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# Evaluation of School-age Hearing Screening Applications: The Tele-audiological Perspective

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## ABSTRACT

**Objective:** Hearing health is one of the areas that should be considered especially in childhood. School-age hearing screening (SAHS) is important for the detection and prevention of hearing loss. The aim of our study is to compare the use of teleaudiological applications for SAHS with standard SAHS applications and to determine possible similarities or differences between the methods.

**Methods:** The study was carried out with a total of 224 students who were first-year students in the same primary school within the borders of Istanbul. The study was completed in two phases with a test session at 15-day intervals. In the first stage, video-otoscope images of all individuals who would be subjected to standard SAHS were recorded and tympanometry test was performed. In the second stage, SAHS results were recorded with the tele-audiological method.

**Results:** According to the tympanometry results obtained from the participants, it was determined that the rate of abnormal hearing was 4.5%. According to the video-otoscope results, which were evaluated as asynchronous, the number of students suspected of dense earwax plug and membrane pathology was 6.7% in the left ear and 5.8 in the right ear. According to the SAHS method results, the average rate of passing and failing the test in the standard method was 12.9% in the right ear, and 12.9% in the left ear. According to the results of the tele-audiological method of the same student group, the rate of failing the test was 16.1% in the right ear and 15.2 in the left ear.

**Conclusion:** Measuring tele-audiologically or using the standard method did not affect the test results. Accordingly, the test result is independent of whether the test is performed with the tele-audiological or standard method.

**Keywords:** Hearing screening, telehealth, tele-audiology, school-age hearing screening, tympanometry video-otoscopy

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## INTRODUCTION

Hearing loss has a detrimental effect on an individual's speech production, language development, and academic performance. Hearing loss may develop after birth in babies without any problems detected in newborn hearing screening and may be diagnosed during childhood; thus, childhood is an important period that needs special attention in the evaluation of hearing health. Hearing loss in children has also been reported to cause decreased social skills, emotional problems, and executive dysfunctions (1). While the rate of hearing loss in newborns is around 1-3/1000 worldwide, this rate rises to 2-4% in newborns who need intensive care (2). However, the prevalence rates of childhood hearing loss also differ. Studies have shown that the prevalence rates of childhood hearing loss vary greatly between 1.4% and 17.5% (3-5). School-age hearing screening (SAHS) is as important as newborn hearing screening in terms of detecting and preventing hearing loss. Therefore, SAHS becomes as important as newborn hearing screening in terms of detecting and intervening in hearing loss. Several studies suggest that SAHS may allow timely detection of childhood hearing loss and provide favorable financial conditions to address the burden of undiagnosed hearing loss in school-aged children (6-8). However, hearing screening at school-age may also cause some additional problems. The studies have reported that the increase in the number of students, the reliability of the results, and the adequacy of the staff to participate in the screening poses great challenges in the practice of hearing screening (9,10). Tele-audiological applications should be considered as an alternative to traditional applications for the solution of existing problems in screening programs. To use telehealth systems, two basic modeling systems have been accepted according to the interaction between health professionals and health service providers. The first model is called the "store and forward" or "asynchronous" telehealth model, which involves transferring pre-recorded information from one location to another. The second model is the "real-time" or "synchronous" telehealth application (11).

Our study aims to compare the use of tele-audiological applications for SAHS with standard (traditional) SAHS applications and to determine possible similarities or differences between the methods.

## METHODS

The Clinical Research Local Ethical Committee with the registration number 83045809-604-01.02-A01 (İstanbul University-Cerrahpaşa, Cerrahpaşa Medical Faculty Ethical Committee) approved our study (approval no: 52131, date: 06.09.2018). Written consent was obtained after all participants were informed about the study.

### Subjects

The research was carried out with a total of 224 children, 97 (43.3%) girls, and 127 (56.7%) boys, who were first-grade primary school students in İstanbul. The mean age was 73.56±2.21 (70-77) months. The results are shown in Table 1.

