OCCURRENCE OF HEARING LOSS

&

MIDDLE EAR DYSFUNCTION AMONG

PRIMARY SCHOOL CHILDREN

IN THE

CHRISTCHURCH AREA

A thesis submitted in partial fulfilment of the
requirements for the Degree
of Master of Audiology

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By Phoebe Annie Patricia Thompson

University of Canterbury

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2 Abstract

The present study tested the hearing of primary school children, in three different years, from four schools in the Christchurch area. 195 children participated in the study. Testing was undertaken on school grounds and children with results outside the normal range on the screening tests were offered follow-up audiological testing. The study investigated the percentage of children with a hearing loss, the type of hearing loss and whether a particular hearing loss is more common to one ethnic group than the others. The study also looked at the use of distortion-product otoacoustic emissions (DPOAEs) as a screening tool. The results were compared to those of other published studies to determine whether the children in the present study have approximately the same occurrence of hearing loss and middle ear dysfunction as other areas in the developed world. The occurrence of confirmed hearing loss was estimated at 7.6% and the occurrence of middle ear dysfunction was estimated to be 3%. Both these results were found to be consistent with previous literature. DPOAE findings were consistent with previous findings.

3 Prevalence of Hearing Loss & Middle Ear Dysfunction Affecting Primary School Children in the Christchurch Area

Background

Hearing Loss in children is an important health issue and is estimated to affect 3 children in 1000 (Northern and Downs, 2002). Hearing Loss is frequently described as the invisible disability, as it can be difficult to know when someone has difficulty hearing. This is especially evident in children, as they are often unable to tell anyone they are having difficulty hearing; as a consequence, hearing loss in children may go undetected for years. This delay in identification of hearing loss can lead to many children missing out on auditory information during their formative years and is more common where the hearing loss is mild or fluctuating (Bess, 1998). These undiagnosed hearing losses may have a great impact on a child's development in many areas including speech and language, social and education. (Northern and Downs, 2002)

It is widely accepted that classrooms are poor listening environments for children. There are often high levels of background noise and the teacher frequently speaks to the children from a distance, resulting in the loss of much of the speech energy. Background noise can be caused by; external sources outside the building, such as traffic and playgrounds, and internal noise from inside the building, such as other children talking and furniture being moved (Crandell & Smaldino, 2000). Children require a higher signal to noise ratio (SNR) for speech perception, than adults, especially if they have a hearing loss (Berg,

1998). SNR is the ratio of the target signal (the speaker's voice) with reference to the competing noise, measured in decibels. For example, a SNR of 0 means that the target signal and competing noise are at equal loudness. A positive SNR means the target signal is louder than the competing noise, with a negative SNR meaning that the competing noise is louder than the target signal. For optimal speech perception, normally hearing children require a SNR of greater than +6dB, whilst children with a hearing loss need a SNR of greater than +12dB (Berg, 1998). This level is rarely achieved in classrooms, which may lead to children having difficulty understanding instructions (Berg, 1998). Finitzo-Hieber & Tillman (1978) found that children with sensori-neural hearing loss performed worse in speech perception tasks, than normal children. The difference was especially evident when the signal to noise ratio was at a level similar to that of normal classrooms. It is very important, therefore, that children with hearing loss are identified as early as possible so that they can receive additional help. (Berg, 1998)

4.2 Hearing Loss

Hearing loss can be divided into Conductive, Sensori-neural and Mixed hearing loss. Conductive hearing loss is the hindrance of sound traveling between the external ear and the inner ear. Patients with a conductive hearing loss have an inner ear that is functioning normally. However, the signal is diminished, prior to reaching the inner ear. Common causes of conductive hearing loss are Otitis Media (middle ear disease, such as glue ear), impacted wax and damage to the ossicles or tympanic membrane. Conductive hearing loss can be identified when air-conduction hearing thresholds are abnormal in the presence of normal bone conduction thresholds (Northern and Downs, 2002; Roeser, Buckley and Stickney, 2002).

Sensori-neural hearing loss is a result of a loss of function of the inner ear (cochlear) or beyond the inner ear along the auditory pathways. Sensori-neural hearing loss is generally considered to be permanent, whereas many causes of conductive loss can be temporary (Northern and Downs, 2002; Roeser, Buckley and Stickney, 2002). There are many causes of sensori-neural hearing loss; nine common risk factors for infants are;

1. Family history of hearing loss
2. Jaundice requiring exchange transfusion
3. Craniofacial abnormalities
4. Ototoxic drugs
5. Mechanical ventilation lasting five or more days
6. Low Apgar scores (0 to 4 one minute or 0 to 6 at five minutes)
7. Birth weight less than 1500 grams
8. Bacterial meningitis
9. Infection such as rubella, herpes and toxoplasmosis and those associated with hearing loss

(National Audiology Centre, 2007)

Mixed hearing occurs when both a sensori-neural and a conductive hearing loss are evident. This can be identified when both bone conduction and air conduction thresholds are abnormal but are significantly different (15dB apart) (Northern and Downs, 2002; Roeser, Buckley and Stickney, 2002). This can occur when a child has a sensori-neural hearing loss in conjunction with Otitis Media. When this occurs the child has a greater hearing impairment than they were originally diagnosed with. Hearing Loss is categorized by the severity of the loss and has differing effects depending on its severity. Normal

hearing thresholds are approximately 20dB HL and below. This thresholds The following table displays the common classification of hearing loss and its effects on speech understanding.

Table 1. (Northern & Downs, 2002; Jerger, 1980)

Average Hearing Level (500-2000) dBHL	**Classification**	**Missing speech components**	**Effect on development**
26-40	Mild	Missing majority of speech sounds with exception of loud voiced sounds	Auditory learning dysfunction, mild speech delays. Inattention
41-55	Moderate	Miss almost all speech sounds at normal conversational level	Language dysfunction, speech delays, inattention and learning difficulty
56-70	Moderately Severe	Unable to hear any speech components at normal speaking volume	Inability to develop speech and language spontaneously without amplification. Severe speech & language problems, associated educational delays
71-90	Severe	No speech or other sounds	Unable to develop language without special intervention. Severe speech & language problems, associated educational delays
91 +	Profound	As above	As above

Recently, the importance of slight hearing loss has been of great discussion. Slight hearing loss is considered to be between 16dBHL and 25 dBHL. Bess, Dodd-Murphy & Parker (1998) found that 13% of the children they tested, had a slight hearing loss and these children performed significantly worse on academic sub-tests and 37% were educationally delayed compared with only 3% of the control group. Crandell (1993) found that children, with a slight hearing loss, performed significantly worse than normal children on speech perception tasks, when tested with common classroom signal to noise ratios. It is therefore important to consider children, with even a slight hearing loss, as being disadvantaged, especially in the classroom environment.

Hearing loss in New Zealand

The rate of hearing loss, in New Zealand Children, is currently based on the National Audiology Centre database and estimates from the failure rates of screening tests and National health surveys (New Zealand Health and Disability Survey, 1996). In the most recent report for the year 2005, the incidence of children reported to the Deafness Detection Database was 209 (National Audiology Centre, 2007). To be included in the analysed data for the report, the children had to meet the following inclusion criteria;

"*Children under 18 years with congenital hearing losses or any hearing loss not remediable by medical or surgical means, and who require hearing aids and/or surgical intervention. They must have an average bilateral hearing loss (over four audiometric frequencies 500-4000Hz), greater than 26dBHL in the better ear."(* (National Audiology Centre, 2007).)

From the 209 children reported to the database, 93 were included for analysis. This was reported to be slightly reduced, compared with previous years, and it was thought that this was due to the earlier identification of children with moderate hearing loss. The most

common degree of hearing loss, identified in 2005, was moderate (39%), followed closely by mild/moderate (34%). The most common cause of hearing loss was unknown (58%), with family history being the highest predictor at 32%. Maori children were over represented, with 43% of all children reported. Although information in this report is useful, only the incidence of hearing loss is able to be obtained from the data reported. (National Audiology Centre, 2007)

Currently New Zealand runs a screening program that targets children at School Entry and in pre-school. Since not all children attend pre-school, a large proportion of children are not tested at the preschool age. However, as schooling in New Zealand is compulsory, almost 100% of children are screened on school entry. These hearing screens are conducted by hearing and vision screeners. A failure is two thresholds of >45dBHL on one testing session or one or more thresholds exceeding 30dBHL (500Hz) or 20dBHL (1000-4000Hz) on two separate testing sessions. Parents of the children who fail screening are notified and are recommended to be referred for full audiologic examination. Nationally, the failure rate for audiometry was 6.6% (June 2005-June 2006) which is relatively high, and failure rates varied from 1.0-10.8% (National Audiology Centre, 2006). More specifically, the failure rate for Canterbury was 5.4%. Pacific Island and Maori children had the highest failure rates of 16.5% and 14.1% respectively; it is suspected that the higher rate is due to genetics (National Audiology Centre, 2007). It is important to note that the validity of the failure rate is equivocal as 6 regions of New Zealand have exceptionally high failure rates and unreliable coverage rates.

Unfortunately, the reported incidence of hearing loss, from health care professionals, included in the Deafness Detection database and the results from the New Entrant screening are not compared in any way. It is also worthwhile noting that there is no record

of the number of children that receive full diagnostic testing, following the screening failure, and are in turn confirmed to have a hearing loss.

Many studies have been conducted overseas which look at the prevalence of hearing loss in children. However, a lot of these studies are retrospective in design and therefore only report the prevalence of hearing loss in children known to the health system. Moreover, studies using hearing tests to identify the prevalence of hearing loss in children use varying methodologies, such as different referral criteria and the use of different audiological tests. These differing methodologies can, in turn, produce differing results, which can make comparing prevalence data difficult.

Fortnum and Davis (1998) conducted a retrospective study looking at the prevalence of permanent hearing loss in children born between 1985 and 1993 in the Trent region, in the United Kingdom. The coverage rate was 100% and the study reported a prevalence rate of 1/750. The criterion for a hearing loss was greater than a 40dBHL averaged threshold. Using this criterion would exclude all children with a slight or mild hearing loss and consequently underestimate the true prevalence of hearing loss. There is evidence to suggest that children with mild hearing loss still require health assistance, such as listening devices and special needs interventions (Bess, Dodd-Murphy & Parker, 1998). Further research by Fortnum, Summerfield, Marshall, Davis and Bamford (2001) found that the prevalence of hearing loss rose to 1.65/1000 in children 9-16 years. It was suggested that this increase was due to progressive or acquired hearing loss.

Similar studies were undertaken by Uus and Davis (2000), and Varainen, Kempinen, Karjalainen (1997), between 1985 and 1990 respectively. Uus and Davis (2000) found a

prevalence of hearing loss, of 172/100,000 in their study, looking at children born between 1974 and 1987 in Estonia. Similar to the Fortnum and Davis study, this study also used a threshold of >40dB HL as the criteria for inclusion. They found that 8.9% of the children had acquired hearing loss, 88.7% had congenital hearing loss and 2.4% had a hearing loss of unknown cause. Varainen et al. (1997) reported a higher prevalence rate of 2.1 per 1000 live births. They used a slightly less stringent inclusion criteria, with averaged thresholds of >25dB HL in the better ear. This study found 41% of the hearing loss to be as a result of a genetic defect, 13% non-genetic defect, delayed-onset in 16% and 30% had an unknown cause. Both these results were very similar to the Fortnum and Davis (1998) study, which suggests that the prevalence of identified hearing loss is 1.3-2.1 /1000 live births in European nations.

Unilateral hearing loss is more common than bilateral hearing loss. Berg (1972) stated that 13/1000 children in the USA have a unilateral hearing loss. Unilateral hearing loss often is not included in prevalence rates, as in the past it has been suggested that it does not have a significant impact on children's development (Northern and Downs, 1978). As a result of this, many hearing screenings do not target unilateral hearing loss and thus, it can often go unidentified for extended periods. Tarkkanen & Aho (1966) reported that 13/1000 American school children have a unilateral hearing loss. Bess and Tharpe (1984) found that children with unilateral hearing loss can be affected by a variety of listening deficits, which can in turn impact on their educational achievements. The study found that this educational impact can lead to significant delays, with 35% of the children failing at least one grade. Further limitations were; significant difficulty with sound localization, difficulty understanding speech in presence of a competing message. Northern and

Downs (2002) state that a child with a unilateral hearing loss is disadvantage educationally.

