Contents

5.1 Phase I: Development and evaluation of a community-based hearing screening program

5.1.1 Training Village health workers in hearing screening using Distortion Product Oto Acoustic Emissions (DPOAE) and assisting in ABR testing

5.1.2 Community-based hearing screening by VHW for infants and young children

5.1.3 Validation of DPOAE screening conducted by VHW using tele-ABR as gold standard

5.2 Phase II: Efficacy of tele-audiological diagnostic follow-up versus face-to-face diagnostic follow-up

5.2.1 Comparison of the follow-up of tele-audiological diagnostic testing with the face-to-face diagnostic testing

5.2.2 Cost effectiveness for using tele-audiological diagnostic follow-up as compared to face-to-face diagnostic follow-up

5.2.3 Parental perception regarding tele-audiological testing
5.1 Phase I: Development and evaluation of a community based hearing screening program

5.1.1 Training village health workers in hearing screening using Distortion Product Oto Acoustic Emissions (DPOAE) and assisting in ABR testing

Hearing screening programs have routinely trained nurses to conduct OAE and/or AABR screening in many hospital-based programs in India. It is the audiologist who conducts the screening (Nagapoornima et al., 2007; John et al., 2012; Roopa et al., 2006; Vaid et al., 2009). One centralized program in a tertiary care hospital in Cochin, Kerala, was reported to use a trained computer technician for OAE and AABR screening, however details regarding the training provided is not available (Paul, 2011). Under the NPPCD program, grass root level workers are trained to provide hearing screening using high risk checklist and behavioural observation (Garg et al., 2009), however the limitations of screening hearing using checklist and subjective measures is well documented. Only 50% of the children with sensorineural hearing loss exhibit any of the risk factors and hence checklist-based hearing screening results in high misses. Such methods produce high levels of both false negatives and false positives with babies less than 12 months old (Mauk, White, Mortensen, & Behrens, 1991; WHO, 2009) whereas objective screening using OAE/AABR is known to have higher sensitivity and specificity (Bantock et al., 1998; Liao, Wu, & Zhou, 1999; Kennedy, McCann, Campbell, Kimm, & Thornton, 2005), hence objective screening is desirable. This is the first known attempt to engage VHWs to conduct objective hearing screening using systematic training and evaluation in India.

In developing countries like Brazil, and African countries, community-based health workers have been trained for ear and hearing health. While some studies have reported on
the specifics of their training program (Alvarenga et al., 2008; Araújo et al., 2013), others have only mentioned that training was conducted (Olusanya et al., 2007; Owen et al., 2001). There is no documented report of a systematic training program for community health workers, which is both knowledge and skill based. Only one study reports a CD-ROM based training with simulation activity delivered in distance mode for community health workers (Araújo et al., 2013).

In this study, VHWs underwent a five-day training program, where information was provided on ear and hearing, early identification and intervention of hearing loss. Demonstration and hands-on training in DPOAE screening and ABR assistance. Knowledge retention was assessed post-training using a questionnaire in which VHWs achieved between 80-86%. Skill in conducting screening was evaluated in a OSCE format and accuracy of testing was evaluated by comparing results of screening obtained by VHW with that obtained by Audiologist on the same individual. Results showed an agreement in results between VHWs and audiologist in the range of 80-90%.

Regular training and supervision is recommended to improve the health workers ability to succeed in the screening (Hansen et al., 2008), therefore regular review of manual, CD and troubleshooting procedure was encouraged. Monthly review meetings were used as another opportunity to reiterate screening protocols, information to be disseminated in the community, documentation and equipment maintenance.

Such refresher training resulted in retention of information and skill, which was reflected in the performance of VHWs in the periodic evaluations conducted at 6 months, 1 years and 1½ years post-training.
5.1.2 Community-based hearing screening by VHW for infants and young children

Hospital-based hearing screening programs for infants are evaluated widely using the JCIH benchmark. In developing countries, due to lack of infrastructure and manpower, there is progress towards community based hearing screening programs for early identification and intervention as an alternate for “do nothing”. Since the perspectives and process of community-based approach is different, it is desirable to formulate separate guidelines for such programs. However, in the absence of such guidelines, JCIH, 2007 has been used as a reference to discuss the findings of this study.

