The Chinese Hearing Questionnaire for School Children

Xingkuan Bu*
Xiaolu Li*
Carlie Driscoll†

Abstract

Hearing loss is the most common of all disabilities in China, with three million of the 1.4 billion population affected. Recently, the release of an official neonatal hearing screening consensus has drawn attention to the importance of continued surveillance throughout childhood and the need for a system that is suited to the Chinese situation. The current research aimed to develop and evaluate a questionnaire for mass screening of school children in China. In Jiangsu Province, 317 rural students were screened using the Chinese Hearing Questionnaire for School Children (CHQS) and otoacoustic emissions (OAE). Test performance measures for the questionnaire method revealed average overall accuracy (A’ = 0.54), while higher system accuracy was obtained for the OAEs (A¨ = 0.85). The OAE screening also produced very high efficiency and specificity values with reasonable sensitivity. Unlike the OAE protocol, the CHQS will require substantial modification to improve its sensitivity prior to utilization as a mass screening tool.

Key Words: Hearing screening, otoacoustic emissions, questionnaire, school children

Abbreviations: A’ = overall accuracy; CHQS = Chinese Hearing Questionnaire for School Children; CMEDHQ = Childhood Middle Ear Disease and Hearing Questionnaire; EF = efficiency index; HR = hit rate; OAE = otoacoustic emissions; OME = otitis media with effusion; Pr[D/+] = positive posterior probability; Pr[N/-] = negative posterior probability; ROC = receiver operating characteristics; SNR = signal-to-noise ratio; TEOAE = transient evoked otoacoustic emissions; TN = true negative rate

Sumario

Los trastornos auditivos son la forma más común de discapacidad en China, con 3 millones afectados en una población de 1.4 billones. Recientemente, la presentación de un consenso oficial sobre tamizaje auditivo neonatal ha llamado la atención sobre la importancia de una vigilancia continua a través de la infancia y sobre la necesidad de establecer un sistema adecuado a la situación china. La actual investigación tuvo el propósito de desarrollar y evaluar un cuestionario para tamizar masivamente a los niños escolares en China. En la provincia de Jiangsu, se evaluó a 317 estudiantes rurales utilizando emisiones otoacústicas (OAE) y el Cuestionario Chino de Audición para Niños Escolares (CHQS). Las mediciones del desempeño para el método de cuestionario revelaron una exactitud promedio global (A’ = 0.54), mientras que se obtuvo una exactitud mayor con las OAE (A¨ = 0.85). El tamizaje con OAE...
Health authorities have often criticized hearing screening at school entry, in view of the less than ideal performance offered by the pure-tone sweep test (Hind et al, 1999). Some health authorities, and indeed countries, do not have school hearing screening programs in place, and some are even discontinuing their use due to under-specificity (Hind et al, 1999). However, continual screening throughout childhood has been recognized in many official guidelines concerning neonatal programs (e.g., NIH Consensus Statement, 1993; European Consensus Statement, 1998; JCIH, 2000) as being vitally important in the early identification of hearing impairment. Therefore, alternative options for screening require consideration and, particularly for mass and rural/remote populations, should be characterized by low reliance on highly trained personnel, good time efficiency, cost-effectiveness, and acceptable test performance that does not lead to unnecessary follow-up assessments. Questionnaire methods, although previously regarded as inadequate, have recently displayed the potential to be feasible and effective means of identifying children and adults at risk of significant otological disorders.

Hind et al (1999) developed the Childhood Middle Ear Disease and Hearing Questionnaire (CMEDHQ) for screening of entry-level school children, in an attempt to find an alternative to the pure-tone sweep test. Their studies revealed the questionnaire to have better specificity for medical referral and potentially better test sensitivity than the traditional test method. However, the CMEDHQ was designed for English-speaking children in a developed region of the United Kingdom and predominantly targeted middle ear disease. Wang et al (2003) created a Chinese version of the Chronic Ear Survey (CES). In their validation study, the authors demonstrated the questionnaire to be a sensitive, reliable, and valid tool for the identification of chronic suppurative otitis media (CSOM). This survey instrument, however, was also mainly concerned with middle ear disease, particularly treatment effectiveness in adults. Newton et al (1999) constructed a two-stage questionnaire for six- to eight-month-old babies in urban China. Their preliminary work showed great promise; the questionnaire demonstrated 70% sensitivity and 96% specificity. Yet, none of the abovementioned surveys could be directly utilized for the detection of hearing impairment, with or without middle ear disease, in school-aged children of rural/remote communities in China, where the present research took place.

