Ear health and hearing in urban Aboriginal children

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Abstract

Objective: Evaluate ear health and hearing among urban Aboriginal children and quantify relationships with child, family and social factors.

Methods: Baseline questionnaire and ear health examinations from 1430 children with diagnoses (0.5-18 years) attending Aboriginal Health Services enrolled in SEARCH. Ear health outcomes were Otitis Media (OM), and hearing loss (three-frequency average hearing loss >20dB) diagnosed using pneumatic otoscopy, tympanometry, and audiometry.

Results: Half the children 0.5-3 years had OM (51.5%, 136/264). One third 0.5-18 years (30.4%; 435/1430) had OM, including 1.8% (26/1430) with perforation (0.8% chronic suppurative OM, 0.6% dry perforation and 0.4% acute OM with perforation). One quarter 0.5-18 years (25.7%; 279/1087) had hearing loss; 12.4% unilateral, 13.2% bilateral (70.6% with bilateral loss had concurrent OM). OM was associated with: younger age (0.5-<3 years versus 6-18 years) age-sex-site; adjusted prevalence ratio (aPR)=2.64, 95%, 2.18-3.19); attending childcare/preschool (aPR=1.24, 95%CI, 1.04-1.49); foster care (aPR=1.40, 95%CI, 1.10-1.79); previous ear infection/s (aPR=1.68, 95%CI, 1.42-1.98); and ≥2 people/bedroom (aPR=1.66, 95%CI, 1.24-2.21). Hearing impairment was associated with younger age (0.5-<6 years vs. ≥6 years aPR=1.89, 95%CI, 1.40-2.55) and previous ear infection (aPR=1.87, 95%CI, 1.31-2.68).

Conclusions: Half the urban Aboriginal children in this cohort had OM and two-thirds with hearing impairment had OM.

Implications for Public Health: Findings highlight importance of early detection and support for ear health, particularly in pre-school-aged children with risk factors.

Key words: otitis media, ear health, hearing, Indigenous, Aboriginal

Introduction

Aboriginal and Torres Strait Islander language systems are diverse, with more than 150 traditional languages currently spoken across Australia.[1] Oral systems of knowledge and storytelling are central to Aboriginal and Torres Strait Islander identity and culture.[2] Healthy ears early in life are essential for spoken language[3] and critical for spiritual and cultural wellbeing and, to meet academic, social, and life potential,[4] for Aboriginal and Torres Strait

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Islander children. In fact, hearing loss has been found to negatively influence self-concept, educational attainment and social skills that consequently increase the risk of contact with the justice system.[5] Despite this, otitis media (OM) has been a major public health issue for Aboriginal and Torres Strait Islander children, with the prevalence of OM in some remote areas over 90%.[6] However, there are limited data on OM subtype frequency or the factors related to ear health and hearing outcomes in urban settings.[7–13] These data are necessary to inform prevention and treatment strategies in the areas where most Aboriginal and Torres Strait Islander children live.[14]

OM risk factors include day care attendance, exposure to tobacco smoke, asthma, allergies, craniofacial abnormalities, living with siblings and age,[15–17] with breastfeeding being protective.[16–18] Amongst Aboriginal and Torres Strait Islander populations, determinants of OM are less clear and have largely been reported in rural and remote settings.[3] In urban settings, data are scarce, but household crowding has been identified as a determinant of both OM[18] and OM-associated bacterial colonisation.[20,21] These determinants are not choices, but rather are the consequences of policies,[22] and include racism, crowded and poor quality housing, poverty and exposure to tobacco smoke.[3,23] The deficit discourse continues to depict Aboriginal and Torres Strait Islander people as the problem rather than colonisation and government policies[22] that have contributed to, and perpetuated, the disproportionate burden of these OM determinants.

Study of Environment on Aboriginal Resilience and Child Health (SEARCH)[24] is the largest cohort study of urban Aboriginal and Torres Strait Islander children. It is grounded in co-creation and participatory action research principles to strengthen the cultural safety and redresses the power imbalance in Aboriginal and Torres Strait Islander research.[25,26] It is accepted that Aboriginal and Torres Strait Islander health research has historically been problematic and non-participatory.[27–29] There is an ongoing shift away from this traditional research paradigm, where research was 'done on' communities, toward co-created approaches where research is 'done with' communities. Furthermore, co-creation has been acknowledged as supporting community members and service users to be coactive participants rather than passive end users.[27] Importantly, co-creation acknowledges the importance of community knowledge and lived experience and ensures community and cultural relevance is central to the research and research translation.[27–29] For over a decade, SEARCH has built and maintained successful relationships with Aboriginal communities to support community ownership of the research and data and to ensure community voice guides policy, research and service provision.[27–29]

The SEARCH partnerships with Aboriginal and Torres Strait Islander communities highlighted ear health and hearing as research priorities. In this study, we report OM and hearing outcomes in the cohort and associated child, family and social characteristics to inform policy and practice initiatives to improve ear health and hearing outcomes.

Methods

Study design

SEARCH is a cohort study of 1669 urban Aboriginal and Torres Strait Islander children (aged 0-18 years) from four participating Aboriginal Medical Services.[24] The Aboriginal Medical Services supported investigators to enrol participants (2008-2012).[8] Children and caregivers were interviewed by an Aboriginal and Torres Strait Islander research officer and offered comprehensive ear health assessments. Carers completed a detailed health and wellbeing questionnaire.[7] We present cross-sectional ear health data at SEARCH enrolment.

