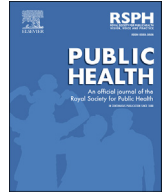




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Original Research

Trajectories of otitis media and association with health determinants among Indigenous children in Australia: the Longitudinal Study of Indigenous Children

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ABSTRACT

Objectives: Indigenous children in Australia experience high burden of persistent otitis media (OM) from very early age. The aim was to identify distinct trajectories of OM in children up to age 10–12 years and examine the association with socio-economic determinants.

Study design: A multistage clustered national panel survey.

Methods: The study analysed the birth cohort of the Longitudinal Study of Indigenous Children from 2008 to 2018, comprising 11 study waves. Group-based trajectory modelling was used to identify different trajectories of OM outcome. Multinomial logistic regression was applied to examine the relationship between trajectories and individual, household and community-level socio-economic determinants.

Results: This analysis included 894 children with at least three responses on OM over the 11 waves, and the baseline mean age was 15.8 months. Three different trajectories of OM were identified: non-severe OM prone, early/persistent severe OM and late-onset severe OM. Overall, 11.4% of the children had early/persistent severe OM from birth to 7.5 to nine years, while late-onset severe OM consisted of 9.8% of the children who had first OM from age 3.5 to five years. Children in communities with middle and the highest socio-economic outcomes have lower relative risk of early/persistent severe OM (adjusted relative risk ratio = 0.39, 95% confidence interval = 0.22–0.70 and adjusted relative risk ratio = 0.22, 95% confidence interval = 0.09–0.52, respectively) compared to children in communities with lowest socio-economic outcomes.

Conclusion: Efforts to close the gap in the quality of life of Indigenous children must prioritise strategies that prevent severe ear disease (runny ears and perforation), including improved healthcare access, reduced household crowding, and better education, and more employment opportunities.

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Introduction

Otitis media (OM) is the inflammation and the presence of fluid in the middle ear.¹ It is one of most common infections in children, particularly in the first year of life,² and can cause major morbidities in childhood if left untreated.^{1,3} OM is an array of diseases, including OM with effusion (OME), acute OM without perforation (AOMwoP), acute OM with perforation (AOMwiP), dry perforation

(DP), and chronic suppurative OM (CSOM).^{3,4} A 2014 review of literature shows that Aboriginal and Torres Strait Islander children (hereafter respectfully referred to as Indigenous children) have 7.1%–12.8%, 10.5%–30.3% and 31%–50% prevalence of AOM, active chronic OM, and tympanic membrane perforation (AOMwiP, DP, or CSOM), respectively.⁵ Failure to monitor and manage AOMwoP and OME can progress to CSOM, which can cause permanent damage to middle ear or be a risk factor for permanent sensorineural hearing loss.³

Hearing loss is a major public health problem and has a high disease burden, especially among Indigenous children with OM.^{6,7} All forms of OM cause hearing loss, with potential progression to major problems in speech, language development and education in

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children,^{6,8} and it is associated with poor school attendance, performance and child maltreatment.^{9,10}

OM pathogenesis starts with early and dense bacterial colonisation of the nasopharynx by one or more of the three dominant bacterial otopathogens (*Streptococcus pneumoniae*, *Haemophilus influenzae* and *Moraxella catarrhalis*).^{3,8} Perforation of the tympanic membrane with purulent discharge indicates bacterial infection and systemic and topical antibiotic treatment are highly recommended by clinical guidelines.¹¹ Infant vaccine trials show that current pneumococcal conjugate vaccine formulations protect from vaccine-serotype infection but do not protect from early-onset OM and nasopharyngeal carriage in this population due to emergence of non-vaccine pneumococcal serotypes and persistence of other otopathogens.^{12–14} Whilst many studies have focused on the clinical and pharmacological strategies for prevention¹³ and treatment/management of OM in high-risk populations,^{15,16} analyses have generally identified non-significance of known risk factors of OM. In the Northern Territory, neither maternal age, education, smoking, nor household crowding were significant predictors of suppurative OM (AOMwoP, AOMwiP or CSOM).^{7,17} In Western Australia, exposure to environmental tobacco smoke increased the risk of OM in Indigenous children.¹⁸ A randomised control trial of maternal smoking cessation strategy focussing on infant health found that the strategy did not reduce smoke exposure nor infant cough.¹⁹ A few studies have described the structural and environmental determinants of OM among Indigenous children;^{17,20} however, intervention studies to reduce or mitigate impact of determinants, such as poor access to health care or overcrowding have not been undertaken.²¹