Another alternative to the pure-tone sweep test is transient evoked otoacoustic emission (TEOAE) screening. This test of outer hair cell function has displayed definite potential as a sensitive and successful method of identifying school children at risk of significant hearing impairment (Nozza et al, 1997; Harrison and Norton, 1999; Sabo et al, 2000; Taylor and Brooks, 2000; Driscoll et al, 2001). Succinctly, the advantages of using TEOAE technology as a hearing screening tool for school children in rural/remote regions of China include the expediency of testing, relative technical simplicity of test
administration, noninvasiveness, objectivity, and resilience in non-sound-treated environments.

There has never been a more relevant time for undertaking investigations of this nature in China. Although audiology is a very new profession in this republic, only coming into existence in 1996, it has received much public attention recently given the advent of the first official consensus statement regarding immediate implementation of universal neonatal hearing screening. Currently, there are estimated to be fewer than 2000 audiologists employed in China for the servicing of a population of 1.4 billion, which is largely rural based. Hearing impairment, of a moderate or greater degree, has been reported as the most common of all disabilities in China, affecting at least 2.04% of the population or 2.9 million persons (WHO, 2002a). Additionally, it is thought that 20,000–40,000 children are born with a significant loss each year (CCRDC, 1987). Thus, an effective means of detecting this impairment is desperately required and must be specific to the Chinese situation.

The primary aim of the current research is to develop a questionnaire for mass hearing screening of school children in rural Chinese communities and to conduct a preliminary investigation into the questionnaire’s test performance through comparison with a “gold standard” audiological battery. Additionally, TEOAE screening would be conducted for comparative purposes. Implicitly, it was envisaged that through this collaborative project, a contribution would be made to the development of effective hearing screening programs and the promotion of the profession of audiology in the Asia-Pacific region.

METHODS

Participants

The participating group was comprised of 317 children studying in a rural primary school in Nanjing, Jiangsu Province, People’s Republic of China. Approximately 50 participants were required from each of Grades 1 to 6 (all the grades of the school). Participants ranged in age from 5.5 to 12.75 years (mean = 9.43 years, SD = 1.79) and represented both genders in essentially equal proportions (157 male, 160 female). No particular selection criteria were used to restrict involvement. All participation in the study was voluntarily undertaken, and only children who had returned consent forms signed by their primary caregivers were included as participants.

Procedure and Materials

Project information sheets and consent forms were delivered to the involved school by post from Jiangsu Province Hospital. Teachers were required to distribute these forms to randomly selected children and to collect signed consent forms once returned. A total of 519 forms were distributed in order to attract the 317 participants (61% return rate). Upon receipt of consent, a hearing screening questionnaire (the Chinese Hearing Questionnaire for School Children [CHQS]) was forwarded via participants to their caregivers for completion and return.

Two weeks following the questionnaire distribution, TEOAE screening was conducted. Participants received this screening, along with the gold standard audiological assessment (otoscopy, tympanometry, and pure-tone audiometry), in quiet rooms within the school and during normal attendance hours. Further details of each test appear below. Ambient noise levels during testing, as measured by an ND2 Xing-Qiu sound level meter, ranged from 35–40 dB A. For all participants, otoscopy was performed first, followed by tympanometry and pure-tone audiometry in alternating order per participant. The test session required approximately 20 minutes to complete for each child and was led by a chief otolaryngologist/professor from a major university hospital in the same province as the targeted school. This team leader (the first author) was assisted by one otolaryngologist, three audiologists, and three nurses, all from the same university hospital and all with specific training in their required duties.

A sample of 95 participants was given repeat gold standard audiological assessment in the same manner as above at eight weeks after the first session. The sample included all 16 participants who had failed the initial assessment as well as 79 participants who had passed.

