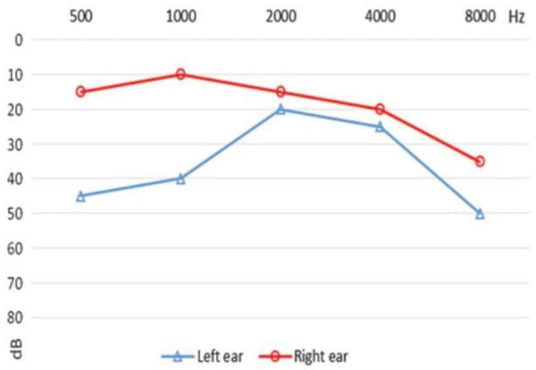


**Figure 1A.** Audiogram of the child with eardrum perforation and tympanoplasty ordered (case #1).

## Discussion

The primary purpose of this study was to investigate the rate of hearing disorders in school-age children in Bishkek and, if tested positive, refer them for detailed diagnosis. An additional goal of the

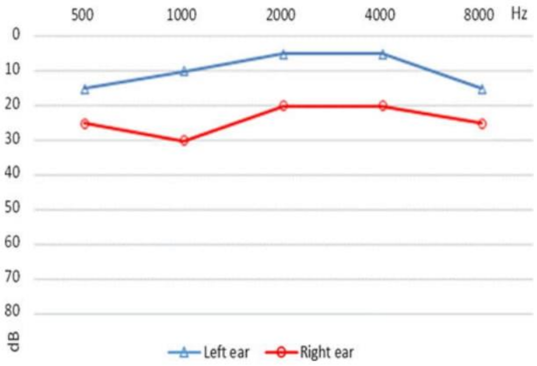


**Figure 1B.** Audiogram of the child with earwax (case #2).

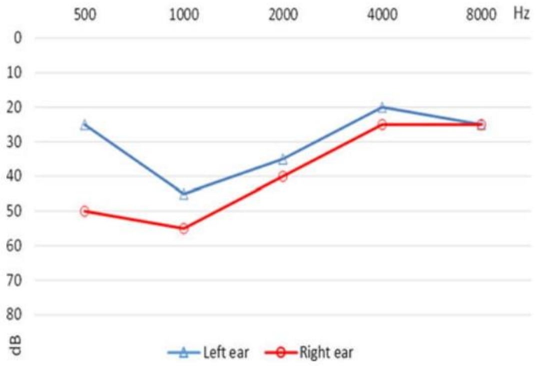


**Figure 1C.** Audiogram of the child with acute otitis media (case #3).

screening program was to alert parents and the school more generally to children's hearing problems. These activities were part of a general effort to improve the state of medical care in Kyrgyzstan using information technology. The effectiveness of using an asynchronous model of screening for hearing impairment in children from primary school was also evaluated. The telemedical model of screening was aimed at improving the hearing health services for children in Kyrgyzstan where long-distance travel to regional or city centers is often difficult and sometimes impossible.

In Kyrgyzstan, screening for newborn and school-age children is not done due to lack of equipment and qualified personnel. The limited access to specialist doctors is associated with a high percentage of people with various hearing disorders. In this study, the observed prevalence of hearing impairments was 27.2%. This figure is similar to other studies conducted in Tajikistan, where hearing impairment was found in 23.7% of the surveyed school-age children (Skarzyński *et al.*, 2016). In the study conducted by Niskar *et al.* (1998), almost 15% of children aged 6–11 years had positive screening results. Feder *et al.* (2017) found that 7.7% of Canadian children aged 6–19 had HL at one or more pure-tone frequencies. Govender and Mars (2018) assessed 146 ears and found that 23 ears of 20 children (16%) presented with hearing loss. In rural areas of Poland, the rate of positive results of hearing screening was 16.4% (Skarżyński *et al.*, 2020). The variability in prevalence may be explained by different sample numbers, different evaluation protocols (Tarczyński and Piotrowska, 2016), and by the various ages of the children. In addition, the prevalence of hearing loss in children in developed countries is typically lower than in developing countries (Mahomed-Asmail *et al.*, 2016). Fortnum *et al.* (2001) suggested that reasons for the differences include the absence of hearing screening programs, the impact of poverty and malnutrition, stigma, lack of education about hearing disorders, and limited access to health care in developing countries.

Our results indicate that 7.2% of children with positive screening results had a LFHL. Data from an American study indicate a similar incidence of LFHL – 7.1% (Bess, 1985). A higher incidence of this type of hearing disorder was reported in a Polish study (Skarżyński *et al.*, 2019), where 23% of the screened children were classified as having LFHL. In a Nigerian study (Oyewumi and Adejumo, 2011), 33.4% (167 out of 500 examined children) were found to have LFHL in their right ear and 7.8% in their left. Similar data have been reported in Tajikistan, where 34% of children were diagnosed with LFHL (Skarzyński *et al.*, 2016). In some cases, a LFHL may be temporary and, depending on the individual case, pharmacological or surgical intervention may be effective. One of the most common reasons for temporary LFHL is inflammation of the middle ear. Otitis media with effusion is one of the most common childhood diseases (Minovi and Dazert, 2014). The delayed detection of otitis media with effusion in young children is a serious matter. Another reason for temporary hearing loss is upper respiratory tract infection (URTI). Czech *et al.* (2011) observed that children suffering from URTI often have temporary conductive hearing loss. As with congenital malformations, the benefits of early intervention in children with otitis media with effusion far outweigh the cost of screening, which provides good justification for conducting them (Hunt *et al.*, 2017).

In this study, 47% of the children with positive results were diagnosed with HFHL. A similar incidence of HFHL – 43.9% – was obtained in a Polish study (Skarżyński *et al.*, 2019). In comparison, the hearing screening in Tajikistan found that the percentage of children with HFHL was 25.5% (Skarzyński *et al.*, 2016). Children with HFHL may appear normal, but they may experience difficulties in many situations. For example, they may seem distracted because of a difficulty in understanding speech in a noisy background. In HFHL, speech disorders and articulation problems can also arise. It is important that children with HFHL should be permanently supported in school and in their home environment (Stelmachowicz *et al.*, 2004).

Unilateral hearing loss (65%, 80/123) was more common than bilateral losses, in line with results reported by Skarzyński *et al.* (2019). A unilateral hearing loss can affect many areas of a child's development, can cause difficulties in sound source location, and problems with perceiving speech in background noise. In addition, there can be problems associated with loss of binaural summation and sound localization, causing delays in speech-language development and impairments to school performance (Skarżyński and Ludwikowski, 2018). On this basis, identification of hearing loss, whether unilateral or bilateral, calls for effective management so as to minimize these adverse effects (Grandpierre *et al.*, 2018).

In the current study, we were only able to collect follow-up data from 27 children who had a positive result. The low follow-up rate among students referred from the school suggests a low level of support for the program from caregivers. This could be because of lack of knowledge about hearing disorders or problems with traveling to the medical center. Engagement of parents and school personnel with the school screening program is essential if the prevalence of treatable ear diseases and associated hearing disorders in children is to be reduced.

The data from the present study suggest that it is possible to use a telemedicine model to assess the hearing status of school-age children and to provide long-distance expert assistance. It is necessary to train local medical staff to perform hearing screening. However, health care personnel involved with hearing services in less modern locations need consistent training, oversight, and feedback by experienced audiologists in order to provide quality services. Hearing screening opens up the possibility of detecting hearing problems and then directing the children to further specialist diagnostic evaluation and intervention.

## Limitation

The present study was confined to the capital city of Kyrgyzstan, and it is difficult to generalize the findings to the whole pediatric population of the country. Moreover, only air conduction thresholds were measured; there was no bone conduction, otoscopy, tympanometry, or otoacoustic emission measurements.

**Acknowledgments.** The authors thank all the children and their parents for participation. The authors acknowledge Dr Andrew Bell for proofreading the manuscript.

**Financial support.** This research received no specific grant from any funding agency, or from any commercial or not-for-profit sector.

**Conflicts of interest.** None.

**Ethical standards.** The study was approved by the Ethical Committee of the Institute of Physiology and Pathology of Hearing (KB:IFPS:26/3/2018) and conforms to the Declaration of Helsinki. Prior to testing, the children's parents were informed of the testing procedures and signed a written consent form for their children to participate in the hearing screening examination.

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# Pilot Hearing Screening of School-age Children in Lagos, Nigeria

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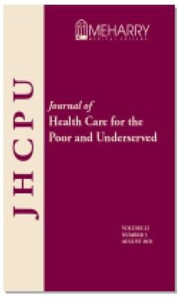
Journal of Health Care for the Poor and Underserved, Volume 32, Number 3, August 2021, pp. 1444-1460 (Article)




Published by Johns Hopkins University Press
*DOI: https://doi.org/10.1353/hpu.2021.0143*

ORIGINAL PAPER

# Pilot Hearing Screening of School-age Children in Lagos, Nigeria

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*Abstract:* **Objectives**. The aim of this pilot study is to assess the prevalence of hearing disorders in school-age children in Lagos, Nigeria. **Methods**. The study group consisted of 236 children aged 5 to 11 years old. Children were assessed by otoscopy, transiently evoked otoacoustic emissions, and pure-tone audiometry screening. **Results**. Abnormal audiograms were found in 46 (19.5%) of the tested children. Otoscopy data suggest that the most frequent hearing abnormalities were related to cerumen and otitis media. Low agreement (55%) was found between otoacoustic emissions outcomes and pure-tone audiometry data. **Conclusion**. Given the high prevalence of hearing problems in this group of primary school students, there is a strong need to monitor the hearing status of children in this geographical area.

*Key words:* Hearing screening, school-age children, hearing loss, pure tone audiometry, TEOAEs.

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 Journal of Health Care for the Poor and Underserved 32 (2021): 1444–1460.

Hearing is crucial for the development of speech, language, communication, and learning. Hearing difficulties can disrupt the emotional and social development of a child and can have a significant impact on quality of life.[1]

Ear diseases and hearing impairment in school-age children is a neglected public health problem, especially in developing countries. It is estimated that approximately two-thirds of cases of hearing impairment (among all ages) occur in developing countries. The greatest burden of hearing impairment is thought to lie in the Asia Pacific area, sub-Saharan Africa, and southern Asia.[2] The underlying reasons include: (i) no regular hearing screening program; (ii) poverty and malnutrition; and (iii) a lack of readily available health care.[3] Approximately one in 1,000 infants born in a developing country has a significant hearing deficit, and the prevalence of hearing loss increases dramatically with age. In 2013, the World Health Organization (WHO) estimated that globally the number of children younger than 15 years presenting a hearing deficit (mean hearing threshold > 40 dB HL), was approximately 32 million.[4] Data from a recent systematic review and meta-analysis showed that in children 0 to 18 years of age the prevalence of hearing loss (>15 dB HL; decibels hearing level) was estimated to be 13.1% (data from United States, Canada, Australia, the Netherlands). The authors found that from 1990 to 2010, hearing loss in children had risen substantially.[5] There is a significant difference in the prevalence of ear diseases between developed and developing countries.[6] Epidemiological data from regions with low gross national income show that the prevalence of hearing impairment in children and adults is twice that as in high-income countries.[7]

In Nigeria (Lagos), the hearing profile of school entrants was investigated by Olusanya et al.[8] There were 359 children from 76 schools, aged 4.5–10.9 years. The prevalence of hearing loss was estimated to be 13.9%. Adebola et al. carried out audiological examination among 101 pre-school children (aged 3.5–6 years) in Nigeria (Ogbomoso). The rate of failed (i.e., abnormal) results, referred for specialist diagnostics, was 21.3%.[9]

The figures show a strong need for hearing screening among not only newborns, but for children of all ages. In some countries hearing screening programs for schoolchildren have been introduced but having them is not a worldwide standard.[10]

Screening is considered the method of secondary prevention, involving the use of relatively simple and inexpensive testing procedures, for assessing large population groups in order to detect early stages of a disease.[11] Early hearing intervention is defined as "a set of services for children younger than six years who are at risk of or who currently have developmental delays or social emotional problems."[12 [p. 7]] A basic premise of early intervention is that the developmental or social/emotional problems experienced by untreated hearing-impaired children can be either prevented or resolved through special therapies that improve development.[13] Furthermore, early intervention is recommended by the fact that the first five years of life are crucial for neurological development; an intervention in this time-window may prevent and reverse childhood developmental problems. The rapid brain growth that occurs at this time is believed to be a critical period during which children are for a limited period of time neurologically able to benefit from developmental stimulation matched to their individual needs and abilities. The general idea of critical periods in human development holds that there are clearly defined times when the physiological readiness of the organism coincides with necessary, specific, external experiences.[14] Caregivers and health practitioners must particularly guard against the possibility that an undiagnosed hearing impairment might, in effect, close the window of a neurological critical period, causing a forever-missed neurological opportunity.

In many countries in Europe and in the Americas, a school-entry hearing screening occurs, as does a universal newborn hearing screening.[15] However, there are still many countries—Nigeria included—that do not have a robust newborn screening service in place.[16] Furthermore, school screening practices consist of a one- or two-stage screening prior to a referral to a center for diagnostic assessment. Usually, parents or specialists (teachers) refer children directly for assessment. Where school-entry hearing screening does not exist, this is typically the main channel by which hearing impairment is identified.[9]

A very important purpose of a successful screening is eliminating false negatives or minimization of hearing impairment. Both false negatives and minimization increase the likelihood that the identification of a hearing impairment will be delayed or never happen at all. In countries where the screening is delayed, screening errors might contribute to a heavier impact on the linguistic development of a child.[16]

Linguistic development is one of the central neurological/psychosocial developments during early childhood (and one that underlies many other cognitive developments). Undiagnosed hearing impairment can easily prevent the child from experiencing language by hearing/seeing others use it, which is necessary for learning language. Sign languages are manual languages with the grammatical breadth of other (spoken) natural languages; sign languages are accessible to hearing impaired people with normal vision and offer the opportunity for normal linguistic neurological development. However, if a hearing impairment is undiagnosed, and the child sees no sign language and hears spoken language poorly or not at all, the critical period for language development (roughly, the first five years of life) will pass and the child is likely to miss the opportunity for normal linguistic competence.[17,18]

The fact that in developing countries such as Nigeria audiological assessment of school-age children is not routine can be attributed to a shortage of audiologists, lack of awareness of hearing screening and the unavailability of audiological equipment such as audiometers, auditory brainstem response (ABR), and otoacoustic emission (OAE) devices.[19]

In developing countries such as Nigeria, general awareness of hearing disorders is not well-developed; lack of resources has led to very few hearing screening programs across the country; as we have seen, the number of Nigerian children with hearing loss is relatively high.[8,9,20] Parents and teachers often do not recognize signs of hearing loss in early childhood (*pre-lingual* hearing loss) because they misread poor communication as a sign of a general developmental delay.[20] Other children may develop hearing loss after the development of speech and language (*adventitious* or *post-lingual* hearing loss). The hearing loss of many of these children, too, may remain undetected until school begins; even if it is detected, however, some of these children may be inadequately treated (perhaps because of the low socioeconomic status of their parents or lack of skilled professionals and facilities), meaning that the loss leaves the child open to educational and social disadvantages. A major problem is that hearing loss is such a gradual, slow, and often imperceptible decline that most people are unaware it is happening. Because of the gradual nature of hearing loss, people affected by the complaint tend to believe it is not due to their ears failing.[21]

According to the guidelines of the European Scientific Consensus on Hearing (European Federation of Audiology Societies Congress, June 2011, Warsaw, Poland), the detection and treatment of communication disorders in early school-age children is of the highest social importance.[22] Since 2012, the Institute of Physiology and Pathology of Hearing in Warsaw, Poland has initiated a series of pilot programs across various countries of the world, in order to promote better awareness of the issues related to childhood hearing deficits. This paper reports the data (feasibility and performance) from a pilot hearing screening of school-age children in Nigeria.

## Methods

**Participants**. The participants were recruited from the Rose Valley School in Lagos, Nigeria between June and November 2018. Children from the age of five attend the school. It is a private and government-approved educational institution; it was nominated by local authorities and school management approved its choice. The study has been approved the Ethical Committee of the Institute of Physiology and Pathology of Hearing (KB.IFPS:26/16/2018). Prior to testing, the children's parents were informed of the testing procedures and signed a consent form for their children's participation in the hearing screening examination. If the parents gave written consent, the child was assessed audiologically. Children and their families were not compensated for their participation. The students were native speakers of English; 236 primary school children (120 females, 116 males) aged 5–11 years ($M = 7.17$; $SD = 1.63$) were tested. The subjects were sub-divided into two age groups, namely 5–7 years (132 students) and 8–11 years (104 students).

**Procedure**. All audiological tests were performed by skilled technicians from the Institute of Physiology and Pathology of Hearing in Warsaw. The screening assessment consisted of the following three steps:

(i) otoscopy: performed by a Delfino device (Inventis, Italy), to assess pathological changes in the outer and middle ear, such as excessive earwax, acute or chronic otitis media, changes due to fungal infection and morphological changes in the tympanic membrane;

(ii) transient evoked otoacoustic emissions (TEOAEs): to assess cochlear functionality. TEOAE responses were acquired with a Sentiero-Advanced device (Path Medical, Germany), using a non-linear stimulus protocol at 80 dB SPL. Scores on TEOAEs were considered normal (PASS), when the signal to noise ratio in three out of the four tested frequencies (2, 3, 4, 5 kHz) was ≥ 3 dB;

(iii) screening pure tone audiometry: This procedure was performed by the Sensory Organs Examination Platform, developed by the Institute of Physiology and Pathology of Hearing and the Institute of Sensory Organs in Warsaw, Poland (additional details on the platform are presented in the Appendix).

According to previously established criteria, an audiometric test was considered abnormal (positive), if the hearing threshold was found above 20 dB HL, in one or more frequencies, in at least one ear.[23] Hearing levels ≤ 20 dB HL, in the range 500–8000 Hz, were considered normal.