A study, looking more specifically at testing for hearing loss in school-aged children, was undertaken in the USA (Niskar, Kieszak, Holmes, 1998). This study included children with slight hearing loss (16-25dB) in their report of prevalence. In this study 14.9% of children were found to have a slight hearing loss or worse. Of this 14.9% only 10.8% of the children had an identified hearing loss. This result highlights the importance of testing children to get accurate prevalence rates. The high prevalence rate of this study comes from the inclusion of slight hearing loss as well as unilateral hearing loss, which researchers argue can negatively impact a child's development and educational outcomes (Bess, Dodd-Murphy & Parker, 1998).

Similar studies carried out around the world have found prevalence rates ranging from 2.1%-43% (Homoe, Christensen and Breatlau, 1995; Hornby, Stabler, Alleyne, Cunberbatch and Sargenant, 2000; Jacob, Rupa, Job and Joseph, 1997; Mikaellan and Barsoumian, 1971; Minja and Machemba, 1996; Robinson, Anderson, Moghadam, Cambon and Murray, 1967). This variation is due to the use of different thresholds, to classify hearing loss. Studies, with higher prevalence rates, included milder degrees of hearing loss in their results, compared with those with the lower prevalence rates. Prevalence rates also varied, depending on whether they reported solely on permanent sensori-neural hearing loss or for all hearing loss. Studies that reported temporary conductive hearing loss, as well as sensori-neural hearing loss, had higher prevalence rates, due to the high rate of Otitis Media among children. Studies from countries in the developing world tend to have higher prevalence rates compared with that of other

countries; this is thought to be due to the lack of quality medical care, distance to medical care, ethnic differences and a lack of education on hearing loss.

Identification of Hearing Loss

Identification of hearing loss in New Zealand is late, with the average age of identification at approximately 35 months (Flynn Austin, Flynn, Ford, Buckland, 2004). Currently, New Zealand is trialing newborn hearing screening, however, until this has been implemented nationwide, children will continue to be identified late. Children with minimal or mild hearing loss are often identified the latest, as their symptoms can be overlooked. If a child with a hearing loss is not identified until school age or later they will have missed out on at least 5 years of adequate speech and language learning (Alberti, Corbin, Riko & Fitzhardinge, 1985)

Otitis Media

Otitis Media is the most common cause of hearing loss in children in New Zealand (National Audiology Centre, 2007) and around the world (Graham, Delap and Goldsmith, 2002). Otitis Media is inflammation of the middle ear. This is most commonly caused by the build up of fluid behind the ear drum, as a result of a blockage to the Eustachian tube (Jordan & Roland, 2000). Otitis Media is more common in children, as their Eustachian tube is shorter and more horizontal than adults and is made up of more flaccid cartilage, which can impair its opening (Northern and Downs, 2002). Otitis Media can cause a mild to moderate hearing loss, due to the fluid interfering with the transmission of sound through to the inner ear. It can often affect the tympanic membrane causing it to retract or become inflamed. The fluid can cause the tympanic membrane to bulge and become

inflamed and occasionally the tympanic membrane will perforate (Jordan & Roland, 2000)

There are three common types of Otitis Media. These are Acute Purulent Otitis Media, Chronic Suppurative Otitis Media and Otitis Media with Effusion. Acute Purulent Otitis Media is the viral or bacterial infection of the middle ear. Chronic Suppurative Otitis Media (CSOM) is the chronic drainage of fluid through a perforated ear drum. Otitis Media with Effusion is mucous or watery effusion usually without infection (Hasenstab, 1987).

Symptoms of Otitis Media can be variable and it is difficult for children to explain the cause of their problem. This can result in Otitis Media remaining undiagnosed, for significant periods. The most important risk factor of Otitis Media is the structure and function of the Eustachian tube in conjunction with an immature immune system (Bluestone, 1999; Hasenstab, 1987). Other risk factors include ethnicity, socio-economic status, age and season. The season is a risk factor, as Otitis Media is highly correlated with upper respiratory tract infections, which are more common during the colder months (Henderson, et al, 1982). A child's age affects the likelihood of them suffering from Otitis Media, as it is more common in children less than 7 years. This is as a result of the level of maturation of the Eustachian tube and immune system. Otitis media also is more commonly reported at age 2 and 5, as a result of entrance into pre-school and school respectively. Socio-economic status can increase the risk of developing Otitis Media, due to poor living conditions and reduced availability of health care. Finally, certain ethnicities are thought to have a higher likelihood of suffering from Otitis Media than

other ethnic groups. This point will be discussed in more detail in the coming paragraphs. (Daly, 1997)

Tympanometry is often used in the diagnosis of Otitis Media and other middle ear disorders. Sassen, Aarem and Grote (1994) in their study found that, overall; the sensitivity of tympanometry in the diagnosis of middle ear effusion was 76%. A type B tympanogram identified 88% of children with middle ear fluid. Type C2 identified middle ear fluid in 26% of children. A further study by Grimaldi (1975) also stated that the most reliable tympanometry indicator of fluid present in the middle ear is a low compliance reading (type B tympanogram). It was also stated that the majority of tympanometry results, that suggested fluid, were in agreement with a medical finding of fluid. Sassen et al (1993) also stated that otoscopy has limited predictive value of middle ear fluid in school-age children.

Suffering from Otitis Media can be upsetting for children, as it can be associated with pain and hearing loss. It is important; therefore, that Otitis Media is identified and treated promptly, in order to minimize any long-term effects (Northern and Downs, 2002). Such negative effects may include speech and educational delays, as well as behavioural problems. Although it is commonly reported, that speech and educational delays spontaneously resolve, it is evident that these delays do, in fact, exist, especially if the child goes for an extended period before being diagnosed; these children still need to catch up with their peers. Behavioural problems can also develop due to the unpleasant nature of the condition. Children often have pain in their ears and feel unwell; this combined with a hearing loss can lead to misbehaviour which may develop into poor behavioural patterns. (Wallace and Hooper, 1997)

Paradise et al (1997) undertook a study looking at Otitis Media in children in the Pittsburgh area. The children were enrolled at 2 months of age, were healthy at the time of enrollment, and were followed for their first 2 years of life. The study found that children from lower socioeconomic backgrounds were more likely to experience Otitis Media than children from higher socioeconomic backgrounds. It was also noted that children from households where a family member smoked, that were in daycare, were male and / or were breast fed for less than 4 months, had a higher prevalence of Otitis Media. A similar study (Williamson, Dunleavey, Bain and Robinson 1994) in South West Hampshire looked at the incidence and prevalence of Otitis media in children aged 5 to 8 years. It was reported that Otitis Media is more common in 5 year olds. Prevalence rates were also affected by season as it more commonly occurred in winter.

Studies into the prevalence of Otitis Media have found that Otitis Media affects more children in aboriginal or indigenous populations than other ethnic groups. Bluestone (1999) suggested that this higher prevalence may be a result of different anatomical features, in the face, affecting the function of the Eustachian tube. It was also noted that this was compounded by colonization and the subsequent introduction of new diseases. Certain ethnic groups are more greatly affected than others. Inuit's and Australian aboriginals have amongst the highest prevalence rates, with the USA and the UK amongst the lowest rates, of less than 1% (Bluestone, 1999). The study in South West Hampshire in the UK (Williamson et al, 1994) found that only 2.7 % of the children had persistent Otitis Media.

A report looking at Otitis Media in Australian Aboriginal children found that they had a greater than 50% prevalence of conductive hearing loss (Leach, 1999). This hearing loss is thought to be an important contributing factor to the poor numeracy and literacy achievements of these children. The majority of the children were reported to have experienced Otitis Media from the age of 3 months and continuing throughout early childhood. In 60% of the children Otitis Media progressed to Chronic Suppurative Otitis Media.

A longitudinal study on the prevalence of Otitis Media in Inuit children found that they too had high prevalence rates, ranging from 13%-57% (Baxter, 1999). Another study by Julien, Baxter, Crago, Ilecki, Therien (1987) found that 78% of the children studied showed evidence of Otitis Media. This was significantly higher than Indian children, also studied, that only revealed 11% with evidence of Otitis Media. Homoe (1999) found that the children of 3 major cities in Greenland (a country with a large number of Inuit children) had a high rate (23.5) of Otitis Media sequlae.

The New Zealand Maori population is known to have one of the highest rates of Otitis Media in the developed world. In 1991, a study on the prevalence of Chronic Suppurative Otitis Media in children living in a North Island community found that 4 % of children had CSOM (Giles and Asher, 1991). Similar studies have shown that even after the introduction of medical care, the rate of Otitis Media continues to be high in the rural Maori community (Giles and O'Brien, 1991). National new entrant screening results also show higher failure rates in areas with a high Maori population (National Audiology Centre, 2007).

Other studies from developing countries and studies that contain a large proportion of indigenous children as participants, also state high rates (5.5-17.6%) of Otitis Media (Homoe, 1999; Homoe, Christensen, and Breatlau, 1995; Jacob et al, 1997; Minja and Machemba, 1996).

The New Zealand Vision and Hearing Screening testers (National Audiology Centre, 2006) used tympanometry to screen for middle ear disease. Unfortunately only a combined pure-tone audiometry and/or tympanometry referral rate was reported instead of just the tympanometry referral rate on its own. The combined referral rate was 8.5%. This rate does not include children that only failed the tympanometry screen and not the pure-tone audiometry screen. The tympanometry referral rate was, however, reported for the preschool screen, which was 6.4%.

National prevalence data, on Otitis Media in children, does not exist in New Zealand. Without such data it is difficult to state whether the rate of Otitis Media is disproportionately high in Maori and Pacific Island children or in the New Zealand child population as a whole. How the prevalence rate of middle-ear disease differs, among children of various ethnic and socio-economic backgrounds, in multicultural and multiethnic New Zealand, is not known.