Setting

Three metropolitan and one large regional Aboriginal Medical Services in New South Wales.

Participants

SEARCH ear health protocols have been previously published.[24] Overall, there were 1669 children enrolled (Figure 1) with differential diagnostic data for the presence or absence of OM in 1430. We excluded children younger than 6 months (n=24, 1.4%), as ear health assessments in this age are technically difficult and less reliable. We excluded assessments conducted by audiometrists (ear health workers) rather than audiologists (n=11). There were 152 children not assessed and a further 52 with missing OM diagnoses, following reclassification (see below). We examined for demographic differences between the 1430 children with and 215 children without ear health diagnoses. For hearing outcomes, children younger than 3 years were excluded (n=285) as assessment at this age is less reliable. A further 110 children did not have a hearing assessment, leaving 1087 children with hearing outcome data. The main reason for missing assessments was caregiver refusal.[11]

Outcomes

Otitis media

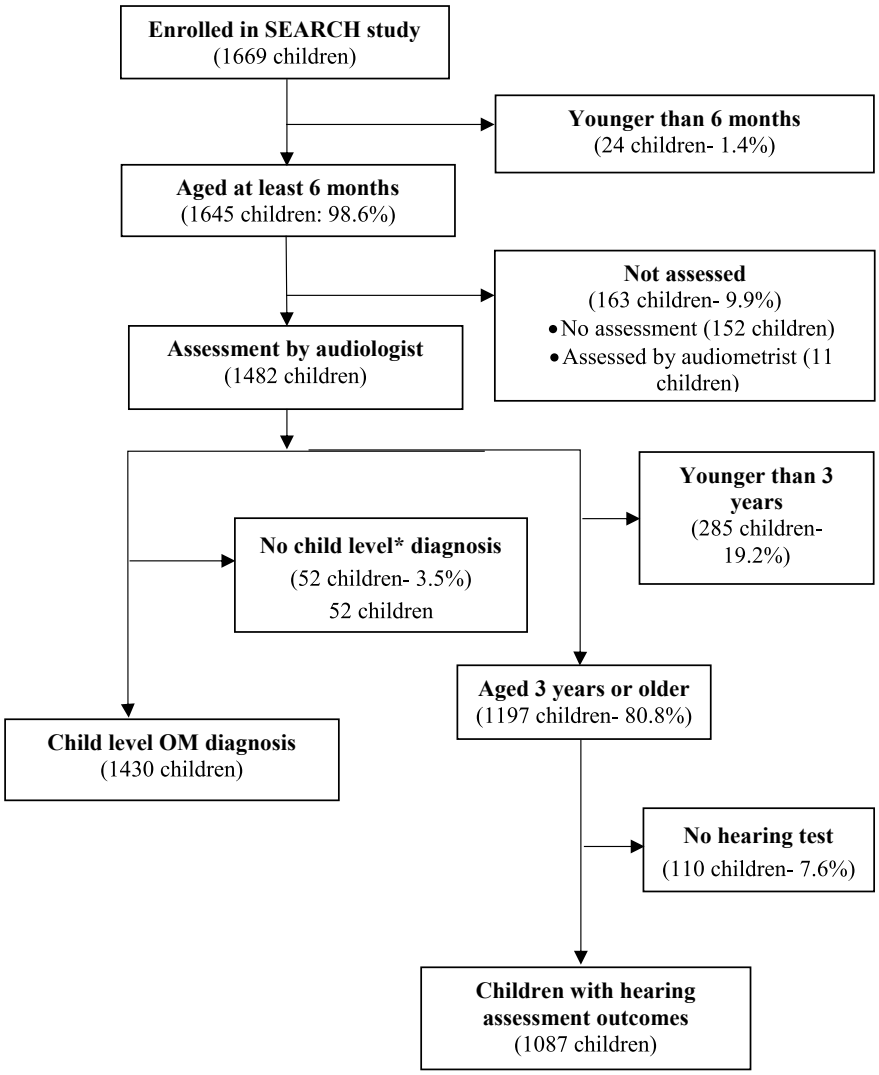
We reported rates by child (i.e. in either or both ears) and ear (i.e. separately right ear and left ear) and categorised diagnoses using this hierarchy: chronic suppurative OM; dry perforation; acute OM (with perforation, recurrent then without perforation), OM with effusion; OM undifferentiated. For the ear health analysis, we used a dichotomous variable (any OM/no OM).

Each child was assessed by one of five audiologists, and the results of these assessments were confirmed by one of three otolaryngologists. We reported the audiologists' findings here as we have previously demonstrated near perfect agreement between the audiologists and otolaryngologists, and the audiologist dataset is larger.[8] When audiologists did not choose a diagnosis, two independent reviewers (HG and JD) reclassified the comments 'wax', 'Eustachian tube dysfunction', 'ventilation tubes *in situ*' and 'tympanic membrane scarring' as 'No OM' and type B tympanograms (i.e. objective middle ear assessment suggestive of middle ear dysfunction) as 'OM' according to an *a priori* algorithm. If comments were insufficient for a reclassified diagnosis (n=95 ears), data were excluded. As OM diagnoses are subjective, we separately report type B tympanograms and tympanic perforation rates.

