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Paediatric diagnostic audiology testing in South Africa

Selvarani Moodley

Centre for Deaf Studies, University of the Witwatersrand, South Africa

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ABSTRACT

Introduction: With the increased emphasis on the importance of early identification of paediatric hearing loss within developing countries such as South Africa and Nigeria there has been a recognition of the ethical obligation to ensure access to timely diagnostic and intervention services for children identified with hearing loss; regardless of their geographic or socioeconomic status. There are limited studies on diagnosis of paediatric hearing loss in a developing world context.
Objectives: The objective of this study was to determine processes used for diagnosis of paediatric hearing loss in South Africa, across the private and public healthcare sectors, and to profile the age of testing for each component of the diagnostic test battery.
Methods: Diagnostic audiology testing data of 230 children enrolled in an early intervention programme was analysed to profile the reporting of diagnostic audiology testing as well as diagnostic audiology procedures employed. Results were analysed according to province as well as healthcare sector to compare diagnostic services across regions as well as healthcare sectors.
Results: The differences in audiology practice and tests employed with paediatric clients across the regions of Gauteng, Kwazulu Natal and Western Cape indicates that services across regions and across the public and private sector are not equitable. Each region is equally unlikely to complete a full, comprehensive diagnostic evaluation on paediatric clients. The age of testing highlights the increased age of diagnosis of hearing loss.
Conclusion: Paediatric diagnostic audiology is a section of Early Hearing Detection and Intervention services that requires attention in terms of the appropriateness of procedures as well as equity of services. Further studies on diagnostic practice and resources in South Africa will provide information on factors that are preventing adherence to international best practice guidelines for paediatric diagnostic audiology.

1. Introduction

The prevalence of hearing loss in newborns has been recorded as 2 to 4 per 1000 live births in developed countries and 6 per 1000 in developing countries [1]. These statistics indicate an estimated 17 babies born with hearing loss daily in South Africa [2]. In order to ensure that hearing loss is identified as soon as possible after birth, with referral and intervention shortly thereafter, the Early Hearing Detection and Intervention (EHDI) pathway was instituted, with many international countries adopting the Joint Committee on Infant Hearing (JCIH) [3] recommendation of screening for hearing loss by 1 month of age, diagnosis of hearing loss by 3 months and referral to early intervention services by 6 months. The EHDI system ensures that the transition from screening to diagnosis to intervention is managed effectively. This drive towards early identification and subsequent early intervention has as its goal typical developmental outcomes for children with hearing loss.

Within the EHDI pathway internationally, the primary focus to date has been on the implementation of newborn screening programmes and the statistics relating to number of children screened, screening procedures and data management within screening programmes [4–8]. However, beyond this screening process, where USA is reporting a 96% coverage rate for screening of all newborns [9], few studies relating to the diagnosis of paediatric hearing loss have been published [10–13]. A systematic review of research related to the EHDI pathway in South Africa indicates a mirroring of this international trend [14]. Research focussing on the procedures followed for diagnosis of paediatric hearing loss in a developing country context is an area that is lacking in evidence-based research. Also lacking are studies related to data management and sharing of results from screening and diagnostic audiology testing [14].

E-mail address: selvarani.moodley@wits.ac.za.

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The goal of a diagnostic assessment is to determine the type, degree and configuration of hearing loss in each ear [15]. Internationally, specific protocols and guidelines exist for both the screening process [3] and for the diagnostic testing of children within specific paediatric age groups [15]. In this regard South Africa has the Health Professions Council of South Africa (HPCSA) document on guidelines for screening [16], drawn primarily from the international protocols. However protocols for diagnostics within the paediatric population in South Africa have not yet been fully explored. South Africa has (through the Health Professions Council of South Africa) released a draft document on diagnostic guidelines for the paediatric population, for comment by audiologists [17]. This is an indication of the impetus to move forward in establishing guidelines for ensuring consistency and accuracy in diagnosis of paediatric hearing loss, as the next step in the EHDI pathway. With the increased emphasis on the importance of early identification of paediatric hearing loss within developing countries such as South Africa and Nigeria [18–24], there has been a recognition of the ethical obligation to ensure access to diagnostic and intervention services for children identified with hearing loss, regardless of their geographic or socioeconomic status [25].