Closing the Gap is a national strategy to overcome the inequities experienced by Indigenous peoples and achieve equal life outcomes to other Australians.^{22,23} The strategy has so far achieved some gains for maternal and child health, early childhood education, and year 12 educational attainment, but much remains to be done to achieve parity across 17 social and health and well-being indicators. One of the Closing the Gap targets that remains unmet is to see children thrive in their early years.²² The persistent high burden of OM in children significantly contributes to this disparity. Efforts to closing the gap in ear health of Indigenous children must address the identification of interventions that combine targeted pharmacological treatment with strategies to improve social and economic determinants alongside environmental health determinants. Individuals, families, and communities need to be supported to reduce the modifiable risk factors associated with OM. Prevention, early identification and effective treatment of middle ear disease by increasing capability, knowledge and skills in primary healthcare services to identify, treat and manage disease before it progresses to chronic severe OM is needed.²⁴ The World Health Organisation (WHO) is currently advocating for the creation and maintenance of healthy environmental determinants as a global priority for primary prevention of infectious diseases.^{26,27} More specifically, to address the global shortage of ear, nose and throat specialists and audiologists, the WHO highlights the importance of health workers and doctors and integrating ear and hearing care within primary care.

Understanding the distinct trajectories of OM among Indigenous children will be useful in identifying strategies to prevent and manage OM and related complications across the life course.²⁷ Using data from the Footprints in Time Longitudinal Study of Indigenous Children (LSIC), this study aims to identify individual, household and community-level social and economic determinants associated with specific hearing health trajectories in children in the first 10–12 years of life.

Methods

Study population and design

The Footprints in Time LSIC is a national panel study with a multistage clustered survey design coordinated by the Department of Social Services, Australia. The first stage of sampling in 2008 (wave 1) involved the selection of 11 sites (or clusters) across Australia with locations ranging from very remote communities to major capital cities in New South Wales, Victoria, Queensland, Western Australia, South Australia and the Northern Territory. The study design involved a two-stage approach, where sites were first selected and then the children within those sites. The sites were purposively selected to be representative of the Indigenous Australian community. Within these sites, a non-representative purposive sampling design was implemented, from which all eligible families were approached, and voluntary consent was obtained. In total, 1670 Indigenous children born between December 2003 and November 2004 (Kindergarten cohort) or between December 2006 and November 2007 (birth cohort) were sampled, including their families. In each area, between 64 and 239 study children and their families were surveyed.²⁸ Families in the study were recruited using residential addresses provided by Centrelink, Medicare Australia and other informal sources such as word of mouth, local knowledge and study promotion methods.²⁹ Eleven waves of LSIC data had been released at the time of this study. This work included survey data on hearing health and its potential determinants from wave 1 (2008 – at age six to 24 months) to wave 11 (2018 – at age 10.5–12 years) for the birth cohort. The average time between current and previous waves for the 11 waves of data collection ranged between 9.3 and 12.4 months. Retention rate from previous waves is at least 81.9%.²⁸ The kindergarten cohort was not eligible for this analysis because the children in the cohort were not followed from birth rather from the age of 3.5–4.5 years.

Ethics clearance

Ethics approval for the LSIC study was obtained from the Australian Government Department of Health Departmental Ethics Committee, which is the primary Human Research Ethics Committee (HREC) for the study. Also, from mid-2018, ethics approval was granted by the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) HREC. Exemption from Ethics Review was approved by the University of Queensland HREC (2022/HE000804).