Coverage of screening is one of the benchmarks of hearing screening programs and is reported as number screened out of the total number of births. Hansen et al., 2008 suggests that community health worker based programs increase the coverage and equity of health service delivery. In this community based study, infants and young children up to 5 years of age were included. Therefore, coverage was obtained for the 0-3 months age group and the average coverage was found to be 77% with VHWs achieving 65% coverage in Group A villages and 90% in Group B villages. The coverage was less than the recommended coverage for hospital-based programs (95%). Hospital-based programs have the opportunity to screen before the child is discharged, which is not relevant to door-to-door screening in the community. However, coverage shows that it has been successful in screening infants and young children who would have otherwise not received screening services.

In another community-based hearing screening model, the coverage rate achieved by nurses in a community clinic-based screening in South Africa, was 32.4%. Multiple responsibilities shouldered by nurses along with hearing screening was reported to be one
of the major reasons for poor coverage (Friderichs et al., 2012; Olusanya et al., 2007). As a result, the researchers recommend appointing dedicated screening personnel as opposed to sharing existing manpower (Olusanya et al., 2007). In this study, dedicated personnel were available to conduct screening and this could be the reason for better coverage.

The average time taken for screening was 18 minutes with a range of 10-60 minutes. The testing time included the settling time as well as documentation time. Since screening was conducted at homes, the environment had to be prepared in addition to preparing the child for screening. Therefore, it is reasonable to expect the time taken for screening to be more. Notably, time taken for screening by VHWs in this study is similar to that reported in studies conducted by health visitors in the community in UK, where 20 minutes per screening has been reported (Uus et al., 2006) and 12.2 minutes was reported by Owen et al., 2001.

Based on the health workers monthly report it was noted that some children required more settling time and this resulted in longer testing time. In a hospital-based screening program in India, settling time was reported to have increased the average time for testing, with some cases taking up more than 30 minutes (John et al., 2009). VHWs reported that if the child was not cooperative, they encouraged the mother to put the child to sleep, and returned back after conducting screening or disseminating information regarding hearing screening in the neighbourhood.

**Follow-up rate for 2\textsuperscript{nd} screening**

Hearing screening programs have often been able to ensure high participation in the first screening but a major challenge in most countries has been in ensuring subsequent follow-
up (Scheepers, Swanepoel, & Roux, 2014; Olusanya, 2009; Liu, Farrell, MacNeil, Stone and Barfield, 2008; Mukari, Tan, & Abdullah, 2006).

In this study, the median follow-up rate for 2nd screen among infants was 80% (68% to 92%) and among young children was 97.35% (58% to 100%). Relocation of mothers from maternal home to husband’s home, and nomadic tribes frequently changing their settlement to another village post the 1st screening, contributed significantly to poorer follow-up.

The follow-up rate for 2nd screening in this study is better than those reported in hospital-based hearing screening programs in India, where 43% was reported by Vaid et al., 2013, and 70% follow-up was reported by Jewel et al., 2009. Even in community-based hearing screening programs, the loss to follow-up for 2nd screening was reported to be 52% despite free transportation and no fee (Olusanya et al., 2008). One community clinic-based program in South Africa, reports follow-up rate of 85%, ranging between 50-100% across eight community clinics, which is similar to the findings of this study (Friderichs et al., 2012).

Better follow-up for 2nd screening in this community-based program can be attributed to the door-to-door screening protocol, where the onus is on the health worker. It can be surmised from the above studies that when the onus of follow-up is on the parents, follow-up is poorer. In addition, monthly monitoring of screening data by the investigator further helped to minimise loss to follow-up.

**Refer rate**

In this study, the median of the 1st screening refer rate was 4.4%, ranging between 2-10% across the age groups. The 2nd screening refer rate was less than 1% for children less than 3
years of age, and less than 2% for children between 3-4 years of age. High refer rate of 6.25% was noted only among 4-5 year old children. Thus, with increasing age, the refer rate was higher. In a community based program in Nigeria, a similar trend of increasing refer rate with age was reported with TEOAE screening conducted by auxiliary nurses (Olusanya et al., 2008). This can be attributed to greater movement in older children and transient middle ear conditions that are more common in the 2 to 6 years age group.