International best practice for diagnosis of paediatric hearing loss includes the JCIH [2] guidelines relating to paediatric diagnostic testing for the 0–5 year age group. South Africa lacks a nationally agreed upon battery of tests and protocols for diagnosing hearing loss for infants and babies and a lack of comprehensive studies relating to the practice of paediatric diagnostic audiology.

The current study aims to describe the documented audiology procedures used for diagnosis of paediatric hearing loss for children enrolled in an early intervention programme in Gauteng, Kwazulu Natal and Western Cape. The objectives of the study are to:

(1) document the reporting procedures employed by audiologists for recording and reporting on diagnostic testing of paediatric clients, and
(2) document the tests used for diagnosis of paediatric hearing loss including evaluation of the middle ear, and use of behavioural testing and electrophysiology testing (including the ages at which these tests are used).

2. Methods

A retrospective record review of the patient files of 711 children referred to the HI HOPES Early Intervention programme from September 2006 to December 2011 was conducted. Children identified with hearing loss are referred to the programme to receive home-based, family-centred early intervention. All identifying information from the paediatric audiology records have already been removed by the early intervention programme and a coding system for tracking and storage of information for data analysis is used. This ensures privacy and confidentiality of data. Parents have signed consent forms providing permission for accessing all data, including paediatric audiology records, to be used for research purposes. University of the Witwatersrand Ethical Clearance (Medical) Board provided ethical clearance for a comprehensive survey study and the University of the Witwatersrand Ethical Clearance (Education) Board provided permission for the study of all data and records relating to the early intervention programme.

2.1. Study population

The research population recruited through nonprobability convenience sampling comprises of 711 deaf and hard of hearing children enrolled in an early intervention programme in South Africa, who had diagnostic audiology testing conducted in one of three provinces (Gauteng, Kwazulu Natal and Western Cape) in South Africa. This research forms part of a longitudinal study of 160 variables profiling children with hearing loss enrolled in the HI HOPES early intervention programme during this period [26]. The sample comprised of 131 males (57%) and 99 (43%) females. The average age of initial testing for 167 children where age is provided is 36.5 months (SD $\pm$ 23.6, range 1–142 months). For the remaining 67 children the age at which initial diagnostic testing was conducted is not available due to this information not being included in the reports or diagnostic testing information included with the referral documents.

2.2. Procedures

The files of the children enrolled in the early intervention programme between September 2006 and December 2011 were examined to obtain audiology records. Audiology records were drawn from the files and reviewed. Information pertaining to diagnostic audiology testing was logged onto a data collection sheet specially designed to collate and facilitate analysis of the diagnostic audiology data. Variables included reporting format, middle ear assessment (tympanometry and acoustic reflex testing), behavioural testing method and age (air and bone conduction), and electrophysiology testing method and age (air and bone conduction). Demographic data included province in which testing was conducted and healthcare sector (public or private health).

Collated data from the data collection sheet was transferred to an excel sheet to electronically capture all details included in the reports so as to systematically document and analyse the information.

2.3. Data analysis

Data analysis techniques included basic descriptive statistics (average values, standard deviation, frequencies and percentages). Data was grouped and analysed according to the variables of private vs. public practice and the province in which the practice is located to determine the variation in diagnostic practice with respect to these variables.

Hypothesis testing (chi-square) using a significance level of 5% allowed the determination of whether there is a statistically significant difference between the private and public sector for specific variables [27].