**Data collection**. According to previously established protocols[24] the data related to abnormal audiometric patterns were assigned to three categories:

- *Low frequency hearing loss* (LFHL): for cases presenting a hearing threshold at 500 and/or 1000 Hz above 20 dB HL, while the threshold for the other tested frequencies was normal.
- *High frequency hearing loss* (HFHL): for cases presenting a hearing threshold at 4000 and/or 8000 Hz above 20 dB HL, while the hearing threshold for other tested frequencies was normal.
- *Other*: cases where the hearing threshold was above 20 dB HL at two or more arbitrary frequencies.

**Statistical analyses**. A chi-square test for independence was conducted to assess gender and age effects on hearing. Contingency tables (2x2) were used to assess the sensitivity and specificity of the audiological tests. Accuracy (agreement) was calculated by dividing the number of concordant responses by the number of all responses (concordant and discordant summarized). The prevalence rate of positive hearing screening outcomes was calculated by dividing the number of positive assessments by the number of assessed individuals.

Statistical significance was established as a p-value less than .05. Analyses was conducted using IBM SPSS Statistics for Windows, version 24.[25]

## Results

Forty-six (46) students (19.5%) demonstrated abnormalities in their audiometry tests. Bilateral hearing loss was detected in 22 (9.3%) and unilateral hearing loss in 24 (10.2%) students. For the latter, seven children (3%) presented deficits in the left ear and 17 children (7.2%) in the right ear. The percentages reported are calculated considering the total number of 236 assessed students.

**Gender effects**. In terms of gender, more female students ($n$ = 28; 23.3%) showed greater hearing deficits than males ($n$ = 18; 15.5%), but the difference was not statistically significant ($\chi^2$ = 2.30; $p$ = .130). Table 1 shows the distribution of unilateral and bilateral hearing loss ($\chi^2$ = 2.35; $p$ = .309) across the two genders.

**Age effects**. In the group of younger children, hearing loss was detected in 20 (15.2%) students. In the older group the prevalence was slightly higher ($n$ = 26; 25%), but the difference was not statistically significant ($\chi^2$=3.60; $p$ = .058). In terms of unilateral or bilateral hearing loss, the two groups did not differ significantly ($\chi^2$=3.71; $p$ = .157).

**Type of hearing deficit**. The three types of abnormal audiograms (low frequency hearing loss, LFHL; high frequency hearing loss, HFHL; other) were analyzed for each ear. The majority of deficits (68 ears) were from the LFHL category. The data are summarized in Table 2.

**Results from otoscopy**. Otoscopy was conducted in all children. It was found that 112 children (47.5%) had a normal and 124 children (52.6%) had an abnormal oto-

## Table 1.

### RESULTS OF HEARING SCREENING

| | Normal Audiogram | Abnormal Result | | | Total |
|---|---|---|---|---|---|
| | | Overall | Bilateral | Unilateral | |
| Females | 92 (76.7%) | 28 (23.3%) | 13 (10.8%) | 15 (12.5%) | 120 |
| Males | 98 (84.5%) | 18 (15.5%) | 9 (7.8%) | 9 (7.8%) | 116 |
| 5–7 years old | 112 (84.8%) | 20 (15.2%) | 9 (6.8%) | 11 (8.3%) | 132 |
| 8–11 years old | 78 (75%) | 26 (25%) | 13 (12.5%) | 13 (12.5%) | 104 |
| Total | 190 (80.5%) | 46 (19.5%) | 22 (9.3%) | 24 (10.2%) | 236 |

## Table 2.

### AUDIOGRAMS DIVIDED INTO THREE TYPES OF HEARING DEFICITS

| Type Of Hearing Loss | Total Number Of Ears | | |
|---|---|---|---|
| | Number of left ears | | Number of right ears |
| Only low frequency hearing loss—LFHL | 13 | 33 (48.6%) | 20 |
| Only high frequency hearing loss—HFHL | 5 | 11 (16.2%) | 6 |
| Other type of hearing loss | 11 | 24 (35.2%) | 13 |

scopic field. For the latter, 70 cases (29.7%) presented abnormalities in both ears, 26 cases (11%) in the left ear, and 28 cases (11.9%) in the right ear. The most frequent abnormalities were wax, otitis media with effusion, fungal ear infection (otomycosis), an eardrum perforation, tympanosclerosis, and inflamed eardrum. The data are summarized in Figure 1.

In order to estimate the specificity and sensitivity values of the otoscopy testing, the data were compared with the audiometry data (which was considered the gold standard). Twenty-seven of the 46 children who failed the audiometry screening presented abnormalities in their otoscopy, resulting in a sensitivity value of 58.6%. From the 190 children with normal hearing, 93 presented a normal otoscopy, resulting in a specificity value 48.9%. The overall accuracy of the otoscopy was estimated as 51%. The data are summarized in the top part of Table 3.

**Results from the TEOAE screening**. For technical reasons (see discussion section) TEOAE testing was conducted only in 108 children: 46 children (42.6%) passed the TEOAE screening criteria and 62 (57.4%) failed. For the latter, 33 (30.6%) presented a bilateral hearing deficit, 17 (7.2%) a hearing deficit in the left ear and 12 (5.1%) a hearing deficit in the right ear.

To assess the sensitivity and specificity values of the TEOAE procedure, the TEOAE

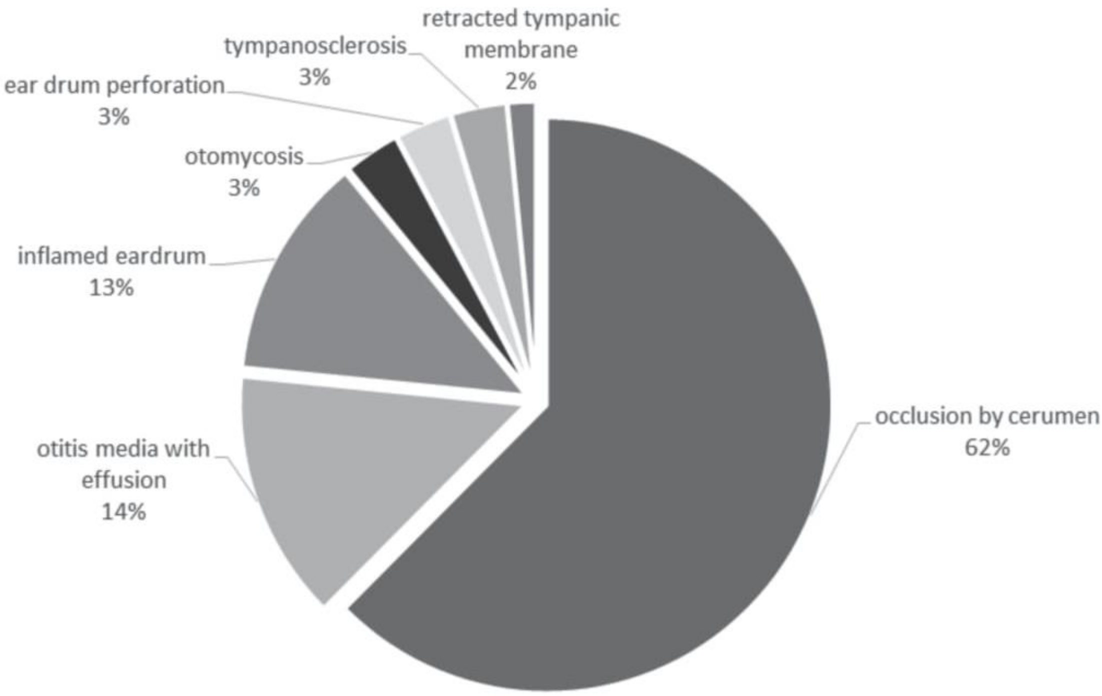


Figure 1. Results of otoscopy

data were compared with the audiometry data from the 108 children tested with the TEOAEs. The 13 children who failed the audiometry screening presented abnormal TEOAE responses, resulting in a TEOAE sensitivity of 100%. From the 95 children with normal audiometry profiles 46 presented normal TEOAE responses, resulting in a TEOAE specificity of 48.4%. The TEOAE accuracy was estimated as 55%. The data are summarized in the lower part of Table 3.

## Discussion

The presence of hearing disorders among school-age children has been widely reported.[9,16,26] Beyond the newborn period, close to 20% of permanent bilateral and unilateral impairments (whether mild, moderate, or greater, and attributable to progressive or delayed-onset hearing loss) remain to be identified around the time of school entry.[26,27] Unfortunately, in emerging countries such routine hearing screening among school-age children is still not carried out, as most primary schools view this as not feasible in economic terms.

The data from the pilot screening project show that a significant percentage of the assessed students (46 = 19.5%) presented hearing deficits. The findings are in line with those reported by Adebola et al. (21.3%)[9] and somewhat higher than those shown by Olusanya et al. (13.9%).[8] The tested children were sub-divided into two age groups in order to assess the relationship between age and hearing loss. The data suggest that age is not a statistically significant factor in the observed hearing losses.

Without timely detection, children with hearing deficits are often at risk for serious developmental delays or deficits. Pilot hearing screening projects, conducted by the

## Table 3.

### VIDEO-OTOSCOPY AND TEOAE FINDINGS COMPARED TO THE AUDIOMETRIC DATA

| | Pure Tone Audiometry | |
|---|---|---|
| | **Abnormal (*n*=46)** | **Normal hearing (*n*=190)** |
| Video-otoscopy abnormal (***n***=124) | 27 | 97 |
| Video-otoscopy normal (***n***=112) | 19 | 93 |
| Video-otoscopy | Sensitivity 27/46= **58.6%** | Specificity 93/190= **48.9%** |
| | Accuracy (27+93)/236= **50.8%** | |
| | **Abnormal (*n*=13)** | **Normal hearing (*n*=95)** |
| TEOAE abnormal (***n***=62) | 13 | 49 |
| TEOAE normal (***n***=46) | 0 | 46 |
| TEOAE | Sensitivity 13/13= **100%** | Specificity 46/95= **48.4%** |
| | Accuracy (13+46)/108= **54.6%** | |

**Mean (weighted)**
**Sensitivity:** ((.586*236) + (1*108))/(236+108) = .716=>71.6%
**Specificity:** ((.489*236) + (.484*108))/(236+108) = .486=> 48.6%
**Accuracy:** ((.508*236) + (.546*108))/(236+108) = .520=>52%

Institute of Physiology and Pathology of Hearing, in other African countries (Cameroon, Congo, Ghana, Ivory Coast, Rwanda, Senegal, and Tanzania) have shown a similar prevalence of hearing loss (18%–34%).[28] Data from other pilot programs conducted by the Institute in Armenia, Azerbaijan, Kazakhstan, Kirgizstan, Siberia, Tajikistan, and Uzbekistan have shown indices of hearing loss in the range of 15.9–24.1%.[24,28,29] In comparison, the prevalence of hearing loss in school-age children from rural areas in Poland has been estimated as 16.4%.[23]

Sekhar et al.[30] examined a group of 296 children from Pennsylvania and found that 67 (22.6%) had a hearing impairment, of whom 59 (88%) presented unilateral hearing deficits. In our study the prevalence of hearing loss was similar (19.5%), but the rates of unilateral and bilateral impairment were almost the same. Kuppler et al.[31] reported that unilateral hearing loss was the most common form of hearing impairment, finding it in about 3% of their school-age children. Niskar et al.[32] screened 6,166 American children aged 6–19 years and found that in almost 15% of the cases, a low or a high frequency hearing loss was present, which in 82% of the cases was unilateral. In the present study we found that 52.2% of children with abnormal hearing screening results had unilateral hearing disorders (24/46 cases). In the hearing screening conducted by the Institute in Tajikistan, the result was comparable and amounted to 50% (17/34 cases).[24]

Failure to identify students with even mild high-frequency hearing loss may have long-term consequences.[33] The data from this pilot study indicate that HFHL was observed in 16.2% of the impaired ears. Similar findings were reported in the Tajikistan screening, where 25.5% of the tested children presented HFHL.[24] Johnson et al.[34] conducted a study on 2,867 children in the United States and found that 7.6% had HFHL. Children with high-frequency hearing loss may appear normal but experience difficulties in certain situations. They may seem distracted because of difficulties in understanding speech in noise. Lunchtime and breaks can be very noisy, which can lead to social problems if the child is unable to hear or misinterprets instructions. In this type of hearing loss, the presence of a speech disorder is quite probable. For all these reasons, it is important that children with high-frequency hearing loss have a permanent support system in place both at school and at home.[35]

In the present study, low-frequency hearing losses were identified in 48.6% of the impaired ears. In comparison, data from a study of an American population indicated a significantly lower prevalence of LFHL (7.1%).[36] A previous study in Nigeria on 500 children reported an LFHL prevalence of 33.4% in their right ear and 7.8% in their left.[37] Similar data were reported from the Tajikistan screening project, where 34% of tested children presented LFHL.[24] In some cases, a low-frequency hearing loss may be temporary,[38] and in others depending on the specifics of the individual case pharmacological or surgical intervention may be effective. One of the most common reasons for temporary LFHL is inflammation of the middle ear, with otitis media with effusion being one of the most common diseases in childhood.[39] In the current study the causes of LFHL were wax, ear drum perforation, tympanosclerosis, otitis media with effusion, and fungal ear infection.

Numerous studies suggest that otoacoustic emissions may be more sensitive than audiograms in detecting the subtle changes in cochlear function which are the early signs of hearing loss.[40] Hearing screening using TEOAEs is quick and effective.[41] Yin et al.[42] screened 744 preschool students using TEOAEs, and the authors found a failure rate of just over 12%. In another study by Tamanini et al.,[43] TEOAEs were used to test 391 school-age children, and a failure rate of 5.2% was reported. The failure rate found in the present study, 57.4% (62/108 cases), is much higher. In fact, the frequency of TEOAE failures found generally in the literature diverges considerably from the figure observed in the present study. There are many technical factors influencing the OAE screening outcomes, and one of the most influential is the choice of screening criteria.[44] Usually strict criteria (S/N > 6 dB in three or more tested frequencies) are chosen for neonatal screening projects to avoid undetected cases—false negatives[45]—but there is no consensus on what criteria should be used in children's screening. For example, using as a pass S/N ratios > 3 dB in two of the four tested frequencies, the outcome number of passes changes significantly.

The accuracy between TEOAEs and screening pure tone audiometry in the present study was 55%. This low figure reflects also some technical challenges of the project, in acquiring data in more or less the same acoustical conditions. In many instances during data acquisition a nearby power generator was activated and despite multiple testing sessions some of the TEOAE records were contaminated by noise. Excluding the cases where issues of noise contamination were present, TEOAEs reflected faithfully problems related to the transmission of sound to the cochlea, due to wax or middle ear inflammation.

An alternative method for the evaluation of the screening results could be based on the net estimates of sensitivity and specificity. The net estimates of these indices are reported in the bottom of Table 3. A net estimate is in reality a weighted average estimate that considers the contributions of all the secondary methodologies employed in a particular screening paradigm (in this case tympanometry and otoacoustic emissions). With this understanding, the net-sensitivity of the pilot screening program was estimated as 71.6% and the net-specificity as 48.6%. The latter reflects the low specificity index of the otoacoustic emissions testing. Clearly these numbers refer to a particular status of the screening program (initial phase) and as the testers gain experience or the screening conditions become more favorable to testing, fewer technical errors will occur, and the reported net values will raise. From a public health point of view, it is very important to raise the net-sensitivity to at least a value of 90%. It should be noted that these estimates reflect the capabilities of secondary procedures such as tympanometry and otoacoustic emissions in the detection and correct identification of normal hearing children and children with hearing deficits. The data from the gold standard (screening audiometry) already present more acceptable indices from a public health point of view.

Middle ear pathology remains a risk factor for hearing loss in the pediatric population. Cerumen is a natural substance, normally expelled from the external canal without any symptoms. However, if cerumen production is excessive, it may cause complications, including hearing loss.[46] In the present study, excess cerumen was the most common alteration observed in otoscopy. A study to determine predictors of hearing loss in impoverished children living in Peru found that untreated middle-ear disease in the context of limited access to pediatric care was a major risk factor for hearing impairment.[47] Similarly, high rates of prevalence of otitis media, especially with effusion, have been found to be the most common cause of hearing loss in children in studies conducted in Denmark, Malaysia, India, Turkey, Bangladesh, Swaziland, Egypt, and Nigeria.[48,49] Otitis media is a common disease in children and can occur after viral or bacterial infections of the upper respiratory tract.

Nigeria has a high incidence of both AIDS and malaria. As a result, antimalarial drugs (for instance quinine or hydroxychloroquine) used to treat malaria may cause adverse events, including ototoxicity. In evaluating drug safety, one study hypothesized that hydroxychloroquine may give rise to hearing problems in children at lower doses than in adults, and this can occur more quickly.[50] Minor adverse events are common with quinine, but serious toxicity is rare. However, one side effect of the regular intake of quinine is cinchonism, which results in tinnitus, reversible high-tone hearing impairment, vomiting, nausea, and dysphoria. It has been shown that transient hearing loss is common after quinine therapy, which may cause temporary outer hair cell dysfunction.[51] Avoiding drug-induced ototoxicity means eliminating risk factors, but this is not always possible. Monitoring serum drug concentration is important but is sometimes very hard to do in Africa; similarly, it is not simple to monitor renal function and cochlear function in Africa, not only after therapy but also during it.[52] Discontinuing therapy because of symptoms of ototoxicity may sometimes be necessary in order to reduce the risk of permanent damage.

In view of the significant number of children in the present study with positive screening results, we conclude it is imperative to implement universal pre-school and school hearing screening programs in Nigeria.[53] Early diagnosis allows referral to specialists, who can then provide appropriate rehabilitation and thereby minimize or eliminate negative effects on a child's cognitive, linguistic, social, emotional, and communicative abilities.