### Procedure

In our study, hearing screening application at 15-day intervals took place. Those screenings were completed in individuals in the same primary school and classes in two stages. In the first stage, a tympanometry test was completed by an audiologist for all individuals who would undergo standard SAHS. A pressure range of 300 dPa to +200 dPa at 85 dB SPL with a probe tone of 226 Hz was used for tympanometry evaluation. The static admittance range of 0.3-1.5 mmho and pressure range of +100/-120 dPa were considered normal. Tympanograms that did not meet the criteria were considered abnormal and classified into appropriate categories (for instance, B or C). In addition to the tympanometry examination, video-otoscope images of all participants who would undergo SAHS were recorded. The obtained images were evaluated asynchronously by the otolaryngologist. Individuals with normal external auditory canal opening and membrane appearance on the video otoscope image were considered normal. Visualization of pathological findings on the tympanic membrane surface or the presence of intense ear wax were considered suspicious pathology. After the video-otoscope evaluation, all participants were subjected to the hearing screening test's Hughson & Westlake threshold measurement procedure. The participants were switched from 20 dB HL in 5 dB increments until the threshold level was determined (12). As a passing criterion, the 20 dB HL threshold was determined at 0.5 Hz, 1 kHz, 2 kHz, and 4 kHz frequency. Responses below the threshold level were considered abnormal. Standard SAHS was completed.

Before the second test session, a teacher selected from the school was given tele-audiology training and was appointed as a test assistant. In addition, the school's internet network and system requirements were actively checked for the smooth progress of the tele-audiological SAHS. In the second stage, the same audiologist who performed the standard hearing screening completed the Hughson & Westlake hearing threshold measurement procedure with the trained assistant by connecting to the test environment via video method over the internet connection at the study center. At this stage, as a passing criterion, the 20 dB HL threshold level was determined at 0.5 Hz, 1 kHz, 2 kHz, and 4 kHz frequencies. Responses obtained at the threshold level below this were considered abnormal (Figure 1).

### Equipment

Equipment used in SAHS with standard and tele-audiological methods included two portable computers (Lenovo ThinkPad

**Table 1. Gender distribution by age**

| Gender | Female n=97 (43.3%) | Male n=127 (56.7%) | t value | Sig. (p-value) |
|---|---|---|---|---|
| | **Mean ± SD** | **Mean ± SD** | | |
| Age (month) | 73.28±2.17 | 73.78±2.21 | -1.693 | 0.092 |

n: frequency, %: percent, SD: standard deviation, t: statistical significance of t-test value, sig: statistically significant

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T480 14" HD Business Laptop Intel 8th Gen Quad-Core i5-8250U, 16GB DDR4 RAM, China), software to provide a remote connection between the computers (teamwiver-version13), portable audiometer device that could be connected to a computer (Oscilla Peltor H7A, Italy), Otometrics Madsen Otoflex 100 Diagnostic Tympanometry Device (USA), Video-otoscope device (Otocam-300, USA), a webcam device (4 TECH, HD 1080p, China), and two loudspeakers (Genius SP S110, China).

### Statistical Analysis

The analysis of the data included in the research was carried out with the SPSS (Statistical Program in Social Sciences) 25 program. The Kolmogorov-Smirnov test was used to check whether the data included in the study complied with the normal distribution (13). Comparisons between measures were performed with the paired t-test. The Pearson correlation coefficient was also calculated. Values frequently used in the evaluation of the findings were as follows; 0.00-0.19 no relationship (negligible low relationship), 0.20-0.39 weak relationship, 0.40-0.69 moderate relationship, 0.70-0.89 strong relationship, and 0.90-1.00 very strong relationship (13). Interrater reliability was used to show variability between 2 or more raters measuring the same group of participants (14). Intraclass correlation coefficients (ICC) were used to assess interobserver reliability. Since the subjects were evaluated by the same observer, the ICC (1,1) model was used. ICC values below 0.40 showed weak, 0.41-0.70 acceptable, 0.71-0.90 good, and above 0.91 excellent reliability (15). The McNemar chi-square ($\chi^2$) test was used to analyze dependent categorical variables. All participants included in the study were provided with similar test setups and conditions, and the measurement values of the tests were recorded.