3. Results

Of the 711 children referred to the early intervention programme between September 2006 and December 2011, audiology reports of 230 children (32% of the total referrals) were available. Reports were obtained either from parent records or directly from the referring audiologist. With logging of references to previous testing included in the reports, as well as reports from additional testing sessions for some children, audiological data includes reference to 390 audiology testing sessions.

3.1. Reports

Of the 230 children where there is some reference to diagnostic testing in the early intervention programme records, 121 children had a single assessment session only, 76 children had 2 assessment sessions, 23 had 3 assessment sessions and 7 had 4 assessment sessions. Three children each had 5, 6 and 9 assessment sessions respectively. This amounts to a total of 390 audiology testing sessions. Assessment data included 262 audiology testing sessions (67%) in Gauteng, 94 (24%) in Kwazulu Natal and 34 (9%) in the Western Cape. In terms of healthcare sector 319 (82%) reports were from the public sector, 51 (13%) were from the private sector and 20 (5%) were from university audiology departments (education and training sector).

The public/private healthcare split for each province is consistent with the 86% public health and 14% private health use reported in Theunissen and Swanepoel [28].

Assessment records comprised of: (1) formal reports detailing the different aspects of testing, protocols used and results of the tests completed, (2) assessment summaries in which a list of tests completed at different testing sessions is listed, (3) assessment templates which included filling in results on a template of all tests that could be completed as part of the test battery, (4) an audiogram with notes written on the sheet or (5) a referral letter/email that provided a list of testing completed. Referral letters lacked the comprehensiveness and details of a formal report. Electrophysiology reports included a report with testing completed filled in on a template or a report template generated by the Biologic evoked potential equipment. Formal reports provide comprehensive details of the testing, and results and recommendations for further management. The use of templates and summaries provided less comprehensive information and often just indicated whether a procedure had been completed. The indication of dates of when testing was completed for specific aspects of a template or summary was not always clear. The biologic evoked potential report generates a summary of the testing parameters in terms of stimulus type and rate. Details in terms of responses and results or recommendations and management could be typed in or handwritten on the template generated.

Of the 390 assessments done on the sample of children 269 (69%) had some form of a written record, while for 121 (31%) (Fig. 1) information was obtained from: (1) reference to testing in subsequent reports or (2) electrophysiology reports detailing the previous attempts at behavioural testing.

Of the 269 written records 102 (38%) were in the form of a formal comprehensive report and 23 (9%) were in the form of an ABR/Biologic evoked potential report template. The remaining 144 (54%) records were comprised of assessment summaries, hospital assessment templates, audiograms with notes, a template for referral to HI HOPES, and a referral letter or email stating the testing procedures completed.

A test of significance in terms of provision of a formal report indicates a significant difference ($p = 0.04$), with the private sector more likely to provide a formal report of results obtained from audiology testing.

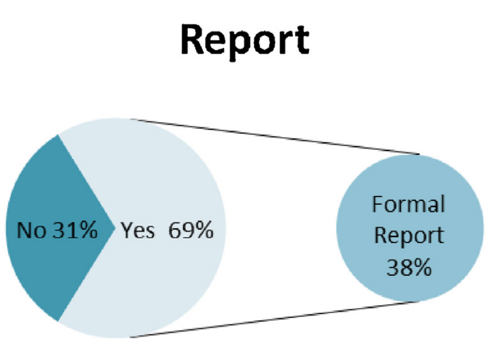

Fig. 1. Diagnostic reporting.

3.2. Diagnostic assessment

The information from the different report formats provided information on the different tests used in the diagnostic assessment. Diagnostic testing comprises of a test battery which includes (1) assessment of the middle ear system (tympanometry and acoustic reflexes), behavioural testing which is the actual physical response of the child to a sound stimulus and electrophysiology testing which includes objective testing procedures which does not require an overt response from the child to a sound stimulus. The test battery is used for differential diagnosis of the type, degree and configuration of the hearing loss. Electrophysiology testing may be included, depending on whether the child can be conditioned to consistently respond to a frequency specific sound stimulus and accurate thresholds obtained. A complete evaluation of the auditory system will include middle ear testing (tympanometry and acoustic reflex measures), air conduction frequency specific threshold testing and bone conduction frequency specific threshold testing.