Hearing

Hearing loss was defined as 3 frequency averages (3FAHL 0.5, 1 and 2kHz) >20dB, consistent with contemporary recommendations.[30] Hearing impairment was defined as bilateral hearing loss and categorised by the results for the best ear as follows: mild (21 to 45dB); moderate (46 to 65 dB); severe (>65dB). For the hearing impairment analysis, we used a dichotomous variable (yes/no). We

Figure 1: Flowchart of children with otitis media (OM) and hearing data included in the analysis.



*Child level = results corresponding to either or both ears (using the hierarchy)

also report findings by the recently published World Health Organization hearing classifications.[19]

Child, family and social factors

Child-related outcome measures included sex, age group, in utero exposure to cigarettes, in utero exposure to marijuana, ever had an ear infection, and ever breastfed.

Family-related outcome measures included relationship to child, carer education, government financial support, carer allowance, parental psychological distress, parental/carer removal from family, fortnightly household income, employment status and carer regular smoker or more than one person smoking within home.

Social-related outcome measures included assessment season, number of houses lived in since birth, attends childcare, housing tenure, people per bedroom and housing problem.

The housing problems variable related to the participants current residence and was defined as 'yes' to any questions about: 'rising damp'; 'damp on walls/ceilings/windows'; 'major plumbing problems'; 'cockroaches/mice/vermin'; 'structural problems (cracks, sinking foundations, sagging floors, walls/windows not straight or wood rot/termite damage)' or the house being 'too small'. Time-specific survey data (e.g. ever had an ear infection, number of houses lived in since birth, current exposure to cigarette smoke) were set to missing if either (i) the audiology assessment was more than 6 months before or after the survey (for children <2 years at the time of the assessment) or (ii) the audiology assessment was more than 1 year before or after the survey (for children ≥2 years at the time of the assessment). If the audiology assessment was completed after a survey with a response 'yes' to 'ever had an ear infection?', we included these data as the response would not have changed.

Statistical methods

Log-binomial regression was used to calculate prevalence ratios (PRs) for the association between: (1) OM; (2) hearing loss; (3) each child, family and social characteristic and the two outcome measures. Parameter estimation was performed within the generalised estimating equations framework with an exchangeable correlation

structure to account for children within families. We report unadjusted PRs and PRs adjusted (aPR) for aboriginal medical services, age and sex. The functional form of age was checked using fractional polynomials. To assess for bias due to missing data, analyses were repeated with multiple-imputed data for the risk factors. Multilevel multiple imputations were performed using REALCOM-IMPUTE software[31] with the outcomes and all risk factors in the imputation models. We created 50 imputed datasets, which incorporated variability due to uncertainty in the exact values, with a burn-in period of 2500 iterations and 500 iterations between imputations. Estimates of coefficients obtained for each dataset were combined using Rubin's rules.[32] Sensitivity analyses were conducted varying the time period permitted between the child survey and the audiology assessment to assess if the choice of time period influenced the results. The first analysis included data for children with any length of time between the audiology assessment and the second limited the gap permitted to one month. All analyses were conducted in Stata version 16.1 (StataCorp, College Station, TX, USA).

Results

Of 1669 SEARCH participants, 1482 (88.8%) participants had an audiology assessment and 1430 (85.6%) had an ear health diagnosis and were included in the analysis (Table 1; Figure 1). Included children were similar to excluded children, except they were less likely to have been assessed in summer and were slightly older (see Supplementary Table 1).

Children were aged 6 months to 18.9 years (median 6.4 years; interquartile range 3.7-10.2 years) at the audiology assessment. Of the 1430 children, 995 (69.6%) had no OM and 435 (30.4%) had OM (Table 2), including 26/1430 (1.8%) with a perforated tympanic membrane. Audiologists were more likely to diagnose acute OM without perforation (110/1430; 7.7% children), than otolaryngologists (~1% children; with the rest labelled OM with effusion), but their diagnoses were otherwise similar. Of 2,354 ears with both tympanometry and otoscopic data, 436 (18.5%) had type B tympanograms (123/436 had bulging) and 1918 (81.5%) had non-type B tympanograms (37/1918 had bulging).

Hearing data were available for 1087 children (aged 3 to 18.9 years; median 8.2 years, interquartile range 5.7–11.5 years). Of these, 279/1087 (25.7%) had hearing loss; 144 (13.2%) bilateral and 135 (12.4%) unilateral. Of the 136 children with hearing impairment (bilateral hearing loss) and an ear health diagnosis, 96 (70.6%) had OM. Children with OM were more likely to have hearing impairment than those without OM (aPR=7.28, 95% CI 4.99-10.62).

OM and hearing impairment were most common among the youngest age groups, with OM identified in: 136/264 (51.5%) children <3 years, 148/396 (37.4%) children ≥3 years to <6 years, 123/537 (22.9%) children ≥6 to <12 years and 28/233 (12.0%) children ≥12 years. Compared to children six years or older, OM adjusted PRs for children ≥6 months to <3 years were 2.64 (95% confidence interval (CI) 2.18-3.19) and 1.86 (95%CI 1.53-2.26) for children ≥3 years to <6 years. Hearing impairment was identified in 63/316 (19.9%) children ≥3 to <6 years, 60/536 (11.2%) children aged ≥6 to <12 years and 21/235 (8.9%) children ≥12 years.