Participants were provided with written
feedback forms for their caregivers immediately following completion of each testing session. Those identified from pure-tone audiometry results as having a unilateral or bilateral hearing impairment of at least a mild degree were directed to the appropriate medical and rehabilitation services. Those identified from otoscopy/tympanometry as having probable middle ear pathology were referred for medical treatment. In addition, participants who failed any part of the gold standard test battery were provided with information sheets, for school and home use, that described practical environmental modifications, basic ear care, hearing conservation, and communication strategies.

**Survey Instrument**

The CHQS was devised, by the investigators, with the aim of identifying cases with at least a mild unilateral hearing impairment and/or otitis media with effusion (OME). Thus, a wide range of questions concerning risk factors for hearing impairment and middle ear disease were included. Such factors were identified from review of related investigations (Scanlon and Bamford, 1990; Watkin et al, 1990; Hammond et al, 1997; Hind et al, 1999; Diefendorf, 2002; Northern and Downs, 2002) and in view of current high-risk register guidelines (JCIH, 2000). However, particular attention was given to the rural Chinese environment and previous otological research conducted in Chinese populations (e.g., Bu, 2002; WHO, 2002a; Yunguo and Bloom, 2002; Chen et al, 2003; Wang et al, 2003). Generic guidelines for constructing an appropriate health-related questionnaire were obtained from relevant sources (Alreck, 1995; Cox, 1996; Frazer and Lawley, 2000; Aday, 2002). A summary of the features of the CHQS has been included in Appendix A. In total, the CHQS included 34 items within eight domains.

Possible responses to questionnaire items were typically discrete (e.g., Item 3.3 = “Was your child in the neonatal intensive care unit after birth for two days or more?” Answer 3.3 = tick box for Yes/No/Not sure response). Many opportunities also existed for respondents to provide open-ended answers in addition to their closed-set responses (19 of the 34 items). For analysis purposes, individual closed-set responses were scored with one point awarded for each positive response supplied and zero points for each negative response. Cumulative points were tallied to provide a total questionnaire score. Qualitative responses were not scored but coded in order to provide further information for later questionnaire development.

A parallel model was employed for instrument translation. Composed in English, the CHQS was first translated into Mandarin Chinese and then back into English by two bilingual academics. Once the versions were considered interchangeable, a bilingual layperson was used to check the questionnaire’s comprehensibility, to highlight errors and omissions, and to identify culturally inappropriate or ambiguous questions. The questionnaire was utilized in its Chinese form.

**TEOAE Screening**

The portable TEOAE system was comprised of a Madsen Celesta 503 connected to a laptop computer and was used as a screening tool for comparison with the gold standard battery. TEOAEs were collected with a new, disposable probe tip per subject, and the order of testing left and right ears was alternated per subject. Adequacy of probe fit was inspected prior to the commencement of data acquisition. Default settings were altered until they closely matched those of the Madsen Capella and ILO Otodynamics Analyzer, as it is these, more modern, machines that are most frequently reported of in the research literature. The new stimulus consisted of nonlinear, broadband clicks delivered at 80 dB pk SPL, of 0.08 msec duration and at a rate of 50/sec. The new noise rejection level was set to approximately 47.3 dB SPL. The window for response collection was adjusted to 2.5–12.5 msec post-stimulus. The response was 3000 times time-averaged to enhance the signal-to-noise ratio (SNR) and then automatically analyzed by fast Fourier transform. Participants who displayed SNR values (an average of 1.5–4 kHz) of at least 3 dB and whole wave reproducibility (REPROW) of at least 50% were considered to have passed TEOAE screening. Testing was manually stopped if a passing result was evident after 260 accepted/quiet responses had been collected; otherwise testing continued until the default stop at 1000 responses.
Otoscopy

Visual inspection of the outer ear was performed using a Welch Allyn otoscope. The purpose of conducting this test was to detect any pathologies of the outer/middle ear that may require medical attention and to note any conditions that may affect the results of the other hearing tests. In the event that impacted cerumen was noted, the participant proceeded to pure-tone and tympanometry testing. If an associated conductive hearing loss was then revealed, cerumen removal would be performed by an on-site nurse, and audiometric testing would be repeated. Results obtained post–cerumen removal were included in the current analysis.