The following results are presented for the total of 230 children and outlines whether tests in each specific category were completed for the total sample at any of the assessment sessions conduced.

3.2.1. Tympanometry

The initial test in a diagnostic assessment (after completion of an otoscopic examination) is tympanometry. Assessment of middle ear compliance and pressure through the use of tympanometry testing (a measure of the admittance changes in the tympanic membrane with applied air pressure [29]) allows for determination of the ability of the middle ear system to conduct sound through the air conduction pathway.

For the 230 children in the research sample, 4 children were unable to have a tympanometry assessment completed due to an atresia and 3 had cerumen or discharging ears. For the remaining 223 children, 40 (18%) did not have a tympanometry assessment, 163 (73%) have a record of a completed tympanometry measure and 20(9%) it was unable to be determined if a tympanometry measure was completed due to this information not being stated in the reference to previous testing included in reports.

Since tympanometry only provides an indication of the pressure and compliance of the middle ear system, an acoustic reflex measure is a necessary addition to tympanometry to provide an indication of the functioning of the middle ear system. The acoustic reflex is useful in diagnostic evaluation of infants as a present reflex adds support to a classification of normal middle ear function, can be used for ruling out conditions such as auditory neuropathy and sets the upper limit for auditory threshold (as a reflex will never be elicited at a level that is below the actual auditory threshold) [30]. 223 children were eligible to have an acoustic reflex measure completed (4 children had a microtia/atresia and 3 were stated to have either cerumen or discharging ears). 72 (32%) of these 223 children had an acoustic reflex measure completed in addition to the tympanometry, and thus had a complete assessment of the functioning of the middle ear system.

A breakdown of acoustic reflex testing in terms of healthcare sector indicated that the private sector conducts slightly more acoustic reflex testing than the private sector. However, a chi-test yielded a p-value of 0.18, indicating that the difference was not statistically significant.

After evaluation of the middle ear system, diagnostic testing proceeds to determine the degree and configuration of hearing loss across the frequency spectrum. Behavioural testing includes the subjective evaluation of the child's response to sound using age-appropriate behavioural testing methods, while electrophysiology testing is the objective evaluation of the auditory system and brain in response to a sound stimulus.

3.2.2. Behavioural

Behavioural testing involves the evaluation of the child's physical response to a sound stimulus and thus requires overt cooperation and participation from the child. It is dependent on appropriate equipment e.g. visual reinforcement materials for VRA, as well as audiologists skilled in conditioning a child to respond to tones and in accurately detecting response to sound. In this sample of audiology records objective behavioural testing included noisemakers, air conduction testing and bone conduction testing.

3.2.2.1. Noisemakers. Noisemakers are not frequency specific and provide an indication of whether a child responded to a toy/object that makes a sound within a frequency range. Noisemakers are used in contexts where equipment for obtaining frequency specific information is not readily available.

For 14 children noisemakers were used as an assessment tool for the initial evaluation. The ages of these children ranged from 7 to 62 months with an average age of 23 months (SD ±15.5). 2 of the 14 children had an additional disability.

3.2.2.2. Air conduction testing. Air conduction testing involves the child responding to sound presented to the ear through free-field speakers, earphones or insert phones.

Of the 230 children in the research sample air conduction testing was used as an assessment tool and results provided for 140 children. Age of testing is available for 107 children, with the age range as well as province and healthcare sector breakdown shown in Table 1.

Although (in this sample of children enrolled in an early intervention programme) the public sector is likely to start using air conduction testing on younger children, the average age of testing for the private sector is almost half of that in the public sector (Table 1). This indicates that electrophysiology thresholds for classification of degree and level of hearing loss hearing loss is more likely to be accurately verified with behavioural thresholds at an earlier age in the private sector.