Similar to the findings of this study, UNHS programs using OAE have reported refer rate to reduce from 6.5% to 13% in 1st screening to 1% to 1.5% in 2nd screening (Chen, Yi, Chen, Dong, Yang, & Fu, 2012; Vohr et al., 1998; Vohr et al., 2001). Similarly, in a hospital based hearing screening program in South India, the refer rate was reported to be 6.4% in 1st screening and reduced to 1.6% on repeat testing with OAE (John et al., 2009).

It is noteworthy that, in this community based screening program the 2nd screening refer rates were very low (less than 1% in the infant group and less than 2% in the young children group, except in 4-5 years age group). The refer rate is much lower than the reported refer rate (3% to 19.4%) in other community based programs from the African region, where two-step screening using TEOAE/AABR and DPOAE/DPOAE has been conducted in immunization clinics (Olusanya et al., 2008; Friderichs et al., 2012), having higher noise levels.

In this study, the GSI Audioscreener+ was used in “noisy” setting as the screening was conducted in the community. VHWs were trained to recognise the “noisy” message that appears in the screener when the environment is not conducive and pause screening. In
addition, having dedicated personnel (VHWs) for screening, gave them sufficient time to make several attempts during 2\textsuperscript{nd} screening to ensure that “refer” was not due to noise.

As per JCIH 2007, the “refer” percentage of all infants who fail initial screening and fail any subsequent rescreening before comprehensive audiologic evaluation should be less than 4\%. This suggests that the community based screening program, inspite of being conducted in a non-sound treated environment, has been successful in meeting the standards set by JCIH for hospital-based programs.

5.1.3 Validation of DPOAE screening conducted by VHW using Tele-ABR as gold standard

The merit of a screening program lies in its validity (JCIH, 2007). Over referral, can result in unnecessary diagnostic testing which, in turn, increases costs and makes the program less viable. On the other hand, under referral can result in missing children who may potentially have hearing loss, thereby defeating the purpose of the screening program. In this study, VHWs conducted DPOAE screening in the community. The validity of their screening was estimated using sensitivity, specificity, negative predictive value and positive predictive value.

In all, 197 ears of infants and children who underwent DPOAE screening by VHW were tested using tele-ABR, irrespective of the result of screening. The results showed that the community based hearing screening program achieved a high negative predictive value of nearly 99\%, but a low positive predictive value of 27\%. In agreement with these results, Keren et al., 2002 and Burke et al., 2012 reported that, the positive predictive value of
hearing screening programs is low, owing to the low prevalence of congenital deafness, and shortcomings in screening tests.

The sensitivity and specificity of DPOAE screening by VHWs was 75% and 91%, respectively. Norton et al. (2000) as cited in Priewe et al., 2013, used behavioural audiometric thresholds as gold standard to validate DPOAE screening at L1/L2 of 65/50 dB SPL, and the sensitivity was 88% and specificity was 83%. Few studies using two-step DPOAE screening compared their results with ABR as gold standard to obtain 97 to 100 sensitivity and 79 to 94% specificity (Liao, Wu, & Zhou, 1999; Xu, Li, Hu, Sun & Shen, 2003; Iwanicka-Pronicka, Radziszewska-Konopka, Wybranowska, & Churawski, 2008).

Several hospital-based studies using TEOAE have reported specificity of 80 to 85% and sensitivity of 90 to 99% (Keren, et al., 2002; Johnson et al, 2005., Lin et al, 2005., Hall, Smith and Popelka., 2004 as cited in Olusanya, 2010, pp. 536). Though the sensitivity of the present community-based program is lower, the specificity is higher than the hospital-based programs using TEOAE and DPOAE screening. Lower sensitivity (80%) and higher specificity (99%) have been reported in another community-based infant hearing screening program using TEOAE, where babies who passed the screening underwent AABR for sensitivity evaluation, while those with ‘refer’ underwent diagnostic evaluation (Olusanya et al., 2008). In a trade-off between sensitivity and specificity, lower sensitivity is acceptable, since there is greater emphasis on achieving low false negatives (higher specificity) in hearing screening programs, as children with hearing loss must not be missed (Keren et al., 2002; Burke et al., 2012).
Most studies (Freitas et al., 2009; Lim, Kim, & Chung, 2012; Owen et al., 2001), which refer to validity of hearing screening have not followed-up babies who passed the screening test for diagnostic testing, or have compared one screening technique (e.g. OAE) with another (e.g. AABR) to establish validity (White, 1997). Studies conducted on community-based models have often not been able to report validity (Owen et al., 2001). This may be largely due to unwillingness to participate in diagnostic testing among babies who pass screening, owing to extra travel and “unnecessary” testing. This study presented the opportunity of using tele-ABR testing as gold standard, which was provided in close proximity to children’s homes, hence compliance to participate was better. Therefore, this is one of the very few studies that has included a sub-section of children who passed the screening in addition to those with “refer”.