Impact of Hearing Loss and Otitis Media

Hearing Loss in children is an important health issue, as it impacts on many areas of a child's life. Hearing Loss can impact a child's expressive and receptive language. For children whose hearing loss exists prior to language acquisition, speech and language delays are often evident. Speech development and understanding are often greatly

affected when hearing fluctuates. This is often a result of an inconsistency in the speech signal from time to time (Northern and Downs, 2002). In classroom situations children with a hearing loss can find it particularly difficult to perceive speech, due to poor listening conditions. A loss of greater than 16dBHL can result in the child missing >10% (depending on severity of loss) of a speech signal, when the teacher is at a distance greater than 3 feet (Anderson and Martin, 1998). Children with hearing loss, although able to identify that someone is speaking, have difficulty understanding the message, due to the distorted signal (Northern and Downs, 2002) Children with an undiagnosed hearing loss may be labeled as naughty or inattentive, due to them not hearing instructions or missing cues in speech. A child's social development may also be impacted upon negatively, as a result of not being able to communicate with other children. A child's behaviour may be seen as inappropriate, due to missing subtle cues in speech (Anderson and Martin, 1998). Hasenstab (1987) stated that children, with a hearing loss, are 5 times more likely to have social and emotional problems, than their normal hearing peers. Children are delayed socially, due to fewer interactions with others, as they are more inclined to withdraw from social situations, especially if the social interaction is difficult. Children with hearing loss are also more likely to use aggression, to control situations, which leads to other children avoiding contact with them (Hasenstab, 1987). Hearing loss can lead to greater fatigue, especially at school, due to a greater effort being required for listening and understanding instructions. Hearing loss can have a negative impact on education, often as a result of inattention and a delay in language development which affects language-based aspects of education (Hasenstab, 1987). Educational progress can also be delayed, as a result of difficulty in understanding tasks (Northern and Downs, 2002)

Distortion Product Otoacoustic Emissions

Otoacoustic emissions (OAE) were first discovered in 1977 by David Kemp. Distortion Product Otoacoustic Emissions occur when 2 tones that are presented to the subject's ear interact in the cochlea. This interaction results in the production of a third tone, which is then recorded, by a microphone in the DPOAE system. The third tone needs to be strong enough to be visible above any interference. DPOAEs are found in all normally hearing ears and are more prominent, especially in the high frequencies, than other OAE's which makes them a reliable tool for hearing screening. (Nozza, 2001) DPOAE screening is sensitive to all, but mild hearing loss, at higher stimulus intensities and often is not evident or is weak, in ears that have middle ear dysfunction (due to a loss of signal strength to and from the cochlea). Modern DPOAE screening tools are simple to use and often have a pass/fail criteria built into the equipment which removes the requirement for any kind of interpretation of the results which means they can be used simply, by hearing and vision screeners, who are not trained in the interpretation of OAE readings. DPOAEs have been implemented into new-born screening protocols, as infants are unable to provide a definitive, subjective response to sound. However, a study investigating the use of DPOAE in screening of school age children found that Pure Tone Audiometry is still the most reliable indicator of a hearing loss, however, as DPOAEs are a reliable indicator of normal hearing. Their use, as a follow-up measure to failed pure-tones testing, may further reduce false-positive rates, by providing an objective cross check, that rules out factors such as concentration, task understanding and malingering (Krueger and Ferguson, 2002). Lyons, Kei and Driscoll (2004) also undertook a study in this area, comparing the benefits of including DPOAEs in the screening protocol. They found that DPOAE screening enhanced the effectiveness of standard pure tone and tympanometry

screening and that DPOAEs had a high hit rate for identifying hearing loss in the children tested.

Summary

Hearing Loss is an important health problem, especially in children, as it has a significant impact on their development and educational achievement. In New Zealand, the prevalence of hearing loss in children can only be estimated, based on the results of hearing screening failure rates and health and disability surveys. Overseas, studies, on Hearing Loss in children, have reported varying prevalence rates, as a result of the differing methodologies used.

Otitis Media is the most common cause of hearing loss in children and has a greater prevalence amongst indigenous populations. Otitis Media is often difficult to diagnose due to variable symptoms which can lead to delayed interventions.

Although DPOAEs have been confirmed as a useful screening tool in newborn hearing screening, there is only limited evidence suggesting the use of DPOAEs in the screening of school aged children.

The general purpose of this study is to determine the prevalence of hearing loss in a cross-section of the school age population in Christchurch, and, to investigate whether DPOAEs would be a useful tool to include in the screening protocol.

The specific aims of the present study are:

1. To investigate the prevalence of hearing loss and middle ear dysfunction in Christchurch primary school children
2. To investigate if the prevalence rates of hearing loss vary amongst children of certain ethnic and socio-economic status
3. To determine whether DPOAEs would be a useful hearing loss screening tool for use in a small sample of the school children.

4 Method

4.1 Screening Testing

4.1.1 Recruitment

The recruitment of the participants was through each individual school selected. A total of eight schools were invited to participate and of these, only four schools were included in the study as the other schools either declined participation or did not reply to the letter or phone call. Each of the eight schools was sent a letter, (appendix A) inviting them to participate in the study. The letter was sent out, three months prior to the commencement of the study. A follow-up phone call was then made, one week after the letter had been sent, to confirm the schools' participation in the study. During the phone call, a meeting time was made, to discuss details of the study, face to face, with each of the principals involved in the study. This meeting provided the principals with the opportunity to ask questions and address any concerns that they may have had with the study. The schools chosen were all co-educational state-funded schools. Schools were also selected in order to ensure a mix of socio-economic backgrounds; therefore one high decile (decile ten) school, two mid decile (decile five and decile six) schools and one low decile (decile 2) school were selected. The decile ten school was located in a rural area on the outskirts of the city; the decile five school was located in a suburban area in the North East region of the city; the decile six school was located in a suburban area in

the Northern region of the city; and finally, the decile two school was located in an industrial area on the east side of the city. 380 children (all children in years one, three and six from each of the four schools) were invited to be a part of the study. Within the schools, three year levels were selected, as time restraints made it impractical to test all year levels. Years one, three and six were chosen, in order to get a reasonable spread of ages and to avoid those children in New Entrants, which are screened on school entry. All children were provided with an information sheet (Appendix B_1), and a consent form (Appendix B_2), at least ten school days prior to the scheduled screening at their school, as part of the recruitment process. Written consent was obtained from the children's parents/ caregivers, prior to the commencement of the study. The children also consented to participate, verbally, prior to the commencement of testing. Parents were provided with a contact phone number, to call if they required more information, or needed to discuss an issue relating to their child's participation. Parents were also invited to attend the hearing screening tests and were notified of the proposed time for testing, if required.

4.1.2 Participants

A total of 195 children were tested (112 males and 83 females) as part of voluntary involvement in the study. Overall, children were evenly distributed across the three year levels; 68 year one's, 62 year three's and 65 year six's. Children came from a mix of ethnic backgrounds (as shown in Figure 1). 39 (20%) children were from a high socioeconomic (high decile) area, 135 (69%) children were from mid socioeconomic

(mid decile) areas, and 21 (11%) were from a low socioeconomic (low decile) area. The decile 10 school had a population of 135 in the sample year levels, a total of 39 children participated. The potential sample population was made up of 126 European, three Maori, one Pacific Island, zero Asian and zero Indian and five children of other ethnicities. However, the actual sample included in the study was 38 European children, and one Maori child. The decile five

school had a population of 133, and a total of 82 children participated. The potential sample population was made up of 93 European, 17 Maori, 13 Pacific Island, six Asian and 3 Indian children and one child of other ethnicity. However, the sample included in the study was 115 European, nine Maori, five Pacific Island and three Asian children and one Indian child. The decile six school had a population of 97, a total of 53 children

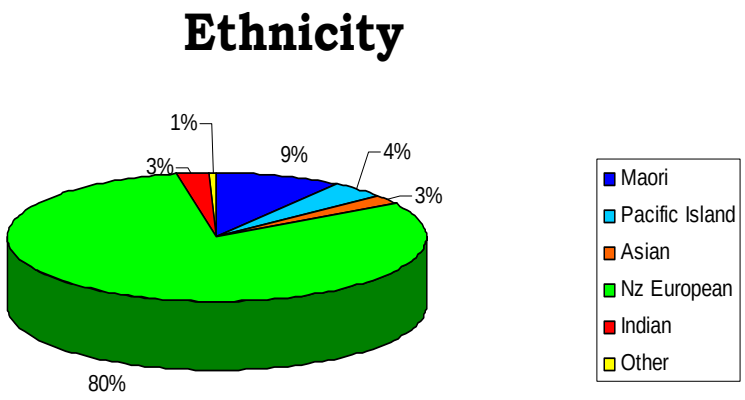

Figure 1. Percentage of children in each ethnic group

participated. The potential sample population was made up of 76 European, nine Maori, two Pacific Island, five Asian, three Indian and

two children from other ethnicities. However, the sample included in the study was 68 European, four Maori, zero Pacific Island, two Indian and two Asian. The decile two school had a population of 65, a total of 21 children participated. The potential sample population was made up of 32 European, 19 Maori, seven Pacific Island, five Indian children and two children from other ethnicities. However, the sample included in the study was 12 European, five Maori, three Pacific Island children and one Indian child.

4.1.3 Materials

An Interacoustics AS208 screening audiometer was used for the behavioral test of hearing in conjunction with a pair of Peltor super-aural headphones used to transmit the sounds from the audiometer. An Interacoustics MT10 screening tympanometer was used to test ear drum mobility, ear canal volume and middle ear pressure. A set of rubber probes in different sizes was used to obtain a pressure seal for tympanometry. The probe tip had three small holes, one containing a microphone, another that emits a 220Hz tone and the third used to create positive, negative or atmospheric pressure in the ear canal. An Otometrics screening DPOAE system was used to test inner ear function. A standard Welch Allyn otoscope was used to inspect the ear canal and the condition of the ear drum. Medi-wipe anti-bacterial wipes were used to ensure the testing was hygienic. Results of the testing were recorded on a University of Canterbury Communications Disorders Speech and Hearing Clinic screening form.

4.1.4 Test Environment

The test environment was chosen, based on ease of accessibility, availability and presence of external and internal noise.

Decile Ten: A small room (approximately 3m x 2m), within the office building was provided for testing at the Decile ten school. The room was very quiet and was not connected to any classrooms or rooms that emitted a lot of noise. Testing was carried out over four days and the average ambient noise level was 31.3dBA.

Decile Six: A large room (approximately 3m x 9m), at the rear of the children's cloakroom, was provided for testing. The room was very quiet and was not connected to any classrooms or rooms that provided a lot of noise. Testing was carried out over three days and the average ambient noise level was 33.4dBA.

Decile Five: A large room (approximately 5m x 3.5m), within the office building, was provided for testing. The room, at times, could be affected by noise as it was near the photocopier, staffroom and reception area. Testing was carried out over five days and the average ambient noise level was 41.5dBA.

Decile Two: An empty classroom (approximately 6m x 8m), next to the office building, was provided. The room was relatively quiet even though it was connected to other classrooms. Testing was carried out over two days and the average ambient noise level was 35.8dBA.

4.1.5 Procedure

Screening testing commenced in late winter and ended in early spring. The decile five school was tested first followed by the decile ten school, the decile six school and the decile two school was tested last. The order of testing was carried out based on the largest population of the school (largest first and smallest last) in an effort to make efficient use of available time. Prior to testing each day, the ambient noise levels were recorded, for the rooms to be used for testing. Permission, to remove each child from class, was sought from the classroom teacher, at the time each child was collected from their class. The child was then taken to the testing area. The testing was explained, in simple terms, to the child, so that they understood what was expected of them. Any child, that stated that they did not want to participate, was allowed to return to class. Throughout the testing, children received praise and appropriate feedback, to ensure that they did not lose interest in the task. The order of testing was random and included the following tests;

1 Visual inspection of the ear (otoscopy). All ears were examined with an otoscope to ensure there was no impacted wax or foreign bodies in the ear canal. The ear drum was inspected for any signs of abnormality. The results were recorded on a screening audiometry form.

2. Ear drum mobility test (Tympanometry). Tympanogram's were obtained, by placing a probe tip into the child's ear and forming an airtight seal. Tympanometry results were classified as Type A (single peak < -100 air pressure), Type B (no pressure peak), Type C_1 (single peak -100 to -149 air

pressure) Type C_2 (single peak <-150 air pressure). The results were recorded on a screening audiometry form.

3. Hearing test (Pure tone Audiometry): The headphones were wiped with anti bacterial wipes, prior to fitting to each child. Headphones were then fitted, carefully, to the child's ears, ensuring correct placement of the speaker. Frequency modulated tones were presented, at a screening level of 20 dBHL at the frequencies; 500Hz 1000Hz, 2000Hz and 4000Hz. Children were asked to respond to the tones, by pressing a button. A pass, at each frequency, required a response to the tone, twice. If the child did not respond at 20dBHL, their hearing thresholds were then obtained using the modified Huson Westlake procedure. The results were recorded on a screening audiometry form.

4. Inner ear function test (DPOAE): A sample of 59 children from the Decile 5 school received the DPOAE screen. 27 were male and 32 were female. DPOAEs were tested in these children to measure the functioning of the outer hair cells of the inner ear or cochlea. A plug was placed in the child's ear and the DPOAE system played two different pure tone frequencies, into the ear and recorded the tonal responses, produced by the cochlea. The amplitude of the DPOAE responses was required to be 5dB above the noise floor, to be accepted as a pass. DPOAEs were tested at 2, 3 and 4 kHz. Only these frequencies were tested in an attempt to save time and avoid noise interference. The results were recorded on a screening audiometry form.