Boys had a similar likelihood of hearing impairment to girls (aPR=0.88, 95% CI 0.65-1.219). OM was more common among children who were younger, attended childcare or preschool (assessed for all children <6 years); were in foster care, ever had a previous ear infection; had more people per bedroom in the home (Table 3). Hearing impairment was more common among children who were younger and had a history of ear infection.

Sensitivity analyses

Supplementary Table 2 shows similar associations when using imputed data for missing values. Sensitivity analyses varying the time permitted between audiology assessments and surveys were also consistent with the primary analysis results.

Discussion

Approximately half of the children in our cohort aged six months to three years, a critical age for speech and language development,[3] had some form of OM. Overall, about one third of children aged six months to 18 years at baseline had OM. One in seven children had bilateral hearing impairment, two thirds of those with hearing impairment presented with concurrent OM and less than 2% had tympanic membrane perforation. Factors associated with OM and/or hearing impairment were childcare attendance, previous ear infection, younger age, foster care and living in crowded houses. Socioeconomic factors such as carer education level, household income, employment status, home ownership and having government financial support were not associated with OM or hearing impairment in this cohort.

Our study provides the first contemporary view of OM and hearing impairment in urban Aboriginal and Torres Strait Islander children since a small cross-sectional study of Aboriginal and Torres Strait Islander primary school children in Perth in 2009.[12] However, a recent study from Western Australia of 67 urban Aboriginal and Torres Strait Islander children aged 9-12 months[13] reported hearing loss prevalence of 31.3% of 67 children, and type B tympanograms in 46.2% of 65 children without reporting OM diagnoses or associated factors, and assessed only younger children. A 2023 follow-up to this study reported OM diagnoses in 125 Aboriginal infants aged two to 12 months.[6] In this study,[6] approximately half of the participants aged six months had OM, and those with OM at age two or six months were more likely than those without to have OM at age 12 months. This is consistent with the association between OM and previous ear infection found in our study. The earlier Perth study[12] found 19.3% of 119 children had OM (excluding Eustachian tube dysfunction) and 19.1% of 94 children tested had mild-moderate hearing impairment. In the SEARCH cohort, 30% of children had OM and 25.6% had a hearing impairment at baseline, although the sampling methods preclude reliable extrapolation to the overall population of urban Aboriginal and Torres Strait Islander children in NSW. Our higher prevalence of hearing impairment in SEARCH (13% bilateral hearing loss at 20dB vs. 4% bilateral hearing loss at 25dB in Perth study) may reflect differences in the decibel (dB) definition of impairment. Less than 2% of children in this study had tympanic membrane perforation, significantly lower than the 12-14% reported by a 2016 study[33] of 651 Aboriginal and Torres Strait Islander children in remote Northern Territory and the 21% reported in a 2022 study[34] of 19 Aboriginal and Torres Strait Islander children in remote South Australia. To date, the recent Western Australia study[6] of 125 infants is the only other reporting child, family and social factors in relation to OM among urban Aboriginal and Torres Strait Islander children.

Table 1: Child, family and social characteristics of participants, by otitis media and hearing impairment outcomes.