When analysed according to province, it is evident that behavioural air conduction testing is not routinely conducted at younger ages (under 24 months) in any of the provinces. The age of pure tone air conduction testing in the WC (average 31.1 months, SD: ±13.6) is lowest and Kwazulu Natal the highest (average 56.2 months; SD: ±28.8). Both the private and public sector age of testing is well above the HPCSA (2007) recommendation of diagnosis by 6 months.

3.2.2.3. Bone conduction testing. Frequency specific bone conduction testing is necessary for accurate classification of the type of hearing loss. The child responds to frequency specific sounds presented via a bone conductor.

Of the 230 children that are part of the research sample, bone conduction testing was recorded for 22 children (9.5%). The age of first completion of pure tone bone conduction testing was available for 16 children (average: 56 months; SD: ±26.3; minimum: 10 months; maximum: 113 months). All children who had behavioural bone conduction testing completed were in the public sector.

Average age of bone conduction testing was higher in KZN than Gauteng. Although the average age in the Western Cape was very much younger, it was based on an *n* value of only 2. These data could be indicative of lack of adherence to a test battery for diagnosis and classification of hearing loss or poor data management in terms of accurate recording of assessment measures completed.

3.2.3. Electrophysiology

In addition to behavioural air and bone conduction threshold measures, electrophysiology is part of the test battery for confirmation of thresholds, as well as for assessment of the integrity of the neurological auditory pathway. 171 of the 230 children (74%) had some form of electrophysiology testing.

3.2.3.1. Auditory Brainstem Response. ABR can serve as a peripheral neurodiagnostic tool as well as a tool for estimation of auditory thresholds. The usefulness as a thresholding tool is for prediction of the pure tone audiogram in subjects who are not able to actively cooperate in providing a response with behavioural testing [31]. In the paediatric population this includes infants, as well as older children with a disability that makes detection of behavioural responses difficult.

154 children (67%) had at least a single Auditory Brainstem Response air conduction measure completed. Age of the test being conducted is not available for 12 children as the test was referenced in a referral letter and no date or age of testing was provided. The age of testing for the remaining 142 children is presented in Table 2 (average: 35.3 months SD: 22.7 months; minimum: 1 month; maximum: 142 months).

The largest number of auditory brainstem air conduction measures was completed in the 5–24 month age range.

When analysed according to province and sector, it is evident that the KZN private sector has the lowest average age of ABR air conduction testing while the KZN public sector has the highest average age.

Three children had ABR bone conduction measures completed. Two children with atresia were assessed with BC ABR only and one child (with atresia) had ABR BC in addition to the ABR AC and ASSR. All ABR BC measures were completed in the GT province, 2 in the private sector and 1 in the public sector. Average age of ABR BC testing was 21 months (SD ±14 months).

Table 1
Behavioural air conduction diagnostic testing.

Behavioural air conduction										
Age group	GT Public	KZN Public	WC Public	GT Private	KZN Private	WC Private	GT Univ.	KZN Univ.	WC Univ.	Total
Birth to 4 months	1 (1.5%)	–	–	–	–	–	–	–	–	1 (1%)
5–24 months	6 (8%)	4 (10.5%)	3 (23%)	5 (56%)	–	–	1 (25%)	–	–	19 (13.5%)
25–36 months	12 (16.5%)	2 (5%)	5 (39%)	2 (22%)	1 (100%)	–	3 (75%)	1 (100%)	–	26 (18.5%)
37–60 months	25 (34%)	11 (28%)	3 (23%)	1 (11%)	–	–	–	–	–	40 (28.5%)
>60 months	12 (16.5%)	9 (23%)	–	–	–	–	–	–	–	21 (15%)
Unknown	17 (23.5%)	13 (33.5)	2 (15%)	1 (11%)	–	–	–	–	–	33 (23.5%)
n	73 (100%)	39 (100%)	13 (100%)	9 (100%)	1 (100%)	–	4 (100%)	1 (100%)	–	140 (100%)
Average	45.2	56.2	31.1	24	–	–	27.3	–	–	43.9
Std Dev	18	28.8	13.6	9.6	–	–	4.5	–	–	22
Range (months)	4–101	10–121	9–52	13–23	–	–	22–33	–	–	4–121

Table 2
ABR air conduction diagnostic testing.