The testing was carried out by the experimenter (a second year Master of Audiology student), the study supervisor (Doctor of Audiology) and two Introduction to Audiology students .To maintain hygiene, the headphones were

wiped with anti bacterial wipes, prior to fitting to each child. In addition, disposable otoscope tips were used, as well as a new probe tip, per child for both the and the tympanometry. The probe tips were sterilized at the end of each day. The experimenters also regularly washed their hands.

4.1.6 Pass/Fail Criteria

Children were considered to have failed the screening if their results showed any of the following:

- a Type C2 or B tympanogram,
- at least one hearing threshold outside the normal range,
- a refer result, on DPOAE screen or
- Significant otoscopic findings (cholesteatoma, fluid behind ear drum, foreign object in canal, tympanic membrane perforation).

All children received a copy of their screening test results, accompanied by a letter (appendix C_1), briefly stating whether the child had passed or failed the screening.

4.2 Follow-Up Testing

4.2.1 Follow-up Recruitment

A letter (appendix C_2) was posted to the parent's of those children who failed the screen, offering full diagnostic testing, free of charge, at the University of Canterbury Speech and Hearing Clinic. A copy of the test results was included with this letter. A copy of these results was also sent to the child's GP, if this

had been requested on the consent form. Permission was sought, to obtain recent records from children with pre-diagnosed hearing loss.

4.2.2 Participants

A total of 28 children (16 males and 12 females) participated in the follow-up testing. Two more children's parents indicated that they had a pre-diagnosed hearing loss and allowed access to their audiological history. The time elapsed between the screening tests and follow-up testing varied between four weeks and three months, depending on when the parents made contact with the researcher.

4.2.3 Materials

A diagnostic tympanometer (GSI Tympstar, Welch Allyn, NY. USA) was used to test middle ear function. The calibration date of this equipment was 15th of November 2007. A diagnostic audiometer (GSI G1 Audiometer, Welch Allyn, NY. USA) was used to obtain hearing thresholds. The calibration date of this equipment was the 21st of February 2009. Ear-tone insert earphones, with pediatric ear tips, were used to present tones to the children's ears. A Welch Allyn otoscope was used to inspect the children's ear canals and tympanic membranes. A Madsen Capella DPOAE system was used to test the inner ear function. Windows XP operating system was used to run the software.

4.2.4 Procedure

Follow-up testing was carried out at the University of Canterbury Speech and Hearing Clinic. The time elapsed between screening testing and follow-up testing varied from three weeks to 3 months. Follow-up testing commenced in middle of spring and continued until early summer.

1. Case History: A thorough case history was taken (see Appendix D for case history form).
2. Otoscopy: Following this the child's ear canals and tympanic membranes were inspected with an otoscope to ensure the ear canals were clear for insert earphone positioning and to check for any abnormalities. The results were recorded on the audiogram.
3. Audiometry; The child was seated in a sound proof booth. Their parent(s) and other family members were asked to sit outside the room and observe the child through the window. The child was told the testing was like the testing at school, and was reminded how to respond to the tones that they heard.

    3.1. Air conduction: The child's hearing thresholds were obtained using the modified Huson Westlake procedure, which involves decreasing the stimulus intensity in 10dB steps, until the participant has stopped responding and then increasing the stimulus again in 5dB steps, until the participant starts to respond again. The threshold for each frequency is accepted as the lowest dBHL, at which responses occur, on at least one-half of ascending trials, with a minimum of two responses out of three presentations at that level (University of Canterbury Speech and Hearing

clinic protocols, 2007). The following frequencies were presented to the child in the order stated: 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz, retest 1000 Hz (reliability check), 500 Hz, and 250 Hz. Each ear was tested individually. The right ear was always tested first, unless the child or parent suggested that there was a better hearing ear and in these cases the better hearing ear was tested first. Normal hearing was classified as <15dBHL. Hearing loss was classified as slight (16-25dBHL) mild (26-40 dBHL), moderate (41-50 dBHL), moderately severe (51-70 dBHL), severe (71-90 dBHL) and profound (>91dBHL). With the exception of slight, these classifications are appropriate classifications, as stated in the University of Canterbury Speech and Hearing Clinic protocols, 2007.

3.2. Bone Conduction: When a hearing loss was present at 500 Hz, 1000 Hz, 2000 Hz and/or 4000 Hz, bone conduction was performed on the same ear. The worst ear was tested first, if both ears exhibited a hearing loss at that test frequency. The starting level for Bone Conduction audiometry should be 10-15 dB above the level of the better Air Conduction threshold. The bone-conduction threshold was then obtained, as with the air conduction threshold, using the Modified Huson Westlake procedure. Step Masking was used, if there was a gap between the air conduction threshold and the bone conduction threshold of greater than 15 dB. The masking tone was a narrow-band noise and was played at a level 20 dB higher than the air conduction threshold of the non-test ear. The bone conduction threshold was then sought, with the modified Huson Westlake procedure. No further masking was required in any child.

4. Speech Audiometry: Speech audiometry is included in the test battery, as a cross check of the pure-tone audiogram. The following procedure is consistent with that stated in the University of Canterbury Speech and Hearing Clinic protocols, 2007. Each ear was tested individually, with the ear identified during pure-tone audiometry as the better hearing ear, tested first. The child's speech reception thresholds, in each ear, were obtained using the Millennium Consonant Vowel Consonant word lists. These speech lists are lists of ten phonetically balanced words, presented by an adult male voice, with a New Zealand accent. The child was told to repeat back the words that they heard and if they did not hear the word clearly, they were encouraged to guess the word. The Performance Intensity maximum score was obtained by playing a list at 35dBHL, in children with normal hearing thresholds, or 30dBHL above the child's pure tone average (average of thresholds at 500Hz, 1 kHz and 4 kHz). The performance intensity max is the level at which the patient scores maximally. PI max was accepted, if the PI max obtained was greater than 80% (each word scored on the number of phonemes correct out of 3, one correct = 3 marks, 2 correct = 7 marks and 3 correct = 10 marks). If the threshold was less than 80%, a second list was played at a higher intensity, which varied (the intensity was increased by 10dB until the score was greater than 80%) depending on the score obtained. A half peak measure, which is the level where the patient scores approximately 50%, was obtained by playing another speech list at a reduced intensity of approximately 15-20dBHL.

Extra word lists were played, at either higher or lower intensities if required, to obtain an accepted threshold of 45 to 60dBHL. NB: a PI max or half peak measure was not always obtained, as a small number of the younger children, especially those whose first language was not English, found the task too difficult, when the lists were played at soft presentation levels. None of these children exhibited a hearing loss.

5. Tympanometry: Following the hearing test, the child's middle ear function was tested with a tympanometer. Each ear was tested twice to ensure reliability. Ear canal volume, middle ear pressure and static compliance were recorded. Tympanometry results were classified according to Jerger (1970) as Type A (single peak < -100 air pressure), Type B (no pressure peak), Type C_1 (single peak -100 to -149 air pressure) Type C_2 (single peak <-150 air pressure). 5.
6. Distortion Product Otoacoustic Emissions: When appropriate, (for cross checking pure-tone results, no middle ear effusion and when time allowed) DPOAEs were tested, by placing a probe tip in each ear and testing thresholds at 1kHz, 1.5kHz, 2kHz, 3kHz, 4kHz, 6kHz and 8kHz. An acceptable probe fit was first checked, prior to commencement of the test. A signal to noise ratio of at least 6dB is required for an emission to be accepted as a valid response.
7. Explanation of Results: At the close of the appointment, the results were explained to the parent and the appropriate follow-up was explained.

A report of the results was written and the results and recommendations outlined. The report, accompanied by a copy of the audiogram, was sent to the child's GP and parents.

4.3 Analysis of Results

Results were analysed separately, for screening and follow-up testing. Failures on screening tests were analysed with descriptive statistics, in terms of year level, decile rating of school, ethnicity of the child, and the type of test each child had failed on. The follow-up results used a descriptive analysis of the otoscopic and audiometric data, to examine the percentage of children with hearing loss, middle ear dysfunction and inner ear dysfunction. The hearing loss, middle ear and inner ear function data, of the children tested, was analyzed in terms of age, ethnicity and socio-economic levels. The DPOAE screening results were compared to the results from the full diagnostic testing.

5 Results

5.1 Screening Testing

A total of 195 children were tested during the screening process. This number was reduced from the potential 380 pupils due to the number of consent forms that were not returned. The results from the screening were analysed based on year level, ethnicity of the child, decile rating of the school that the child attended and which tests the child failed on. Overall a total of 51 (26%) children had scores outside the normal range on the screening tests and 144 (74%) children had scores within the normal range on the screening tests.

5.1.1 Pure-Tone Audiometry Screening

The pure-tone audiometry results revealed 34 (17.4%) children had results outside the normal hearing range on the pure tone audiometry screening on at least one threshold. Of these children nine children were referred for follow-up testing based solely on pure tone audiometry results. 25 children were referred based on pure-tone audiometry results in conjunction with abnormal results on other tests. A total of 11 (5.6%) children had a maximum of one tone outside the normal range, 23 (11%) children had two or more tones outside the normal range in at least one ear. One child had results outside the normal range on the low frequency tone (500Hz), 12 children had results outside the normal range on mid frequency tones (1000-2000Hz) three children had results outside the normal range on a combination of low and mid frequency tones, seven children had results outside the normal range on a combination of mid and high

frequency tones, two children had results outside the normal range on the high frequency tone (4000Hz) and nine children had results outside the normal range on all the tested tones in the worse ear. 12 of the children had results outside the normal range on the pure-tone audiometry bilaterally and 21 children had results outside the normal range the on the pure-tone audiometry unilaterally. Two children had thresholds greater than 45dbHL.

5.1.2 Tympanometry Screening

A total of 41 (21%) children had abnormal tympanometry results. The most common abnormal tympanometry resulting in referral was a Type C2 (negative middle ear pressure) with a total of 32 children obtaining this result. 6 (3%) children had type B tympanogram's. 132 children had type A tympanograms and 25 children had type C1 tympanograms (of which three were referred for follow-up testing as a result of other concerns). 27 of the children had abnormal tympanometry results in both ears with nine children having the same type in both ears and 17 having different types in each ear. Five had abnormal results in the left ear only and 7 had an abnormal result in the right ear only.

5.1.3 Otoscopy

No children were referred for follow-up testing based solely on a significant otoscopic finding. However, 14 children had abnormal otoscopic findings in conjunction with other abnormal results. This was most evident in the children that had results outside the normal range on all three screening tests with nine

children obtaining this result. Four children that had normal pure-tone audiometry results but had abnormal tympanometry results also had abnormal otoscopic results. This resulted in a total of 12 (31%) children having both abnormal otoscopic results in conjunction with abnormal tympanometry results. Only one child that had results outside the normal range on the pure-tone audiometry screen also had abnormal otoscopic results. Of the 14 children with abnormal otoscopic results two were due to inflamed tympanic membranes and four were due to visible fluid two were due to retracted ear drums, six were due to other concerns (tympanosclerosis, blood in canal, impacted wax and grommets)

5.1.4 Referral Type Comparison

The tests results were categorised according to the referral type. The results have been compared based on the percentage of children with results outside the normal range on each different test. As can be seen in Figure 2 the most common referral result, for all children tested was a result outside the normal range on pure tone audiometry, in conjunction with an abnormal tympanometry result with 15 children returning this result (29% of all children). 13 (25% of all children with results outside the normal range) children had results outside the normal range solely on tympanometry, Nine (18% of all children with results outside the normal range) of all the children had results outside the normal range solely on pure tone audiometry. Four (8% of all children with results outside the normal range) children had abnormal tympanograms in conjunction with abnormal otoscopic findings, one (2% of all children with results outside the normal range) child had results outside the normal range on pure tone

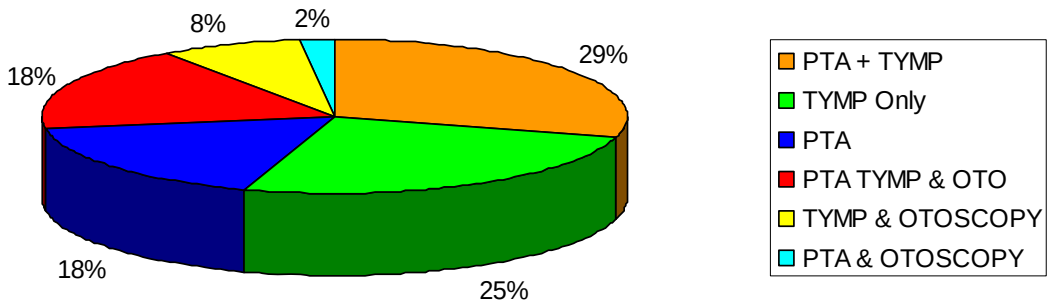

Figure 2. Percentage of children referred for different tests

audiometry in conjunction with abnormal otoscopy result and nine (18% of all children with results outside the normal range) children had results outside the normal range on all three screening tests.