## RESULTS

In our study, according to the tympanometry evaluation results applied to all participants, type B, and type C results were considered abnormal. Accordingly, it was determined that the abnormal response rate in right and left ears was 4.5%. In addition

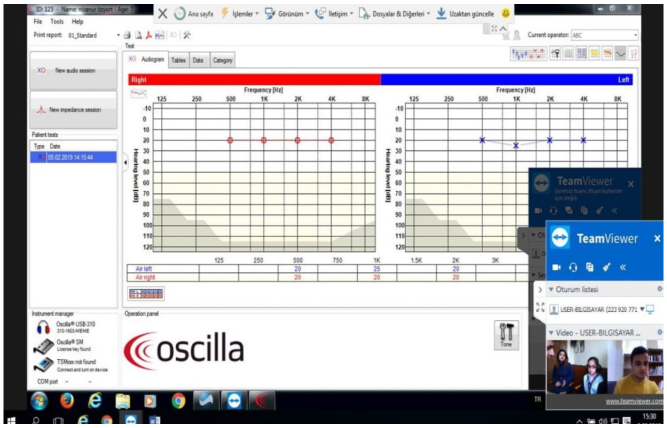


**Figure 1.** Screenshot of test recording screen (including the images of the remote audiologist and the assistant personnel with the student being screened)

to the results of the tympanometry evaluation, the number of students with intense suspicion of earwax and membrane pathology was determined according to the video-otoscope image results evaluated by the otolaryngologist with the asynchronous tele-audiology method. Accordingly, it was 6.7% in the left ear and 5.8 in the right ear. According to these results, according to the video otoscope image evaluation of the right ear, 3.6% had earwax density and 2.2% had a suspicion of eardrum pathology (eg, otitis media). And in the left ear, earwax density was observed at the rate of 4%, and suspicion of membrane pathology was observed at the rate of 2.7% (Table 2).

The tympanometric and video-otoscopic evaluation results of the students participating in the study were compared. Accordingly, there was a statistically significant relationship between right ear video-otoscopic examination and right ear tympanometry finding (p=0.023). There was a statistically significant correlation between left ear video-otoscopic examination and left ear tympanometry finding (p=0.039) (Table 3).

The passing and failing rates were evaluated according to the SAHS method results of the students participating in the study. Accordingly, the average rate of referral in the right ear of individuals who underwent SAHS with the standard method was 12.9%, and the rate of referral in the left ear was 12.9%. According to the tele-audiological method results of the same student group, the rate of failing the screening test in the right ear was 16.1%, and 15.2% in the left ear (Table 4). There was no statistically significant difference between the results of standard and tele-audiological methods according to left and right 0.5 Hz, 1 kHz, 2 kHz, 4 kHz and mean measurements (p>0.05) (Table 5).

Using tele-audiological or standard methods did not affect the test results. Accordingly, the test result was independent of

**Table 2. Demographic information and ear findings**

| Variable | Groups | Frequency | Percent |
|---|---|---|---|
| Gender | Female | 97 | 43.3 |
| | Male | 127 | 56.7 |
| Right ear tympanometry | Normal | 214 | 95.5 |
| | Pathological | 10 | 4.5 |
| Left ear tympanometry | Normal | 214 | 95.5 |
| | Pathological | 10 | 4.5 |
| Video-otoscopic left ear | Open external ear canal | 209 | 93.3 |
| | Dense ear wax | 9 | 4.0 |
| | Membrane pathology | 6 | 2.7 |
| Video-otoscopic right ear | Open external ear canal | 211 | 94.2 |
| | Dense ear wax | 8 | 3.6 |
| | Membrane pathology | 5 | 2.2 |

whether the test was performed with the tele-audiological or standard method. All results are shown in Table 6.