Tympanometry

A clinical tympanometer (Madsen Zodiac 901 Middle Ear Analyzer) collected tympanometric data. Tympanometry was used to detect the possible presence of middle ear pathologies. Although myringotomy is considered the gold standard for diagnosis of middle ear effusion (Page et al, 1995), it is an inappropriate technique within the context of school screening. Tympanometry, in combination with pneumatic otoscopy, can produce acceptable accuracy values of >95% (Chen et al, 2003). Participants who displayed bilateral tympanograms of a type other than “B” (in accordance with the Jerger [1970] system) were considered to have passed tympanometry testing. Refer to Appendix B for further detail of tympanogram types.

Pure-Tone Audiometry

This gold-standard, diagnostic test of overall hearing function obtained air- and bone-conduction thresholds at 0.5, 1.0, 2.0, and 4.0 kHz using Madsen Orbiter and Danplex audiometers fitted with TDH-39 headsets. Although pure-tone testing at 500 Hz can be problematic in non-sound-treated environments, it was included in this investigation in view of the fact that it is routinely used in hearing screening programs, that ambient noise levels in the test sites were particularly low, and that this frequency is included in WHO (2002b) definitions of disabling hearing impairment. Participants were required to display normal audiograms bilaterally, in accordance with WHO (2002b) grades of hearing loss (four frequency average of thresholds ≤20 dB HL), in order to pass pure-tone testing.

Statistical Analysis

Analysis of the resulting data was completed using the Statistical Package for the Social Sciences (SPSS) software (version 9.0.0) and included the provision of descriptive statistics for each test and combinations of tests. Additionally, signal detection theory was employed to determine the test performance of the CHQS in comparison with the audiological test battery. In particular, the hit rate (HR, probability of a positive result given a positive case), true negative rate (TN, probability of a negative result given a negative case), test performance index (A’, overall accuracy of system), efficiency index (EF, proportion of test results that were correct), and posterior probabilities (Pr[D/+], probability that case is positive given a positive result, and Pr[N/-], probability that case is negative given a negative result) were calculated. Some of these test performance measures were also calculated for TEOAE screening.

RESULTS

Gold Standard Audiological Battery

As revealed through otoscopic investigation, impacted cerumen was evident in 39 of 632 ears (6.2%). Twenty-two ears (3.5%) displayed signs of middle ear pathology (e.g., inflammation of tympanic membrane, retraction of tympanic membrane, bubbles visible behind the tympanic membrane, etc.).

Tympanometry testing of the 317 participants showed type A tympanograms to be found in 588 ears (92.7%), type Ad in 13 ears (2.0%), type As in 14 ears (2.2%), type C1 in 10 ears (1.6%), and type C2 in one ear (0.2%). The remaining eight ears (1.3%) displayed type B tympanograms and, hence, failed tympanometry testing. This equated to the failure of at least one ear of six participants (1.9%).

Pure-tone audiometry performed in 317 participants revealed abnormal results for 18 ears (2.8%) or in at least one ear of 13 participants (4.1%). As seen in Table 1, all but
one of these displayed a mild degree of hearing loss (determined according to WHO [2002b] grading system); the loss was usually sensorineural in nature, and approximately half of the losses were bilateral. In addition, the majority of abnormal results were failures that occurred across the frequency spectrum; only two subjects displayed losses with a low-frequency emphasis.

The combined gold standard test protocol of tympanometry and pure-tone audiometry was failed by 16 participants (5%). No significant grade effect was evident on tympanometry, pure-tone audiometry, or combined protocol failure rates, using Chi-squared analysis.

The abovementioned protocol was repeated eight weeks later for 95 cases. A significant change in pass/fail outcomes between test sessions was found using McNemar’s Chi-squared analysis (\(p = 0.039\)), indicative of unstable point prevalence. Specifically, while only 1.3% of sample participants who passed the initial session failed upon retest, approximately 50% of those who initially failed the battery passed upon retest.

**Questionnaire Outcomes**

Notable findings from the CHQS included that 91% of children were reported to have no current ear pathology, and at least 95% had no current problems hearing soft-/mid-/high-level sounds or the telephone. Further, over 95% had no history of diagnosed ear pathology or specialist consultation. However, 8% had experienced ear discharge and ear pain, respectively. Current episodes of dizziness were reported for 6% of children, while over 10% of children were experiencing tinnitus. Noisy work machinery was regularly used at home by 12% of children. Less than 4% of children had reportedly received previous hearing testing. Familial hearing loss was noted by 6% of respondents.