ABR air conduction										
Age group	GT Public	KZN Public	WC Public	GT Private	KZN Private	WC Private	GT Univ.	KZN Univ.	WC Univ.	Total
Birth to 4 months	1 (2%)	3 (8%)	1 (5%)	1 (6%)		–	–	–	–	6 (4%)
5–24 months	15 (24%)	3 (8%)	9 (45%)	10 (62.5%)	2 (50%)	–	5 (36%)	–	–	44 (28.5%)
25–36 months	18 (29%)	6 (16%)	6 (30%)	3 (19%)	1 (25%)	–	3 (21%)	–	–	37 (24%)
37–60 months	15 (24%)	14 (37%)	2 (10%)	2 (12.5%)		–	4 (29%)	–	–	37 (24%)
>60 months	6 (10%)	10 (26%)	–	–	–	–	2 (14%)	–	–	18 (11.5%)
Unknown	7 (11%)	2 (5%)	2 (10%)		1 (25%)	–	–	–	–	12 (8%)
n	62 (100%)	38 (100%)	20 (100%)	16 (100%)	4 (100%)	–	14 (100%)	–	–	154 (100%)
Average	35	48.4	25	14	22.3	–	37.4	–	–	35.3
Std Dev	18.8	28.4	11.7	11.3	6.7	–	25.7	–	–	22.7
Range (months)	3–101	1–142	4–48	2–38	18–30	–	5–96	–	–	1–142

3.2.3.2. Auditory Steady State Response. Auditory Steady State Response (ASSR) is an auditory evoked potential that is periodic in nature, in direct relation to the periodic nature of the auditory stimulus applied [32]. ASSR is more objective than ABR as it does not require the audiologist to determine replicability and location of peak waves.

76 children had an ASSR conducted in addition to the ABR measure and 17 children had only an ASSR completed. This amounts to a total of 93 ASSR measures completed. Age of completion of ASSR testing according to province and sector is detailed in Table 3. The age of testing for 4 children is unknown due to date of testing not being included on the reports. The KZN public sector is most likely to conduct ASSR testing, with an increased range and average age of ASSR testing. The youngest average age of ASSR testing is in the Gauteng private sector.

4. Discussion

Studies in South Africa have focused on screening of paediatric hearing loss. A recent study on age of diagnosis in a single province in South Africa concluded that hearing loss was diagnosed significantly earlier in children who had newborn hearing screening [39]. However, tests used for diagnosis of hearing loss were not included as part of this study. The opportunities and possibilities for screening in resource constrained settings, as identified by Petersen and Ramma [40], does not include any mention of diagnosis once hearing loss is identified through screening. Due to the continued lack of focus on diagnosis, this study focused on this gap in knowledge in the EHDI pathway in South Africa by investigating the diagnosis of paediatric hearing loss (including reporting, tests completed and age of completion of each diagnostic procedure).

The geographic spread of the research sample includes 3 provinces that make up more than 50% of the population and is representative of the population statistics in terms of public and private healthcare sectors. The 13% private and 87% public (82% public hospitals and 5% university audiology departments) is very similar to the healthcare sector spilt of 86% public and 14% private sector reported by Theunissen and Swanepoel [28]. The high average age of initial testing as well as the large range is indicative of the disparities in services for identification of hearing loss as well as the lack of newborn programmes and thus late age of identification of hearing loss.