	Otitis Media at child level[a]			Hearing impairment[b] at child level		
	No Otitis Media	Any Otitis Media	Total	No	Yes	Total
	n =995	n =435	n =1430	n =943	n =144	n =1087
	n (%)	n (%)	n	n (%)	n (%)	n
Sex						
Female	447 (68.8)	203 (31.2)	650	432 (86.1)	70 (13.9)	502
Male	548 (70.3)	232 (29.7)	780	511 (87.4)	74 (12.6)	585
Age at audiology assessment						
6 months to <3 years	128 (48.5)	136 (51.5)	264			
3 to <6 years	248 (62.6)	148 (37.4)	396	253 (80.1)	63 (19.9)	316
6 to <12 years	414 (77.1)	123 (22.9)	537	476 (88.8)	60 (11.2)	536
12 to 18 years	205 (88.0)	28 (12.0)	233	214 (91.1)	21 (8.9)	235
Number of houses lived in since birth						
1	165 (59.6)	112 (40.4)	277	130 (81.8)	29 (18.2)	159
2	163 (65.2)	87 (34.8)	250	135 (84.9)	24 (15.1)	159
3	142 (68.6)	65 (31.4)	207	158 (86.3)	25 (13.7)	183
≥4	242 (81.2)	56 (18.8)	298	245 (89.7)	28 (10.3)	273
Missing	283 (71.1)	115 (28.9)	398	275 (87.9)	38 (12.1)	313
Attends childcare/preschool (<6 years)						
No	190 (59.7)	128 (40.3)	318	114 (82.6)	24 (17.4)	138
Yes	150 (53.8)	129 (46.2)	279	115 (76.2)	36 (23.8)	151
Missing	36 (57.1)	27 (42.9)	63	24 (88.9)	3 (11.1)	27
Assessment season						
Winter/Spring	603 (67.4)	292 (32.6)	895	577 (85.5)	98 (14.5)	675
Summer/Autumn	392 (73.3)	143 (26.7)	535	366 (88.8)	46 (11.2)	412
Relationship to child						
Parent	842 (70.3)	355 (29.7)	1197	774 (86.6)	120 (13.4)	894
Other relative	95 (68.8)	43 (31.2)	138	106 (86.9)	16 (13.1)	122
Foster carer	53 (59.6)	36 (40.4)	89	60 (88.2)	8 (11.8)	68
Missing	5 (83.3)	1 (16.7)	6	3 (100.0)	0 (0)	3
In utero exposure to cigarettes						
No	403 (71.3)	162 (28.7)	565	362 (86.8)	55 (13.2)	417
Yes	415 (67.6)	199 (32.4)	614	397 (85.6)	67 (14.4)	464
Missing	177 (70.5)	74 (29.5)	251	184 (89.3)	22 (10.7)	206
In utero exposure to marijuana						
No	657 (69.7)	286 (30.3)	943	601 (85.6)	101 (14.4)	702
Yes	144 (67.3)	70 (32.7)	214	146 (88.5)	19 (11.5)	165
Missing	194 (71.1)	79 (28.9)	273	196 (89.1)	24 (10.9)	220
Ear infection (parent report)						
No	465 (76.6)	142 (23.4)	607	403 (91.0)	40 (9.0)	443
Yes	299 (60.5)	195 (39.5)	494	326 (81.7)	73 (18.3)	399
Missing	231 (70.2)	98 (29.8)	329	214 (87.3)	31 (12.7)	245
Ever breastfed						
Yes	455 (68.6)	208 (31.4)	663	418 (87.1)	62 (12.9)	480
No	351 (70.1)	150 (29.9)	501	328 (84.1)	62 (15.9)	390
Missing	189 (71.1)	77 (28.9)	266	197 (90.8)	20 (9.2)	217
Carer regular smoker or ≥1 person smokes inside house						
No	272 (69.6)	119 (30.4)	391	271 (88.0)	37 (12.0)	308
Yes	500 (69.3)	222 (30.7)	722	467 (85.5)	79 (14.5)	546
Missing	223 (70.3)	94 (29.7)	317	205 (88.0)	28 (12.0)	233
Carer education						
< Year 10	156 (64.5)	86 (35.5)	242	138 (84.7)	25 (15.3)	163
Year 10	199 (72.6)	75 (27.4)	274	181 (87.0)	27 (13.0)	208
Year 11 - 12	102 (70.3)	43 (29.7)	145	80 (80.0)	20 (20.0)	100
Trade/certificate/diploma	362 (71.5)	144 (28.5)	506	344 (87.8)	48 (12.2)	392
University	60 (69.0)	27 (31.0)	87	71 (89.9)	8 (10.1)	79
Missing	116 (65.9)	60 (34.1)	176	129 (89.0)	16 (11.0)	145
Fortnightly household income						
≤ $599	216 (67.5)	104 (32.5)	320	198 (87.6)	28 (12.4)	226

(continued)

TABLE 1. Continued

	Otitis Media at child level[a]			Hearing impairment[b] at child level		
	No Otitis Media	Any Otitis Media	Total	No	Yes	Total
	n =995	n =435	n =1430	n =943	n =144	n =1087
	n (%)	n (%)	n	n (%)	n (%)	n
$600 - $799	138 (67.0)	68 (33.0)	206	129 (85.4)	22 (14.6)	151
$800 - $1999	378 (71.2)	153 (28.8)	531	358 (86.3)	57 (13.7)	415
≥$2000	80 (69.6)	35 (30.4)	115	74 (88.1)	10 (11.9)	84
Missing	183 (70.9)	75 (29.1)	258	184 (87.2)	27 (12.8)	211
Employment status						
Employed/Studying (full or part-time)	288 (72.5)	109 (27.5)	397	291 (88.7)	37 (11.3)	328
Unemployed/Home duties/Retired	621 (68.7)	283 (31.3)	904	560 (85.9)	92 (14.1)	652
Missing	86 (66.7)	43 (33.3)	129	92 (86.0)	15 (14.0)	107
Housing tenure						
Own/Mortgage	160 (71.7)	63 (28.3)	223	160 (89.4)	19 (10.6)	179
Rent	167 (70.8)	69 (29.2)	236	152 (86.4)	24 (13.6)	176
Public housing	557 (68.8)	253 (31.2)	810	519 (85.6)	87 (14.4)	606
Missing	111 (68.9)	50 (31.1)	161	112 (88.9)	14 (11.1)	126
Average people per bedroom						
≤1	210 (77.5)	61 (22.5)	271	182 (89.7)	21 (10.3)	203
>1, <2	485 (69.8)	210 (30.2)	695	458 (87.1)	68 (12.9)	526
≥2	191 (63.2)	111 (36.8)	302	190 (84.4)	35 (15.6)	225
Missing	109 (67.3)	53 (32.7)	162	113 (85.0)	20 (15.0)	133
Housing problem[c]						
No	229 (70.7)	95 (29.3)	324	209 (86.0)	34 (14.0)	243
Yes	652 (69.2)	290 (30.8)	942	615 (86.6)	95 (13.4)	710
Missing	114 (69.5)	50 (30.5)	164	119 (88.8)	15 (11.2)	134
Govt financial support						
None	100 (71.9)	39 (28.1)	139	97 (91.5)	9 (8.5)	106
Family/parent/age only	740 (69.4)	327 (30.6)	1067	702 (86.5)	110 (13.5)	812
Disability/Sickness/ Unemployment	83 (72.8)	31 (27.2)	114	67 (84.8)	12 (15.2)	79
Missing	72 (65.5)	38 (34.5)	110	77 (85.6)	13 (14.4)	90
Carer allowance						
No	784 (69.4)	345 (30.6)	1129	741 (87.0)	111 (13.0)	852
Yes	139 (72.8)	52 (27.2)	191	125 (86.2)	20 (13.8)	145
Missing	72 (65.5)	38 (34.5)	110	77 (85.6)	13 (14.4)	90
Parent/carer psychological distress (K10 score ≥22)[d]						
No	811 (69.9)	349 (30.1)	1160	761 (86.9)	115 (13.1)	876
Yes	51 (65.4)	27 (34.6)	78	50 (89.3)	6 (10.7)	56
Missing	133 (69.3)	59 (30.7)	192	132 (85.2)	23 (14.8)	155