Pure tone audiometry screening using the Sensory Organs Examination Platform is a cost-effective and safe tool for cooperative children. With appropriate screening equipment and protocols, and in close collaboration with pediatric otorhinolaryngologists, our study shows it is feasible for a medical team to conduct and monitor hearing screening among school-age children in developing countries, using properly trained technicians. This protocol appears to be effective in identifying cases of early hearing loss, allowing timely delivery of early intervention services.

The authors recognize some limitations in the present datasets, which call for additional research in order to define more robust guidelines for a hearing screening program in Nigeria.

1. The pilot study protocol was based on experiences acquired in previous pilot studies, but undoubtedly there is a strict need to customize the screening protocol to the population under assessment. For example, it might be more practical to use standard or multi-frequency tympanometry and not TEOAEs in the assessment of the middle-ear. Bone-conduction (BC) threshold assessment can be a valuable asset in the evaluation of the hearing status of a child but presents numerous technical difficulties for a screening implementation in a free field (mainly problems with the masking levels). Traditionally it is not included as a testing procedure in contexts outside a controlled clinical reality.

2. The present study was confined to Lagos (after a recommendation from Nigerian authorities), and so it is not possible to generalize the findings to the whole pediatric population of Nigeria. However, in conjunction with the data from Adejumo[39] in a different Nigerian region, it can be postulated that hearing losses in Nigerian schoolchildren are significant and require closer attention.

3. As of this moment, the authors do not have a detailed report on what has happened to the 24 students who were identified with a bilateral hearing loss. The 22 students identified with a unilateral hearing loss were placed in a monitoring program.

The data from the Lagos pilot program suggest that it is possible and affordable to develop a children's screening program in the geographical context of Nigeria. The employed screening technologies are not expensive, the necessary internet and computer instrumentation are considered standard today, and the only additional requirement is the proper training of technicians who can acquire the data.

Some technical issues related to the level of ambient noise during the data-acquisition can be resolved relatively easily, but they definitely require collaboration from the school headmaster, who must be informed about the serious objectives of the screening procedures.

## Acknowledgments

The authors would like to thank an anonymous reviewer for his /her contribution in the discussion section of the paper.

## Financial support

This research received no specific grant from any funding agency, or from any commercial or not-for-profit sector.

## Competing interests

The author(s) declare that they have no competing interests.

## Ethics approval and consent to participate

The study was approved by the Ethics Committee of the Institute of Physiology and Pathology of Hearing (KB:IFPS:26/16/2018) and conforms to the Declaration of Helsinki.

## Appendix

The Sensory Organs Examination Platform developed by the Institute of Physiology and Pathology of Hearing and the Institute of Sensory Organs in Warsaw, Poland is a PC-based system designed to perform hearing screening via a tele-audiology model.[15] The platform is an internet solution which interfaces a central computer system, in Warsaw, with a number of portable computers (remote client devices in the location of the pilot screening project) equipped with audiometric headphones and a response button. The platform allows the user to perform air conduction audiometric testing for each ear separately over a frequency range of 500 Hz to 8000 Hz at hearing thresholds up to 80 dB HL. An audiometric test is considered abnormal if the hearing threshold is found above 20 dB HL, in one or more frequencies, in at least one ear.[14] The audiological data (hearing levels, otoscopy outcomes, TEOAE outcomes) are transmitted to the central data base at the Institute of Physiology and Pathology of Hearing in Warsaw, Poland. There, within a short period of time, analyses can be performed and the results can be evaluated by ENT specialists. The use of the teleaudiology platform allows the identification and diagnosis of unilateral or bilateral hearing losses in the assessed pediatric patient.

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# PILOT HEARING SCREENING IN SCHOOLCHILDREN FROM ARMENIA, RUSSIA, KYRGYZSTAN, AND AZERBAIJAN

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

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## Abstract

**Background:** A number of pilot hearing screening programs have been started in various countries, promoting hearing-loss detection and treatment of communication disorders in school-age children. The aim of the study was to evaluate the hearing status of schoolchildren from selected schools in Armenia, Russia, Kyrgyzstan, and Azerbaijan.

**Material and methods:** Hearing screening was performed in 1022 children aged from 6 to 12 years in Armenia, Russia, Kyrgyzstan, and Azerbaijan. The study was carried out with the use of the Sensory Examination Platform. Pure-tone air-conduction hearing thresholds were obtained at 0.5–8 kHz. Hearing loss was defined as a loss of more than 20 dB in one or both ears in at least one of the following: high-frequency pure-tone average (HFPTA) and low-frequency pure-tone average (LFPTA) and others.

**Results:** Normal hearing was observed in 75.4% of children. Hearing loss was observed in 13.4% of the children unilaterally and 11.2% bilaterally. Overall, the results of screening indicate higher incidence of LFHL in children than HFHL.

**Conclusions:** The high prevalence of hearing loss in children from the studied countries indicates the need to conduct further hearing screening programs in this part of the world. This would allow earlier diagnosis of hearing problems and enhance the options for introducing proper diagnostic and therapeutic approaches, leading to better outcomes.

**Key words:** screening programs • hearing • children • school-age • pure-tone audiometry

## WYNIKI PILOTAŻOWYCH BADAŃ PRZESIEWOWYCH SŁUCHU WŚRÓD UCZNIÓW W WYBRANYCH KRAJACH AZJATYCKICH

### Streszczenie

**Wprowadzenie:** Pilotażowe programy badań przesiewowych rozpoczęto w różnych krajach, aby promować wczesne wykrywanie zaburzeń słuchu i leczenie zaburzeń komunikacyjnych wśród dzieci w wieku szkolnym. Celem niniejszej publikacji jest ocena częstości występowania zaburzeń słuchu u uczniów w wybranych krajach azjatyckich.

**Materiał i metody:** Badania przesiewowe przeprowadzono w grupie 1022 dzieci w wieku od 6 do 12 lat w czterech krajach azjatyckich: Armenii, Rosji, Kirgistanie i Azerbejdżanie. Badania wykonano za pomocą Platformy Badań Zmysłów. Wartości progowe dla przewodnictwa powietrznego określono w zakresie częstotliwości 0,5–8 kHz. Nieprawidłowym wynikiem testu była wartość progowa dla przewodnictwa powietrznego wynosząca więcej niż 20 dB HL dla co najmniej jednej częstotliwości w co najmniej jednym uchu. Nieprawidłowe wyniki podzielono na niedosłuch wysokoczęstoliwościowy (HFHL), niskoczęstoliwościowy (LFHL) oraz na inne.

**Wyniki:** Prawidlowy wynik badania uzyskano wśród 75,4% zbadanych dzieci. Jednostronny niedosłuch wykryto wśród 13,4% zbadanych dzieci, natomiast obustronny u 11,2%. Uzyskane wyniki wskazują, że niskoczęstoliwościowy niedosłuch występował częściej niż wysokoczęstotliwościowy.

**Wnioski:** Wyniki potwierdzają dużą częstość występowania problemów ze słuchem u dzieci z wybranych krajów azjatyckich. Wskazuje to na potrzebę prowadzenia programów przesiewowych badań słuchu w tej części świata, które pozwoliłyby na wcześniejsze rozpoznanie problemów ze słuchem i zwiększyłyby możliwość wdrożenia właściwego podejścia diagnostycznego i terapeutycznego, co pozwoliłoby na poprawę wyników.

**Słowa kluczowe:** program badań przesiewowych • słyszenie • dzieci • wiek szkolny • audiometria tonalna

## Background

According to global estimates of the prevalence of hearing loss by the World Health Organization (WHO) in 2018, there are 466 million people with disabling hearing loss worldwide, 93% of them adults and 7% children [1]. Between 1990 and 2016, hearing loss was the second most prevalent disability among children younger than 5 years in 195 countries and territories, with the highest prevalence in South Asia in 2016 [1–3].

There are many risk factors for hearing loss, such as exposure to loud sounds in occupational and recreational settings, chronic ear infections, and ototoxicity [1]. The distribution of disabling hearing impairment across different regions of the world and age groups reveals the highest prevalence in South Asia, East Asia, Sub-Saharan Africa, and the Asia Pacific [1,3]. Once again, the highest prevalence of hearing loss in children (0–15 years) is found in South Asia, Sub-Saharan Africa, and the Asia Pacific. There are a number of reasons for the hearing loss in children from these countries, which range from genetic defects related to marriage between close relatives [4], exposure to ototoxic drugs, or a higher prevalence of infectious disease [2].

Children with hearing impairments are likely to show delays in the production of speech as well as in other important aspects of nonverbal development, such as motor control [5]. According to the European Scientific Consensus agreement (defined and signed during the European Federation of Audiology Societies meeting in Warsaw, June 2011), untreated hearing loss of > 20 dB can have a negative impact on speech, language, and cognitive development, and, subsequently, on academic achievement [6–8].

School-age children with even mild hearing losses, who often appear to function normally in everyday situations, are nonetheless at considerable risk of academic, social, and behavioral problems. Earlier diagnosis of hearing problems in an infant or child enhances options for proper diagnosis and therapy. Timely intervention is an important component of any Early Hearing Detection and Intervention screening program (7,8), so that effective treatments can be undertaken to prevent negative consequences [6].

As a result of the European Scientific Consensus agreement, a number of pilot hearing screening programs were started in various countries, promoting hearing-loss detection and treatment of communication disorders in young school-age children [7]. Pilot hearing screening programs have been carried out in schools in Europe and in Central Asia and Africa (including Poland, Moldova, Romania, Russia, Ukraine, Tajikistan, Kyrgyzstan, Azerbaijan, and Armenia) [6,7,9,10]. However, in developing countries hearing screening programs do not exist. Implementing them is extremely challenging due to long-standing health disparity issues. A major one is a basic lack of funding for health programs [11]. The aim of the current study was to investigate the hearing status of schoolchildren from selected countries (Armenia, Russia, Kyrgyzstan, and Azerbaijan) and, by doing this, to further raise awareness among parents, schools, and governments of the need to conduct hearing screening programs and implement effective treatments.

## Material and methods

The hearing assessment took place in public schools in four countries: Armenia, Russia, Kyrgyzstan, and Azerbaijan (Figure 1). In Armenia, the pilot hearing screening took place at one of the schools in the capital, Yerevan. In Russia, the pilot hearing screening was performed at one of the schools in Krasnoyarsk. In Kyrgyzstan, the pilot hearing screening was carried out at three schools in the capital, Bishkek. In Azerbaijan, the pilot hearing screening took place at one of the schools in the capital, Baku. All schools were selected by local coordinators. A school was chosen if a large proportion of parents agreed that their children could take part in the screening, and that it was not a special school. The pilot hearing screening in schoolchildren was performed on 1022 children: 590 aged 6–7 years old (57.7%) and 432 who were 11–12 years old (42.3%) (Figure 2).

The schools were nominated by local authorities and approval from school management was obtained. Significant differences in the socioeconomic levels were the reason for excluding elite private schools. The study was approved by the Ethics Committee of the Institute of Physiology and Pathology of Hearing (KB:IFPS:26/1/2018) and conforms to the Declaration of Helsinki. Prior to testing,

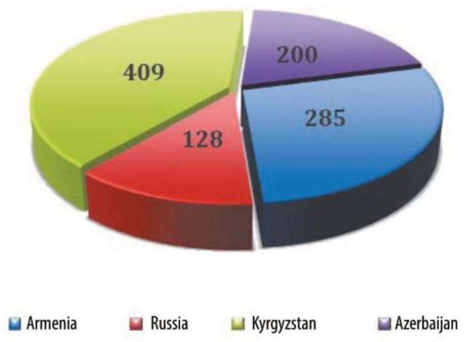


**Figure 1.** Number of tested children divided by country

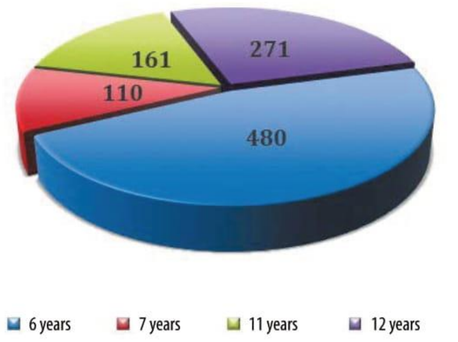


**Figure 2.** Number of tested children divided by age

**Table 1.** Results of hearing screening

| | Normal audiogram | Abnormal result | | |
|---|---|---|---|---|
| | | Overall | Bilateral | Unilateral |
| Armenia | 222 (77.9%) | 63 (22.1%) | 25 (39.7%) | 38 (60.3%) |
| Azerbaijan | 106 (53%) | 94 (47.0%) | 54 (57.4%) | 40 (42.6%) |
| Kyrgyzstan | 331 (80.9%) | 78 (19.1%) | 30 (38.5%) | 48 (61.5%) |
| Russia | 112 (87.5%) | 16 (12.5%) | 5 (31.3%) | 11 (68.8%) |
| 6–7 years old | 438 (74.2%) | 152 (25.8%) | 61 (40.1%) | 91 (59.9%) |
| 11–12 years old | 333 (77.1%) | 99 (22.9%) | 53 (53.5%) | 46 (46.5%) |
| Total | 771 (75.4%) | 251 (24.6%) | 114 (45.4%) | 137 (54.6%) |

the children's parents were informed of the testing procedures and gave written consent for their children to participate in a hearing screening examination. All children whose parents agreed to participation were scheduled for a screening test. The principals of the schools and the parents of the children were informed about the results of the study and advised that they should undergo further clinical assessments to confirm the screening results.

For screening purposes, the Platform of Sensory Organs Examination was used. The Platform is used within the telemedicine model SZOK for screening and testing hearing, which is built on a powerful, central computer system and a number of portable computers equipped with audiometric headphones and a response button for the tested person. Portable computers communicate with the central database via the Internet [12]. Testing was performed by experienced audiologists from the Institute of Physiology and Pathology of Hearing.

For reliable pure tone audiometry results, undisturbed, quiet conditions are required. Hence, all measurements were performed in quiet rooms available in the schools where noise levels were sufficiently low (not exceeding 40 dBA) for testing purposes. The test procedure complied with the standardized protocol applied in previous studies [7,9,10,13].

The platform allows air conduction audiometry testing to be performed for each ear separately over a frequency range of 0.5 to 8 kHz. It is limited to hearing thresholds below 80 dB HL. The data of the hearing tests were sent via an Internet connection to the SZOK system and safely stored in our database.

The eligibility criteria while screening the children's results for the purpose of the current study were: good cooperation with the child, low noise level during the examination, and the ability to measure hearing thresholds at all evaluated frequencies.

Although the definition of disabling hearing loss proposed by WHO refers to hearing loss greater than 40 dB in the better hearing ear in adults (15 years or older) and greater than 30 dB in the better hearing ear in children (0 to 14 years), in hearing screening of schoolchildren the criteria are more restrictive. According to already published studies [2], a positive result of a hearing screening is established if the hearing threshold is over 25 dB at one or more audiometric frequencies in at least one ear. In addition, mild hearing loss was defined as >20 to 40 dB, whereas moderate or worse hearing loss was defined as above 40 dB according to the BIAP classification.

The positive results of the screening test were selected and classified into two groups: unilateral or bilateral hearing losses. Subsequently, positive results of the screening in each group were assigned to three corresponding audiograms according to the previous criteria [9,10,12,13]:

- Low-frequency hearing loss (LFHL) – when the value of the hearing threshold for frequencies of 500 Hz and/or 1000 Hz and/or 2000 Hz was at least 25 dB HL, while the hearing threshold for the frequencies of 4000 Hz and 8000 Hz did not exceed 20 dB HL;
- High-frequency hearing loss (HFHL) – when the value of the hearing threshold for frequencies of 4000 Hz 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 – when the hearing threshold exceeded 20 dB HL for at least two different, non-consecutive frequencies.

## Results

Positive results of hearing screening, according to the adopted criterion, were obtained in 251 children (24.6%), while the other 771 children (75.4%) had audiometric thresholds equal or below 20 dB. Results of hearing screening for the whole group and according to country and age are shown in Table 1. The frequency of positive hearing screening results ranged from 12.5% in Russia to 47% in Azerbaijan. The distribution of positive results was similar for 6–7 years and 11–12 years of age.

In general, unilateral hearing loss was found in the majority of children with a positive result of hearing screening (54.6%). Only in Azerbaijan was this not the case, where bilateral hearing loss was found in 57.4% of children. Positive results in one ear were more frequent in younger children (59.9%) than in older children (46.5%).

Overall, the rate of LFPTA HL was estimated to be 32.6%, while the ratio of HFHL was 29.9%. However, in Russia and Kyrgyzstan HFHL was more frequent than LFHL

**Table 2.** Frequency of different types of audiograms among ears with a positive hearing screening result

| | Ears with positive result | LFHL | HFHL | Other |
|---|---|---|---|---|
| Armenia | 88 | 31 (35.2%) | 31 (35.2%) | 26 (29.6%) |
| Azerbaijan | 148 | 72 (48.6%) | 24 (16.2%) | 52 (35.2%) |
| Kyrgyzstan | 108 | 9 (8.3%) | 44 (40.8%) | 55 (50.9%) |
| Russia | 21 | 7 (33.3%) | 10 (47.6%) | 4 (19.1%) |
| 6–7 years | 213 | 71 (33.3%) | 63 (29.6%) | 79 (37.1%) |
| 11–12 years | 152 | 48 (31.6%) | 46 (30.3%) | 58 (38.1%) |
| Total | 365 | 119 (32.6%) | 109 (29.9%) | 137 (37.5%) |

(Table 2). The estimated prevalence of HL type was similar among children aged 6–7 years and older.

The prevalence of mild hearing loss (>20 dB) was 7.6% and was more common than moderate or worse HL (0.8% of tested children) for each PTA.

## Discussion

Based on our findings, the countries tested seem to be characterized by a high prevalence of hearing loss, which accords with WHO estimates [1]. Importantly, based on data from previous hearing screening tests [10, 14], the rate of positive hearing screening was the highest among all countries evaluated so far.