The sensitivity, specificity, positive and negative predictive values obtained in this study using village health workers is acceptable and comparable to findings reported in other studies. This study adds further to the body of literature that supports the increasing role of grass-root workers in the provision of community-based health care services (Olusanya et al., 2008).
5.2 Phase II: Efficacy of tele-audiological diagnostic follow-up versus face-to-face diagnostic follow-up

5.2.1 Comparison of the follow up of tele-audiological diagnostic testing with the face-to-face diagnostic testing after 2nd screening

The advantage, if any, of a tele-audiological follow-up for diagnostic testing was studied by comparing with the traditional face-to-face follow-up. The results of this study showed that the follow-up rate for tele-ABR was 15% better than that of face-to-face ABR. As per the benchmarks for hospital-based programs, at least 70% of infants requiring diagnostic evaluation should be assessed. While the rate of follow-up obtained in this study for tele-audiological follow-up was well above this benchmark (90%), the face-to-face follow-up just satisfied the criteria (75%).

Around the world, achieving 100% follow-up for diagnostics has been a challenge. Some hospital-based programs in USA, France, Malaysia showed higher follow-up rate between 81 to 91% (Asma et al., 2008; Ohl, Dornier, Czajka, Chobaut, & Tavernier, 2009). Some other programs in the USA reported follow-up rates as low as 11% (Liu et al., 2008). In one hearing screening program in the USA conducted on 4 year old children, the follow-up rate was only 10% (Allen, Stuart, Everett, & Elangovan, 2004). All hospital-based programs in India have reported poor (12% and 21%) follow-up for diagnostic assessment (Vaid et al., 2009; Nagarajan et al., 2008). Though there are very few community-based studies, it is noteworthy that community clinic-based studies have shown high (91%) follow-up rate (Friderichs et al., 2012; Spivak, Sokol, Auerbach, & Gershkovich, 2009), as they may have the advantage of lesser travel for patients.
The follow-up rate obtained in this study, irrespective of tele-audiological or face-to-face follow-up is better than the previous reports of follow-up in India, and is comparable to the high follow-up rates obtained in community clinic-based programs. This suggests that in general, community-based programs have had more success with follow-up. In this program, the better follow-up compliance may be attributed to the VHWs efforts in mobilizing and monitoring follow-up and thereby, strongly supports a community-based model of hearing screening. Though there are no reports of systematic application of tele-audiology in hearing screening programs, better follow-up for tele-audiological method in this study is comparable to the community clinic-based approach, where diagnostic testing was made available locally.

The median time taken between 2nd screening and tele-audiological follow-up for ABR was 30 days (10-189 days) and for face-to-face follow-up for ABR was 31 (30 – 36 days). Therefore, irrespective of the follow-up method, the time between screening and diagnostic was one month. These findings are similar to a hospital program where, the median time for diagnostic follow-up was 28 days (ranging from 1–1036 days) (Liu et al., 2009). The minimal difference between the two methods of follow-up suggests that the time gained by tele-audiological follow-up is not substantial. In a mobile ear-screening service, the time between screening and teleENT evaluation reported to have consistently reduced over three years of the program. This suggests that with time, the tele-audiological follow-up may show significant time gain between screening and diagnostic follow-up.

Through this community-based hearing screening program, eight infants and young children were identified with varying degrees of hearing loss via the tele-audiological and face-to-face follow-up method. The program was successful in identifying even mild and
unilateral hearing losses (two children with mild hearing loss at less than 2 years of age and one child with unilateral mild conductive hearing loss at 3 years of age). It is reported that even mild hearing loss, unilateral or bilateral, when left untreated, has costs associated with it (Bess, Dodd-Murphy, and Parker, 1998).