[a]Child level=results corresponding to either or both ears (using the hierarchy).
[b]Hearing impairment=bilateral hearing loss at least 20dB based on 3 frequency average.
[c]Housing problem = rising damp, damp on walls/ceilings/windows, major plumbing problems, cockroaches/mice/vermin, structural problems (cracks, sinking foundations, sagging floors, walls/windows not straight, wood rot/termite damage) or house too small.
[d]The Kessler 10 question psychological distress scale.

This study[6] reports an association with OM and having more than one person per room living in the home. Our finding that was associated with OM is consistent with this and other studies of OM among Aboriginal and Torres Strait Islander children in regional and remote areas.[3] OM was more common among children attending childcare in our study, similar to studies of other populations of children, likely from increased exposure to upper respiratory infections.[21] Although previous studies in remote settings have shown that socioeconomic factors are associated with OM among Aboriginal and Torres Strait Islander children, we did not find an association between ear health outcomes and income or education, only crowded housing and out of home care. However, we have previously shown that Aboriginal and Torres Strait Islander children had fewer ventilation tube insertions compared with same-age non-Aboriginal children in NSW, and socio-economic indicators were associated with this inequity.[35]

The timeframes for implementing authentic co-design and community-controlled research partnerships have meant that these data are a decade old but remain the most comprehensive and most contemporary ear health and hearing loss analysis in this population to date. These data are essential to inform policy, practice and public health approaches. Our diagnostic assessments were gold standard (tympanometry and pneumatic otoscopy) and conducted by experts (audiologists with confirmation by otolaryngologists with near perfect agreement).[8] We acknowledge OM and associated hearing loss fluctuates and assessments at one time point are not synonymous with lifetime burden of OM. Within the dataset, acute OM diagnoses were lower for otolaryngologists than audiologists (otolaryngologists ~1%; Audiologists ~7%). This did not impact the analysis, which was at the level of OM vs. 'No OM'. This difference in acute OM could be due to otolaryngologist reviews being asynchronous and without

Table 2: Otitis media and hearing loss diagnoses in participating children and for each ear.

Otitis media (N=1430)						
Diagnosis by ear	Right ear		Left ear		Diagnosis at child level	Child level	
	n	%	n	%		n	%
Chronic suppurative OM[b]	6	0.4	7	0.5	Chronic suppurative OM	11	0.8
Dry perforation	7	0.5	6	0.4	Dry perforation	9	0.6
Acute OM with perforation	2	0.1	6	0.4	Acute OM with perforation	6	0.4
Recurrent acute OM	3	0.2	4	0.3	Recurrent acute OM	4	0.3
Acute OM without perforation	92	6.4	86	6.0	Acute OM without perforation	110	7.7
Chronic OM with effusion	25	1.7	28	2.0	Chronic OM with effusion	30	2.1
OM with effusion	101	7.1	95	6.6	OM with effusion	119	8.3
OM (undifferentiated)	103	7.2	96	6.7	OM (undifferentiated)	137	9.6
No OM	1086	75.9	1097	76.7	No OM in either ear	995	69.6
Missing	5	0.3	5	0.3	Missing	9	0.6
Total	1430	100	1430	100	Total	1430	100
Hearing impairment (N=1087)							
Hearing loss by ear	Right ear		Left ear		Hearing impairment by child	Child level	
	n	%	n	%		n	%
Normal hearing	880	81.0	869	79.9	No impairment	806	74.1
Mild hearing impairment	190	17.5	199	18.3	Unilateral impairment	135	12.4
Moderate hearing impairment	17	1.6	17	1.6	Bilateral impairment	144	13.2
Missing	0	0	2	0.2	Missing	2	0.2
Total	1087	100	1087	100	Total	1087	100
Hearing impairment using World Health Organization Hearing (WHO) classification (N=1087)[a]							
Hearing loss by ear	Right ear		Left ear		Hearing loss by ear	Child level	
	n	%	n	%		n	%
Normal hearing	822	75.6	812	74.7	No impairment	730	67.2
Mild hearing loss	206	19.0	214	19.7	Unilateral impairment	172	15.8
Moderate hearing loss	48	4.4	50	4.6	Bilateral impairment	183	16.8
Moderately severe hearing loss	10	0.9	7	0.6	Missing	2	0.2
Severe hearing loss	1	0.1	2	0.2			
Missing	0	0.0	2	0.2			
Total	1087	100	1087	100	Total	1087	100

[a]The WHO hearing classification[19] was not used in the analysis for this paper, as the analysis was performed prior to its publication. For transparency, we have presented relevant hearing loss data here and note a lower percentage of 'normal hearing' and higher percentage of mild and moderate hearing impairment in this cohort when using the updated WHO guidelines. Hearing impairment as classified by WHO: mild (20 to <35dB); moderate (35 to <50dB); moderately severe (55 to <65dB); and severe (65 to <80dB).