Measures

OM and hearing health outcomes

Parents and carers reported the hearing health of study children for waves one to nine and 11 for the birth cohort. Parents and carers were asked if they had any health problems that made it difficult to look after the study child and if the children had any health problems. Problems with ears or hearing for the child and parents recorded were (1) runny ears, (2) perforated eardrum (hole in eardrum), (3) total deafness, (4) deaf in one ear, and (5) hearing loss/partial deaf.

This study only included children with reported runny ears and perforated eardrum as the OM outcome measure.

Covariates

Individual level. Individual-level explanatory variables for the study child included were age, gender, Indigenous status, gestational age at birth, birth weight category, body mass index based on z-scores, breastfeeding status, and general health measure.

Household level. Ear health condition of the primary caregiver, number of children and adults living in the same house at the time of survey, level of education and employment status of the primary caregiver, whether anyone smokes in the house, and net household income per fortnight.

Community level. Community-level explanatory variables considered were geographical remoteness assessed using the level of relative isolation (LORI) and area-level disadvantage measured by the index of relative Indigenous socio-economic outcome (IRISEO). LORI is an extension of the Accessibility/Remoteness Index of Australia (ARIA++) to capture the contribution of Indigenous language and other culturally specific geographical characteristics.³⁰ IRISEO is specifically calculated for Indigenous Australians and measures community-level socio-economic advantage based on nine variables from the 2006 Census – three related to employment, three related to education, two related to housing and one related to income.³¹

Statistical analysis

Descriptive statistics. Descriptive statistics were used to summarise baseline characteristics (individual, i.e., child and primary caregiver, household, and community-level factors) of the study population. Mean and standard deviation were used to summarise continuous normally distributed variables, and median and interquartile range were used to summarise non-normally distributed variables. Categorical variables were presented as counts and percentages.

Group-based trajectory modelling. Group-based trajectory modelling (GBTM) was applied to identify distinct subgroups within the population that follows a specific OM outcome trajectory across waves (2008–2018) of data collection.^{32,33} Children with at least three responses on OM outcome (runny ears or perforated eardrum) across waves were included in the modelling. Missing data were assessed, and iterative multiple imputation was conducted using chained equations.³⁴ The number of latent classes

following the GBTM was determined based on minimum Bayesian Information Criterion, Akaike Information Criterion, maximum entropy value and interpretability based on clinical relevance.³⁵

Multinomial logistic regression. Multinomial logistic regression was used to assess the relationship between the group membership of the specific OM outcome trajectories and determinants of OM. The operational definition of group membership was based on the trajectory probabilities. The trajectory with consistently low probability of reported runny ears or perforation was defined as the non-severe OM prone; trajectory with consistently high probability (≥ 0.5) of reported runny ears or perforation from 0.5–2 to 7.5–9 years: early/persistent severe OM; while late-onset severe OM group was based on trajectory that has low-high probability (Fig. 2). The non-severe OM prone group was the outcome's reference category. Univariable analysis was conducted to determine the association of individual-, household- and community-level determinants and the membership of specific hearing health outcome trajectories. The overall effect of individual determinants with *P*-value < 0.3 was used for the univariable filtering and for inclusion in the multivariable model to account for confounding effects of the determinants. Estimates of the univariable and multivariable models are reported as crude relative risk ratio (RRR) and adjusted RRR, respectively (with their 95% confidence interval [CI]). The Hausman–McFadden test of independence of irrelevant alternatives was used to assess the assumption that preference for a given choice of response level is unaffected by the presence of the ones not involved in the RRR estimation.³⁶ Multiple imputation with chained equation was also used to impute covariates with missing values. These included variables such as study child being breastfed (19.9% missing), study child ever breastfed (0.6%), primary caregiver currently employed (0.7%), anyone smokes in the house (0.2%), birth weight (21.1%), gestational age (7.2%), primary caregiver's general health (1.6%), primary caregiver had any ear problem (1.1%), net household income per fortnight (6.9%) and LORI (0.6%; [Supplementary Table S3](#)). Sensitivity analysis was carried out by