According to Thompson et al., 2001, in the US, good-quality studies show that 2041-2794 low-risk and 86-208 high-risk newborns were screened to find 1 case of moderate-to-profound permanent hearing loss. Though this study included children up to 5 years of age, 4 out of the 2815 screened were identified with moderate to profound hearing loss between 3-5 years of age and were recommended a hearing aid trial. Even though, return rate for diagnostics was good, only two parents followed-up for hearing aid trial and fitting. This can be attributed to the need for extra travel to the hospital. Spivak et al., 2009, reported similar non-compliance for hearing aid fitting especially in infants with unilateral hearing loss.

5.2.2 Cost-effectiveness of using tele-audiological diagnostic follow-up as compared to face to face diagnostic follow-up

The results of this study suggests that in a community-based hearing screening program, tele-audiology resulted in better follow-up as compared to a hospital-based face-to-face follow-up. While these results are promising, for large scale adoption, it should be understood if this is a cost-effective method to which health resources can be allocated. Cost effectiveness analysis is said to be the only approach to evaluate programs for early identification for hearing impairment in developing countries in Africa and Asia (Uus et al., 2006).
Cost-effectiveness analysis was carried out between tele-audiological follow-up and face-to-face to follow-up in the community-based hearing screening program for infants and young children. In this study, tele-audiological follow-up was conducted using two methods; one was by using the mobile tele-van with satellite connectivity and the other was by using broadband internet in an NGO. The number of visits using each of these methods was equal. Cost-effectiveness analysis was conducted by combining costs of both these methods of tele-audiological follow-up and compared with the face-to-face follow-up. Since the infrastructure, environment and set-up cost for mobile tele-van and broadband internet were different, cost-effectiveness was calculated individually for the two methods of tele-audiological follow-up with face-to-face follow-up. For the purpose of comparability, all costs have been converted to Int$ using purchasing power parity conversion factor obtained from the United Nations Statistics division for the year 2012 (http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=699).

Results showed that from the perspective of the provider, capital cost for tele-audiological method was substantially higher than face-to-face method when using the mobile tele-van, but only marginally higher when using broadband internet in NGO. The recurrent cost was higher for tele-audiological method irrespective of whether mobile tele-van or broadband internet in NGO were used.

From the patient’s perspective, the cost incurred in tele-audiological follow-up was lower than that of face-to-face follow-up. The average cost for parent, including wage loss and travel cost, to avail tele-ABR was Rs.174 comprising, and for face-to-face ABR was Rs.397. The difference in average cost for parent between the two methods is Rs.223 per child ($Int 9.29). Only one study has reported cost to family in a hearing screening
program, where, cost of a neonatal hearing screening program conducted in hospital after discharge was compared with Infant Distraction Test Screening (IDTS) conducted by health visitors in the community. The average cost to family was greater for IDTS by £ 0.14 ($Int 0.2) (Uus et al., 2006). Though this study pertains to screening, the hospital-based screening after discharge and community-based screening by health visitor is parallel to face-to-face ABR at hospital versus tele-audiology w.r.t the location of service.

In the present study, the cost for parent was much higher for face-to-face follow-up.

With respect to the effectiveness, the follow up for tele-audiological diagnostic method was better by approximately 2 per 1000 screened. Maximizing the rate of follow-up to diagnostic evaluation has the potential for long-term cost-savings as better follow-up can increase the chances of identifying hearing loss compared with no screening (Keren et al., 2002; Davis et al., 2014). In the USA, the cost of untreated deafness to society is estimated to be $1,126,300 (Keren et al., 2002). While there have been no studies with regard to cost of deafness in the countries of South-East Asia, WHO predicts that deafness would cost 2.5-3% of Gross National Product of individual countries (WHO, n.d). As of the year 2014, this, for India, would be approximately Rs.28,012,922. Therefore, tele-audiology presents the opportunity for such long-term cost savings.