5.1.5 Year Level Comparison

Table 2 shows that overall, Year one had the most children referred for follow-up testing (37% of all year one children tested), with Year three and Year six having an equal number of children referred for follow-up testing (13%).

Table 2. Year Level Comparison

	Pure Tone Audiometry			**Tympanometry**	
Year	*PTA Only (including otoscopy)*	*& Type C2*	*& Type C1*	*B*	*C2*
1	2 (3%)	12 (18%)	1 (1%)	4 (3%)	6 (9%)
3	4 (6%)	4 (6%)	-	2 (3%)	3 (5%)
6	4 (6%)	5 (8%)	2 (3%)	-	2(3%)

Children in Year one had a greater number of abnormal tympanometry findings (34%) than the children in the other two year levels (14% and 15%). Results outside the normal range on pure tone audiometry, in the absence of other abnormal results, was more common in children in Year 3 and Year 6 (6%) than children in Year one.

5.1.6 Ethnicity

As can be seen in Table 3, Pacific Island children had the highest overall rate of results outside the normal range (50%) and New Zealand European children had the lowest rate of results outside the normal range (25%). 25% of Pacific Island children had results outside the normal range on pure-tone audiometry, 15% of the Maori children had results outside the normal range on pure the pure tone audiometry screen. 18% of European children and no Indian children had results outside the normal range on the pure-tone audiometry. Only Maori and children of European decent had results outside the normal range solely on the pure-tone audiometry screen with the same rate of 5%. Pacific Island children had the highest abnormal tympanometry results at 50% and children of European decent had the lowest abnormal tympanometry at 19%. 21% of Maori children and 40% of Indian children had abnormal tympanometry results. The Asian children and children from other ethnicities included in the study had a 100% pass rate.

Table 3. Ethnicity Comparison

Ethnicity	**Pure Tone Audiometry**			**Tympanometry**	
	PTA Only (including otoscopy)	*C2*	*C1*	*B*	*C2*
Maori	1 (5%)	3 (16%)		1 (5%)	
Pacific Island		2 (26%)	1 (13%)		1 (13%)
Indian				1 (20%)	1 (20%)
European	9 (6%)	18 (12%)	2 (1)	4 (3%)	7 (4%)

5.1.7 Decile Comparison

Children from the decile two school had the lowest number of results outside the normal range with a rate of 10%. Children from the decile five school had the highest number of children with results outside the normal range at 33%. As can be seen in table 4, children in all schools

Table 4. Decile Comparison

School	**Pure Tone Audiometry**			**Tympanometry**	
	PTA Only (including otoscopy)	*& Type C2*	*& Type C1*	*B*	*C2*
Decile 6	6	13	2	2	4
Decile 5	2	4	-	3	5
Decile 2	-	-	-	-	2
Decile 10	2	4	1	1	-

had higher abnormal tympanometry results than results outside the normal range on pure tone audiometry testing. The children from the decile six school

also had the highest abnormal tympanometry results with the decile two school having the lowest number of abnormal tympanometry results.

5.1.8 Distortion Product Otoacoustic Emissions(DPOAEs)

Only 59 children were tested with DPOAEs. Of the 59 children tested, 20% (12) had abnormal results on at least two frequencies. 70.5% of the children tested with DPOAE, which had a referral result on both the pure-tone also had referral result on the screen. 29.5% of children, tested with DPOAE, which had results outside the normal range on pure tone audiometry passed the DPOAE test. It was more common for children to have abnormal results on all frequencies in the DPOAE testing (9) in at least one ear. Five children had abnormal DPOAE results in both ears. Two children had abnormal DPOAE results solely in the left ear and five children had abnormal DPOAE results solely in the right ear.

5.2 Follow-Up Testing

A total of 26 children received follow-up testing. A further two children included results from previous testing. This number was only 54.9% of the total children referred for follow-up. Of the 28 children with follow-up results eight (29%) had normal hearing and middle ear results. 15 (54%) of the children had a hearing loss and five (18%) of children had middle ear concerns in the absence of a hearing loss.

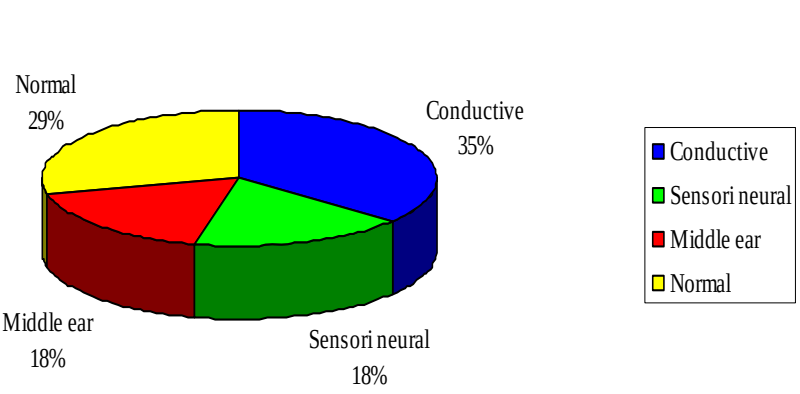

Figure 3. Follow-up diagnostic hearing test results

10 (35%) children had a conductive hearing loss. Five (18%) children were found to have a Sensori-neural hearing loss. Unilateral hearing loss was found in nine (32%) children and bilateral hearing loss was found in six (21%) children.

5.2.1 Normal Results

Eight children were found to have normal follow-up results. Five children had a significant history of middle ear infections, of which two children had recently been prescribed antibiotics. Three children had had ventilation tubes fitted in the past. Seven of the children that had normal follow-up results had abnormal tympanogram's on the screening test. Five of these children had a type C2 tympanogram, one had a type C1 tympanogram and one had a type B tympanogram. Seven of these children had a mild hearing loss on at least one frequency on the pure-tone audiometry screening, three had results outside the

normal range on at least two frequencies. One child had a mild hearing loss on one frequency on the pure-tone audiometry screening.

5.2.2 Sensori-neural Hearing Loss

A total of five children were found to have a sensori-neural hearing loss, this was 2.5% of all the children tested. One (0.5%) child of all the children tested had a unilateral hearing loss and four children (2%) had a bilateral hearing loss. There was not a marked difference in the degree of hearing loss among the children. Two children had a mild hearing loss, one had a moderate hearing loss and one had a severe hearing loss. Two of the children with a hearing loss were born prematurely. Three children had a history of middle ear infections, one child had a pre-diagnosed hearing loss due to ototoxicity. One child had a high frequency hearing loss (the child with the severe loss), two had low frequency hearing loss (one moderate due to ototoxicity and one mild loss with a history of ventilation tubes) and two had mid frequency hearing loss (one slight and one mild). All five children that were found to have sensori-neural hearing loss had results outside the normal range on the pure-tone audiometry screening test. One child had one frequency outside the normal range on the pure-tone audiometry screening, four children had results outside the normal range on at least three frequencies two with bilateral results.

5.2.3 Conductive Hearing Loss

Of all the children that participated in the study, 5% (10) were found to have a confirmed conductive hearing loss. A unilateral conductive hearing loss was found

in eight children which was 4% of all the children tested in the screen and two children had a bilateral hearing loss which was 1% of all the children tested. As can be seen in Figure 3 seven (70%) children that had an abnormal test result had a mild conductive hearing loss. The most severe conductive hearing loss was moderate and only one (10%) child had this degree of hearing loss.

Two (20%) children had a slight hearing loss. Eight children had a significant history of ear infections with four children having had ventilation tubes fitted in the past. The remaining four children had been treated with

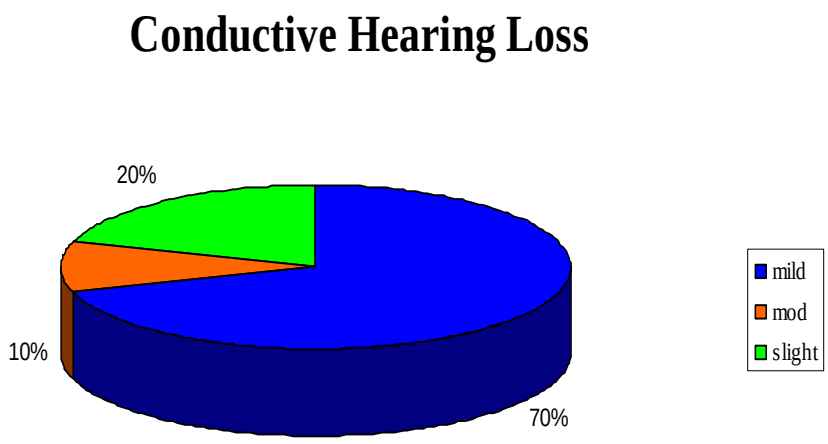

Figure 3. Degree of conductive hearing loss

antibiotics. One child was unable to provide any history regarding middle ear dysfunction and one child had no history. One child had had an identified speech delay in the past but has since recovered. All ten children found to have a conductive hearing loss on the follow-up tests had a type C2 or B tympanogram on their screening tests. All ten children had a hearing loss on at least one frequency on the screening test. Two children had a moderate hearing loss (one bilateral) and eight children had a mild hearing loss. The two children with moderate hearing loss

had a loss on a minimum of two frequencies on the pure-tone audiometry screening Four children had a mild hearing loss on one frequency and four had a mild hearing loss on two or more frequencies.

5.2.4 Middle Ear Dysfunction

Results from the tympanometry testing revealed abnormal results in 14 children. Nine children had a conductive hearing loss and five children had no hearing loss at all. Six children had type B tympanogram's, which was 3% of all the children tested in the screen. Five of which also had a conductive hearing loss. Seven children had a type C2 tympanogram of which four also had a conductive hearing loss. One child had a type C1 tympanogram which appeared to have no effect on the child's hearing. Of the children with no hearing loss four had a history of hearing loss and one did not. Two of these children had received ventilation tubes and two had been treated with antibiotics. One child had an earlier speech delay but has since recovered. All five children that had middle ear concerns in the absence of hearing loss on the follow-up results had abnormal tympanogram's on the screening tests. Four children had abnormal pure-tone results on the screening test, one child had two frequencies with a mild hearing loss on the screening test.

5.2.5 Distortion Product Otoacoustic Emission Follow-up

Ten children that received the DPOAE screen also received follow-up testing. Five were found to have a hearing loss (Three sensori-neural, two conductive hearing losses). Two of these children had abnormal results on the DPOAE screen (one sensori-neural and one conductive). The two children that passed the DPOAE

screen but were then identified with a sensori-neural hearing loss had a loss outside the frequencies tested during the DPOAE screen. Three children were found to have middle ear dysfunction in the absence of hearing loss of which one had abnormal results on the DPOAE screen. Both of the children that had passed the DPOAE screen had abnormal results on the tympanometry screen and one had results outside the normal range on the pure-tone audiometry screen. Three children that received the DPOAE screen had normal results on the follow-up testing. Two of these children had abnormal results on the DPOAE screen and one had passed the DPOAE screen. The two children that had abnormal results on the DPOAE screen had abnormal tympanometry results and had results outside the normal range on the pure-tone screen. The child that passed the DPOAE screen had abnormal results on the tympanometry screen.