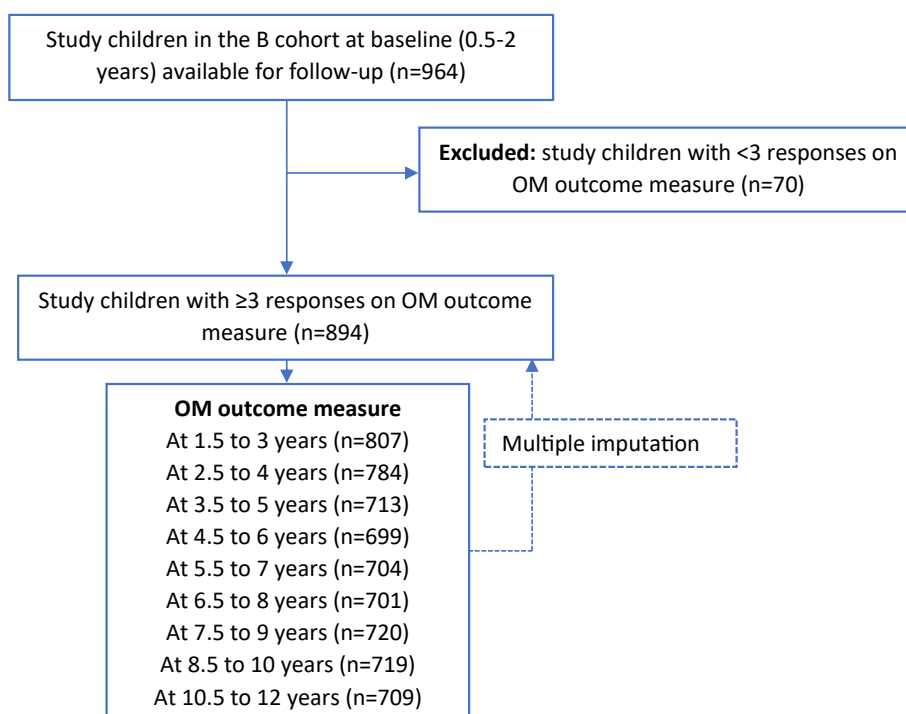


Fig. 1. Flowchart of the study population.