On evaluating the incremental cost-effectiveness ratio (ICER) based on the cost-consequence matrix (McIntosh and Cairns, 1997) for a single program, the use of mobile tele-van for tele-audiological follow-up is beneficial in comparison to face-to-face follow-up, but at higher costs. Similar findings were reported in a tele-consultation service for pediatric cardiology, where the cost of tele-consultation was higher by C$92092 (Int$ 71946), but the patient journey was reduced by 42%. In order to reduce cost and thereby
increase the overall cost-effectiveness, multi-medical specialty consultation was recommended (Norum et al., 2007). A similar approach may be taken in using the mobile tele-van, by involving other specialties that concern childhood disabilities.

The ICER was considerably low when broadband internet-based tele-audiological follow-up was conducted as the costs were only marginally higher, but the follow-up was better than face-to-face, thereby reducing cost per follow-up. Sensitivity analysis showed that, lower estimate of equipment and manpower generally resulted in cost saving (Rs.4132 or Int$ 172) when using tele-audiological follow-up using broadband internet, and ICER was further reduced at the higher range of follow-up (Rs. 3640 or Int$ 152). When evaluated based on the cost-consequence matrix, the tele-audiological follow-up using broadband internet is worthwhile, as there is a cost saving with beneficial consequence. Even though, at the highest estimate of equipment and manpower cost, at both ranges of follow-up, the ICER did not show cost saving, the extra cost was lower than using mobile tele-van (Rs.30,294 or Int$1263 to Rs. 32,938 or Int$1373). Cost saving was obtained per case identified with hearing loss using broadband internet based tele-audiological follow-up (Rs.1,88, 282 or Int$7848 to Rs.2,05,393or Int$8561) per case identified with hearing loss was obtained using broadband internet follow-up for diagnostic testing.

Cost saving has been reported in economic analyses of teleradiology (Roine, Ohinmaa, & Hailey, 2001) and tele-consultation for allied health assessments including speech and language, occupational and physical therapy (Hassall et al., 2003) and teleENT service for pediatric population (Xu et al., 2008).

There were other indirect benefits of the community based screening and tele-audiology testing which could not be quantified in cost terms in this study. Increased awareness
regarding hearing, self-referral by older adults for hearing testing to the van, requests for testing hearing in older siblings of infants are some of the indicators of indirect benefits.

This study involved the development of a community based hearing screening program with two methods of follow-up. If outcomes are achieved at a lower cost than a comparator then the technology or intervention is considered to be cost-effective (Colgan et al., 2012). In this study, the ICER between the two methods shows a cost-saving using broadband internet based tele-audiological follow-up when compared to the traditional face-to-face follow-up. However, in reality, there is an absence of a systematic hearing screening program from infants and young children in this country, therefore any expenditure is therefore an increase from the present cost, which is zero. When planning a scalable program, the costs and effectiveness obtained in the present study should also be viewed with reference to cost of ‘doing nothing’.

4.2.3 Parental perception regarding tele-audiological testing

In tele-practice, the focus has been on technical aspects and feasibility with little weightage to human dimensions such as parent’s perception (Whitten & Mair 2000). In this study, parental perception of tele-audiological testing was obtained from 87 mothers of children who underwent DPOAE screening and tele-ABR.

Unlike a hospital visit for hearing testing, tele-hearing testing was conducted in mobile tele-van or in the NGO, therefore it was important to know if mother’s understood the purpose of their visit. All mothers of children who had ‘refer’ were aware that they were referred for tele-hearing testing to rule out hearing loss, and in general all mother’s were aware that tele-hearing testing was a better or detailed test as compared to the screening
conducted by VHWs at home. They were also aware that a professional will conduct the test.

Concern regarding hearing loss seems to have driven majority of the parents to avail tele-hearing testing without hesitation. Though small number in number, testing at “no cost” seems to have had some influence too. However, a quarter of the mothers reported some apprehensions about the testing as the child was very young or it was the first time they were subjecting child to any test. On their experience of tele-hearing testing, mother’s reports suggests that ABR testing seems to have evoked some anxiety among mothers due to the use of wires (electrodes) for ABR and the difficulty in having the child asleep throughout testing without sedation. On the other hand, majority of the mothers expressed excitement about the novelty of the tele-hearing testing, and their ability to see the audiologist on a TV screen. Child sleeping throughout the testing influenced mothers to perceive tele-hearing testing as a comfortable process. These findings clearly suggests that while, the apprehensions of tele-hearing testing were attributed to ABR testing, and the positive experiences were attributed to the novelty in the process of remote tele-hearing testing. This suggests that, when need is felt, tele-mode of testing, in itself, is not a barrier for availing hearing testing services.