6 Discussion

The purpose of the present study was to investigate the prevalence of hearing loss and middle ear dysfunction in a sample of Christchurch school children. A total of 195 children from four primary schools were screened for hearing loss and middle ear dysfunction. The results were analysed in two sections the screening data and the follow-up data. Comparative analysis of the screening results was made based on the year level of the children that failed the screen, the decile rating of the school, the ethnicity of the child and the type of tests that the children had abnormal results on. Comparative analysis of the follow-up results were based on the degree of hearing loss and the origin of the hearing loss (conductive versus sensori-neural). DPOAE screening results were compared to the results of follow-up tests to identify the accuracy of the screener. Also, as well as the percentage of children that had results outside the normal range on the pure-tone audiometry test in the absence of abnormal DPOAE screening results to identify the number of false positives and false negatives.

Screening Results

Pure-tone Audiometry screening

Overall, 12% of the children had results outside the normal range on the pure-tone audiometry screening. This rate is higher than the New Zealand Vision and Hearing screening results from 2006 of 5.4% in the Christchurch region (National Audiology Centre, 2006). This result is mostly like due to the different referral criteria. In the current study a referral was determined as one or more thresholds of

greater than 20dBHL. The New Zealand Vision and Hearing used a less conservative referral criterion of two thresholds of greater than 45dBHL or one or more thresholds greater than 30dBHL at 500 Hz or 20dBHL at 1000-4000 Hz on two separate occasions. It was more common for children to have results outside the normal range on two or more tones, than an abnormal result on just one tone. If only the children that had results outside the normal range on two or more thresholds were anylised then the referral rate is still considerably higher than the New Zealand new entrant screening results. However, if these children were screened twice it is possible that this number would have been further reduced.

The more conservative criteria of the current study may have led to the higher rate of referral results; however it may also have been due to the inclusion of Year 3 and Year 6 as it has been shown that prevalence of hearing loss increases with age (Fortnum et al, 2001). In the follow-up study undertaken by Fortnum et al (2001) it was found that the prevalence rates climbed from 0.91/1000 for 3 years olds to 1.65/1000 when children between 9 and 16 were included in the data.

The results of the current study were closer to those found in the study carried out in the USA that found 14.9% of school children had at least a slight hearing loss in at least one ear (Niskar et al, 1998). This study included lesser degrees (16dB +) of hearing loss as well as unilateral hearing loss. As stated above the current study used a threshold cut-off of 20dBHL

More children had a unilateral loss than a bilateral loss which is to have been expected as unilateral hearing loss is more common than bilateral hearing loss (Berg, 1972). This result is also consistent with the study by Niskar et al (1998) that found that the majority of the children in their study had slight or unilateral hearing loss.

Tympanometry Screening Result

The overall tympanometry referral rate was 21% of all the children tested. This rate was slightly higher than those found in developing countries, 5.5%-17.6% (Homoe, 1999; Homoe et al, 1995; Jacob et al, 1997; Minja and Machemba, 1996). This rate is relatively high in comparison with previous studies in developed countries such as the study by Williamson, et al (1994) that found a prevalence Otitis media of 2.7%. However, the referral rate of the current study is not an actual prevalence rate of Otitis Media. The vast majority of tympanometry referrals were type C2 which is an extreme negative middle ear pressure consistent with Eustachian tube dysfunction. A type C2 tympanogram and can often be associated with the early or final stages of a middle ear infection and indicates fluid in approximately 26% of children (Sassen et al 1993).

The tympanometry result most commonly associated with Otitis Media is a type B tympanogram which studies have shown indicates middle ear fluid in approximately 88% children (Sassen et al 1993). Only 3% of children screened in this study revealed a type B tympanogram. This rate of potential Otitis Media was consistent with previous findings that would suggest that a developed country would have a rate of Otitis Media between 1-4% (Bluestone, 1999; Williamson, et al, 1994). The result is lower than that found in the New Zealand pre-school screen that had a referral rate of 6.4% where a referral was on a type B tympanogram. The prevalence of Otitis Media declines with age, with a high point prevalence at age two and again at age five. This decline is likely to be the reason behind the lower rate of Otitis Media found in the current study compared with the result from the national pre-school screen.

It was significantly more common to have abnormal tympanometry results in both ears (27 children) than in just one ear (12 children). The children with abnormal tympanometry results tended to have a different tympanometry result in each ear with only nine children found with the same tympanometry type in both ears.

Otoscopy Results

No children referred based solely on a significant otoscopic finding. Fourteen children had abnormal otoscopic findings in conjunction with other abnormal results.

Referral Type Comparison

Otitis Media is the most common cause of hearing loss which is the most in children (Graham et al, 2002). It would therefore be expected that more children would be referred for hearing and middle ear concerns following a screening test. Of the children that had results outside the normal range on the current screen the majority were referred based on a combination of both abnormal tympanometry results and results outside the normal range on pure-tone audiometry tests.

Paradise et al (1997) found that by the age of two years 91.1% of children had experienced at least one episode of Otitis Media. The South West Hampshire study (Williamson et al, 1994) found that 27% of the children tested had at least one type B tympanogram (often indicating middle ear fluid) and 20.2% had abnormal tympanogram's throughout the study. The results of the current study are consistent with these previous studies indicating the high prevalence of middle ear

dysfunction amongst children. Overall, in the current study more children were referred based on abnormal tympanometry results than were referred based on results outside the normal range on the pure tone audiometry screen; 80% compared with 67%. A similar result was also evident in the children that had results outside the normal range on only one test; 13 children were referred based exclusively on tympanometry results compared with nine children that were referred solely on pure tone audiometry results. The results of this study are likely to be due to the high prevalence of middle ear disease among children that often starts with Eustachian tube dysfunction both of which can be indicated by abnormal results on tympanometry (Jordan and Roland, 2000).

Middle ear dysfunction can have an effect on the tympanic membrane such as retraction, inflammation, bulging and visible fluid (Jordan and Roland, 2000). 13 (25% of children referred) children that had abnormal tympanogram's also had abnormal otoscopic findings and nine (18%) children had results outside the normal range on all three screening tests. This result suggests that the child was suffering from middle ear dysfunction that caused changes in the tympanic membrane that were visible when viewed with an otoscope. Tympanometry is more reliable for diagnosis of middle ear dysfunction than otoscopy which may be the reason not all children with abnormal tympanometry results had abnormal otoscopy results (Sassen, et al, 1993).

One child that had results outside the normal range on pure tone audiometry screening also had an abnormal otoscopy result which may have been a result of a middle ear infection that had not been identified by the tympanometry testing.

Year Level Comparison

Children in Year one had the highest overall referral rate including the highest number of referrals on pure tone audiometry screening. Middle ear dysfunction can affect the conduction of sound through to the inner ear which results in a conductive hearing loss (Jordan and Roland, 2000). The high number of children that had results outside the normal range on the pure-tone audiometry screening is likely to be linked to the high number of referrals of year one children for middle ear concerns.

The South West Hampshire study (Williamson et al, 1994) found that middle ear dysfunction was more common in five year old children (17%) compared with eight year old children (6%). Referral due to middle ear concerns (abnormal tympanometry result) was found to be more common in children in Year one (24 or 37%) than the other two year groups by more than double the number. This finding is consistent with previous studies and respected literature that states that middle ear dysfunction and Otitis Media is more prevalent in children at age five and decreases in older children.

Nearly all children in New Zealand are screened for hearing loss and middle ear dysfunction upon school entry (National Audiology Centre, 2006). Children with results suggesting hearing loss or middle ear dysfunction are referred for medical management. In the current study the referrals based exclusively on pure-tone audiometry screening, (suggesting a sensori-neural hearing loss) was less common in Year one (1 or 1%) than in Years three (4 or 6%) and six (4 or 6%). This result may indicate that the majority of sensori-neural hearing loss in the children in Year

one was identified in the school entry hearing screenings a year prior to the current study.

Fortnum et al (2001) revealed in their study that the prevalence of hearing loss continues to increase through out childhood. In the current study a higher number of children were referred based solely on pure-tone audiometry result in Year three and Year six. This may have been as a result of progressive or acquired hearing loss that was not present at the time of testing.

Ethnicity Comparison

The New Zealand Deafness Notification Data (2007) stated that Maori and Pacific Island children continue to be over represented in the number of children that have hearing loss. The highest overall pure-tone audiometry referral rate was within the Pacific Island ethnic group at 25% and Maori children had the lowest pure-tone audiometry referral rate at 15%. Children from European descent fell in the middle of these two that had an overall pure-tone audiometry referral rate of 18%. No Indian and Asian children were referred for results outside the normal range on pure-tone audiometry. Only Maori and European children had results outside the normal range solely on the pure-tone audiometry screen (suggesting sensori-neural hearing loss), with both ethnicities having a 5% referral rate. Although it would be expected that Pacific Island children would have the highest number of referrals based on pure-tone audiometry results, it was unexpected that Maori children would have a lower referral rate than children from European descent. It has been suggested that the higher prevalence of hearing loss found in Maori children is likely to be due to genetics (New Zealand Deafness Notification Data, 2007). This

genetic predisposition may differ between iwi (tribe) and may be less prominent in South Island Iwi. A larger population of Maori live in the North Island and this may have influenced the higher prevalence rate recorded.

It is well known that indigenous populations have higher rate of middle ear dysfunction. Pacific Island children had the highest abnormal tympanometry results at 50%. 21% of Maori children and 40% of Indian children had abnormal tympanometry results. Children from European descent had the lowest abnormal tympanometry at 19%. These results are consistent with the New Zealand Vision and Hearing screening report (National Audiology Centre, 2006) results that showed a higher rate of failure in both Maori and Pacific Island populations, however these results are much higher than those found in the New Zealand New Entrant Screen of 14.1 and 16.5 (National Audiology Centre, 2006). The Asian children, and children from other ethnicities included in the study, had a 100% pass rate.

Due to the small sample of ethnicities outside European the results of the ethnic comparisons may not reflect the actual prevalence rates in the general population.

Decile Rating Comparison

Children from the decile two school had the lowest number of children with results outside the normal range with only two (10% of children from school screened) children referred for follow-up testing. This result was unexpected as low socioeconomic status is a known risk factor for middle ear dysfunction in children (Henderson et al, 1982). It would have been expected that the decile 10 school

would have had the lowest referral rate, however they actually had the second lowest referral rate. However the decile two school had the second lowest return of consent and therefore only a very small sample was included which may have led to the results being unreliable. Children from the decile five school had the highest referral rate at 33%. Children in all schools had a higher number of abnormal tympanometry results than the number of results outside the normal range on the pure tone audiometry screen. The children from the decile five school also had the highest abnormal tympanometry results with the decile two school found to have the lowest number of abnormal tympanometry results. This may have been as a result of the small sample size of the decile two school. However, the season may also have been a contributing factor as the decile five school was tested first during winter and the decile two school was tested last during the early spring. The prevalence of Otitis Media is known to coincide with season (Henderson et al, 1982; Daly, 1997) as it is closely linked with upper respiratory infections which are more common during the colder months.

Distortion Product Otoacoustic Emissions

Due to equipment failure only 59 children were able to be tested with DPOAEs during the screening. Of these children, 12 (20%) had abnormal results on at least two frequencies. The DPOAE had an agreement with the pure-tone audiometry screening 70.5% of the time with only five children, which had results outside the normal range on pure tone audiometry, passing the DPOAE test. This result is highly consistent with the results found by Krueger and Ferguson (2002) who found that DPOAE were in agreement with pure-tone screening on 70% of the tests. Another study (Lyons et al, 2004) looking at the hit rate of DPOAE found

slightly more reliable results with hit rates of 0.89 with SNR referral criteria of 5dB. However, unlike the study by Lyons et al (2004), neither the screening results of the current study or the study by Krueger and Ferguson (2002) were actually confirmed hearing losses and it is possible that the result on the pure-tone audiometry was a false negative (the child may have exhibited a hearing loss due to excessive background noise or by not understanding the task.) It is also possible that the child did have an actual hearing loss that the loss was too mild for the equipment to pick up.