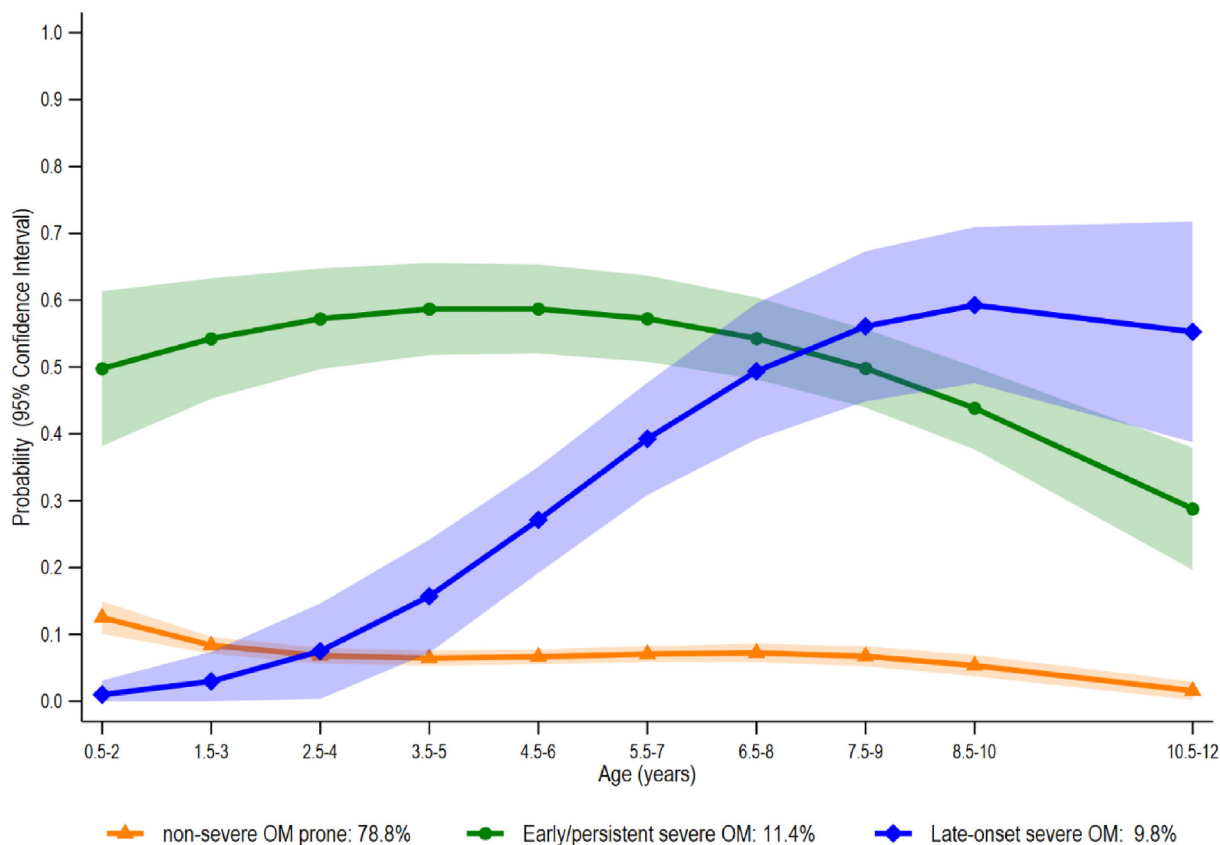


Fig. 2. Trajectory of otitis media in the first 10–12 years of life (0.5–2 to 10.5–12 years).

comparing estimates of imputed model, which is the primary analysis and complete case analysis. Statistical significance was set at $P < 0.05$. Statistical analysis was conducted using Stata 17 (StataCorp, TX, USA) statistical software.

Results

The study children, parents and caregivers participated in 11 waves of data collection with children's mean age of 133 months at the last follow-up (wave 11). Over 90% of interviews occurred at least six months apart, with the average time between current and previous survey waves of between 9.3 and 12.4 months. Fig. 1 shows the flowchart of the study population. Of the 964 children in birth cohort at baseline, 894 had three or more OM responses over the 11 survey waves and were included in the analysis.

Baseline characteristics

The baseline characteristics of the study population are presented in Table 1. The average age of children in the B cohort was 15.8 months. There was equal sex distribution, and the large majority were Aboriginal. Primary caregiver indicated 237 (33.1%) were still being breastfed, and 664 (80%) and 570 (80.9%) children were born at term and with normal birth weight, respectively. The proportions of children with overweight and obesity were 97 (18.6%) and 67 (12.9%), respectively. Of all children, 137 (15.4%) and 3 (0.3%) were reported to have runny ears and perforated eardrums, respectively. Of the 888 primary caregivers who reported employment status, 637 (71%) were employed at the time of the survey. The median number of people and children living in one household was four (Q1–Q3: 3–6) and 2 (Q1–Q3: 1–4), respectively. Regarding the highest

educational qualification completed by primary caregivers, 613 (76.7%) have completed at least year 12.

Trajectories of OM

The result of the GBTM showed three distinct trajectories of OM (Fig. 2). The probability of the children being in the non-severe OM prone group was 78.8% (Class 1), and 11.4% had reported early and persistent severe OM (Class 2). The late-onset severe OM (Class 3) constituted 9.8% of the study population, who were more prone to first ever experience of severe OM from the age of 3.5–5 years. A combination of BIC (–3313), entropy (0.84), class solutions >5% of the study population and interpretability favoured a three-class solution (Supplementary Table S1).

There were similar findings between the imputed primary analysis and the complete case sensitivity analyses (Fig. 2 and Fig. S1).

Characteristics of children, primary caregivers/household and community-level factors with the groups

The characteristics of children, primary caregivers, household, and area-level factors in relation to the classes are presented in Table 2. The number of adults in a household and index of relative Indigenous socio-economic status showed statistically significant association with the three distinct trajectory group.

Relationship between the OM trajectory and determinants

Univariable relationship. The univariable analysis of the association between each of the determinants of childhood OM and the OM trajectories is presented in Table 3.