Majority of the mothers reported the experience of remote testing to be as good as face-to-face, a small number of mothers felt that the tele-hearing testing was better than the face-to-face testing. Twenty percentage of mothers did express some dissatisfaction with tele-hearing testing. All the phrases used to describe satisfaction or otherwise concerned their experience with video-conferencing quality. And these results are comparable to the mothers report on their experience with video conferencing during tele-hearing testing.
Majority reported that they could see and hear the audiologist well through the video conferencing system. Poor video-conferencing experience was attributed to inability to see the audiologist clearly, and often they did not know that there was a professional at the remote end. Similar findings were reported among a very small number of participants in an island territory of the US, where families reported their satisfaction with a tele-ABR service, but did not know that there was an audiologist who provided the diagnostic hearing tests (Hayes et al., 2012). In this study, even though a small percentage reported such problems, reasons for poor test experience should be addressed.

Majority of the mothers report to have asked their doubts and understood what the audiologist explained via video-conferencing. But a small group of parents, did not ask doubts directly to audiologist as they did not know that an audiologist was present remotely. Frequent loss of connectivity during tele-ABR testing in an infant hearing screening program, is reported to have degraded the audio quality and thereby counselling (Hayes et al., 2012). In another program using tele-AVT in Australia, poor connectivity is reported to have resulted in audio delays and static video (Constantinescu, 2012).

Overall, majority of the mothers reported no difficulty in tele-hearing testing. Only a very small group of mothers reported difficulty due to poor signal, followed by difficulty in making the child sleep for ABR testing. In a telemedicine project in Karnataka, quality of connectivity (signal) was reported to be acceptable in 72% of the rural centres using telemedicine for consultations, however difficulties were reported in the remaining centres (Holla et al., 2013). Therefore, concerns regarding connectivity exists in other programs in the country as well, but with time the connectivity is only expected to improve (Internet & Mobile Association of India [IAMAI], 2014).
With regard to the access to tele-hearing testing, results show that, in general, majority of the mothers travelled less than half hour for seeking health care. Similar travel time was reported to access tele-hearing testing by majority of the mothers. Information was obtained on time taken, rather than distance travelled, as some locations, though less in distance, were inaccessible by road and lacked adequate public transportation. The travel time by public transport from the bus terminus of the nearest major town to the nearest private hospital with diagnostic ABR facility was estimated to be 1 hour 12 minutes using Google maps and to the nearest Government centre is 1 hour 38 minutes. It is reported that in India, 32% of people living in rural areas travel over 5 kms for basic health care as compared to 8% of people in urban areas (Aitken et al., 2013). These results show that tele-hearing testing has the potential to reduce travel time considerably.

Mothers preferred to come to the tele-van for hearing testing, followed by a preference for the local NGO, only one mother preferred to avail hearing testing at the hospital. Since there was no difference in the distance to be travelled for mobile tele-van and NGO, the preference for tele-van reported as ‘good test experience’ reported as majority of mothers may be due to a more stable connectivity (satellite), bigger TV screen for video conferencing, and possibly a novelty factor. However, no mother had prior experience with face-to-face hearing testing in a hospital. When satisfaction is expressed about a facet of health care for which patient has no experience, the expression may not be truly reflective of the quality of the actual health care (Williams et al., 2001). Therefore, their non-preference for face-to-face may be biased by travel distance alone.

It is noteworthy that a small percentage of mothers were only willing to get their child tested at home but not motivated to travel even for tele-hearing testing available in their
community. VHWs assistance in accessing tele-hearing testing by accompanying them to testing site seems to have facilitated compliance for follow-up rather than parent’s own motivation. This shows the strength of a grass root approach to early identification programs.