A positive history of health problems during pregnancy was reported by less than 2% of respondents and a positive history of perinatal problems in 5%. Approximately 10% of children were required to spend two or more days in the neonatal intensive care unit. Moderate or low Apgar scores were noted for 11% of children. Congenital ear or facial malformations were reported for less than 1% of children. Under 10% of children were of low birth weight (<2 kg).

Currently, the general health of the children was rated as excellent or good in 91% of cases, fair in 5%, and poor in fewer than 1% (3% undisclosed). However, 9% of children were regularly taking medication of a potentially ototoxic nature. Respondents reported that 7% of children had experienced serious accidents/illnesses, and 11% had experienced head injuries. Frequent head colds were reported for 23% of children.

The current academic performance of children was considered by respondents to be excellent or good in 75% of cases, fair in 17%, and poor in 2% (6% undisclosed). Additionally, the balance skills of 4% of children and the attentional skills of 15% were reported as fair or poor. Writing skills were said to be fair or poor for 11% of cases. Speech clarity was considered to be fair or poor in 7%, and the language skills of 19% of cases were reported to be fair or poor. Further, 8% of children were reported to be fair or poor in their ability to follow instructions and 17% fair or poor in their problem-solving capacity.

Feedback from respondents regarding the appropriateness of questionnaire structure and content was generally positive. Approximately 22% of respondents chose not to supply their opinions. Nonetheless, of those

<table>
<thead>
<tr>
<th>Hearing Loss</th>
<th>Conductive</th>
<th>Sensorineural</th>
<th>Mixed</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Bilateral</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Mild</td>
<td>4</td>
<td>7</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Moderate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moderately Severe</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Severe</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Profound</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
who did, over 84% found the CHQS to be easy to read, understand, and complete, and considered the questions posed to be of an important and polite nature. However, 33% felt that the questionnaire was too lengthy.

**Questionnaire Test Performance**

Firstly, responses on individual closed-set items of the CHQS were compared with outcomes from the gold standard audiological battery to produce sensitivity, specificity, efficiency, and posterior probability measurements. For this purpose, responses in the “not sure” category were not included in the analysis. HR values for single items of the questionnaire ranged from 0.07 to 0.42, and Pr[D/+] values ranged from 0.03 to 0.33. TN rates ranged from 0.76 to 0.99. EF values ranged from 0.75 to 0.95 and Pr[N/-] values from 0.95 to 0.96.

Second, cumulative scores for the total questionnaire were compared with outcomes from the gold standard audiological battery to produce a receiver operating characteristics (ROC) curve (refer to Fig. 1). A’ values for this analysis did not exceed 0.54.

**TEOAE Test Performance**

TEOAE screening was performed for all 317 participants. SNR values in the cohort ranged from -1.30 to 6.70 dB (mean = 5.74 dB, SD = 0.95) and 0.10 to 7.00 dB (mean = 5.70 dB, SD = 1.14) for right and left ears, respectively. REPROW values ranged from -15 to 71% (mean = 60%, SD = 10) and 1 to 72% (mean = 60%, SD = 11) for right and left ears, respectively. To reiterate, a passing result was defined as SNR values of at least 3 dB and REPROW of at least 50%. A total of 21 participants (6.6%) failed TEOAE screening in at least one ear.

Results from TEOAE screening per ear were compared with results from the “gold standard” audiological battery per ear, to produce sensitivity, specificity, efficiency, and posterior probability values. Specifically, an HR of 0.73 and TN rate of 0.98 were obtained. Pr[D/+] and Pr[N/-] values were 0.53 and 0.99, respectively. The EF index was 0.97, and the A’ value for this analysis was 0.85.

**DISCUSSION**

The current study sought to develop a questionnaire suitable for the mass hearing screening of school-aged children in rural Chinese communities and to conduct preliminary investigations into its test performance. Comparison was made with a “gold standard” audiological battery. In addition, TEOAE screening was completed for contrasting purposes.