Table 1
Baseline characteristics of child and primary caregiver.

Study characteristics	Total	
	N	n (%)
Study child		
Age (mo), mean (SD)	894	15.8 (5.3)
Gender	894	
Male		454 (50.8)
Female		440 (49.2)
Indigenous status	894	
Aboriginal		780 (87.2)
Torres Strait Islander		55 (6.2)
Both Aboriginal and Torres Strait Islander		59 (6.6)
Still being breastfed?	716	
Yes		237 (33.1)
No		479 (66.9)
Ever breastfed	889	
Yes		716 (80.5)
No		173 (19.5)
Gestational age at birth		
Preterm (<37 wk gestation)	830	99 (11.9)
Term (>37 < 42wk gestation)		664 (80.0)
Post-term (≥42 wk gestation)		67 (8.1)
Birth weight category		
Low <2500 g	705	63 (8.9)
Normal		570 (80.9)
High >4000 g		72 (10.2)
General health measure		
Fair-to-poor	891	25 (2.8)
Good		160 (18.0)
Very good-to-excellent		706 (79.2)
Body mass index	521	
Underweight		26 (5.0)
Normal weight		331 (63.5)
Overweight		97 (18.6)
Obese		67 (12.9)
Runny ears	887	
No		750 (84.6)
Yes		137 (15.4)
Perforated eardrum	887	
No		884 (99.7)
Yes		3 (0.3)
Primary caregiver/household		
Age (y), mean (SD)	894	28.3 (7.2)
Currently employed	888	
No		637 (71.7)
Yes		251 (28.3)
Number of children in household, median (Q1-Q3)	894	2.0 (1.0–4.0)
Number of adults in household, median (Q1-Q3)	894	2.0 (1.0–2.0)
Total number of people in household, median (Q1-Q3)	894	4.0 (3.0–6.0)
Number of children in household	894	
≤2		460 (51.5)
3–14		434 (48.5)
Number of adults in household	894	
≤2		683 (76.4)
3–19		211 (23.6)
Total number of people in household	894	
≤2		77 (8.6)
3–5		539 (60.3)
6+		278 (31.1)
Anyone smokes in the house	892	
No		687 (77.0)
Yes		205 (23.0)
Highest completed qualification	799	
Never attended school		5 (0.6)
At least Year 12		613 (76.7)
Certificates/diploma		128 (16.0)
At least bachelors		53 (6.6)
Net Income per fortnight	832	
<\$300–\$499		190 (22.8)
\$500–\$1199		334 (40.1)
\$1200–\$1999		208 (25.0)

(continued on next page)

Table 1 (continued)

Study characteristics	Total	
	N	n (%)
≥\$2000		100 (12.0)
Global health measure	880	
Fair-to-poor		90 (10.2)
Good		357 (40.6)
Very good-to-excellent		433 (49.2)
Runny ears	884	
No		855 (96.7)
Yes		29 (3.3)
Perforated eardrum	884	
No		879 (99.4)
Yes		5 (0.6)
Had any ear problem	884	
No		829 (93.8)
Yes		55 (6.2)
Community-level factors		
Level Of Relative Isolation	889	
None		248 (27.9)
Low		424 (47.7)
Moderate		125 (14.1)
High/extreme		92 (10.3)
Index of relative Indigenous socio-economic outcomes	894	
Lowest		182 (20.4)
Middle		528 (59.1)
Highest		184 (20.6)

Children with a primary caregiver currently employed compared with those not employed had a lower relative risk of being in the late severe OM class (RRR = 0.51; 95% CI = 0.27–0.94) relative to the non-severe OM prone group. Households with more than two adults compared to those with ≤2 adults had higher relative risk of having early/persistent severe OM relative to the non-severe OM prone group (RRR = 1.75; 95% CI = 1.10–2.78).

Socio-economic advantaged communities compared with disadvantaged communities were associated with lower relative risk of late-onset severe OM (RRR = 0.45; 95% CI = 0.21–0.97) and early/persistent severe OM (RRR = 0.34; 95% CI = 0.17–0.68) relative to the non-severe OM prone group.