Our study used the ICC (1,1) model to evaluate the reliability between measurements. Accordingly, the ICC between the standard and tele-measurements of the right 0.5 kHz value was calculated as 0.411 [95% confidence interval (CI); 0.234-0.547]. The ICC between the standard and tele-measurements of the right 1 kHz value was calculated as 0.431 (95% CI; 0.259-0.562). The ICC between the standard and tele-measurements of the right 2 kHz value was calculated as 0.371 (95% CI; 0.182-0.517). The ICC between the standard and tele-measurements of the right 4 kHz value was calculated as 0.331 (95% CI; 0.158-0.257) Accordingly, the ICC between the standard and tele-measurements of the right ear mean value was calculated as 0.334 (95% CI; 0.133-0.488). The ICC between the standard and tele-measurements of the left 0.5 kHz value was calculated as 0.497 (95% CI; 0.345-0.613). The ICC between the standard and tele-measurements of the left 1 kHz value was calculated as 0.547 (95% CI; 0.411-0.652). The ICC between the standard and tele-measurements of the left 2 kHz value was calculated as 0.226 (95% CI; 0.017-0.405). The ICC between standard and tele-measurements of the left 4 kHz value was calculated as 0.256 (95% CI; 0.168-0.219). The ICC between the standard and tele-measurements of the left mean value was calculated as 0.312 (95% CI; 0.105-0.471) (Table 7). The calculated ICC values show that the agreement between the measurements is acceptable (13).

## DISCUSSION

The World Health Organization estimates that 466.46 million people have hearing loss worldwide, of whom 34 million are children (5). In children under 15 years of age, 60% of hearing impairment results from preventable causes, 31% of which are related to infections such as mumps, measles, rubella, meningitis, cytomegalovirus infections, and chronic otitis media (6). Investing in early detection, diagnosis, and rehabilitation of hearing impairment is essential for creating hearing health promotion programs for schoolchildren (7,16). Community-based hearing programs have been proposed to improve access to ear and hearing care (17). Complete evaluation of patients with ear disease requires direct imaging of the ear canal, tympanic membrane, and middle ear structures to make an accurate diagnosis and initiate appropriate treatment. Tele-audiology applications have the potential to be important tools for accessibility to community-based hearing programs. Using telehealth systems in school-age hearing screening is advantageous in reaching more students for hearing assessment, reducing the number of personnel required, and evaluating results by field experts. In addition, by training healthcare providers in tele-audiological applications, hearing assessment, diagnosis of hearing loss and intervention services can be provided relatively easily (18).

The gold standard for hearing screening of schoolchildren is pure tone audiometry. Either acoustic immittance or otoscopy performed by otorhinolaryngologists is usually recommended to detect middle ear alterations in schoolchildren (19).

Tympanometry has been suggested as a very useful test in many studies for the evaluation of middle ear pathologies in SAHS. In addition, otoscopic evaluation has been suggested to identify outer and middle ear problems (9,20,21). However, it has been reported that the Video Otoscope application facilitates remote consultations in patients in whom the examination is required and otoscopic evaluation cannot be performed. In a study that evaluated pure tone audiometry and tympanometry findings

**Table 3. Comparison of tympanometry and video-otoscopic examination situations**

| Variable | Groups | n/% | Tympanometry | | Total | $\chi^2$ | p-value (Sig.) |
|---|---|---|---|---|---|---|---|
| Right | | | Right normal | Right pathological | | | |
| Video-otoscopic right | Open external ear canal | n | 204 | 7 | 211 | 7.521 | 0.023* |
| | | % | 95.3% | 70.0% | 94.2% | | |
| | Dense ear wax | n | 7 | 1 | 8 | | |
| | | % | 3.3% | 10.0% | 3.6% | | |
| | Membrane pathology | n | 3 | 2 | 5 | | |
| | | % | 1.4% | 20.0% | 2.2% | | |
| Left | | | Left normal | Left pathological | Total | $\chi^2$ | p-value (Sig.) |
| Video-otoscopic left | Open external ear canal | n | 202 | 7 | 209 | 6.498 | 0.039* |
| | | % | 94.4% | 70.0% | 93.3% | | |
| | Dense ear wax | n | 8 | 1 | 9 | | |
| | | % | 3.7% | 10.0% | 4.0% | | |
| | Membrane pathology | n | 4 | 2 | 6 | | |
| | | % | 1.9% | 20.0% | 2.7% | | |
| Total | | n | 214 | 10 | 224 | | |
| | | % | 100.0% | 100.0% | 100.0% | | |

n: frequency, %: percent, sig; *p<0.05, there is a statistically significant difference between the two tests

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of 141 preschool and primary school students, it was reported that there were 12 children with abnormal tympanometry responses (22). Again, in a study conducted in 2016, a total of 1,181 children from kindergarten to ninth grade were evaluated. Accordingly, the tests were repeated two years later, and 862 children were re-evaluated. Four percent of children screened in 2016 (n=27, 4%) and three percent of children screened in 2018 (n=23, 3%) had abnormal otoscopy and tympanometry findings (23). In a study in which 155 children were screened for hearing, it was reported that in children in whom the face-to-face examination was required and otoscopic evaluation could not be performed, results were obtained with remote consultation applications and according to the results of the study, a pathology was detected in 13 ears (4.2%) with the video-otoscopy application (24).