The difference in the provision of audiology services across healthcare sectors is evident in terms of the range of reporting types, with a large number of public institutions using assessment templates and summary records and the private sector being more likely to provide formal reports detailing procedures and results from testing. This is evidence of the shortage of staff at public hospitals as has been previously reported [28], and could result in compromised quality of care across the sectors. The primary function of record keeping is the support of patient care [33], and data sharing between different professionals involved in management of the child's hearing loss. The understanding that geographic and socioeconomic barriers should not have an effect on quality of services [33] means that quality of services (and data for evaluation of services) should be equitable across healthcare sectors as well as provinces.

The importance of data management and recording is highlighted by the number of children requiring additional audiology sessions due to middle ear infections requiring referral to an ENT specialist. A factor that is important in a third world context where ear infections are common amongst the paediatric population, is the availability of ENT specialists for referral and treatment, should this be necessary. This will have an effect on diagnostic appointments, as ear infections will have an effect on accuracy of electrophysiology testing as well as behavioural audiology testing results. It is also therefore important that the test battery include all tests for differential diagnosis and classification and accurate reporting thereof.

Table 3
ASSR diagnostic testing.

ASSR testing										
Age group	GT Public	KZN Public	WC Public	GT Private	KZN Private	WC Private	GT Univ.	KZN Univ.	WC Univ.	Total
Birth to 4 months		2 (5%)	1 (5%)	1 (6.5%)	–	–	–	–	–	4 (4%)
5–24 months	3 (20%)	2 (5%)	6 (32%)	9 (60%)	2 (50%)	–	1 (50%)		–	23 (25%)
25–36 months	2 (13%)	4 (11%)	8 (42%)	4 (27%)	1 (25%)	–	1 (50%)	1 (100%)	–	21 (23%)
37–60 months	8 (53%)	20 (54%)	2 (10.5%)	1 (6.5%)	–	–	–	–	–	31 (33%)
>60 months	1 (6.5%)	9 (24%)	–	–	–	–	–	–	–	10 (11%)
Unknown	1 (6.5%)	–	2 (10.5%)	–	1 (25%)	–	–	–	–	4 (4%)
n	15 (100%)	37 (100%)	19 (100%)	15 (100%)	4 (25%)	–	2 (100%)	1 (100%)	–	93 (100%)
Average	39.4	49.9	26.1	20.5	22.3	–	24.5	–	–	39.1
Std Dev	13.6	25.6	11.5	10.2	6.7	–	3.5	–	–	21.2
Range (months)	4–66	1–142	8–48	2–37	18–30	–	22–27	35	–	1–142

The number of children having a tympanometry measure completed (72%), of which 33% had an acoustic reflex measure completed, indicates the small percentage that had a complete evaluation of the middle ear system, and for whom assistance with confirmation of thresholds and differential diagnosis of auditory neuropathy was possible.

Diagnostic guidelines recommend physiologic assessment of younger children (using auditory evoked potentials, such as the ABR), with behavioural assessment such as VRA being applicable from 5 months of age [15].

With an increase in age and as the child's response to sound becomes clearer and easier to measure and quantify, behavioural testing is used more frequently as part of the diagnostic process. However, electrophysiological testing, including the Auditory Brainstem Response (ABR) and Auditory Steady State Response (ASSR), are often used as objective confirmation of results from behavioural testing. For behavioural evaluation of response to sound, 14 children (6%) had an assessment of their response to noisemakers.

Noisemakers are an unreliable assessment of hearing and do not provide any diagnostic information. Neither frequency specific nor ear specific information is obtained using this method. From the age of 6 months a child can be conditioned to respond to frequency specific behavioural testing.