The CHQS was informally found to be feasible in usage. Printing and distribution/collection costs were minimal. Once constructed, there was no need to employ specialized personnel for its delivery, and a moderate return rate (61%) was obtained. Although such a rate lends weight to the common argument that questionnaire screens can fail to achieve adequate coverage, following up missed cases would still be simpler and more economical than rescheduling sweep test screens (Hind et al, 1999). Further, the vast majority of respondents provided positive feedback on the questionnaire’s style and content. Only one criticism was prominent and concerned the length of the CHQS. However, the researchers expected this sentiment given that the CHQS was utilized in its pilot stage.
Of note, responses on the CHQS revealed how very few of the participants (<10%) had any history of past or current otological problems. Also, it uncovered that a substantial proportion of the children were experiencing tinnitus and were frequently exposed to potentially harmful noise levels (10% and 12%, respectively). Only a small minority of all the school children involved in the study had ever received a hearing assessment (<4%).

Tympanometry results for the cohort showed particularly low failure rates. Less than 2% of participants displayed tympanograms that could be associated with OME. Even if the researchers were to consider all tympanograms other than type A as failures, the failure rate would still be remarkably low (<8%). There are very few large-scale studies available concerning the otological status of Chinese school children with which the results could be appropriately compared. However, Chen et al (2003) reported similarly low failure rates in their investigation of three- to six-year-old Chinese kindergarten children in Taiwan (<7% had tympanograms other than type A), as did Lien et al (1985) for nonaboriginal primary school children in Taiwan (2.3% had type B tympanograms). In a survey of OME in six year olds in Taiwan, Chen et al (1989) reported that less than 1% displayed type B tympanograms. Most often, described rates of tympanometry failure appear to be lower for Chinese children than their Western counterparts, and it has been hypothesized that anatomical differences in eustachian tube function exist between races (Rushton et al, 1997; Wan and Wong, 2002).

Pure-tone audiometry failure rates for the school children of the present investigation were also exceptionally low (<5% of participants) in comparison with those typically reported in Western countries (e.g., Nozza et al [1997] cited 13.2% of five to ten year olds). Sensorineural losses were more common than those with a conductive overlay, and although this is not usually the case in Western populations, it is consistent with the low OME rates revealed by the tympanometry results for the current Chinese cohort. Given that most of the detected cases displayed losses across the frequency spectrum, rather than having a low-frequency emphasis, it is reasonable to conclude that background noise did not exert a notable influence.

In comparison with the gold standard audiological battery, the CHQS was characterized by poor overall accuracy. The hit rates and positive posterior probabilities of individual questionnaire items were low. The true negative, negative posterior probabilities and efficiency rates were high. In essence, the CHQS was quite successful in passing children that did not have otological problems; it was efficiently specific. However, it lacked sensitivity. As such, it displayed, according to Roush (2001), the most serious of all errors; it incorrectly passed high rates of children that did have otological problems. Albeit, high rates in this cohort represented few children in number, due to the exceptionally low prevalence of otologic disorders. Further, the children incorrectly undetected by the CHQS had hearing impairments that were predominantly mild in degree, and it is known that mild losses are the most difficult to reveal through parental questionnaires (Newton et al, 1999).

In contrast, the TEOAE screening protocol was highly accurate in comparison with the gold standard audiological battery. It possessed excellent specificity and efficiency, along with good sensitivity. The low positive posterior probability could be explained by the low prevalence of hearing impairment in Chinese school children. The failure rate of TEOAE testing was comparable with that of the gold standard battery.

Particular attention should be given to the limitations inherent in the current investigation. Firstly, the return rate for participation in the project was not high, perhaps due to the new nature of such research projects in rural Chinese schools. Thus, the sample of children involved in this project may not have been entirely representative of the entire school population. Secondly, it was not possible/ethical to prevent the cohort from receiving medical treatment for otologic pathology in the time period between questionnaire completion and gold standard testing. Similarly, the researchers could not control for medical treatment received between the consecutive gold standard testing sessions. Such may have contributed to the low test performance of the CHQS and the unstable point prevalence of pathology observed in the participants (both may also have been compromised by the fluctuating nature of conductive hearing loss in school children).
Future efforts in this area will be directed toward improving the sensitivity of the CHQS. Specifically, a second version will be trialed and will utilize only those items with the higher test performance values. The time period between questionnaire completion and audiological testing will also be reduced. In view of the superior performance of the TEOAE screening protocol, the feasibility of using that system across Chinese schools will be further explored.