[b]Otitis media.

patient histories. We excluded Eustachian tube dysfunction, although it can be associated with recent or impending OM and may have underestimated the burden of disease. Although SEARCH participants may not be representative of the urban Aboriginal and Torres Strait Islander child population, findings based on internal comparisons, such as PRs, do not require representative sampling.[36] Finally, we acknowledge that missing questionnaire data may have resulted in differential misclassification and affected the aPRs.

OM is treatable and preventable. Early intervention may reduce hearing loss and other downstream adverse health and social outcomes such as involvement in the juvenile justice system.[5] We have identified characteristics of urban Aboriginal and Torres Strait Islander children who may benefit from targeted prevention and early intervention services, including children who: are aged <6 years; have a history of ear disease; live in foster care; attend childcare; live in crowded homes. Younger children, especially those attending childcare, may benefit from routine ear health surveillance. Preschool has important developmental benefits[37] and may be an ideal setting for targeted ear health surveillance, as well as other settings where children and parents are connected with health professionals, such as mother's groups and Aboriginal Medical Services. We found that OM was more common among children in foster care compared with those living with family members, highlighting the importance of health checks and management plans for children in out-of-home care. OM was more common among children living in homes with more than two people per bedroom, emphasising the importance of culturally safe, integrated health and social care to address the social determinants of health, such as crowded housing.[3,38] Increased funding to Australia's Aboriginal Medical Services to ensure this level of culturally safe access to early childhood ear health, speech, language and social services could improve child health outcomes.

The majority of the children in our cohort younger than three years had some form of OM. Given this age period is critical for speech, language and auditory processing development, our findings highlight the potential for long-term health gain, as OM and hearing

Table 3: Unadjusted and adjusted associations between child, family and social factors to ear health and hearing outcomes.

	Otitis media diagnosis at child level				Hearing impairment in better ear			
	Unadjusted		Adjusted[a]		Unadjusted		Adjusted[a]	
	Prevalence ratio (PR) (95% CI)	P value	PR (95% CI)	P value	PR (95% CI)	P value	PR (95% CI)	P value
CHILD FACTORS								
Sex		0.641		0.543		0.593		0.409
Female (ref)	1		1		1		1	
Male	0.96 (0.81,1.13)		0.95 (0.82,1.11)		0.92 (0.68,1.25)		0.88 (0.65,1.19)	
Age group		<0.001		<0.001		<0.001		<0.001
≥6 months to <3 years	2.65 (2.20, 3.21)		2.64 (2.18, 3.19)					
≥3 to <6 years	1.90 (1.56, 2.31)		1.86 (1.53, 2.26)		1.93 (1.42, 2.61)		1.89 (1.40, 2.55)	
≥6 to 18 years (ref)	1		1		1		1	
In utero exposure to cigarettes		0.222		0.092		0.603		0.489
No (ref)	1		1		1		1	
Yes	1.12 (0.93,1.35)		1.16 (0.98,1.37)		1.10 (0.78,1.54)		1.13 (0.80,1.59)	
In utero exposure to marijuana		0.701		0.412		0.250		0.248
No (ref)	1		1		1		1	
Yes	1.05 (0.82,1.33)		1.10 (0.88,1.37)		0.74 (0.45,1.23)		0.74 (0.45,1.23)	
Ever ear infection (parent report)		<0.001		<0.001		<0.001		0.001
No (ref)	1		1		1		1	
Yes	1.72 (1.43,2.07)		1.68 (1.42,1.98)		2.04 (1.42,2.94)		1.87 (1.31,2.68)	
Ever breastfed		0.534		0.935		0.262		0.259
Yes (ref)	1		1		1		1	
No	0.94 (0.77,1.14)		0.99 (0.83,1.19)		1.22 (0.86,1.72)		1.22 (0.86,1.72)	
FAMILY FACTORS								
Relationship to child		0.072		0.022		0.948		0.694
Parent (ref)	1		1		1		1	
Other relative	0.98 (0.73,1.30)		1.09 (0.84,1.41)		0.96 (0.61,1.50)		0.88 (0.56,1.39)	
Foster carer	1.39 (1.05,1.85)		1.40 (1.10,1.79)		0.91 (0.48,1.72)		0.80 (0.43,1.48)	
Carer education		0.323		0.342		0.330		0.373
< Year 10 (ref)	1		1		1		1	
Year 10	0.78 (0.59,1.04)		0.80 (0.62,1.04)		0.87 (0.51,1.50)		0.91 (0.53,1.55)	
Year 11 - 12	0.80 (0.58,1.11)		0.81 (0.61,1.09)		1.32 (0.77,2.28)		1.29 (0.74,2.24)	
Trade/certificate/diploma	0.80 (0.64,1.01)		0.86 (0.71,1.05)		0.83 (0.52,1.32)		0.85 (0.53,1.37)	
University	0.87 (0.59,1.29)		0.96 (0.67,1.39)		0.69 (0.31,1.55)		0.67 (0.31,1.47)	
Govt financial support		0.600		0.575		0.340		0.510
None (ref)	1		1		1		1	
Family/Parent/Age only	1.11 (0.80,1.54)		1.01 (0.77,1.34)		1.57 (0.84,2.95)		1.41 (0.78,2.55)	
Disability/Sickness/ Unemployment	0.95 (0.60,1.53)		0.84 (0.55,1.29)		1.74 (0.72,4.20)		1.46 (0.60,3.54)	
Carer allowance		0.172		0.896		0.783		0.606
No (ref)	1		1		1		1	
Yes	0.83 (0.63,1.09)		0.99 (0.79,1.23)		1.06 (0.69,1.64)		1.12 (0.73,1.72)	