It was more common for children to fail on all frequencies in the DPOAE testing with nine children failing on all three frequencies in at least one ear. Five children had abnormal the DPOAE in both ears. It was more common for a child to be referred for unilateral results, which is consistent with the pure-tone audiometry screening results. Two children had abnormal DPOAE results solely on the left ear and five had abnormal DPOAE results solely on the right ear.

Follow-Up Results

Unfortunately, only 26 children received follow-up testing. A further two children declined follow-up testing but included their results from previous testing. This number was only 54.9% of the total children referred for follow-up. Of the 28 children with full diagnostic results, 29% had normal hearing and middle ear results

Fifteen of the children had a hearing loss which was 7.6% of all the children tested with the screen. This result was less than that found by Niskar, et al (1998), who also included conductive hearing loss in the prevalence rate f 14.9% found in their

study. Niskar, et al (1998) also included slight hearing loss in the prevalence rate, as did the current study in the follow-up stage. However, the current study may have missed some of the children with slight hearing loss as the referral criteria for the screen was for children with thresholds greater than 20dBHL. This may account for the reduced number of children with hearing loss found in the current study.

The most common hearing loss was a conductive hearing loss, at 36%, compared to sensori-neural hearing loss, at 18%. This result was to be expected as middle ear dysfunction is the most common cause of hearing loss in children and the type of hearing loss caused by middle ear dysfunction is conductive (Progress on Health Outcomes, 1998; Graham et al, 2002). This result is also consistent with the findings of the screening tests which also found that hearing loss in conjunction with tympanometry was the most common referral result.

Unilateral hearing loss was found in 32% of the children and bilateral hearing loss was found in 21%. This result is to be expected as unilateral hearing loss is more common than bilateral hearing loss (Berg, 1972) and the screening results had more referrals for unilateral abnormalities.

Normal Results

Eight children that were referred for follow-up testing were found to have normal follow-up results. Five children had a significant history of middle ear infections, of which two children had recently been prescribed antibiotics. Three children had had ventilation tubes fitted in the past. Seven of the children that had normal

follow-up results had abnormal tympanogram's on the screening test. Four of these children had a mild hearing loss on at least one frequency on the screening pure-tone audiometry, and three had results outside the normal range on at least two frequencies. One child had a moderate hearing loss on one frequency on the pure-tone audiometry screening.

Although Otitis Media is very common in children it has been stated that it is particularly common in the winter months (Henderson et al, 1982; Daly, 1997) and often spontaneously resolves with no lingering effects. In the current study it is likely that only one of the results was in fact a false negative and the other seven children had middle ear dysfunction that had cleared up by the time the follow-up testing was completed. This was almost certainly the case for five of the children with a significant history of middle ear dysfunction particularly the two children that had recently been prescribed antibiotics due to the child's GP following up on the letter sent after the screening tests. It is also likely that the change in season between testing and follow-up may have been a factor in the clearing of middle ear dysfunction as middle ear dysfunction is more prevalent during the winter months (the time of screening tests) and less prevalent in spring and summer (the time of follow-up testing) (Henderson et al, 1982; Williamson et al, 1994).

Sensori-neural Hearing Loss

A total of five children were found to have a sensori-neural hearing loss, this gave an occurrence rate of sensori-neural hearing loss of 2.5% of all the children tested. This result was higher than prevalence rates in other developed nations, 1.65/1000 – 2.1/1000 (Fortnum et al, 2001; Vartianinen, Kemppinen and Katjalainen, 1997; Uus and Davis, 2000;). Fortnum, et al (2001) found a prevalence rate of permanent

hearing loss at 0.33% (1.65/1000) in children aged 9-16years. This rate was lower than that found in the current study however; the previous study used a much larger sample, only included children with a hearing loss of 40dBHL or greater and only children with identified hearing loss. The current study included mild and slight hearing loss and the majority of hearing loss found was unidentified, which could account for the higher rate of hearing loss found.

Of all the children tested in this study 1% of all children tested had a unilateral sensori-neural hearing loss and 2% had a bilateral sensori-neural hearing loss. This result differed from the results found in the screening tests that revealed a higher number of unilateral hearing loss. Unilateral hearing loss is more common than bilateral hearing loss, however not all the children referred for follow-up testing attended. The difference was only very slight and it is therefore possible that the reduced sample may have contributed to this abnormal result.

There was an even spread of the different degrees of sensori-neural hearing loss found, with mild hearing loss only slightly more common than the others. Two of the children had a mild hearing loss, one had a slight hearing loss, one had a moderate hearing loss and one had a severe hearing loss. Slight/ Mild hearing loss tends to be more common than the more severe hearing losses. Niskar, et al (1998) in their study found that the most common loss was slight hearing loss. Mild hearing loss was the second most common hearing loss reported in the New Zealand Deafness Notification Data (2007). However due to the small number of children that attended the follow-up testing and then found with a sensori-neural hearing loss, an accurate comparison cannot be made.

Only one child had a pre-diagnosed sensori-neural hearing loss. The child with the severe high-frequency hearing loss may have previously gone undiagnosed due to the frequency range of screening audiometers. It is unlikely that this hearing loss would have had a significant impact on speech and language development, however when in competition with background noise, such as in classrooms, this child would have difficulty understanding speech (Berg, 1998; Crandell and Smaldino, 2000; Finitzo, Hieber and Tillman, 1978). Another child had a mild low frequency hearing loss with a history of ventilation tubes. One child had a slight middle frequency hearing loss and one had a mild middle frequency hearing loss. These two hearing losses may have been undetected previously due to their mild nature. It's possible that the symptoms of the hearing loss were not noticed by parents or teachers and the loss may have been missed by screening tests. It is important that, even though these children had very mild hearing losses that often do not require assistance from hearing aids, these children were made known to the public health care system to ensure their hearing loss is monitored. It is also important the child's parents and teachers are aware of the loss to ensure the child receives extra help where required.

Two of the children with a hearing loss had been born prematurely, which is one of the 10 key risk factors for congenital hearing loss (New Zealand Deafness Notification Data, 2007). Three children had a history of middle ear infections. One child had a pre-diagnosed hearing loss which is suspected to have been caused by ototoxicity, a known cause of sensori-neural hearing loss. All five children, that

were found to have sensori-neural hearing loss, had results outside the normal range solely on the pure-tone audiometry results.

Only one child had only one frequency outside the normal range on the pure-tone audiometry screen, the other four children had at least three frequencies (two bilateral) outside the normal range on the pure-tone audiometry screen. The other four children that had results outside the normal range on pure-tone audiometry screening did not attend follow-up testing. This result suggests that the pure-tone audiometry screening was fairly accurate as 100% of the children that had results outside the normal range solely on the pure-tone audiometry and attended follow-up testing, also had results outside the normal range on the same test during follow-up testing.

Conductive Hearing loss

Of all the children that participated in the study, 5.1% (10) were found to have a confirmed conductive hearing loss. In all these children Otitis Media is suspected as the cause of the conductive hearing loss. The number of children with a conductive hearing loss is relatively high compared with results from other developed countries that suggest that Otitis Media rates should be below 3% (Bluestone, 1999; Williamson et al, 1994). However, the sample did include Maori and Pacific Island children and it is commonly accepted that these two ethnic groups both have a high rate of middle ear dysfunction (Bluestone, 1999; Giles and Asher, 1991; Giles and O'Brien, 1991). Results from previous studies that included indigenous children showed a higher prevalence of middle ear dysfunction (Baxter, 1999; Homoe, 1999; Leach, 1999).

Most of the children (70%) with results outside the normal range on follow-up testing had a mild conductive hearing loss. Middle ear dysfunction often results in only a mild hearing loss as the sound can still be transmitted through the fluid (Northern and Downs, 2002). The most severe degree of conductive hearing loss was moderate (10%), and 20% of children had a slight hearing loss. This result is to be expected as the degree of conductive hearing loss cannot be worse than a moderate hearing loss; anything greater than this is considered to be a mixed hearing loss, as the skull vibrates at intensities greater than 60-70dBHL allowing the signal to go straight to the inner ear (Roeser, Buckley and Stickney, 2002).

Eight children had a significant history of ear infections, one child was unable to provide any history regarding middle ear dysfunction and one child had no prior history. Four of the children with a significant history of middle ear infections had ventilation tubes fitted in the past. The other four children had been treated with antibiotics is an important finding as it suggests that these children are likely to have had a conductive hearing loss for a significant part of their lives. This may have impacted on their early language learning and their ability to understand instructions in class. Although it may not be a significant difference in comparison with their peers, these children may also not be performing to their potential academically. One child had had a diagnosed speech delay, in the past, but had since recovered with assistance from speech and language therapy. This is important, as this child may have been delayed slightly in other developmental areas, such as reading, behaviour and social skills, as a result of this language delay (Anderson and Martin, 1998; Hasenstab, 1987; Northern and Downs, 2002) and

although the language delay has been addressed the other areas may never have been looked at.

All ten children found to have a conductive hearing loss on the follow-up tests had a type C2 or B tympanogram on their screening tests. All ten children had a hearing loss on at least one frequency on the screening test. Two children had a moderate hearing loss (one bilateral) and eight children had a mild hearing loss. The two children with moderate hearing loss had a loss on a minimum of two frequencies on the screening pure-tone audiometry. Four children had a mild hearing loss on one frequency and four had a mild hearing loss on two or more frequencies. These results suggest that all though the screening referral criteria was more conservative than the New Zealand new entrant screen (National Audiology Centre, 2006) there were few false negative results, and many of the children with a confirmed conductive hearing loss would have been missed if the New Zealand new entrant screen referral criteria had been used (National Audiology Centre, 2006).

Middle Ear Dysfunction

Results from the tympanometry testing revealed abnormal results in 14 children. Nine children had a conductive hearing loss and five children had no hearing loss at all. Six (3% of all children tested in the screening test) children had type B tympanogram's, five of which also had a conductive hearing loss. A type B tympanogram is consistent with fluid in the middle ear and this is more likely to impact on hearing (Sassen, et al 1993). The prevalence rate of Otitis Media in this study is slightly higher than results from studies in developed countries such as the USA and UK (Bluestone, 1999; Williamson, et al 1994) but slightly lower than

those of indigenous children and children in developing countries (Homoe, 1999; Homoe et al, 1995; Jacob et al, 1997; Minja and Machemba, 1996). The prevalence is more consistent with those in developed countries as would be expected in New Zealand which although small, is a developed nation.

Seven children had a type c2 tympanogram of which 4 also had a conductive hearing loss. This hearing loss is due to the retraction of the ear drum, and often residual fluid, affecting the conduction of sound which for some children can lead to a hearing loss (Jordan and Roland, 2000). One child had a type c1 tympanogram which appeared to have no effect on the child's hearing.

Of the five children with abnormal tympanogram's and no hearing loss, four had a history of hearing loss associated with Otitis Media and one did not. Two of these children had received ventilation tubes and two had been treated with antibiotics. One child had an earlier speech delay, but had since recovered. All five children that had middle ear concerns in the absence of hearing loss on the follow-up results had type c2 tympanogram's on the screening tests. Four children had normal pure-tone results on the screening test, one child had two frequencies with a mild hearing loss on the screening test.