HFHL was the most common type of HL among children tested in Russia and Kyrgyzstan. A high prevalence of HFHL was also found in a study by Niskar et al. [16], where this type of HL was also the most common in children aged 6–19 years in the United States. On the other hand, LFHL was the most common type of hearing loss among tested children in Azerbaijan, similar to data from schoolchildren in Africa [10]. This situation may be because the research in Azerbaijan was carried out in the autumn, when there is an increased incidence of upper respiratory tract infections. More than 60% of upper respiratory tract infection episodes are complicated by acute otitis media (AOM) [17,18]. AOM can lead to conductive LFHL [17,18], which may explain the encountered differences.

Regarding the laterality of HL, unilateral hearing loss was found in the majority of children who had positive results of hearing screening. Only in Azerbaijan was bilateral hearing loss more prevalent. So far, we have found no reason to explain this difference. Nevertheless, in general our data are in line with previous results on HL laterality. According to Kuppler et al. [20] and Ross et al. [21], sensorineural hearing loss is the most prevalent form of hearing loss, affecting approximately 77% of positive screening school-aged children. Also, Niskar et al. [16) found that almost 82% of the positive screening children in the USA with HL presented unilaterally and Skarżyński et al. [7] reported the prevalence of unilateral hearing disorders in Tajikistan in 50% of all HL cases. It is worth mentioning that unilateral hearing loss is challenging to recognise by children, parents, and teachers, which underlines the important role of screening programs in its effective detection.

According to Naeem and Newton [4], children in Asia are at increased risk of sensorineural hearing loss and the reasons for that are complex. Hearing loss can be caused by hereditary and non-hereditary genetic factors or by certain complications during pregnancy and childbirth, which includes maternal rubella, syphilis, or certain other infections during pregnancy, low birth weight, birth asphyxia (lack of oxygen at the time of birth), inappropriate use of ototoxic drugs (such as aminoglycosides, cytotoxic drugs, antimalarial drugs, and diuretics) during pregnancy, and severe jaundice in the neonatal period, which can damage the hearing nerve in newborns [1]. Moreover, it is worth mentioning that in countries such as Armenia, Azerbaijan, Kyrgyzstan, and Russia, ototoxic drugs are widely used without audiological monitoring [15].

Also, excessive noise (e.g. during school breaks), meningitis, medications (ototoxic drugs), and congenital syphilis are among the many possible causes of sensorineural hearing loss in children [16]. Noise-induced hearing loss is the most common cause of the HFHL and is a growing problem among schoolchildren [16,19]. Exposure to very loud noise may explain why more children in Russia and Kyrgyzstan had hearing loss at high frequencies than at low frequencies [19].

Our findings showed that mild HL was much more frequent than moderate or worse HL, which is in line with previous research by Bess and Niskar [16,22). In our study, mild HL was found in 7.6% of the children, rates that are higher than Feder [23] reported [3.6–5%].

Finally, it must be mentioned that the differences in the prevalence of hearing loss, especially in countries where only pilot studies have been carried out, could be affected by the choice of schools in which the survey was conducted.

This study was solely a pilot screening; however, it has shown the need to conduct hearing screening programs in these countries. This research has raised many questions that require further investigation: e.g. whether the prevalence of hearing losses is actually as high as we have found.

## Conclusion

The high incidence of hearing loss in children from the four selected countries indicates the need for conducting hearing screening programs in this part of the world, which would allow for earlier diagnosis of hearing disorders. In essence, screening has the goal of identifying individuals at risk of hearing disorders and refer them for otorhinolaryngological and audiological assessment to increase the possibility of introducing a proper diagnostic and therapeutic approach leading to the best results.

## Acknowledgements

We thank all the children and their parents for participation.

## Limitations

The present study was conducted in the chosen schools and it is difficult to generalize findings to the whole pediatric population in these countries. In addition, only air conduction thresholds were measured, without performing bone conduction, otoscopy, tympanometry, or otoacoustic emissions.

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Now Audiofonol, 2018; 7(4): 29–34 DOI: 10.17431/1003134

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Prace badawcze

# Pilotażowe przesiewowe badania słuchu u dzieci w wieku szkolnym z różnych krajów w Afryce

# Pilot hearing screening in school-age children from different countries in Africa

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**Streszczenie**

**Wstęp i cel pracy:** Badania przesiewowe słuchu odgrywają niezwykle ważną rolę w profilaktyce. Pozwalają one na wczesne wykrycie zaburzeń słuchu, umożliwiając w ten sposób szybkie rozpoczęcie leczenia, oraz eliminują lub minimalizują negatywne konsekwencje związane z tego rodzaju dysfunkcją. Dzieci z zaburzeniami słuchu często mają opóźniony rozwój mowy oraz zdolności poznawczych, co może skutkować trudnościami w uczeniu się oraz obniżać wyniki w nauce.
Od wielu lat Instytut Fizjologii i Patologii Słuchu (IFPS) podejmuje szereg inicjatyw w zakresie badań przesiewowych słuchu w wielu krajach na różnych kontynentach. Głównym celem tych działań jest wczesne wykrycie wad słuchu, szczególnie u dzieci, które rozpoczynają naukę w szkole, oraz zwiększanie świadomości rodziców i środowiska szkolnego na temat problemów ze słuchem. Kolejnym celem jest poprawa jakości opieki medycznej i profilaktyki, zwłaszcza w krajach afrykańskich, poprzez umożliwienie dostępu do badań i promowanie zdrowego stylu życia.
**Materiał i metody:** Badaniami objęto łącznie 608 uczniów w wieku od 6 do 12 lat. Badania słuchu wykonano w czterech państwach afrykańskich: w Kamerunie zbadano 260 uczniów, w Nigerii – 196 uczniów, w Rwandzie – 183 uczniów, a w Tanzanii – 199 uczniów. Badania przesiewowe wykonano przy użyciu Platformy Badań Zmysłów (PBZ); z zastosowaniem audiometrycznej procedury pomiaru progu słuchu. PBZ, opracowana przez Instytut Narządów Zmysłów, jest niezbędna w przypadku badań z udziałem dużej liczby osób. Wartości progowe dla przewodnictwa powietrznego określano w zakresie częstotliwości 0,5–8 kHz. Za nieprawidłowy wynik testu uznawano wartość progową dla przewodnictwa powietrznego wynoszącą 25 dB HL i więcej dla co najmniej jednej częstotliwości w co najmniej jednym uchu. W niektórych krajach protokół badań rozszerzono dodatkowo o wideootoskopię.
**Wyniki:** Nieprawidłowy wynik przesiewowy uzyskano u 188 osób, tj. u 22,4% badanych dzieci. Wśród dzieci w wieku 6–9 lat uzyskano 20,8% wyników dodatnich, natomiast wśród dzieci w wieku 10–12 lat – 24,5%. Stwierdzono dużą liczbę jednostronnych ubytków słuchu. Z przeprowadzonych badań wynika, że we wszystkich krajach uczestniczących w programie przesiewowym skala ubytków słuchu wśród dzieci w wieku szkolnym jest znaczna.
**Wnioski:** Pilotażowe badania przesiewowe wykazały, że opracowany w Polsce model organizacyjny badań przesiewowych oraz stosowane w nich metody, urządzenia i systemy informatyczne mogą być z powodzeniem wykorzystywane nie tylko w krajach europejskich, lecz także afrykańskich. Należy podkreślić, że wykonywane przez IFPS przesiewowe badania słuchu były jednocześnie pierwszym screeningiem przeprowadzonym w szkołach znajdujących się w omawianych krajach afrykańskich. Uzyskane w ramach tego pilotażu wyniki wskazują na dużą częstość występowania problemów ze słuchem u dzieci w wieku szkolnym. W krajach tych zaleca się zatem wdrożenie badań przesiewowych słuchu jako rutynowej procedury w opiece medycznej.
**Słowa kluczowe:** badania przesiewowe • dzieci w wieku szkolnym • audiometria tonalna • Afryka

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## Abstract

**Background and aim of study:** Hearing screening have an extremely important preventive task, being the primary means of secondary prevention. They allow for an early detection of hearing disorders, thus enabling treatment and eliminating or minimizing the negative consequences associated with this type of dysfunction. Hearing-impaired children often experience delayed development of speech, language and cognitive skills, which may result in slow learning and difficulty progressing in school. For many years the Institute of Physiology and Pathology of Hearing has undertaken a variety of initiatives in countries across continents, which include screening for hearing. The primary goal of the program is early detection of hearing impairment, especially in children who start school and at raising awareness among parents and the school environment about hearing problems. These efforts are aimed at improving the state of medicine abroad, especially in African countries, enabling access to health care and promoting healthy lifestyle.
**Material and methods:** Hearing screening was performed in group of 608 children aged from 6 to 12 years. Hearing tests were performed in four African countries: Camerun – 260 children, Nigeria – 196 children, Rwanda – 183 children and Tanzania – 199 students. Screening was performed using the Sensory Organs Platform; based on an audiometric hearing threshold measurement procedure. A modern platform developed by the Institute of Sensory Organs is essential for the affordable and universal study of a large population of children. The threshold values for air conduction were determined in the frequency range of 0.5 - 8 kHz. The abnormal test result was the threshold value for air conduction of 25dB HL and more for at least one frequency in at least one ear. In addition, in some countries, the study protocol was extended to include video-otoscopy.
**Results:** Positive hearing screening result was found in 188 pupils, 22.4% of the examined children. Among children aged 6-9, the percentage of positive results was 20.8%, while in children aged 10-12, it was 24.5%. In addition, there was a large number of unilateral hearing losses. Studies have shown that the scale of hearing loss among school-age children is significant in all countries participating in the program.
**Conclusion:** Pilot hearing screening has shown that the organizational model of screening developed in Poland and the methods, devices and information systems used in the studies can be successfully implemented not only in European countries, but also in African countries. It should be emphasized that hearing screening performed outside of Poland was the first hearing screening test conducted in schools in the surveyed countries.
The results confirm the high incidence of hearing problems in school children. Based on the results, it is strongly recommended to implement hearing screening in the countries concerned as a routine procedure in medical care.

**Key words:** hearing screening • school-age children • pure tone audiometry • Africa

## Wprowadzenie

Uszkodzenie słuchu jest jedną z najczęstszych przyczyn problemów w komunikowaniu się. Prawidłowy słuch ma bowiem kluczowe znaczenie dla rozwoju mowy, języka, porozumiewania się oraz uczenia się [1]. Zaburzenia słuchu są jednym z głównych problemów w dziedzinie zdrowia publicznego w krajach rozwijających się [2]. Zauważalna jest znaczna różnica w częstości występowania chorób uszu między krajami rozwiniętymi i rozwijającymi się. Szacuje się, że około 2/3 osób z wadami słuchu pochodzi z tych ostatnich krajów [3,4].

Od wielu lat IFPS podejmuje różnorodne inicjatywy, w tym przede wszystkim przesiewowe badania słuchu, w krajach znajdujących się na trzech kontynentach. Zasadniczym celem tych działań jest wczesne wykrycie zaburzeń słuchu, przede wszystkim u dzieci rozpoczynających naukę w szkole, oraz uwrażliwienie rodziców i środowiska szkolnego na problemy dzieci związane ze słyszeniem [5]. Działania te mają ponadto na celu poprawę jakości opieki medycznej i profilaktyki, w szczególności w krajach Afryki, Bliskiego Wschodu i Europy Środkowo-Wschodniej, poprzez umożliwienie dostępu do opieki zdrowotnej i promowanie zdrowego trybu życia [6,7]. Sprawdzony polski model organizacyjny badań przesiewowych, oparty na mobilnych urządzeniach do badań oraz unikalnych systemach informatycznych umożliwiających zarządzanie badaniami, gromadzenie danych oraz nadzór nad jakością badań, umożliwia podjęcie w odpowiedzialny sposób działań promocyjnych i wdrożeń badań przesiewowych u dzieci w wieku szkolnym nie tylko w Polsce [8], lecz także poza jej granicami. Program badań przesiewowych obejmuje w szczególności kraje rozwijające się, charakteryzujące się niższym poziomem rozwoju medycyny i profilaktyki [2,9].

Efektem prac zespołu IFPS i negocjacji prowadzonych podczas prezydencji Polski w Radzie UE było przyjęcie konkluzji Rady UE w sprawie wczesnego wykrywania i leczenia zaburzeń komunikacyjnych u dzieci, z wykorzystaniem narzędzi e-zdrowia i innowacyjnych rozwiązań. Została ona przyjęta przez ministrów zdrowia wszystkich państw członkowskich UE na spotkaniu EPSCO w Brukseli. Było to wydarzenie kluczowe, zamykające działania realizowane podczas polskiej prezydencji w Radzie UE, stanowiące integralną część priorytetu w dziedzinie zdrowia publicznego, pod kątem zapewnienia równych szans rozwoju dzieciom z zaburzeniami komunikacyjnymi [10–12]. Dlatego jednym z priorytetowych działań IFPS jest program badań przesiewowych słuchu dla dzieci w wieku szkolnym. W wyniku podjętej współpracy przeprowadzono pilotażowe badania przesiewowe słuchu w szkołach w Europie oraz w Azji Centralnej i Afryce (m.in. w Polsce, Mołdawii, Rumunii, Rosji, na Ukrainie, w Tadżykistanie, Kirgistanie, Azerbejdżanie, Armenii, a także w Senegalu i na Wybrzeżu Kości Słoniowej) [13].

Celem przesiewowych badań słuchu jest identyfikacja dzieci z ubytkami słuchu, mogącymi wpływać na ich rozwój intelektualny, emocjonalny, społeczny lub utrudniać kontakt z innymi osobami. Wczesna diagnoza i interwencja daje możliwość wdrożenia szybkiej rehabilitacji, mającej na celu zmniejszenie negatywnego wpływu uszkodzenia słuchu na rozwój dziecka [14].

## Materiał

Pilotażowy program badań przesiewowych słuchu zrealizował zespół Instytutu Fizjologii i Patologii Słuchu. Badaniami objęto łącznie 608 uczniów w wieku od 6 do 12 lat. Badania słuchu wykonano w czterech państwach afrykańskich: w Kamerunie zbadano 260 uczniów, w Nigerii – 196 uczniów, w Rwandzie – 183 uczniów, a w Tanzanii – 199 uczniów. Z uwagi na występujące znaczne różnice w zamożności społeczeństwa do badań pilotażowych wybrano losowo szkoły powszechne i ogólnodostępne, rezygnując z badań w szkołach elitarnych – prywatnych. We wszystkich odwiedzonych szkołach nauka odbywała się w języku angielskim.

Przed badaniem wszyscy rodzice zostali poinformowani o procedurze badania oraz wyrazili pisemną zgodę na udział dziecka w programie. Ostateczne wyniki zostały przekazane dyrektorom szkół, którzy następnie udostępnili je rodzicom. Dzieci, które miały pozytywny wynik badania przesiewowego, otrzymały wskazówki i zalecenia w celu uzyskania dalszych ocen klinicznych i informacji na temat obserwowanych deficytów słuchu.

## Metody

Protokół przesiewowego badania słuchu stosowany w Nigerii, Rwandzie oraz Tanzanii obejmował wideootoskopię oraz audiometrię tonalną, natomiast w Kamerunie wykonano tylko audiometrię tonalną.

Wideootoskopia to badanie polegające na wizualnej metodzie oceny struktur ucha zewnętrznego oraz środkowego. Podczas tego badania możliwe jest zaobserwowanie patologicznych zmian w uchu zewnętrznym i środkowym, takich jak korki woszczynowe, ostre lub przewlekłe zapalenie ucha środkowego, zmiany spowodowane infekcją grzybiczną i zmiany w błonie bębenkowej.

Audiometria tonalna została przeprowadzona przy użyciu Platformy Badań Zmysłów, systemu opracowanego przez Instytut Narządów Zmysłów we współpracy z Instytutem Fizjologii i Patologii Słuchu. Platforma to system oparty na wydajnym komputerze centralnym i wielu komputerach przenośnych wyposażonych w słuchawki audiometryczne i przycisk do udzielania odpowiedzi. Komputery przenośne komunikują się z centralną bazą danych za pośrednictwem Internetu. Każde urządzenie przenośne jest wyposażone w oprogramowanie umożliwiające wykonanie audiometrii tonalnej [7].

Audiometryczne badania słuchu przeprowadzono przy użyciu modelu telemedycznego – Systemu Zintegrowanych Operacji Komunikacyjnych „SZOK"®. Jest to wysoce zaawansowany system informatyczny wspierający diagnozowanie pacjenta na odległość i zapewniający transfer wyników badań do sektora służby zdrowia. System integruje stosowane w Instytucie Fizjologii i Patologii Słuchu systemy informatyczne i wprowadza nowe rozwiązania – umożliwia przeprowadzanie audiologicznych programów badań przesiewowych w skali ogólnopolskiej i kontynentalnej, wspiera badania naukowe w zakresie gromadzenia, przechowywania, popularyzacji i zarządzania wynikami badań przesiewowych [2].

Wszystkie badania zostały przeprowadzone w cichych pomieszczeniach znajdujących się na terenie szkół. Wykorzystana podczas nich Platforma Badań Zmysłów wyposażona była w słuchawki Sennheiser, które zapewniają skuteczną izolację akustyczną od szumu tła. Wyznaczany był tylko próg przewodzenia powietrznego dla częstotliwości: 0,5; 1; 2; 4 oraz 8 kHz.

Za pozytywny wynik audiometrii tonalnej uznano wartość progu słyszalności 25 dB i więcej dla co najmniej jednej częstotliwości w co najmniej jednym uchu [15,16]. Po przesłaniu wyników audiometrycznych do systemu „SZOK"®, nieprawidłowe – zgodnie z przyjętymi kryteriami – wyniki testu zostały wyselekcjonowane i dokonano podziału na obu- i jednostronne uszkodzenia słuchu.