(continued)

TABLE 3. Continued

	Otitis media diagnosis at child level				Hearing im		better ear	
	Unadjusted		Adjusted[a]		Unadjusted		Adjusted[a]	
	Prevalence ratio (PR) (95% CI)	P value	PR (95% CI)	P value	PR (95% CI)	P value	PR (95% CI)	P value
Parent/carer psychological distress (K10 score ≥ 22)[b]		0.357		**0.211**		0.360		0.239
No (ref)	1		1		1		1	
Yes	1.11 (0.89,1.38)		1.14 (0.93,1.39)		1.21 (0.80,1.82)		1.27 (0.85,1.90)	
Fortnightly household income		0.752		0.751		0.831		0.664
≤ $599 (ref)	1		1		1		1	
$600 - $799	1.04 (0.78,1.39)		1.09 (0.84,1.40)		1.19 (0.71,1.98)		1.22 (0.74,2.01)	
$800 - $1999	0.91 (0.72,1.15)		0.97 (0.79,1.20)		1.12 (0.71,1.78)		1.10 (0.69,1.75)	
≥ $2000	0.96 (0.70,1.33)		0.92 (0.67,1.26)		0.92 (0.48,1.75)		0.86 (0.46,1.60)	
Employment status		0.251		0.930		0.265		0.430
Employed/Studying (full or part-time) (ref)	1		1		1		1	
Unemployed/Home duties/Retired	1.13 (0.92,1.39)		0.99 (0.82,1.20)		1.25 (0.84,1.85)		1.17 (0.80,1.71)	
Carer regular smoker or ≥1 person smokes inside house		0.921		0.691		0.357		0.250
No (ref)	1		1		1		1	
Yes	0.99 (0.80,1.22)		0.96 (0.80,1.16)		1.19 (0.82,1.73)		1.24 (0.86,1.80)	
SOCIAL FACTORS								
Assessment season		0.056		0.072		0.119		0.190
Winter/Spring (ref)	1		1		1		1	
Summer/Autumn	0.83 (0.69,1.00)		0.85 (0.71,1.01)		0.76 (0.53,1.07)		0.79 (0.56,1.12)	
No. houses lived in since birth		<0.001		0.078		0.165		0.359
1 (ref)	1		1		1		1	
2	0.84 (0.66,1.06)		0.89 (0.71,1.10)		0.82 (0.47,1.43)		0.82 (0.48,1.38)	
3	0.74 (0.57,0.96)		1.00 (0.77,1.28)		0.75 (0.44,1.28)		0.77 (0.46,1.29)	
≥4	0.46 (0.35,0.60)		0.72 (0.55,0.95)		0.57 (0.35,0.94)		0.65 (0.40,1.05)	
Attends childcare/preschool (<6 years)		0.195		0.019		0.175		0.421
No (ref)	1		1		1		1	
Yes	1.13 (0.94,1.37)		1.24 (1.04,1.49)		1.37 (0.87,2.17)		1.23 (0.74,2.06)	
Housing tenure		0.714		0.694		0.466		0.298
Own/Mortgage (ref)	1		1		1		1	
Rent	1.07 (0.77,1.47)		0.92 (0.69,1.22)		1.29 (0.71,2.33)		1.21 (0.67,2.16)	
Public housing	1.11 (0.85,1.46)		1.01 (0.80,1.28)		1.36 (0.84,2.21)		1.44 (0.89,2.32)	
People per bedroom		0.002		0.003		0.311		0.276
≤1 (ref)	1		1		1		1	
>1, <2	1.39 (1.05,1.85)		1.38 (1.06,1.80)		1.24 (0.78,1.96)		1.27 (0.82,1.97)	
≥2	1.71 (1.26,2.31)		1.66 (1.24,2.21)		1.50 (0.89,2.53)		1.49 (0.91,2.44)	
Housing problem		0.618		0.562		0.924		0.957
No (ref)	1		1		1		1	
Yes	1.06 (0.85,1.32)		1.06 (0.87,1.30)		0.98 (0.66,1.45)		0.99 (0.68,1.45)	

[a]Adjusted for age (continuous), sex & Aboriginal Medical Services as appropriate.
[b]The Kessler 10 question psychological distress scale.

impairment are treatable. We need culturally safe integrated models of health and social care addressing the social determinants of health and continuity of care for this priority population. Community-driven, holistic, targeted approaches for urban Aboriginal and Torres Strait Islander children with OM and hearing impairment should be facilitated through community engagement and the delivery of high quality, comprehensive, culturally safe community-based initiatives.

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Ethical approval

All research activities reported in this manuscript received explicit ethical approval from relevant Human Research Ethics Committees including the Aboriginal Health and Medical Research Council.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.anzjph.2023.100075.