Distortion Product Otoacoustic Emissions

Ten (4 pass and 6 fail) children that received the DPOAE screening test also received follow-up testing. Four children (50%) were found to have a genuine hearing loss (Two sensori-neural, two conductive hearing loss) of which two children had abnormal results on the DPOAE screen (one with a sensori-neural

hearing loss and one with a conductive hearing loss). The two children that passed the DPOAE screen but were then identified with a sensori-neural hearing loss on the follow-up testing, had a loss outside the frequencies (2-4 kHz) tested during the DPOAE screen. It is possible that these hearing losses would have been identified, had the DPOAE screen included more frequencies. Three children were found to have middle ear dysfunction in the absence of hearing loss, of which one had abnormal results on the DPOAE screen. Both of the children that had passed the DPOAE screen had abnormal results on tympanometry screen and one had results outside the normal range on the pure-tone audiometry screen. It is possible that the middle ear dysfunction was not severe enough to be detected by the DPOAE screening equipment at the time of screen and had possibly become more severe by the time of the follow-up testing. Three children that received the DPOAE screen had normal results on the follow-up testing. Two of these children had abnormal results on the DPOAE screen and one had passed the DPOAE screen. The two children that had abnormal results on the DPOAE screen had abnormal tympanometry results and had results outside the normal range on the pure-tone screen.. So although these children passed the follow-up screen it is possible that they were not false negatives but instead had middle ear dysfunction that had cleared by the time of the follow-up testing. Overall, the DPOAE screen identified two children with a hearing loss and one child with middle ear dysfunction. Unfortunately, it did not identify two further children found to have a hearing loss which in comparison with the pure-tone audiometry testing was not as accurate. This result is consistent with that found by Lyons et al (2002) that suggested that the DPOAE is not as sensitive as the pure-tone audiometry test and should not be

used in isolation. It is possible the DPOAE screen would have been more accurate had a broader range of frequencies been tested.

Limitations

The current has several limitations. One was the low number of returned consent forms as well as the low rate of return for follow-up testing. The schools that had the higher consent form return rates used incentive's to encourage children to return forms promptly as well as reminders in the school newsletter. The low rate of consent return may have been remedied had an incentive program been included to encourage participation. The low number of consent forms was compounded by the sample of differing ethnic groups and the limited inclusion of children with known audiological problems. The small sample of differing ethnic groups impacted on the ability to compare prevalence rates between different groups with any accuracy. The limited inclusion of children with known audiological problems lead to an unreliable prevalence rate. This could have been avoided by including a section of the consent form allowing parents to indicate an existing hearing loss and provide permission for the researcher to obtain existing Audiology records. The high rate of children lost for follow-up impacted on the ability obtain accurate occurrence rates as almost half the children that failed the screening test did not attend follow-up testing. This may have been due to either parents not receiving the follow-up letter. or not realising the importance of the follow-up testing. This may have been avoided if the study had been less restricted by time allowing for the sending of reminder letters and possibly making phone calls to encourage participation.

A further limitation was the small sample of children tested with DPOAE screener as a result of equipment malfunction early in the study. This meant the results are not as reliable as they would have been with a larger sample.

Beginning the testing in winter and completing it in spring meant that the last school tested was likely to have a lower rate of middle ear dysfunction as a function of the season they were tested in.

Future Research

A bigger study across Christchurch that would provide prevalence rates as well as improving the follow-up rate through reminder letters and phone calls. This larger study would allow for an accurate prediction of the prevalence of hearing loss. It is suggested that future research investigates the differing hearing loss and Otitis Media prevalence rates between New Zealand European and Maori children by using age matched equal sized on a larger sample size. It would be important to have an even distribution of different decile schools for a more accurate comparison of socio-economic differences. Survey the classroom teachers to find out the impact the hearing loss has had on each child's education and provide follow-up service and resources to better support hearing impaired children.

Summary

The purpose of this study is to determine the prevalence of hearing loss and middle ear dysfunction in the school age population of children in Christchurch. Also to investigate if DPOAEs would be a useful tool to include in the screening protocol.

Overall a large number of children were referred for follow-up testing. The majority of these were for hearing loss caused by middle ear dysfunction.

Maori and Pacific Island children had a higher rate of abnormal tympanometry results on the screen than children from European descent. However, due to the small sample size these results cannot be generalised.

The prevalence of confirmed hearing loss was estimated at 7.6% (2.5% sensori-neural hearing loss and 5.1% conductive hearing loss) for all the children screened. However, due to not all children attending the follow-up this result is not a definitive prevalence rate of these children.

Middle ear dysfunction was suspected and consistent in 3% of all the children tested and was consistent with results from other developed countries.

Previous literature has confirmed DPOAEs as a useful screening tool in newborn hearing screening and limited research as stated they are useful in school-age children. The current study was consistent with previous studies suggesting that DPOAEs are not as sensitive to hearing loss as pure-tone audiometry however are useful as part of the screening test battery.

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8 Appendices

Appendix A - Letter to Principals

May 2007

The Principal
XXX School
XXXX St
CHRISTCHURCH

Dear Sir/Madam,

I am a final year Masters of Audiology student at the University of Canterbury. I am currently undertaking a research project investigating the prevalence of hearing loss in Christchurch primary school children. This research involves testing of children's hearing thresholds and investigating their middle ear status. Due to the time restraints of this project testing will be limited to children in years 1, 3 and 6.

I am writing to schools requesting permission to carrying out testing of their pupils on school premises. Testing will be carried out by myself under the supervision of a qualified audiologist and middle ear status will be investigated by and ear nose and throat specialist. The testing is non invasive and seeks to identify children with hearing outside the normal hearing range. Testing will involve each child being out of the classroom for a maximum of 30 minutes on one occasion.

A National ethics application has been submitted. Testing will not commence until ethics approval has been granted. It is anticipated that testing will commence in the third school term of 2007.

All children participating in the research will require written consent from parents. Consent forms and information letters will be provided to schools that have agreed to participate to be sent home with children.

All results will remain confidential. Parents will be provided with written report outlining results of testing.

In order to begin the planning process, I would be grateful if you could notify me of your willingness to allow testing of pupils in your school, as soon as possible.

If you have any questions feel free to contact myself or my supervisor Dr Ravi Sockalingham.

Kind regards,

Phoebe Smith

021 2259999, feebsmith@gmail.com

Appendix B_1 – Information Sheet

SUBJECT INFORMATION FORM

Researcher: Phoebe Smith **Phone:** (03) 3427830 or 0212259999

Supervisor: Ravi Sockalingham, Ph.D., Professor **Phone:** (03) 364-2987 Extn:3052

Title of Project: Prevalence of Hearing Loss in Christchurch School Children

We invite your child to possibly participate in a study in which your child's hearing will be tested. Your child can participate in the study if he/she is in years 1, 3 and 6. Participation in the study is voluntary. Your child will be asked if she/he would like to participate and he/she can withdraw from the study at any time. The study is described in detail in the following paragraphs, including potential benefits to your child, confidentiality and the appropriate individuals to contact if you have any questions or concerns.

All testing will be performed by Phoebe Smith, a Masters Student in Audiology at the University of Canterbury and Dr. Ravi Sockalingham, Senior Lecturer of Audiology at the University of Canterbury. Dr. Sockalingham is also the research supervisor for this study.

Purpose of the study:

Hearing Loss is a significant health problem affecting New Zealand children. This study aims to determine the prevalence of hearing loss in a cross section of the school age population in Christchurch.

Procedure:

Your child will be tested by the researcher at their primary school during school hours. Your child will be accompanied to the testing location and back to the classroom by the researcher. Testing will include:

A) Visual examination of the ear canal and eardrum with an otoscope.

B) Measurement of your child's hearing threshold for tones of varying pitch. Hearing threshold is the softest level at which your child can hear the presented tone.
C) Test of middle ear function, a test in which a rubber plug is inserted into the ear and air pressure in the ear is changed to measure the movement of the ear drum.
D) Inner ear function test (DPOAE), a test where a plug is placed in the ear and two tones are played. The response from the inner ear is recorded to check whether the inner ear is functioning normally.

Testing will take approximately thirty minutes.

Possible risks or discomforts:

There are no risks involved in the testing procedure. All the tests used in the study are painless and will not hurt your child's ears or his/her hearing. For the tests, your child will be out of the classroom for approximately twenty minutes. Your child may feel nervous about having their hearing tested, particularly if they have not had their hearing tested before. In this case, the researcher will provide an opportunity for the child to become more comfortable with testing (i.e., through further explanation, demonstration, and practice trials). There is the possibility of minor discomfort during the middle ear function test when the air pressure in the ear canal changes. However, most individuals experience no discomfort when undergoing this procedure.

Possible benefits:
Your child will have his/her hearing tested and if a hearing loss is detected, the researcher will contact you with the results and will suggest ways to maximize your child's learning in the classroom.

Confidentiality:
All test results obtained by the research student will be kept strictly confidential in a locked cabinet. Your child's records will be coded to ensure that their name will not be revealed during presentation of the data. All test results concerning your child will be made available to you, on request.

Appendix B_2 - Consent Form

CONSENT FORM

STATEMENT BY RELATIVE/FRIEND/WHANAU

Title:

Investigation of Hearing Loss in Primary School children

Principal Investigator:

Phoebe Smith (Master of Audiology Student). Department of Communication Disorders, University of Canterbury.
Ph: 021 2259999

Participant's Name:

_____

I have read and I understand the information sheet attached for children taking part in the study designed to investigate the rate of hearing loss in primary school children. I have had the opportunity to discuss this study. I am satisfied with the answers I have been given.

I believe that my child would have chosen and consented to participate in this study if he/she had been able to understand the information that I have received and understood.

I understand that taking part in this study is voluntary and that my relative/friend may withdraw from the study at any time if he/she wishes. This will not affect his/her continuing health care.

I understand that the procedure involved will be explained to my child and that they may choose not to participate.

I understand that his/her participation in this study is confidential and that no material which could identify him/her will be used in any reports on this study.

I know whom to contact if my child has any side effects to the study or if anything occurs which I think he/she would consider a reason to withdraw from the study.

This study has been given ethical approval by the National Ethics Committee. This means that the Committee may check at any time that the study is following appropriate ethical procedures.

I would like a copy of the results of the study. **YES/NO**

I agree to my child's GP being informed of his/her participation in this study **YES/NO**

Signed: _____ Date _____

Printed Name:

_____

Relationship to Participant:

_____

Address for results :

_____

STATEMENT BY PRINCIPAL INVESTIGATOR

I, Phoebe Smith, declare that this study is in the potential health interest of the group of patients of which your child is a member and that participation in this study is not adverse to the child's interests.

Appendix C_1 – Screening Pass Letter

Hearing Screening

/ /2007

Dear Parent/Caregiver

Today your child had his/her hearing tested as part of a study into Hearing Loss in Christchurch Children. Your child's hearing was tested in 4 ways. Visual inspection of ear (otoscopy), Test of hearing sensitivity (Pure tone audiometry), Test of inner ear function (Distortion Product otoacoustic emissions (DPOAE), and Test of middle ear function (Tympanometry). Your child passed all four of these tests which suggests that they have normal hearing. However, if you ever have concerns about your child's hearing please contact your GP.
Please find attached a copy of the results.

Regards,

Phoebe Smith Ravi Sockalingham

Appendix C_2 – Screening Referral Letter

Referral

/ /2007

Dear Parent/Caregiver

Today your child had his/her hearing tested as part of a study into Hearing Loss in Christchurch Children. Your child's hearing was tested in 4 ways. Visual inspection of ear (otoscopy), Test of hearing sensitivity (Pure tone audiometry), Test of inner ear function (Transient Evoked otoacoustic emissions (TEOAE), and Test of middle ear function (Tympanometry). Your child did not pass one or more of these screening tests (as indicated below). This result may indicate a hearing loss or middle ear dysfunction. It is suggested that your child has a full diagnostic hearing test. This testing is offered free for children that are part of this study. Please contact the Phoebe Smith on 03-342-7830 / 0212259999 to make an appointment. If your child already has a diagnosed hearing loss and/or middle ear problem please make contact on the above number to discuss including your child's records in this study.

TESTS	Pass ☑ / Referral ☒
Tympanometry	☐
Pure Tone Audiometry	☐
DPOAE	☐
Otoscopy	☐

Please find attached a copy of the results.

Regards,

Phoebe Smith Ravi Sockalingham