Kolejnym krokiem przeprowadzonym przez specjalistów z Instytutu Fizjologii i Patologii Słuchu było podzielenie pozytywnych wyników badań słuchu na 3 rodzaje audiogramów (osobno dla każdego ucha) [6]:

- wskazujące na ubytek słuchu w zakresie niskich częstotliwości (LFHL), w którym próg słyszenia dla 500 i/lub 1000 Hz wynosił 25 dB HL i więcej, podczas gdy dla innych częstotliwości nie przekraczał 20 dB HL,
- wskazujące na ubytek słuchu w zakresie wysokich częstotliwości (HFHL), w którym próg słyszenia dla częstotliwości 4000 i/lub 8000 Hz wynosił 25 dB HL i więcej, podczas gdy dla innych częstotliwości nie przekraczał 20 dB HL,
- inne – inne nieprawidłowe wyniki badań przesiewowych, w których wartość progu słyszenia była większa niż 20 dB HL i występowała na co najmniej dwóch arbitralnych częstotliwościach.

## Wyniki

### Otoskopia

Wideootoskopię wykonano u wszystkich dzieci z Nigerii, Rwandy oraz Tanzanii. Analiza wyników wykazała, że 43,8% badanej grupy (253 uczniów) miało nieprawidłowy wynik badania w przynajmniej jednym uchu. Najczęściej nieprawidłowy wynik dotyczył obojga uszu (62,4%). Szczegółowe wyniki zostały zaprezentowane w tabeli 1.

**Tabela 1.** Liczba oraz częstość występowania nieprawidłowych wyników wideootoskopii
**Table 1.** Number and incidence of abnormal results of video-otoscopy

| Kraj | Liczba i procent uczniów z wynikiem nieprawidłowym | Liczba i procent uczniów z wynikiem nieprawidłowym w obojgu uszach | Liczba i procent uczniów z wynikiem nieprawidłowym w uchu prawym | Liczba i procent uczniów z wynikiem nieprawidłowym w uchu lewym |
|---|---|---|---|---|
| Nigeria | 94 (48%) | 54 (57,5%) | 16 (17%) | 24 (25,5%) |
| Rwanda | 84 (45,9%) | 55 (65,5%) | 17 (20,2%) | 12 (14,3%) |
| Tanzania | 75 (37,3%) | 49 (65,3%) | 14 (18,7%) | 12 (16%) |
| **Łącznie** | **253 (43,8%)** | **158 (62,4%)** | **47 (18,6%)** | **48 (19%)** |

**Tabela 2.** Liczba oraz częstość występowania nieprawidłowych wyników badania przesiewowego słuchu oraz częstość występowania niedosłuchów jedno- i obustronnych z podziałem na kraje

**Table 2.** The general percentage of students with hearing loss and the frequency of uni- and bilateral hearing loss, divided into country

| Kraj | Liczba przebadanych uczniów | Liczba i procent uczniów z wynikiem nieprawidłowym | | |
|---|---|---|---|---|
| | | Liczba uczniów z wynikiem nieprawidłowym | Obustronny ubytek słuchu | Jednostronny ubytek słuchu |
| Kamerun | 260 | 60 (23,1%) | 41 (68,3%) | 19 (31,7%) |
| Nigeria | 196 | 48 (24,5%) | 32 (66,7%) | 16 (33,3%) |
| Rwanda | 183 | 40 (21,9%) | 22 (55%) | 18 (45%) |
| Tanzania | 199 | 40 (20,1%) | 17 (42,5%) | 23 (57,5%) |
| **Łączna liczba uczniów** | **838** | **188 (22,4%)** | **112 (59,6%)** | **76 (40,4%)** |
| **Łączna liczba uszu** | **1676** | **300 (17,9%)** | **224 (74,7%)** | **76 (25,3%)** |

Najczęściej obserwowane zmiany to: korki woszczynowe, zrosty, tympanoskleroza, kieszonki retrakcyjne, perforacja błony bębenkowej, wada wrodzona ucha zewnętrznego, wyciek ropny, przewlekłe zapalenie ucha środkowego z wyciekiem.

## Audiometria tonalna

Analiza uzyskanych wyników badań przesiewowych wykazała, że pozytywny wynik audiometrii tonalnej, zgodnie z przyjętym kryterium, stwierdzono u 188 dzieci (22,4% badanej populacji). Zaobserwowano, że wśród wszystkich nieprawidłowych wyników 40,4% wykrytych niedosłuchów (76 uczniów) stanowiły niedosłuchy jednostronne (tabela 2).

Z danych przestawionych w tabeli 3 wynika, że prawie co piąte zbadane dziecko w wieku 6–9 lat miało nieprawidłowy wynik badania przesiewowego słuchu – 98 uczniów (tj. 20,8% grupy badanej). U dzieci w wieku 10–12 lat stwierdzono częstsze występowanie uszkodzeń słuchu, pozytywny wynik badania przesiewowego uzyskano u 90 uczniów (tj. 24,5% grupy badanej).

W grupie uszu z nieprawidłowym wynikiem badania przesiewowego słuchu najczęściej stwierdzano ubytki obejmujące wszystkie badane częstotliwości – 58,9% (132 uszu) (tabela 4). Niedosłuchy niskoczęstotliwościowe (LFHL) stanowiły 30,4% (68 uszu), zaś pozostałe 10,7% (24 uszu) to były niedosłuchy wysokoczęstotliwościowe (HFHL). Inne wyniki uzyskano tylko w Rwandzie, gdzie niedosłuchy na wysokich częstotliwościach zaobserwowano u 29% dzieci z grupy badanej i występowały one częściej niż LFHL (14,5%).

## Dyskusja

Wyniki prezentowanych badań przesiewowych wykazały, że zaburzenia słuchu są problemem często występującym wśród dzieci w wieku szkolnym. W zbadanej populacji od 20,1% do 27,8% młodszych dzieci (6–9 lat) uzyskało pozytywny wynik testu przesiewowego. W trzech krajach, w których przeprowadzono badania przesiewowe u uczniów w wieku 10–12 lat, stwierdzono większy odsetek dzieci z wynikiem pozytywnym. Jedynie w Tanzanii odnotowano nieco mniejszą częstość występowania nieprawidłowych wyników wśród starszych dzieci.

W krajach rozwijających się ogólna świadomość dotycząca występowania ubytków słuchu oraz możliwości ich diagnostyki i rehabilitacji jest niewielka. W krajach, w których zostały przeprowadzone pilotażowe badania przesiewowe, z powodu braku urządzeń i wykwalifikowanego personelu screeningi nie są prowadzone, a ograniczony dostęp do lekarzy specjalistów może powodować, że odsetek osób mających różne zaburzenia słuchu w populacji jest wysoki.

Inne międzynarodowe badania wykazały, że w porównywalnym wieku odsetek pozytywnych wyników wynosi od kilku procent do ponad 30% [17]. Tak duża rozpiętość danych jest związana z różnymi protokołami przesiewowymi i różnymi kryteriami kwalifikującymi do nieprawidłowego

**Tabela 3.** Liczba oraz częstość występowania niedosłuchu z podziałem na wiek

**Table 3.** Number of positive hearing screening results divided into age

| Kraj | Wiek 6-9 lat | | Wiek 10-12 lat | |
|---|---|---|---|---|
| | Liczba uczniów | Liczba i procent uczniów z wynikiem nieprawidłowym | Liczba uczniów | Liczba i procent uczniów z wynikiem nieprawidłowym |
| Kamerun | 144 | 29 (20,1%) | 116 | 31 (26,7%) |
| Nigeria | 108 | 23 (21,3%) | 88 | 25 (28,4%) |
| Rwanda | 77 | 16 (27,8%) | 106 | 24 (22,6%) |
| Tanzania | 141 | 30 (20,3%) | 58 | 10 (17,2%) |
| Łącznie | **470** | **98 (20,8%)** | **368** | **90 (24,5%)** |

**Tabela 4.** Liczba oraz częstość występowania poszczególnych typów audiogramów
**Table 4.** Number and incidence of types of audiograms

| Kraj | Typ uszkodzenia słuchu (liczba i procent uszu) | | |
|---|---|---|---|
| | Tylko niedosłuchy niskoczęstotliwościowe – LFHL | Tylko niedosłuchy wysokoczęstotliwościowe – HFHL | Inne typy niedosłuchów |
| Kamerun | 30 (29,7%) | 7 (6,9%) | 64 (63,4%) |
| Nigeria | 34 (42,5%) | 7 (8,75%) | 39 (48,75%) |
| Rwanda | 9 (14,5%) | 18 (29%) | 35 (56,5%) |
| Tanzania | 17 (29,8%) | 2 (3,5%) | 38 (47,1%) |
| **Łącznie** | **68 (30,4%)** | **24 (10,7%)** | **132 (58,9%)** |

wyniku. Z badań przeprowadzonych w Iranie wynika, że 10% dzieci w wieku 7–8 lat może mieć problem ze słuchem. Mniejsza skala częstości występowania ubytków słuchu może wynikać z testowanego zakresu częstotliwości – irańskie testy przeprowadzono w węższym zakresie (od 500 do 4000 Hz) [18]. W badaniu Niskar i wsp. [16] prawie 15% dzieci w wieku 6–11 lat miało nieprawidłowe wyniki badań przesiewowych. W badaniu pilotażowym przeprowadzonym przez zespół IFPS w krajach afrykańskich (Senegal i Wybrzeże Kości Słoniowej) wykazano, że 1 dziecko na 3 miało problem ze słuchem [7]. W podobnych testach przeprowadzonych w Armenii, Azerbejdżanie, Kazachstanie, Kirgistanie, Uzbekistanie oraz na terenie Syberii – odsetek nieprawidłowych wyników wyniósł 15,9–24,1% [7]. W Azji Centralnej podczas badań przeprowadzonych przez IFPS w Tadżykistanie w 2013 r. stwierdzono zaburzenia słuchu u 23,7% badanych dzieci w wieku szkolnym [2,6]. Ponadto wykazano, że częstość występowania pozytywnych wyników jest o kilka procent wyższa niż w Polsce [5]. Należy również zauważyć, że różnice w częstotliwości występowania zaburzeń słuchu, szczególnie w krajach, w których przeprowadzono tylko badanie pilotażowe, mogą być uzależnione od wyboru szkół, w których wykonywano badanie.

Ponadto kraje afrykańskie, takie jak Kamerun, Nigeria, Rwanda czy Tanzania, mają wysoką zachorowalność na AIDS i malarię. Leki przeciwmalaryczne (na przykład chinina, hydroksychlorochina) stosowane w leczeniu malarii mogą powodować działania niepożądane, w tym ototoksyczność [19]. Oceniając bezpieczeństwo stosowania leku, w jednej międzynarodowej publikacji stwierdzono, że u dzieci mniejsze dawki hydroksychlorochiny mogą powodować problemy ze słuchem niż w przypadku dorosłych [19]. W przypadku stosowania chininy działania niepożądane są bardzo częste, ale mniej dotkliwe – poważna toksyczność występuje rzadko, ze względu na jej wyjątkowo gorzki smak. Jednym ze skutków ubocznych regularnego przyjmowania chininy jest cynchonizm, który powoduje szum w uszach i czasowe zaburzenia słuchu w zakresie wysokich częstotliwości [20]. Wykazano, że okresowy niedosłuch wysokoczęstotliwościowy jest częstym skutkiem ubocznym terapii chininą, powodując okresową dysfunkcję komórek rzęsatych zewnętrznych [20,21]. Unikanie ototoksyczności lekowej oznacza eliminację czynników ryzyka, ale nie zawsze jest to możliwe. Monitorowanie stężenia leku w surowicy jest ważne, ale czasami bardzo trudne do wykonania w Afryce; podobnie nie jest łatwo monitorować czynność nerek i funkcję ślimaka, nie tylko po terapii, lecz także w jej trakcie. Przerwanie leczenia z powodu objawów ototoksyczności może być czasem konieczne w celu zmniejszenia ryzyka trwałego uszkodzenia słuchu [22].

Uzyskanie 22,4% nieprawidłowych wyników w badaniach przesiewowych słuchu opisywanych w ramach niniejszej pracy świadczy o potrzebie intensyfikacji wdrażania programów zapobiegania zaburzeniom słuchu i wczesnego ich diagnozowania. Badanie przesiewowe słuchu w wieku szkolnym jest skutecznym i dostępnym środkiem służącym do identyfikacji zaburzeń, które nie zostały zdiagnozowane aż do wieku szkolnego. Prezentowane badania miały kilka ograniczeń – mierzono tylko próg przewodnictwa powietrznego oraz przeprowadzano badanie otoskopowe, bez wykonywania tympanometrii impedancyjnej lub otoemisji akustycznej (OAE) [23]. Uwzględnienie tych metod diagnostycznych w protokole oceny słuchu może zwiększyć dokładność testowania i rozróżnić niedosłuchy przewodzeniowe i odbiorcze, ale w ramach badań masowych prowadzonych w szkołach jest to trudne do wdrożenia.

## Podsumowanie

Badania pilotażowe pokazały, że model organizacyjny badań przesiewowych wypracowany w Polsce oraz metody, urządzenia i systemy informatyczne zastosowane w badaniach można z powodzeniem implementować nie tylko w krajach europejskich, lecz także afrykańskich. Należy podkreślić, że wykonywane przez IFPS przesiewowe badania słuchu były jednocześnie pierwszym screeningiem przeprowadzonym w szkołach znajdujących się na terenie omawianych krajów.

Poza oczywistą korzyścią płynącą z wykrycia przypadków dzieci z zaburzeniami słuchu i objęcia ich opieką laryngologiczną lub audiologiczną, realizowany program stanowił znakomitą promocję polskich osiągnięć, urządzeń i doświadczeń w zakresie organizacji badań przesiewowych w krajach, które uczestniczyły w programie.

Regularne przesiewowe badania słuchu u dzieci w wieku szkolnym przyczyniają się do tego, że osoby z wykrytym zaburzeniem słuchu mogą skorzystać z odpowiedniego leczenia i rehabilitacji. Program badań przesiewowych słuchu powinien być częścią zintegrowanego szkolnego programu zdrowia i funkcjonować w ramach krajowego systemu opieki zdrowotnej na podstawowym poziomie opieki zdrowotnej. Szkoły prywatne powinny natomiast uwzględnić kontrolę słuchu w ramach własnych systemów administracyjnych.

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International Journal of Pediatric Otorhinolaryngology 128 (2020) 109676

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

# Prevalence of hearing loss among polish school-age children from rural areas – Results of hearing screening program in the sample of 67 416 children

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ARTICLE INFO

*Keywords:*
Hearing screening
Hearing loss
School-age children
Pure-tone audiometry

ABSTRACT

*Background:* Hearing loss in children is a relevant health issue, both for its prevalence and for its physical, emotional and social consequences. Our aim was to estimate the national prevalence of hearing loss in school-age children from rural areas in Poland.
*Methods:* The study was conducted in the general, pediatric, nonclinical population of school-age children from rural areas in Poland. It was a population-based, epidemiological study. The participants were 67416 children (32630 girls and 34786 boys) aged from 6 to 13 years old (M = 8.65; SD = 2.54). Pure-tone air-conduction hearing threshold were obtained at 0.5–8 kHz. Hearing loss was defined as a pure-tone average higher than 20 dB in one or both ears in at least one of the following pure-tone average: four-frequency pure-tone average (FFPTA), high-frequency pure-tone average (HFPTA) and low-frequency pure-tone average (LFPTA).
*Results:* The rate of positive results of hearing screening was 16.4% and it was significantly higher in younger children than in older children. Mild hearing loss was more frequently than moderate or worse hearing loss. The children more often experienced unilateral than bilateral hearing loss.
*Conclusions:* This study reveals that hearing problems are common in this population, especially among younger children. It shows a strong need for systematic monitoring of hearing status among children and increasing awareness of parents and educators of the significance of hearing loss, including unilateral and mild hearing loss. Further studies conducted among children in urban areas are needed to compare the prevalence of hearing loss in children from various environments.

## 1. Introduction

Screening is the method of secondary prevention, concerned with early detection of disease. Community screening programs allow identifying a subgroup of people in whom there is a high probability of finding a disease or a risk factor for developing a disease [1]. But they are also a source of knowledge about health status and health needs of people.

In 1968 Wilson and Gunner defined principles of screening for disease, which apply to date and are considered to be a gold standard [2]. In 2008 these principles were supplemented by Andermann et al. [3].