This study shows that mothers perceived tele-hearing testing to be as good as face-to-face testing, and were mostly satisfied with the test process, counselling and accessibility. Apprehensions about use of new technology or awkwardness in using video-conferencing reported in some studies (Blackmon, Kaak, Ranseen, 1997;Clarke, 1997; Couturier, Tyrrell, Rhul, Franco, 1998 as cited in Whitten et al., 2000, page 418) was not noted in this study. However, testing was not charged, hence its influence on perception cannot be ruled out. Novelty of the procedure may have also influenced the perception to some extent. Though small in number, consistent responses were obtained regarding poor signal quality as a hindrance to seeking quality video conferencing. Therefore, this must be addressed prior to large scale implementation.

**Challenges in conducting Tele-ABR in remote rural areas**

This study required systematic planning, meticulous problem solving, and intensive training. There were considerable challenges with training, connectivity and workspace for conducting tele-ABR in the rural community. The American Speech and Hearing Association (ASHA, 2005) has identified that challenges with reference to tele-practice are often associated with these very same components.

Tele-practice requires trained personnel at the remote end to assist in establishing connectivity, set-up clinical equipment and computers, and prepare patients for the
testing process. The expertise required for establishing satellite connectivity is more than that for broadband internet based tele-practice. There is a dearth of qualified technicians trained in telemedicine and there are too few formal training programs in India. As a result, a technician having a background in electronics and basic computer science was trained on the job and by way of trial and error. This results in a longer period of training and frequent repairs and troubleshooting.

In conducting tele-ABR, remote assistance has been provided by audiologists (Krumm et al., 2005) and ECG/EEG technicians (Smaka & Simon, 2012) in preparing the child for testing. However, in this study, using less skilled personnel such as the VHWs was inevitable, as tele-ABR testing was conducted at remote rural locations. Therefore, rigorous training was given by the investigator to ensure adequacy of skills in assisting for ABR. Joseph, West, Shickle, Keen, and Clamp (2011) report similar staff training issues in telehealth, especially in initial adjustment of staff to machines.

With respect to connectivity used for tele-ABR, there were pros and cons in using satellite and broadband internet. Tele-audiology applications around the world often use broadband internet, as the average speed available in developed countries like the UK, USA, and Australia is 4–5 Mbps. India is ranked 114th in the world on the basis of average internet speed (0.8Mbps) and internet penetration in rural areas is very limited. Such problems exist in many African and Middle Eastern regions as well (Belson et al., 2012). Using broadband Internet at the local NGO for tele-ABR posed challenges due to bandwidth limitations. There were time lags in testing and problems of lowered video quality was encountered. Conducting ABRs using broadband internet in the NGO was impractical during long hours of power shutdown (12-14 hours) in the village. In contrast, the
advantage of using a mobile tele-van for tele-ABR was the availability of a stable IP over satellite connection even in remote rural areas with minimum bandwidth of 256Kbps. The mobile tele-van presented the opportunity of conducting ABR at locations that were accessible to patients without building permanent infrastructure or identifying suitable permanent spaces with internet and power supply. However, the disadvantages of a satellite mobile van is the requirement of special training in establishing connectivity, high maintenance and frequent repairs. Satellite transmission has so far been reported only in one study in Alaska, when it was used for teleconferencing, and they reported "real time delay, audio problems and networking problems (Polovoy, 2008, as cited in Crowell, Givens, Jones, Brechtelsbauer, & Yao, 2011 page 445). A dedicated landline was reported to be better.

Several logistic challenges were encountered in obtaining tele-ABRs in remote villages. One of the major challenges was recording ABRs in natural sleep. Testing newborns was not difficult as they were often sleeping. However, testing children between 1 and 5 years of age (young children) in natural sleep was challenging. Lack of air conditioning or fan posed serious difficulties in facilitating the child to remain asleep. Sedation was not given as there were no medical personnel to prescribe dosage and monitor infant status in the remote locations. It was required to constantly monitor the sources of electrical interference from the environment and consequently filter settings were altered in order to record good quality ABR waveforms. Maintenance of the noise floor to less than 40dBA for ABR was also a challenge.

Therefore, this study demonstrates that tele-audiology has an advantage in improving service penetration, follow-up compliance in hearing screening programs, and can also be
economical viable. It also throws light on the infrastructure, manpower, environmental and logistics factors that must be considered while implementing tele-audiology practice.