In the USA, for children over 6 months of age most audiologists are comfortable using behavioural audiometry to monitor hearing levels and gain from amplification [35]. In South Africa this may not be the case. There appears to be more use of electrophysiology testing for children up to 4 years of age. Whether this is because of a lack of equipment for VRA, difficulty with conditioning of clients or because of audiology training courses will have to be determined. In addition, bone conduction testing was completed on only 22 (9.5%) of children in the sample. had bone conduction testing completed. For 90.5% of children in this sample the diagnosis and classification of hearing loss was based on an incomplete assessment process. A possible reason for assessments being incomplete is the number of appointments required for accurate behavioural testing results to be obtained. In a busy public hospital, there is a need to fit in as many appointments as possible, and for results to be obtained quickly. Electrophysiology testing may thus be a more feasible option in terms of time constraints.

However, Hyde [34] states that 'estimation of threshold' when using tone-pip ABR is dependent on tester accuracy, stimulation and recording parameters, baby management, test strategy and tactics as well as the audiologist's caseload. Other important factors related to electrophysiology testing, as found in the Larsen et al. [12] study include the use of sedation for electrophysiology, availability of support personnel for sedation, protocols for sedation in terms of parent consent and the effect of sedation for electrophysiology on waiting times for diagnostic appointments. The contrast of the KZN public sector having the highest average age of ABR AC testing, while the KZN private sector had the lowest average age is indicative of the differences in audiology services across the private and public sectors.

93 children had ASSR testing for estimation of thresholds, with 17 of these children having had ASSR testing without ABR testing. The accuracy of the threshold estimation is dependent on the age of the subject as well as the actual behavioural threshold, with the ASSR being on average 23–31 dB greater than the behavioural threshold in young children [36]. ASSR accuracy can be improved by extending the duration of the recording [37], but when testing infants and children this may not always be possible. In addition, for children who did not have an ABR measure there was no evaluation of the neurological system before the use of ASSR for thresholding purposes.

Don and Kwong [38] caution that although electrophysiogical response to sound and auditory perception are both as a result of electrical activity in the brain, auditory perception is measured using an overt motor response to sound while electrophysiology measures synchronised neural activity in the auditory system. Physiologic testing using auditory evoked potentials (AEPs) is not a direct measure of hearing and should be complemented with behavioural testing as a measure of the actual response to sound.

5. Conclusion

Diagnostic audiology is an important component of the EHDI pathway in that it provides the link between screening and further management and intervention for the child with a hearing loss. The difficulty is in obtaining accurate diagnostic information for the paediatric population where there is a need for both objective testing (electrophysiology) and subjective confirmation of the child's actual physical response to sound. The test battery for paediatric diagnostic audiology thus has to provide information for accurate differential diagnosis. This has shown to be a challenge internationally, with South African paediatric audiology having its own unique challenges (in addition to limited comprehensive studies in this specific area). This study highlighted the late age of diagnosis, lack of use of a comprehensive test battery for diagnosis and increased use of electrophysiology testing on older children due to being unable to condition children for behavioural testing. These are issues that require further investigation.

The differences indicated in this study across the regions of Gauteng, Kwazulu Natal and Western Cape indicates that services across regions and across the public and private sector are not equitable. Each region is equally unlikely to complete a full, comprehensive diagnostic evaluation on paediatric clients. While opportunities and novel ideas for screening have been identified, further research is necessary to determine if South Africa is ready to cope with the resources, personnel and logistics necessary for accurate and timely diagnosis of paediatric hearing loss.

It is only once the process of diagnosis, audiological management and intervention are in place that the benefits of early screening will be evident.

This study was limited to audiology records of children referred to an early intervention programme (referral to which is not mandated by legislation and is at the discretion of the audiologist) and limited to 3 provinces. Further national studies are necessary to get an accurate depiction of diagnostic procedures employed. An understanding of the diagnostic procedures used and how they relate to the South African situation (in terms of healthcare, equipment, staff and linguistic issues), will provide information on factors that are preventing adherence to international best practice guidelines for paediatric diagnostic audiology and allow for contemplation of how these challenges can be overcome.

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