All these principles should be incorporated in each screening program. In Poland we have a long tradition of hearing screening examinations, especially in newborns. In 1992–1994 the first hearing examination in this group, managed by Henryk Skarzynski and Maria Goralowna was conducted and it resulted in the development of the universal newborn hearing screening program that was implemented in general health care system in Poland [4]. The experience gathered from studies of newborns constituted a basis for epidemiological studies focused on schoolchildren, and afterwards resulted in European Scientific Consensus agreement, which was designed during the 10th Congress of European Federation of Audiology Societies (EFAS), held in Warsaw, Poland, on June 22, 2011 [5–7]. Also in "EU Council Conclusions on Early Detection and Treatment of Communication Disorders in Children, Including the Use of eHealth Tools and Innovative Solutions" (Council of the European Union, 2011) the guidelines how to identify and treat children with hearing, vision and speech disorders through

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https://doi.org/10.1016/j.ijporl.2019.109676
Received 19 June 2019; Received in revised form 8 August 2019; Accepted 8 September 2019
Available online 10 September 2019
0165-5876/ 

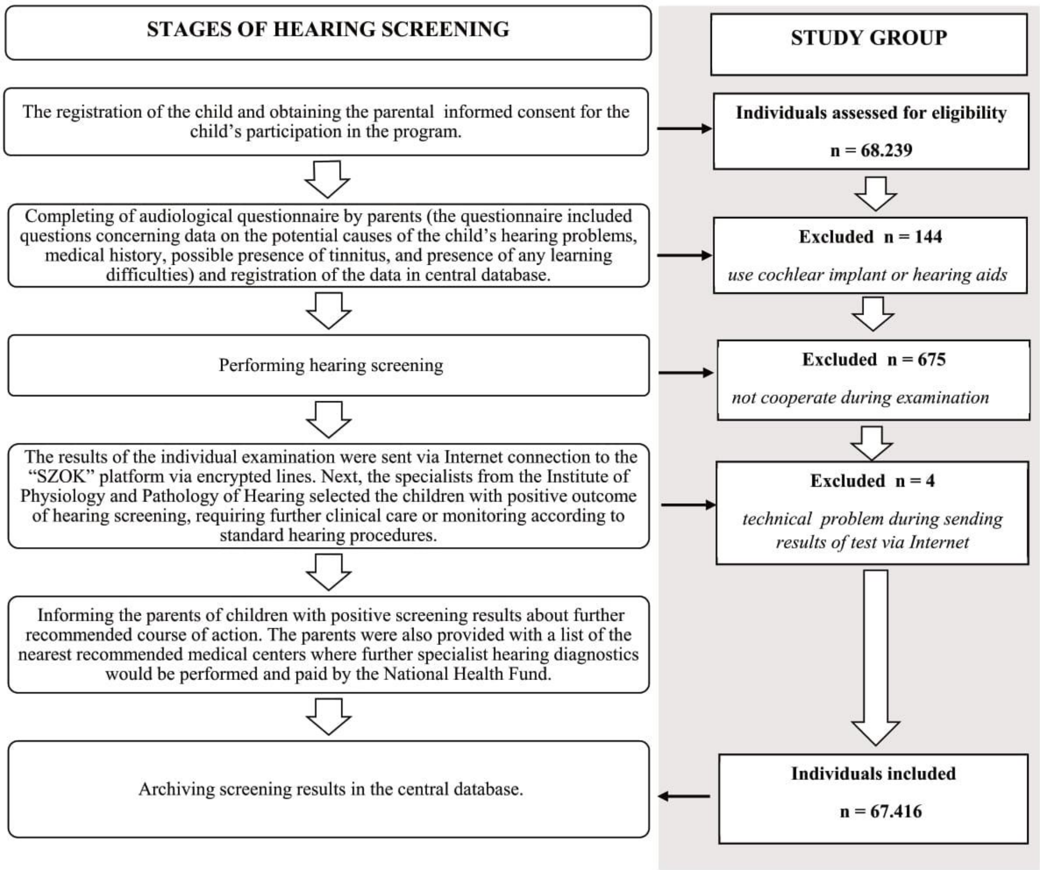


**Fig. 1.** Consecutive exclusions from initial study sample and stages of data collection.

screening programs including modern e-health technologies and tools were formulated [5–7].

As it is known, hearing loss is the most common sensory impairment. According to WHO data, over 5% of the world's population has disabling hearing loss [8]. It is a serious problem at any age, but its consequences are extremely harmful especially in children, because of its negative impact on an overall development.

In 2008, the Institute of Physiology and Pathology of Hearing, in collaboration with the Agricultural Social Insurance Fund implemented a screening program for school children from rural areas and small towns (below 5.000 inhabitants) in Poland [9]. The choice of target population was intentional. Even in developed countries, including in Poland, people in rural areas still face serious challenges in achieving sufficient health care delivery. The reasons for these shortage problems are manifold and are related to various issues [10]. So, there is still a significant need to reduce inequalities in accessibility to health services and therefore the implementation of e-health solutions could help to do so [11].

Until 2018 about one million of children were included in hearing screening programs. In the years 2008–2011 nearly 300.000 children were examined. The rate of positive results (i.e. audiometry in at least one frequency > 20 dB) was from 13.9% to 23.9% in different age groups [12].

These results can be compared with the data reported by Niskar et al. [13] from the National Health and Nutritional Examination Survey (NHANES) that 14.9% of children aged 6–19 years had hearing loss. In the next cycles of NHANES hearing loss prevalence increased to 22.5%, but in the NHANES 2009–2010 it decreased to 15.2% [14]. Recently, Feder et al. [15] published the findings of a representative sample of Canadian youth, aged 6–19 years, wherein 7.7% participants had hearing loss. The same year LeClerque et al. [16] presented the data from the Netherlands, where the prevalence of hearing loss among children 9–11 years old was 17.5%. As we can see, the estimates of prevalence of hearing loss among children vary widely, which was discussed by Lieu [17].

The studied mentioned above were conducted on big samples, still including no more than a few thousands of participants. So it would be worth comparing their results with the data obtained from a sample of over 67 thousand children. The children were 6–13 years old, came from rural areas in Poland and were examined in 2016–2017. Limitation of the study was the fact that only audiometric thresholds were measured, without performing otoscopy and tympanometry or distortion product otoacoustic emissions (DPOAE) testing. Undoubtedly, including these diagnostic methods in the hearing evaluation protocol might increase the accuracy of the testing and differentiate between conductive and sensorineural HL, but in mass screening conducted in schools they are difficult to implement. The authors adopted low-cost procedures that are available for areas where there is a lack of funding to purchase technologies to identify groups at risk of hearing disorders at the earliest possible stage, which will help to reduce inequities in health between the inhabitants of the village and the city.

The objectives of hearing screening in rural areas were: 1) to perform audiometry screening tests in school children and to detect hearing disorders; 2) to broaden the knowledge of parents, children and teachers about the potential causes of hearing loss and the possibilities of prophylaxis, diagnosis, treatment and rehabilitation in case of hearing loss.

The aim of this article is to estimate the national prevalence of hearing loss in school-age children from rural areas.

## 2. Materials

### 2.1. Participants and data collection

It was a population-based, epidemiological study. The participants were recruited from all 16 regions of Poland. Between September 2016 and June 2017 hearing screening was conducted in 4414 schools in 1463 rural districts in Poland (it constitutes 75,6% of the schools qualified for the program). The study has been approved by the Ethical Committee of the Institute of Physiology and Pathology of Hearing (KB·IFPS:June 27, 2018) and conforms to the stipulations of the Declaration of Helsinki. Consecutive exclusions from initial study sample and stages of data collection were shown in Fig. 1.

After the applied exclusions, the study sample consisted of 67416 children (32630 girls and 34786 boys) aged from 6 to 13 years old (M = 8.65; SD = 2.54). The participants were divided into two groups: 6–9 years (n = 44323) and 10–13 years (n = 23093). Such age criterion was applied according to the Polish educational system – 10-year old children ended the stage of primary education and started the new level of education.

### 2.2. Audiometric measurement

Pure-tone audiometric testing was conducted using the Sense Examination Platform, a system developed by the Institute of Sensory Organs in collaboration with the Institute Physiology and Pathology of Hearing [12].

A platform is a system based on an efficient central computer and many portable computers communicating with the central database via the Internet. Each portable device is equipped with software allowing to perform pure-tone audiometry. Audiometric hearing tests were performed using a telemedicine model - the System of Integrated Communication Operations „SZOK"®. The system integrates the information systems used in the Institute of Physiology and Pathology of Hearing and introduces new possibilities – it enables to perform audiology screening programs on worldwide scale, supports scientific research in the collecting, storing, popularizing and managing of screening tests' results. The studies with the use of the SZOK system have been conducted in many European, African an Asian countries [11,18].

In the current study, the results obtained were based on the audiogram test. Only air conduction threshold was measured. All tests were performed in a quiet classroom. The Sense Examination Platform is equipped with Sennheiser HDA200 headphones, which provide effective acoustic isolation of the ear from the background noise. The thresholds for air conduction in the frequency range 0.5, 1, 2, 4 and 8 kHz were determined.

### 2.3. Definitions

The outcome of hearing screening examination was regarded as positive if the result of the air conduction pure tone audiometry was higher than 20 dB in at last one frequency in one or both ears. Such result can indicate any hearing problems, both permanent and periodical and it is a reason for monitoring the hearing status over time. This principle of test evaluation was applied in previous studies [12,18].

Hearing loss was defined as a pure-tone average higher than 20 dB in at least one of the following pure-tone averages: four-frequency pure-tone average (FFPTA), high-frequency pure-tone average (HFPTA) and low-frequency pure-tone average (LFPTA). Firstly, speech relevant hearing loss was defined as the four frequency pure-tone average (FFPTA) at 0.5, 1, 2 and 4 kHz at a value for threshold of > 20 dB [15,19,20]. HFPTA were defined as a pure-tone average above 2 kHz (4 and 8 kHz) [21,22] and LFPTA at 0.5, 1, 2 kHz [14,15] at a value for threshold of > 20 dBHL.

Mild HL was defined as > 20–40 dB, whereas moderate or worse HL was defined as above 40 dB according to BIAP classification. For bilateral HL, the average in the worse ear was used to define the degree of hearing impairment.

These definitions were selected to enable comparison of results of mass hearing screening with data obtained in other studies.

### 2.4. Statistical analysis

The prevalence rate of positive hearing screening outcomes and prevalence of HL were estimated by dividing the number of cases by the number of individuals in the group. Standard error (SE) and 95% confidence interval (95% CI) were calculated as measures of uncertainty. In order to evaluate differences between males and females and between younger and older children, odds ratios (ORs) with 95% CI were estimated. Statistical significance was specified as a p-value less than 0.05. The analysis was conducted using IBM SPSS Statistics 24 and MedCalc.

## 3. Results

### 3.1. Prevalence of positive hearing screening outcomes

The rate of positive results of hearing screening was 16.4% (95% CI, 16.1%–16.6%) (Table 1). It was nearly equal in boys and girls (OR,1.03, 95% CI, 0.99–1.07; Z = 1.37, P = 0.17) but it was significantly higher in younger children than in older children (OR, 2.05, 95% CI, 1.95–2.15; Z = 29.24; P < 0.001).

### 3.2. Prevalence of hearing loss

The outcome of this study indicates that the estimated 9.4% (95% CI, 9.18%–9.62%) of children aged from 6 to 13 years and living in rural areas had hearing loss in one or more ears, based on one or more pure-tone average: FFPTA and/or HFPTA and/or LFPTA (Table 2).

The estimated prevalence of HL was the same among boys and girls (OR,1.00, 95% CI, 0.95–1.05; Z = 0.06, P = 0.95). Among participants aged 6–9 years the rate of HL was significantly higher than in participants aged 10–13 years (OR, 2.21, 95% CI, 2.07–2.35; Z = 24.40; P < 0.001).

The prevalence of four-frequency HL was estimated to be 5.6% (95% CI, 5.5%–5.8%) (Table 2). The ratios among boys and girls were nearly equal (OR,0.94, 95% CI, 0.88–1.01; Z = 1.78, P = 0.08). Again, a significant difference was observed between the age groups (OR,2.28, 95% CI, 2.10–2.48; Z = 19.62, P < 0.001).

The rate of LFPTA HL was estimated to be 6.2% (95% CI, 6.1%–6.4%) (Table 2) with the ratios among boys and girls almost the same. (OR, 0.96, 95% CI, 0.90–1.02; Z = 1.36, P = 0.17). The age groups still differed significantly (OR,2.28, 95% CI, 2.11–2.47; Z = 20.63, P < 0.001).

**Table 1**
Prevalence of positive hearing screening outcomes.

| | N | n | % | SE | 95% CI |
|---|---|---|---|---|---|
| Total | 67416 | 11066 | 16.4 | .143 | 16.1–16.6 |
| Sex | | | | | |
| Male | 34786 | 5776 | 16.6 | .199 | 16.2–17.0 |
| Female | 32630 | 5290 | 16.2 | .204 | 15.8–16.6 |
| Age group (years) | | | | | |
| 6 to 9 | 44323 | 8630 | 19.5 | .188 | 19.1–19.8 |
| 10 to 13 | 23093 | 2436 | 10.5 | .202 | 10.2–10.9 |

N, study sample size; n, number of participants with positive result; SE, standard error; CI, confidence interval.

**Table 2**
Prevalence of hearing loss in 67416 Polish children aged 6 to 13 from rural areas.

| | | FFPTA and/or LFPTA and/or HFPTA HL | | | | FFPTA HL | | | | LFPTA HL | | | | HFPTA HL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | n | % | SE | 95% CI | n | % | SE | 95% CI | n | % | SE | 95% CI | n | % | SE | 95% CI |
| **Total** | **67416** | **6336** | **9.4** | **0.112** | **9.18–9.62** | **3793** | **5.6** | **0.089** | **5.5–5.8** | **4201** | **6.2** | **0.093** | **6.1–6.4** | **5016** | **7.4** | **0.101** | **7.2–7.7** |
| **Sex** | | | | | | | | | | | | | | | | | |
| Male[a] | **34786** | **3267** | **9.4** | 0.156 | 9.09–9.70 | **1904** | **5.4** | 0.122 | 5.2–5.7 | **2125** | **6.0** | 0.128 | 5.9–6.4 | **2654** | **7.6** | 0.142 | 7.4–7.9 |
| Female | **32630** | **3069** | **9.4** | 0.162 | 9.09–9.72 | **1889** | **5.8** | 0.129 | 5.5–6.0 | **2076** | **6.5** | 0.135 | 6.1–6.6 | **2362** | **7.2** | 0.143 | 7.0–7.5 |
| **Age (years)** | | | | | | | | | | | | | | | | | |
| 6 to 9[a] | **44323** | **5062** | **11.4** | 0.151 | 11.12–11.72 | **3065** | **6.9** | 0.121 | 6.7–7.2 | **3392** | **7.7** | 0.126 | 7.4–7.9 | **4020** | **9.1** | 0.136 | 8.8–9.3 |
| 10 to 13 | **23093** | **1274** | **5.5** | 0.150 | 5.22–5.81 | **728** | **3.2** | 0.115 | 2.9–3.4 | **809** | **3.5** | 0.121 | 3.3–3.7 | **996** | **4.3** | 0.134 | 4.1–4.6 |

FFPTA, four-frequency pure-tone average; HFPTA, high-frequency pure-tone average; LFPTA, low-frequency pure-tone average; HL, hearing loss.
N, study sample size; n, number of participants with positive result; SE, standard error; CI, confidence interval.
[a] Reference category.

The prevalence of HFPTA HL was estimated to be 7.4% (95% CI, 7.2%–7.6%) (Table 2). The ratios among boys and girls did not differ significantly (OR, 1.06, 95% CI, 1.0–1.12; Z = 1.03, P = 0.05). Again, significant difference was observed between the age groups (OR,2.21, 95% CI, 2.06–2.38; Z = 21.84, P < 0.001).

The prevalence of mild hearing loss (> 20 dB) was 5% (95% CI, 4.8%–5.1%) for FFPTA, 5.5% (95% CI, 5.4%–5.7%) for LFPTA and 6.3% (95% CI, 6.3%–6.5%) for HFPTA and it was more common than moderate or worse HL for each PTA (Table 3).

The children more often experienced unilateral than bilateral HL. The prevalence of unilateral HL was the highest for HFPTA and it was 5.2% (95% CI, 5.1%–5.2%), lower for LFPTA (4.2%; 95% CI, 4.1%–4.4%) and for FFPTA (3.9%; 95% CI, 3.7%–4%). The data were shown in Table 4.

## 4. Discussion

The aim of this article was to estimate the national prevalence of hearing loss in school-age children from rural areas. Prevalence data on HL from large-scale studies are limited, so our study fills this data gap.

In our study the prevalence of HL was 9.4% and it was equal among boys and girls. Definition of HL applied in the study was similar to Feder [15], so both data could be compared. The prevalence of HL in our study was higher than in the Canadian study (it was 7.7%), but the effect of rural residence must be taken into account. Lin et al. [23] showed the data of hearing impairment among Taiwanese children from rural areas. These findings indicate that in 2004–2010 the prevalence of HL was between 7.88% and 8.07% in rural areas and each year rural areas had higher overall prevalence rates than urban areas. The differences might be attributable to both unequal accessibility to health services and different cultural perceptions of the impact of HL, diagnosis and treatment in rural and urban areas [24].

The results of hearing screening carried out in Poland in 2008–2011, which show that almost 14% of children in school-age have a hearing problem [12,25]. Pilot screening done in the European countries (Moldova, Romania) gave a similar percentage of positive results as the examinations carried out in Poland [18].

We found higher prevalence of HL among younger children than among older children and that result is not wholly consistent with the outcomes of other investigators. Lin et al. [23] demonstrated the increasing trend in the prevalence of HL associated with age – the highest prevalence was in the oldest group. Also Su and Chan [14] showed that older age was associated with increased odds of hearing loss. But on the other hand Feder [15] found higher prevalence of HL in younger children (6–11 year olds) than in older ones (12–19 year olds), however it was rather slight (respectively: 8.1% and 7.4%).Higher prevalence of hearing disorders in younger children might be due to several factors. Firstly, younger children are more likely than older children to get ear infections. If the Eustachian tubes are swollen or blocked with mucus due to a cold or other respiratory illness, fluid may not be able to drain [26]. The decrease in the rate of Eustachian tube dysfunction with age is likely to be associated with the anatomic development of the upper airways [27]. Secondly, a child's immune system is not completely effective because it is still developing and otitis media is often co-morbid with other infections of the upper or lower respiratory tract [28]. In our previous hearing screening we also found that the number of positive results was the highest in the group of the youngest children [12]. We suppose that untreated middle ear disease and limited access to pediatric care may be an important risk factor for HL in younger children.

In the present study 6.2% of tested children were diagnosed with a low-frequency HL. The data reported in a study on American population indicate a higher incidence of LFHL – 7,1% [29]. Niskar et al. [13] showed that low-frequency HL was more frequent in 6–11 age group than in 12–19 age group (respectively: 7.6% and 6.6%). In some cases, a low-frequency hearing loss may be temporary. One of the most common reasons for temporary LFHL are inflammations of the middle ear [30,31].