In our study, according to the ear results of 224 students who underwent tympanometry evaluation, abnormal tympanometric

**Table 4.** Distribution of passing states according to test methods

| Scale | Result | Standard method | | Tele-audiological method | |
|---|---|---|---|---|---|
| | | Frequency | Percent | Frequency | Percent |
| Right 0.5 Hz | Passed | 206 | 92.0 | 204 | 91.1 |
| | Failed | 18 | 8.0 | 20 | 8.9 |
| Right 1 kHz | Passed | 213 | 95.1 | 206 | 92.0 |
| | Failed | 11 | 4.9 | 18 | 8.0 |
| Right 2 kHz | Passed | 215 | 96.0 | 213 | 95.1 |
| | Failed | 9 | 4.0 | 11 | 4.9 |
| Right 4 kHz | Passed | 217 | 96.9 | 214 | 95.5 |
| | Failed | 7 | 3.1 | 10 | 4.5 |
| Right average | Passed | 195 | 87.1 | 188 | 83.9 |
| | Failed | 29 | 12.9 | 36 | 16.1 |
| Left 0.5 Hz | Passed | 202 | 90.2 | 198 | 88.4 |
| | Failed | 22 | 9.8 | 26 | 11.6 |
| Left 1 kHz | Passed | 214 | 95.5 | 208 | 92.9 |
| | Failed | 10 | 4.5 | 16 | 7.1 |
| Left 2 kHz | Passed | 217 | 96.9 | 214 | 95.5 |
| | Failed | 7 | 3.1 | 10 | 4.5 |
| Left 4 kHz | Passed | 216 | 96.4 | 212 | 94.6 |
| | Failed | 8 | 3.6 | 12 | 5.4 |
| Left average | Passed | 195 | 87.1 | 190 | 84.8 |
| | Failed | 29 | 12.9 | 34 | 15.2 |

**Table 5.** Results according to test procedures and descriptive statistical findings of tests

| Group | Tele-audiological method | Standard method | t value | Sig. (p-value) | Pearson r | Sig. (p-value) |
|---|---|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | | | | |
| Right 0.5 Hz | 20.8±3.11 | 20.67±2.64 | 0.571 | 0.568 | 0.262 | 0.001* |
| Right 1 kHz | 20.67±3.07 | 20.42±2.21 | 1.141 | 0.255 | 0.289 | 0.001* |
| Right 2 kHz | 20.6±3.34 | 20.47±2.82 | 0.521 | 0.603 | 0.231 | 0.001* |
| Right 4 kHz | 20.58±3.62 | 20.45±3.04 | 0.428 | 0.669 | 0.017 | 0.799 |
| Right average | 20.69±2.98 | 20.55±2.73 | 0.573 | 0.567 | 0.201 | 0.003* |
| Left 0.5 Hz | 20.89±3.05 | 20.65±2.2 | 1.194 | 0.234 | 0.348 | 0.001* |
| Left 1 kHz | 20.63±2.77 | 20.31±1.61 | 1.848 | 0.066 | 0.433 | 0.001* |
| Left 2 kHz | 20.49±2.68 | 20.27±1.75 | 1.119 | 0.264 | 0.139 | 0.037* |
| Left 4 kHz | 20.58±3.26 | 20.29±1.96 | 1.137 | 0.257 | -0.009 | 0.894 |
| Left average | 20.59±2.43 | 20.38±1.62 | 1.240 | 0.216 | 0.200 | 0.003* |

SD: standard deviation, t: statistical significance of paired t-test value, sig: statistically significant, r: between two observation correlation coefficient, sig; *p<0.05, There is a statistically significant difference between the two tests