CONCLUSION

The Chinese Hearing Questionnaire for School Children (CHQS) was developed, trialed, and evaluated in its ability to detect children at risk of hearing impairment and middle ear pathology. In comparison with a gold standard audiological battery of pure-tone audiometry and tympanometry, the CHQS displayed poor overall accuracy as a screening tool. In contrast, the accuracy measure obtained for TEOAEs as a screening system was vastly superior. Hence, TEOAEs should be seriously considered as a possible replacement for traditional screening methods. The CHQS, however, will require considerable refinement prior to utilization.

Acknowledgments. The authors would like to sincerely thank Mr. Zhou Lulin (headmaster of LongDu Primary School), Mr. Nicholas Culbert (research assistant), Dr. Ross Darnell (statistician), and Ms. Poren Kwong and Ms. Wen-I Lee (translators) for their assistance during the course of this study.

REFERENCES


Appendix A. A Summary of the CHQS Features

<table>
<thead>
<tr>
<th>Domain</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identifying details</td>
<td>Name, date of birth, gender, grade, contact details</td>
</tr>
<tr>
<td>2. Hearing history</td>
<td>Past hearing loss/ear disease particulars</td>
</tr>
<tr>
<td></td>
<td>Past hearing tests, otologic surgery</td>
</tr>
<tr>
<td></td>
<td>Current parental concern</td>
</tr>
<tr>
<td></td>
<td>Ability to hear soft/normal/loud sounds</td>
</tr>
<tr>
<td></td>
<td>Telephone use</td>
</tr>
<tr>
<td></td>
<td>Listening behaviors</td>
</tr>
<tr>
<td></td>
<td>Tinnitus, vertigo</td>
</tr>
<tr>
<td></td>
<td>Noise exposure</td>
</tr>
<tr>
<td>3. Health history</td>
<td>Prenatal and perinatal complications</td>
</tr>
<tr>
<td></td>
<td>Neonatal intensive care, birth weight, Apgar score</td>
</tr>
<tr>
<td></td>
<td>Craniofacial malformations</td>
</tr>
<tr>
<td></td>
<td>Childhood accidents, illnesses, head injury</td>
</tr>
<tr>
<td></td>
<td>Frequency of head colds</td>
</tr>
<tr>
<td></td>
<td>Medication</td>
</tr>
<tr>
<td></td>
<td>General health rating</td>
</tr>
<tr>
<td>4. Developmental history</td>
<td>Rating of motor skills, literacy, speech and language skills, attention,</td>
</tr>
<tr>
<td></td>
<td>cognition</td>
</tr>
<tr>
<td>5. Family history</td>
<td>Hearing impairment</td>
</tr>
<tr>
<td>6. Educational history</td>
<td>Overall ranking in class</td>
</tr>
<tr>
<td></td>
<td>Best/worst performance in subjects</td>
</tr>
<tr>
<td>7. Other issues</td>
<td>(Open-ended response format)</td>
</tr>
<tr>
<td>8. Questionnaire feedback</td>
<td>Questionnaire utility, structure, content</td>
</tr>
</tbody>
</table>

Appendix B. Tympanogram Classification

<table>
<thead>
<tr>
<th>Tympanogram type</th>
<th>Middle ear compliance (ml)</th>
<th>Middle ear pressure (daPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.3 to 1.5</td>
<td>+50 to -100</td>
</tr>
<tr>
<td>A_s</td>
<td>&lt;0.3</td>
<td>+50 to -100</td>
</tr>
<tr>
<td>A_d</td>
<td>&gt;1.5</td>
<td>+50 to -100</td>
</tr>
<tr>
<td>B</td>
<td>No peak</td>
<td>No peak</td>
</tr>
<tr>
<td>C_1</td>
<td>0.3 to 1.5</td>
<td>-101 to -200</td>
</tr>
<tr>
<td>C_2</td>
<td>0.3 to 1.5</td>
<td>&lt; -200</td>
</tr>
</tbody>
</table>