The analysis of results obtained in the high-frequency HL indicates that 7.4% (9.1% in children 6–9 years old and 4.3% in children 10–13 years old) had a positive result. Study conducted by Niskar et al. [13] showed that high-frequency HL occurred nearly as often in 6–11 year olds (12.2%) as in 12–19 year olds (13.0%), but the criterion was different than in our study (> 15 dB). In 2016, Johnson conducted a study on 2867 patients and its result showed that 7.6% had HFHL [19].

**Table 3**
Prevalence of mild and moderate or worse hearing loss in 67416 Polish children aged 6 to 13 from rural areas.

| | No HL loss | | | | Mild > 20 dB–40 dB | | | | Moderate or worse > 40 dB | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | SE | 95% CI | n | % | SE | 95% CI | n | % | SE | 95% CI |
| FFPTA | 63623 | 94.4 | 0.089 | 94.2–94.5 | 3350 | 5.0 | 0.084 | 4.8–5.1 | 443 | 0.6 | 0.061 | 0.6–0.7 |
| LFPTA | 63215 | 93.8 | 0.093 | 93.6–94.0 | 3752 | 5.5 | 0.088 | 5.4–5.7 | 449 | 0.7 | 0.061 | 0.6–0.7 |
| HFPTA | 62400 | 92.6 | 0.101 | 92.4–92.8 | 4254 | 6.3 | 0.094 | 6.3–6.5 | 726 | 1.1 | 0.012 | 1.0–1.2 |

n, number of participants with positive result; SE, standard error; CI, confidence interval.

**Table 4**
Prevalence of unilateral or bilateral hearing loss in 67416 Polish children aged 6 to 13 from rural areas.

| | No HL loss | | | | Unilateral | | | | Bilateral | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | SE | 95% CI | n | % | SE | 95% CI | n | % | SE | 95% CI |
| FFPTA | 63623 | 94.4 | 0.089 | 94.2–94.5 | 2620 | 3.9 | 0.074 | 3.7–4.0 | 1173 | 1.7 | 0.050 | 1.6–1.8 |
| LFPTA | 63215 | 93.8 | 0.093 | 93.6–94.0 | 2856 | 4.2 | 0.078 | 4.1–4.4 | 1345 | 2.0 | 0.054 | 1.9–2.1 |
| HFPTA | 62400 | 92.6 | 0.101 | 92.4–92.8 | 3563 | 5.2 | 0.086 | 5.1–5.5 | 1453 | 2.2 | 0.056 | 2.0–2.3 |

n, number of participants with positive result; SE, standard error; CI, confidence interval.

Children with HFHL are especially sensitive to noise typical of school environment. In the case of this type of hearing loss, speech and articulation disorders may also occur. It is important that children with HFHL should have a permanent support system both at school and at home [32].

The prevalence of FFPTA HL was 5.6% ad it was slightly lower than LFPTA HL (6.2%) and HFPTA HL (7.4%). These results were higher than Feder [15] showed (4.7% for FFPTA HL, 5.8% for LFPTA HL and 6.0% for HFPTA HL). It is known that frequencies 500–4000 Hz are most important for speech recognition [33] so it is especially worrying that 6.9% of younger children exhibited FFPTA HL (whereas it was 3.2% of older children). Once again, it shows that it is younger children in rural areas that especially need audiological care.

Our findings showed that mild HL was much more frequent than moderate or worse HL, and unilateral HL was more frequent than bilateral HL, which was in line with previous research by Bess and Niskar [13,20]. In our study mild HL was found in 5–6.3% of the children and the rates were higher than Feder [15] reported: 3.6–5%. Sekhar et al. [34] reported one-sided hearing loss in as much as 88% (59/67) of the group of 67 children with hearing impairment. According to Kuppler [35], the most common hearing impairment is unilateral hearing loss, which occurs in about 3% of school-age children. Data from the Iranian child population [36] indicate a one-sided hearing loss of 75% of all reported hearing losses.

Mild HL has no established standardized audiological definition and additionally the descriptors such as mild, minimal or slight can make parents (guardians, teachers) minimize the importance of monitoring or intervention [37]. However, mild unilateral and bilateral HL might have negative impact on a child's educational outcomes, language development, as well as emotional and social functioning [20,38]. Children with mild HL show depressed language levels, e.g. in morphosyntax abilities in comparison with their peers with normal hearing [39]. Other researchers reported significant delays in language development, verbal abilities, and reasoning skills in children with mild HL [40]. Especially younger children, who have only started their education, might have disadvantage in classroom when trying to hear a teacher above background noise, so even mild HL might negatively affect their educational achievement. Data concerning delayed language development were not collected but speech and language skills should be screened in a school hearing screening programs and these tasks will be addressed in future investigations.

There are a few limitations of the study. It is known there is a large number of potential covariates in estimating health parameters. Sociodemographic factors such as household income or level of parents' education are vital for hearing impairment but they were not included in the reported hearing screening.

Certainly, the undeniable value of the presented hearing screening was the detection of hearing problems in many children who were referred for further, detailed otorhinolaryngological and audiological diagnostics, which allows to determine the reason for hearing loss and implement appropriate treatment. Hearing screening constitutes a crucial element of health education, dedicated to parents, teachers and children. Health education – in terms of hearing screening program – aims to increase awareness among target population and to form habits promoting hearing- and healthcare.

## 5. CONCLUSION

Nowadays otolaryngology, which are included in preventive medicine, now have many possibilities to assist patients with hearing impairment. However, in order to make full use of these opportunities, hearing disorders should be detected in the early stages. Hence, screening programs for early detection of hearing defects are of highest importance. In an optimal healthcare system, hearing screening should be conducted not only during the neonatal or infancy, but also as a routine procedure in the medical care in schools is strongly recommended. In this way, both congenital and acquired hearing impairments can be detected.

## Conflicts of interest

The authors disclose no conflicts of interest.

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INTERNATIONAL JOURNAL OF AUDIOLOGY
2021, VOL. 60, NO. 8, 614–620
https://doi.org/10.1080/14992027.2020.1849829

ORIGINAL ARTICLE

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# Prevalence of tinnitus in a sample of 43,064 children in Warsaw, Poland

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**ABSTRACT**

**Objective:** Tinnitus affects both adults and children. Children rarely complain spontaneously of tinnitus, and their parents are not aware of the condition. The prevalence of tinnitus in children differs considerably between studies, and large studies are needed to reliably estimate how many children experience tinnitus symptoms. The goal of the study was to estimate the prevalence of tinnitus in a large sample of schoolchildren.

**Design:** This study was population-based, epidemiological research, conducted in the general, paediatric population of school-age children in Warsaw, Poland. Pure-tone audiometric testing was done, and hearing thresholds were determined from 0.5 to 8 kHz. Both the children and parents answered questions about the presence of tinnitus in the child.

**Study sample:** Results from 43,064 children aged 11 to 13 years old, as well as their parents, were collected.

**Results:** The study showed that tinnitus affected 3.1% of the children, but it was significantly more frequent (9%) in children with hearing loss. We found that 1.4% of the parents were aware of the presence of tinnitus in their children.

**Conclusions:** Children should be routinely asked whether they experience tinnitus and if so, they should be included in the thorough assessment and management of the condition.

**ARTICLE HISTORY**
Received 8 April 2020
Revised 23 October 2020
Accepted 23 October 2020

**KEYWORDS**
Tinnitus; prevalence; children; epidemiology

## Introduction

Tinnitus is the phantom perception of sound without any external stimuli (Jastreboff 2015). Affecting both adults and children, it negatively impacts the quality of life and can lead to significant restrictions in everyday activity (Zeman et al. 2014; Hall et al. 2018; Smith et al. 2019). The pathophysiology of the tinnitus remains unclear, although it is thought to be connected with aberrant neural activity generated at some level of the auditory system (Jastreboff 1990; Haider et al. 2018).

For adults, much work has been done over the past several decades concerning tinnitus prevalence, and there are numerous publications (Davis 1995; Axelsson and Ringdahl 1989; Ries 1994; Adams and Marano 1995; Nondahl et al. 2002; Tambs et al. 2003; Fabijańska et al. 2000; Hasson et al. 2011; Shargorodsky, Curhan, and Farwell 2010; McCormack et al. 2016; Khedr et al. 2010). Tinnitus prevalence rates appear to vary from 5% to 30%, the wide range probably being due to different types of methodologies.

How does the prevalence of tinnitus in children compare to adults? The results of research on the incidence of tinnitus in children are not clear-cut. Rosing et al. (2016) undertook a systematic review of the epidemiology of tinnitus and hyperacusis in children and young people based on 25 articles which met their inclusion criteria and which showed rosing sufficient methodological consistency. The authors reported the estimated prevalence of tinnitus to be from 4.7% to 46% in the general paediatric population and among children with normal hearing; 6%–41.9% in mixed study population (children with hearing loss and normal hearing), and 3.2%–62.2% in the hearing impaired children (Rosing et al. 2016). Data from the latest studies are also very divergent. Kim et al. (2017) reported 32.3% tinnitus prevalence in the general population of South Korean adolescents, while the figure showed by Lee and Kim (2018) was 17.5%. Nemholt et al. (2020) published the findings from a study of Danish children aged 10 to 16 years, wherein 66.9% of the participants had tinnitus.

The estimates of tinnitus prevalence among children vary widely, depending on factors such as different criteria used to define tinnitus, different ages of the examined children, the range of questionnaires used interviewing in the child, different procedures, and the statistics used to analyse the results.

From the point of view of clinicians, healthcare providers, and health policymakers, there is a strong need to gauge the extent of tinnitus in the paediatric population accurately. The goal of this study was to assess the prevalence of tinnitus in

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children living in and around Warsaw. To ensure the reliability of the results, we carried out the study for five consecutive years, from 2013 to 2017. The guidelines STROBE Statement (The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (von Elm et al. 2014) were taken into account when reporting the results of the study.

## Materials and methods

This study was a retrospective analysis of the responses of 43,064 school children (21,917 girls and 21,147 boys) and their parents, collected during a hearing screening program conducted from 2013 to 2017 by the Institute of Physiology and Pathology of Hearing. The children were aged 11 to 13 years old (27.9% of them were 11 years old, 67% were 12 years old, and 5.1% were 13 years old). The mean age was 11.77, and the standard deviation of 0.53. The number of children in the study, year by year, was: 8186 children in 2013; 9142 children in 2014; 8307 children in 2015; 9582 children in 2016; and 7847 children in 2017.

The study was conducted following the Declaration of Helsinki and was approved by the Research Ethics Committee (KB.IFPS:28/5/2018). The main objective of this project was to assess the hearing condition of the studied population. All primary schools in Warsaw were informed about the hearing screening and invited to take part in the program. Assessment of the prevalence of tinnitus was a secondary goal.

Before testing, the children's parents were informed of the testing procedure and gave written consent for their children to participate in the hearing examinations. Audiometric hearing tests have been supplemented by a questionnaire completed by parents/legal caregivers and children. Parents were asked to answer the following question – *Does your child complain of tinnitus in their ears/head when in quiet?* by choosing one of the possible answers *very often*, *often*, *rarely*, or *never*. The children were asked to answer a similar question – *Do you hear tinnitus, whistles, or squeaks as you are falling asleep or when it is quiet in your room?* by choosing an answer *yes, all the time*; *yes, periodically and for more than 5 minutes*; *yes, but only for a very short time*; *no* (both the parents and the children were asked the tinnitus question in writing). If the parents answered *very often* or *often*, and the children answered *yes, all the time*; *yes, periodically and for over than 5 minutes* they were considered positive outcomes, i.e. indicating the presence of tinnitus.

For hearing screening, the Sense Examination Platform, which is a portable screening audiometer, was used. The platform consists of a netbook linked to a central computer and several ancillary devices such as audiometric headphones, patient-operated button, and software allowing to perform pure tone audiometry. The platform carries Sennheiser HDA200 headphones which provide effective acoustic isolation of the ear from background noise. Details of the platform can be found in references (Skarżyński et al. 2011; Skarzyński et al. 2016; Skarżyński et al. 2020). Air conduction hearing thresholds were tested in the frequency range 0.5 to 8 kHz. The Hughson and Westlake procedure of threshold measurement was used (i.e. two out of three responses at threshold are required; (Śliwa et al. 2011)). All children were instructed to raise their hand when they hear the sound. When the sound stops, they were asked to lower their hands. Pure tone audiometry screening took place in a quiet room chosen by the school headmaster. Audiometry testing was conducted during school hours, excluding breaks. Experienced audiologists performed testing. The Bureau International d'Audiophonologie (BIAP) recommendation was used to divide children into two groups: children with normal hearing (with pure tone average (PTA) below 20 dB HL for 0.5, 1, 2, and 4 kHz) and children with hearing loss (with PTA above 20 dB HL). (Bureau International d'Audiophonologie and for 1996). Degrees of hearing loss were assessed as mild (21–40 dB), moderate (41–70 dB), or severe (71–90 dB) according to BIAP standards (the worse ear was considered).

The prevalence of tinnitus in children was estimated by assessing the parents' and children's ratings separately. The figures were derived by dividing the number of positive results by the total number of results. Positive results for the parents were two answers: *very often* or *often*; for the children also two answers were considered positive: *yes, all the time*; *yes, periodically and for over than 5 minutes*. Confidence intervals (95% CI) were calculated to indicate uncertainty of estimates. Odds ratios (ORs) were applied to evaluate differences between males and females, children with normal hearing and children with hearing loss, and children with various degrees of hearing loss. Additionally, sensitivity analysis was performed by calculating the rates of tinnitus in a different way. The questions were treated as yes/no questions. If the parents chose other answer than *never* (i.e. *very often; often; rarely*) and the children chose other answer than no (*yes, all the time*; *yes, periodically and for more than 5 minutes*; *yes, but only for a very short time*) they were considered indicating the presence of tinnitus. Statistical significance was specified as a *p*-value less than 0.05. The analysis was performed using IBM SPSS Statistics, version 24 and MedCalc.

## Results

Generally, over the whole period 2013–17, 1.4% of parents said their child had often or very often complained about tinnitus. The rate was almost the same for both boys and girls (OR = 0.86; $p > 0.05$). A little over 12% of the parents reported that their child occasionally complained of tinnitus, and again there was only a slight difference between the answers given by parents of boys or girls. The majority of parents (86.2%) said that their child had never complained of tinnitus, and the difference between the parents of boys and girls was still negligible. The data are set out in Table 1.

Overall, 0.7% of the children reported tinnitus lasting all the time, and 2.4% of children said they experienced tinnitus periodically and that it lasted for more than five minutes. The rate was similar for boys and girls (OR = 0.93; $p > 0.05$). About 28% of children reported tinnitus which happened rarely and lasted for a very short time. Tinnitus was not experienced by 69.1% of the children, boys and girls similarly. Table 2 shows the data.

The parents' assessment of their child's tinnitus complaints was reasonably stable over the whole study period. The data are indicated in Table 3. In the period 2013 to 2017, the prevalence of permanent tinnitus reported by children was stable at 0.6–0.8%, equal between the sexes. The data are presented in Table 4.

Hearing loss was detected in 927 children (2.2%), of which 686 (1.6%) had unilateral hearing loss, and 241 (0.6%) had bilateral hearing loss. Mild hearing loss was observed in 808 children (1.9%), moderate hearing loss – in 104 children (0.2%), and severe – in 15 children (0.03%). Over the span 2013–17, the prevalence of hearing loss was varied slightly – from 2.4% in 2013, 2.6% in 2014, 1.6% in 2015, 1.5% in 2016, to 2.9% in 2017.

Parents of the hearing impaired children noticed tinnitus more frequently (4.1%) compared to the parents of normally

**Table 1.** Prevalence (%) of tinnitus in children as reported by their parents.

| | All | Boys | Girls | Normal hearing | Hearing loss | Unilateral hearing loss | Bilateral hearing loss | Mild hearing loss | Moderate or severe hearing loss |
|---|---|---|---|---|---|---|---|---|---|
| Never | 86.2 [85.9–86.6] | 86.6 [86.1–87.0] | 85.9 [85.5–86.4] | 86.4 [86.2–86.8] | 74.8 [72.0–77.6] | 76.2 [73.1–79.4] | 70.6 [64.8–76.3] | 75.6 [72.7–78.6] | 68.9 [60.6–77.2] |
| Rarely | 12.4 [12.0–12.7] | 12.1 [11.7–12.6] | 12.6 [12.1–13.0] | 12.2 [11.8–12.5] | 21.1 [18.5–23.8] | 20.0 [17.0–23.0] | 24.5 [19.1–29.9] | 20.2 [17.4–22.9] | 27.7 [19.7–35.8] |
| Often | 1.1 [1.0–1.2] | 1.0 [0.9–1.2] | 1.2 [1.1–1.4] | 1.1 [1.0–1.2] | 3.0 [1.9–4.1] | 2.6 [1.4–3.8] | 4.1 [1.6–6.7] | 3.0 [1.8–4.1] | 3.4 [0.1–6.6] |
| Very often | 0.3 [0.2–0.3] | 0.3 [0.2–0.3] | 0.3 [0.2–0.4] | 0.3 [0.2–0.3] | 1.1 [0.4–1.7] | 1.2 [0.4–2.0] | 0.8 [0.0–2.0] | 1.2 [0.5–2.0] | – |
| Odds ratio | | OR = 0.86 [0.74–1.01] $Z = 1.80$; $p = 0.071$ | | OR = 3.13 [2.23–4.37] $Z = 6.66$; $p < 0.001$ | | OR = 1.33 [0.66–2.68] $Z = 0.80$; $p = 0.425$ | | OR = 1.29 [0.45–3.68] $Z = 0.47$; $p = 0.638$ | |

Confidence intervals (95%) are given in the brackets.