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**Table 6.** Evaluation of pass and fail situations

| Variable | Groups | n/% | Standard method right ear | | Total | McNemar $\chi^2$ test p-value | Standard method left ear | | Total | McNemar $\chi^2$ test p-value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Passed | Failed | | | Passed | Failed | | |
| Tele-audiological method 0.5 Hz | Passed | n | 190 | 14 | 204 | 0.856 | 183 | 15 | 198 | 0.608 |
| | | % | 92.2% | 77.8% | 91.1% | | 90.6% | 68.2% | 88.4% | |
| | Failed | n | 16 | 4 | 20 | | 19 | 7 | 26 | |
| | | % | 7.8% | 22.2% | 8.9% | | 9.4% | 31.8% | 11.6% | |
| Tele-audiological method 1 kHz | Passed | n | 198 | 8 | 206 | 0.21 | 201 | 7 | 208 | 0.263 |
| | | % | 93.0% | 72.7% | 92.0% | | 93.9% | 70.0% | 92.9% | |
| | Failed | n | 15 | 3 | 18 | | 13 | 3 | 16 | |
| | | % | 7.0% | 27.3% | 8.0% | | 6.1% | 30.0% | 7.1% | |
| Tele-audiological method 2 kHz | Passed | n | 207 | 6 | 213 | 0.791 | 210 | 4 | 214 | 0.549 |
| | | % | 96.3% | 66.7% | 95.1% | | 96.8% | 57.1% | 95.5% | |
| | Failed | n | 8 | 3 | 11 | | 7 | 3 | 10 | |
| | | % | 3.7% | 33.3% | 4.9% | | 3.2% | 42.9% | 4.5% | |
| Tele-audiological method 4 kHz | Passed | n | 208 | 6 | 214 | 0.607 | 205 | 7 | 212 | 0.481 |
| | | % | 95.9% | 85.7% | 95.5% | | 94.9% | 87.5% | 94.6% | |
| | Failed | n | 9 | 1 | 10 | | 11 | 1 | 12 | |
| | | % | 4.1% | 14.3% | 4.5% | | 5.1% | 12.5% | 5.4% | |
| Tele-audiological method average | Passed | n | 170 | 18 | 188 | 0.361 | 173 | 17 | 190 | 0.522 |
| | | % | 87.2% | 62.1% | 83.9% | | 88.7% | 58.6% | 84.8% | |
| | Failed | n | 25 | 11 | 36 | | 22 | 12 | 34 | |
| | | % | 12.8% | 37.9% | 16.1% | | 11.3% | 41.4% | 15.2% | |
| Total | | n | 195 | 29 | 224 | | 195 | 29 | 224 | |
| | | % | 100.0% | 100.0% | 100.0% | | 100.0% | 100.0% | 100.0% | |

n: frequency, %: percent, McNemar ki-kare test ($\chi^2$) p-value

**Table 7.** ICC value for all measurement

| Measurement | ICC (1,1) | 95% CI | |
|---|---|---|---|
| | | Lower bound | Upper bound |
| Right 0.5 Hz | 0.411 | 0.234 | 0.547 |
| Right 1 kHz | 0.431 | 0.259 | 0.562 |
| Right 2 kHz | 0.371 | 0.182 | 0.517 |
| Right 4 kHz | 0.331 | 0.158 | 0.257 |
| Right average | 0.334 | 0.133 | 0.488 |
| Left 0.5 Hz | 0.497 | 0.345 | 0.613 |
| Left 1 kHz | 0.547 | 0.411 | 0.652 |
| Left 2 kHz | 0.226 | 0.017 | 0.405 |
| Left 4 kHz | 0.256 | 0.168 | 0.219 |
| Left average | 0.312 | 0.105 | 0.471 |

ICC: intraclass correlation coefficient, CI: confidence interval, SEM: standard error of measurement, SD: smallest detectable difference

pressure findings were observed in both ears (types B and C) at a level of 4.5%. In addition, the differences, and similarities between the results of the tympanometric evaluation obtained from the standard SAHS and the results of the video-otoscopic evaluation were evaluated in our study. According to our study, when the right ear was evaluated as asynchronous with a video-otoscopic examination by an otolaryngologist, an abnormal image was obtained at a rate of 5.8% in the right ear of the participants and at a rate of 6.7% the left ear (ear wax and suspicious membrane pathology). According to our study, there was a statistically significant difference between right ear video-otoscopic examination and right ear tympanometry (p=0.023). There was a statistically significant relationship between left ear video-otoscopic examination and left ear tympanometry (p=0.039).

In the literature, many studies evaluate the prevalence of school-age hearing loss. Different prevalence rates have been reported in studies in different countries. While it was 0.9% in Taiwan (25), this rate rose to 34% in Brazil (26). In studies evaluating SAHS in England, Fonseca et al. (27) reported that 9.1% of 109,505 children from 43 centers were referred to audiology clinics or ENT hospitals in the initial stage and 53.4% of these children were found to have hearing loss. In a study using tele-audiology methods, it was reported that abnormal results were obtained at a rate of 14.8% in the hearing screening test in 218 children (28). Mahomed-Asmail et al. (29) compared the results of SAHS with tele-audiological method and traditional screening method. Accordingly, it was

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reported that there was a high level of agreement between both methods.

Considering the 0.5 kHz and 4 kHz averages in our study, the referral rate was 12.9% according to the standard audiological screening method in the right ear, while the referral rate was %16.1 in the evaluation performed with the tele-audiological method. While the referral rate was 12.9% according to the results of the standard method in the left ear, this rate was 15.2% according to the results of the tele-audiological method. When the results of 0.5 kHz, 1 kHz, 2 kHz, 4 kHz, and mean value measurements of each ear were evaluated with the standard or tele-audiological methods, the differences between the rates of individuals who passed and failed the hearing screening test were not statistically significant (p>0.05).

In a study, tablet-based screening results were compared with gold-standard pure-tone audiometry. Diagnostic values varied among the different hearing screening approaches that were evaluated: sensitivities ranged from 60% to 95%, specificities ranged from 44% to 91%, positive predictive values ranged from 15% to 44%, negative predictive values ranged from 95% to 99%, accuracy values ranged from 49% to 88%, and area under curve values ranged from 0.690 to 0.883. Regarding diagnostic values, the highest results were found for the tablet-based screening method and the series approach (30). A study of children aged 5-8 years showed that face-to-face screening showed 87-97% compliance compared to videoconferencing in a school setting. This supports the applicability of teleaudiological methods for hearing screenings.

In our study, we used the ICC (1,1) model to evaluate the reliability between measures. According to the results of our study, it was observed that tele-audiological or standard measurement methods did not affect the test results. The results obtained support the literature and the test result are independent of whether the test is performed with tele-audiological or standardized method. The ICC values obtained according to our study results show that the agreement between the measurements is at an acceptable level.

It is thought that the asynchronous video-otoscope application used in the study can contribute to the consultation skills of otolaryngologists by providing image quality. In addition, the use of the tele-audiological method, especially in hearing screenings, will facilitate access to field experts (for example, an audiologist or an otolaryngologist).

Depending on the rapid change and development in the field of technology; it is inevitable for telehealth systems to be a dynamic and rapidly changing health service delivery tool. It is envisaged that telehealth systems can contribute to the applicable principles of audiology/otolaryngology.

### Study Limitations

The sample size in our study was limited to only 224 children. Therefore, care should be taken when generalizing the results to a common population (external validity). Additional studies with larger sample sizes and the development of current practices are needed to support these findings.

## CONCLUSION

Depending on the rapid change and development in the field of technology; it is inevitable for telehealth systems to be a dynamic and rapidly changing healthcare delivery tool. The findings of our study support the use of tele-audiology applications in SAHS programs in schools with appropriate information-communication equipment and with adequate training of volunteering personnel. There will be significant advances in all areas of tele-audiology, including hearing screening, as it allows experts to evaluate the findings.

**Ethics Committee Approval:** The Clinical Research Local Ethical Committee with the registration number 83045809-604-01.02-A01 (İstanbul University-Cerrahpaşa, Cerrahpaşa Medical Faculty Ethical Committee) approved our study (approval no: 52131, date: 06.09.2018).

**Informed Consent:** Written consent was obtained after all participants were informed about the study.

**Peer-review:** Externally and internally peer-reviewed.

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**Conflict of Interest:** The authors have no conflict of interest to declare.

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