**Table 2.** Prevalence (%) of tinnitus as reported by children themselves.

| | All | Boys | Girls | Normal hearing | Hearing loss | Unilateral hearing loss | Bilateral hearing loss | Mild hearing loss | Moderate or severe hearing loss |
|---|---|---|---|---|---|---|---|---|---|
| No | **69.1** [68.7–69.5] | 68.6 [68.0–69.2] | 69.6 [69.0–70.2] | 69.4 [69.0–69.9] | 54.5 [51.3–57.7] | 55.6 [52.0–59.4] | 51.1 [44.7–57.3] | 54.4 [50.9–57.8] | 55.5 [46.5–64.4] |
| Yes, but for a very short time | **27.8** [27.4–28.2] | 28.4 [27.8–29.0] | 27.2 [26.6–27.8] | 27.6 [27.2–28.0] | 36.5 [33.4–39.6] | 36.2 [32.6–39.7] | 37.3 [31.2–43.5] | 36.1 [32.8–39.5] | 38.7 [29.9–47.4] |
| Yes, periodically and for over five minutes | **2.4** [2.2–2.5] | 2.3 [2.1–2.5] | 2.5 [2.3–2.7] | 2.3 [2.1–2.4] | 7.2 [5.6–8.9] | 7.0 [5.1–8.9] | 7.9 [4.5–11.3] | 7.5 [5.7–9.4] | 5.0 [1.1–9.0] |
| Yes, all the time | **0.7** [0.6–0.8] | 0.7 [0.6–0.8] | 0.7 [0.6–0.8] | 0.7 [0.6–0.8] | 1.8 [1.0–2.7] | 1.2 [0.4–2.0] | 3.7 [1.3–6.1] | 2.0 [1.0–2.9] | 0.8 [0.0–2.5] |
| Odds ratio | | OR = 0.93 [0.83–1.04] $Z = 1.34$; $p = 0.181$ | | OR = 3.25 [2.58–4.10] $Z = 10.00$; $p < 0.001$ | | OR = 1.48 [0.92–2.39] $Z = 0.80$; $p = 0.110$ | | OR = 1.49 [0.70–3.18] $Z = 1.05$; $p = 0.296$ | |

Confidence intervals (95%) are given in the brackets.

hearing children (1.4%) (OR = 3.13; $p < 0.05$). Parents reported tinnitus more often in children with bilateral (4.9%) than unilateral hearing loss (3.8%), but the difference was not statistically significant (OR = 1.33; $p > 0.05$). Parents reported tinnitus slightly more often in children with mild hearing loss (4.2%) than in children with moderate or severe hearing loss (3.4%), but the difference was not statistically significant (OR = 1.29; $p > 0.05$). (Table 1).

Among the children themselves, this tendency was also apparent – 3% of the children with normal hearing reported tinnitus, while the figure was 9% in the case of the children with hearing loss (OR = 3.25; $p < 0.05$). Tinnitus was reported more often by the children with bilateral (11.6%) than unilateral hearing loss (8.2%); however, the difference was not statistically significant (OR = 1.48; $p > 0.05$). Tinnitus was reported more often by the children with mild hearing loss (9.5%) than by those with moderate or severe hearing loss (5.8%), but again, the difference was not statistically significant (OR = 1.49; $p > 0.05$ (Table 2).

The additional results of sensitivity analysis showed that the main rates of tinnitus (1.4% in the parents and 3.1% in the children) would be much higher if three answers (instead of two answers) were taken into account. It would be 13.8% in the parents (5926 respondents out of 43,064) and 30.9% in the children (13,304 respondents out of 43,064).

Table 3. Prevalence (%) of tinnitus in children as reported by their parents (2013–17).

| | All | Boys | Girls |
|---|---|---|---|
| 2013 | | | |
| Never | 88.6 [87.9–89.3] | 88.6 [87.6–89.6] | 88.7 [87.7–89.6] |
| Rarely | 10.6 [9.9–11.3] | 10.6 [9.6–11.5] | 10.6 [9.7–11.6] |
| Often | 0.6 [0.4–0.7] | 0.6 [0.4–0.9] | 0.5 [0.3–0.7] |
| Very often | 0.2 [0.1–0.3] | 0.2 [0.0–0.3] | 0.2 [0.1–0.4] |
| 2014 | | | |
| Never | 86.8 [86.1–87.5] | 87.2 [86.3–88.2] | 86.4 [85.4–87.4] |
| Rarely | 11.9 [11.2–12.5] | 11.5 [10.5–12.4] | 12.2 [11.3–13.2] |
| Often | 1.1 [0.9–1.3] | 1.1 [0.8–1.4] | 1.1 [0.8–1.4] |
| Very often | 0.2 [0.1–0.3] | 0.2 [0.0–0.3] | 0.3 [0.1–0.5] |
| 2015 | | | |
| Never | 84.4 [83.6–85.2] | 85.1 [84.0–86.2] | 83.8 [82.7–84.9] |
| Rarely | 13.7 [12.9–14.4] | 13.1 [12.1–14.2] | 14.1 [13.1–15.2] |
| Often | 1.5 [1.3–1.8] | 1.5 [1.1–1.9] | 1.6 [1.2–2.0] |
| Very often | 0.4 [0.3–0.5] | 0.3 [0.1–0.5] | 0.5 [0.3–0.7] |
| 2016 | | | |
| Never | 85.6 [84.9–86.3] | 85.9 [84.8–86.8] | 85.3 [84.4–86.3] |
| Rarely | 12.9 [12.2–13.6] | 12.8 [11.9–13.8] | 13.0 [12.1–13.9] |
| Often | 1.2 [1.0–1.5] | 1.0 [0.7–1.3] | 1.5 [1.1–1.8] |
| Very often | 0.3 [0.2–0.4] | 0.3 [0.2–0.5] | 0.2 [.1–0.3] |
| 2017 | | | |
| Never | 85.8 [85.1–86.6] | 86.1 [85.0–87.2] | 85.6 [84.5–86.7] |
| Rarely | 12.7 [11.9–13.4] | 12.6 [11.6–13.7] | 12.7 [11.6–13.7] |
| Often | 1.2 [0.9–1.4] | 0.9 [0.6–1.2] | 1.4 [1.1–1.8] |
| Very often | 0.3 [0.2–0.4] | 0.4 [0.2–0.5] | 0.3 [0.1–0.5] |

Confidence intervals (95%) are given in the brackets.

## Discussion

### *Definition of tinnitus*

Comparison across studies of tinnitus prevalence in children is difficult because authors use different definitions. In our research, we asked parents and children about tinnitus experience when the child is falling asleep and in a quiet room (a question asked to children) and when in quiet (a question asked to parents). In such circumstances, the tinnitus is most likely to have an impact on everyday activities (Tyler and Baker 1983; Raj-Koziak et al. 2020). We also asked if they heard other sounds than sustained tinnitus. We consider that if a child perceives a sound other than the typically sustained tinnitus, for example, a short squeak or whistle, the sounds should not be regarded as tinnitus. Children may confuse transient ear noise with chronic tinnitus. What differentiates the two? Dauman and Tyler (1992) suggested that tinnitus must last at least five minutes and occur at least two times per week. Our time criterion for separating chronic tinnitus from occasional ear noises is five minutes and more. A positive indication of tinnitus requires the person to report his/her tinnitus as persistent or, if it is periodic, lasting longer than five minutes.

Table 4. Prevalence (%) of tinnitus as reported by children themselves (2013–17).

| | All | Boys | Girls |
|---|---|---|---|
| 2013 | | | |
| No | 63.9 [62.8–64.9] | 62.5 [61.1–64.0] | 65.2 [63.7–66.6] |
| Yes, but for a very short time | 32.4 [31.4–33.4] | 33.7 [32.2–35.1] | 31.2 [29.8–32.6] |
| Yes, periodically and for over five minutes | 3.0 [2.6–3.4] | 3.0 [2.5–3.6] | 3.0 [2.5–3.5] |
| Yes, all the time | 0.7 [0.5–0.9] | 0.8 [0.5–1.0] | 0.6 [0.4–0.9] |
| 2014 | | | |
| No | 64.5 [63.6–65.6] | 63.7 [62.3–65.1] | 65.4 [64.0–66.8] |
| Yes, but for a very short time | 32.2 [31.2–33.1] | 33.1 [31.8–34.5] | 31.3 [30.0–32.6] |
| Yes, periodically and for over five minutes | 2.5 [2.2–2.8] | 2.5 [2.1–3.0] | 2.4 [2.0–2.9] |
| Yes, all the time | 0.8 [0.6–0.9] | 0.7 [0.4–0.9] | 0.9 [0.6–1.1] |
| 2015 | | | |
| No | 67.1 [66.1–68.1] | 67.0 [65.6–68.5] | 67.2 [65.8–68.5] |
| Yes, but for a very short time | 29.9 [28.9–30.9] | 30.2 [28.7–31.6] | 29.7 [28.3–31.0] |
| Yes, periodically and for over five minutes | 2.3 [1.9–2.6] | 2.0 [1.6–2.5] | 2.4 [2.0–2.9] |
| Yes, all the time | 0.7 [0.6–0.9] | 0.8 [0.5–1.0] | 0.7 [0.5–1.0] |
| 2016 | | | |
| No | 75.6 [74.7–76.4] | 76.2 [75.0–77.4] | 75.0 [73.8–76.2] |
| Yes, but for a very short time | 21.3 [20.5–22.1] | 21.0 [19.8–22.2] | 21.6 [20.5–22.8] |
| Yes, periodically and for over five minutes | 2.4 [2.1–2.7] | 2.0 [1.6–2.4] | 2.7 [2.2–3.1] |
| Yes, all the time | 0.7 [0.6–0.9] | 0.8 [0.5–1.1] | 0.7 [0.4–0.9] |
| 2017 | | | |
| No | 74.1 [73.1–75.0] | 73.1 [71.8–74.5] | 75.0 [73.6–76.4] |
| Yes, but for a very short time | 23.5 [22.6–24.5] | 24.6 [23.2–25.9] | 22.5 [21.1–23.8] |
| Yes, periodically and for over five minutes | 1.8 [1.5–21.1] | 1.6 [1.2–2.0] | 2.0 [1.6–2.4] |
| Yes, all the time | 0.6 [0.4–0.8] | 0.7 [0.4–0.9] | 0.5 [0.3–0.7] |

Confidence intervals (95%) are given in the brackets.

### *Epidemiology*

This study assessed tinnitus prevalence in children over the years 2013 to 2017. Measuring the prevalence of tinnitus is essential to gauge how extensive the condition is. In our study, 3.1% of the children reported tinnitus; 0.7% of them heard the noise all the time, and 2.4% said they experienced tinnitus only periodically, but it did last for more than five minutes. Our results are comparable with those of other authors who have examined the prevalence of tinnitus in children 11–13 years old; Kim and colleagues found a figure of 4.4,% while Mahboubi and co-workers found a figure of 3.0% (Kim et al. 2012; Mahboubi et al. 2013). In comparison, Bulbul et al. described the prevalence of tinnitus in this age group as much higher, 33.5% (Bulbul et al. 2009). The presence of tinnitus in that study was assessed on the basis of the yes/no question *Do you have tinnitus (ringing in the ears)?* Our sensitivity analysis showed that estimating the prevalence of tinnitus based on binary questions may result in elevated rates of tinnitus. We think that a more specific question would distinguish tinnitus from occasional earnoises and would reduce the rate of reported tinnitus.

Compared to the other research carried out in this area, the material presented in this paper is one of the most extensive so far. Our results show that tinnitus in children is a rather uncommon condition. Also, observation of the condition over several years, using the same methodology, allows us to confidently say that the prevalence of tinnitus does not show an upward trend. However, our study does make clear that tinnitus is more frequent in children with hearing impairment, and these children should be carefully but calmly questioned about tinnitus.

### *Interview*

Most authors express the view that interviewing a child about their tinnitus is often tricky because children respond to questions in different ways. If they do not understand the question, they may still want to please the questioner and so answer all questions positively. Conversely, they may be confused by the questioning and respond negatively (Baguley and McFerran 1999). It is well known that children rarely report tinnitus spontaneously, but when asked about the condition in the right way, they can thoroughly explain what they are hearing. Savastano found spontaneously reported tinnitus in 6% of children, but the percentage describing a tinnitus sensation rose to 34% when they were directly asked about hearing the noise (Savastano 2002).

An explanation of why children fail to report tinnitus spontaneously is that children having permanent tinnitus may consider it a normal phenomenon. Similarly, if a family member, e.g. a parent, experiences tinnitus and informs about the condition, a child may consider tinnitus to be normal. Unlike many adults, children can more easily divert their attention to other things, because they are typically actively engaged with external stimuli from the external environment (Viani 1989; Baguley and McFerran 1999; Savastano 2002).

In our study, only 1.4% of parents reported that their children had mentioned tinnitus to them, whereas the children themselves reported it about twice as frequently (3.1%). It indicates that the child is the more reliable source of information and should be directly involved in any tinnitus assessment. Of course, the interview with the child should be conducted carefully so as not to arouse any concerns. The questions have to be adjusted to the child's age and cognitive and linguistic abilities. Some specialists recommend using techniques such as play and drawing to gather information about tinnitus in young children (British Society of Audiology 2015).

It is necessary to rely on children's answers to ensure the reliability of the study. Mills and Cherry (1984) found that below the age of 5 years, consistent answers could not be obtained. This is important for a child-specific measure to include questions at a level of language familiar to the child (Eiser and Morse 2001). When constructing the questions, we had used our experience from previous years, when we examined children aged 7 and 11 (Raj-Koziak et al. 2011, 2013). We believe that children aged 11–13 are able to answer the question about tinnitus knowingly. The oral interview collected with a child may be considered as more accurate as self-reporting to a hearing health care paediatric professional, but this way of collecting data limits testing a larger group of people.

In our study children answered the question at school before a hearing screening test. In case of doubt, the child could ask for re-explanation the question when necessary. Researchers did not report that children had a problem answering the question, despite the fact that it was more accurate than the question to parents. To increase parents' awareness and knowledge of hearing problems a series of information meetings were organised for parents at participating schools.

According to a comprehensive systematic review done by Rosing et al. (2016) such factors as age, gender and hearing status of the study population, and the manner of asking about tinnitus influence the variability of estimates. Results of our research, including 60,212 children, aged 7 y.o., living in villages and small cities in the region of Eastern Poland, were presented in 2011 (Raj-Koziak 2011). The analysis of the survey showed that 13.6% of parents report the occurrence of tinnitus in children. The percentage of children asked about tinnitus occurrence, by the interviewer during the school survey, reached 32.6%. The question addressed to parents was "Does your child complain of tinnitus when in quiet?" Parents were asked to indicate one of the possible answers: *never, rarely, often, very often*. On the day of the screening, children were asked: "Do you sometimes hear any noise, squeaks, buzzing or other sounds in your ears in a quiet environment?". Children could indicate one of the answers: *never, rarely, often, very often*. The answers: *very often, often* and *rarely* were considered positive (Raj-Koziak 2011). Based on this work, we can show that the result of the study depends on the qualification of the answer. Change of the qualification where only the answer *often* and *very often* will be treated as positive completely changes the outcome of the study and the prevalence of tinnitus reported by parents changes and decreases to 1.5% (earlier 13.65%). Whereas the tinnitus reported by children decreases to 5.8% (earlier 32.6%). Regarding the parents' responses, we did not ask who answered the survey (father or mother). We think it would be advisable to include in the subsequent testing additional information on the person who fills in the questionnaire (mother or father).

### *Tinnitus and hearing loss*

Many researchers have found that tinnitus is more common in children with hearing loss than in children with normal hearing (19,26,30,45). Tinnitus is associated with both conductive and sensorineural hearing loss (Baguley and McFerran 2002). We also saw a statistically significant difference in the prevalence of tinnitus between children with normal hearing (3%) and those with hearing impairment (9%). Similarly, parents reported significantly more frequent tinnitus in children with hearing loss

(4.1%) than in children with normal hearing (1.4%), The more frequent reporting of tinnitus from parents of children with hearing loss may be due to the increased concern that their child may have another condition associated with hearing loss. At the same time, our findings need to be put alongside reports from other researchers that parents appear to have difficulty in identifying that their children have impaired hearing (Watkin, Baldwin, and Laoide 1990; Knobel and Lima 2012).

In our study tinnitus was reported less often by the children (and their parents) with moderate or severe hearing loss than by those with mild hearing loss; however, the difference was not statistically significant, and a relationship between tinnitus and the degree of hearing loss was not confirmed. Finally, our study shows the importance of performing hearing screening in school-age children, and for educating parents and caregivers about the symptoms of impaired hearing.

### *Limitations of the study*

Our study is a retrospective analysis of data concerning tinnitus collected during the hearing screening of schoolchildren. The hearing screening program was conducted in all children in the sixth grade of primary schools in Warsaw. Until 2017, the sixth grade was the highest and last level of the Polish primary education system, after which graduates continued their education in lower secondary school. The health protection policy operated by Warsaw city authorities targeted this group of children. For this reason, our sample is not representative of schoolchildren of all ages. Another limitation of the study is a lack of follow-up data.

All Warsaw schools were invited to take part in the hearing screening, however only children of the parents who gave informed consent were examined. Audiological examination was conducted by certified and experienced audiologists, with calibrated equipment and in a controlled environment (in a quiet room, and was stopped when pupils had a break). These efforts were aimed at minimising bias in the study. The value of the study is that over 40,000 children were screened in a consistent way to detect potential hearing disorders; if necessary, they were referred for detailed audiological examinations.

## Conclusion

Results of the study show that there is a need to introduce a routine question about experiencing tinnitus during paediatric check-ups. Particular attention should be paid in cases of children with hearing impairment because of the higher risk of comorbid tinnitus. Further management, if needed, should be conducted in appropriate paediatric settings by health care professionals who have the skills and knowledge to work with children.

## Acknowledgements

We acknowledge Dr Andrew Bell and Kinga Wolujewicz for proofreading the manuscript.

## Statement of ethics

The study was conducted following the Declaration of Helsinki and was approved by the Research Ethics Committee (KB.IFPS:28/5/2018). Written consent was obtained from the children's parents.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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