Multivariable relationship. In the multivariable multinomial logistic regression analysis (Table 4), IRISEO retained strong inverse association with early/persistent severe OM after accounting for the effects of study child's breastfeeding history, primary caregiver's employment, number of adults in household, and LORI. The magnitude of the inverse relationship between child's breastfeeding history and early/persistent severe OM was borderline statistically significant after accounting for the effect of other factors in the model. Also, households with more than two adults compared with those with ≤2 adults retained higher relative risk of having early/persistent severe OM relative to the non-severe OM prone group (RRR = 1.76; 95% CI = 1.08–2.86) in the adjusted analysis. The strength of the inverse relationship between late-onset severe OM and children with more than two adults in household remained strong, and was borderline statistically significant for low vs no isolation.

Discussion

Main findings

This longitudinal study reports distinct trajectories of severe OM (runny ears and perforated eardrums) and factors associated with the different trajectories in the birth cohort of the LSIC data. Three distinct trajectories of severe OM were identified among Australian

Table 2
Characteristics of study child and primary caregiver OM trajectory subgroups.

Study characteristics	Class 1	Class 2	Class 3	P-value
	Non-severe OM prone	Early and persistent severe OM	Late-onset severe OM	
	n = 725	n = 93	n = 76	
	n (%)	n (%)	n (%)	
Study child				
Gender				
Male	371 (51.2)	49 (52.7)	34 (44.7)	0.52
Female	354 (48.8)	44 (47.3)	42 (55.3)	
SC still being breastfed^a				
Yes	185 (32.1)	32 (39.5)	20 (34.5)	0.40
No	392 (67.9)	49 (60.5)	38 (65.5)	
SC ever breastfed^a				
Yes	577 (79.8)	81 (88.0)	58 (78.4)	0.15
No	146 (20.2)	11 (12.0)	16 (21.6)	
Birth weight category^a				
Low <2500 g	52 (9.1)	4 (5.7)	7 (11.3)	0.82
Normal	464 (81.0)	58 (82.9)	48 (77.4)	
High >4000 g	57 (9.9)	8 (11.4)	7 (11.3)	
Gestational age at birth^a				
Preterm (<37wk gestation)	77 (11.4)	13 (15.1)	9 (13.2)	0.87
Term (>37 < 42wk gestation)	543 (80.3)	67 (77.9)	54 (79.4)	
Post-term (≥42 wk gestation)	56 (8.3)	6 (7.0)	5 (7.4)	
P1 currently employed^a				
No	511 (71.1)	63 (67.7)	63 (82.9)	0.06
Yes	208 (28.9)	30 (32.3)	13 (17.1)	
Anyone smokes in the house^a				
No	562 (77.6)	71 (77.2)	54 (71.1)	0.43
Yes	162 (22.4)	21 (22.8)	22 (28.9)	
Number of children in household				
≤2	379 (52.3)	42 (45.2)	39 (51.3)	0.43
3–14	346 (47.7)	51 (54.8)	37 (48.7)	
Number of adults in household				
≤2	558 (77.0)	61 (65.6)	64 (84.2)	0.01
3–19	167 (23.0)	32 (34.4)	12 (15.8)	
P1 general health^a				
Fair-poor	74 (10.4)	9 (9.7)	7 (9.5)	0.68
Good	281 (39.4)	41 (44.1)	35 (47.3)	
Very good-excellent	358 (50.2)	43 (46.2)	32 (43.2)	
P1 had any ear problem^a				
No	676 (94.3)	83 (90.2)	70 (93.3)	0.31
Yes	41 (5.7)	9 (9.8)	5 (6.7)	
Net income per fortnight^a				
<\$300–\$499	156 (23.0)	18 (20.9)	16 (23.2)	0.28
\$500–\$1199	264 (39.0)	34 (39.5)	36 (52.2)	
\$1200–\$1999	177 (26.1)	22 (25.6)	9 (13.0)	
≥\$2000	80 (11.8)	12 (14.0)	8 (11.6)	
Level Of Relative Isolation^a				
None	203 (28.2)	23 (24.7)	22 (29.3)	0.14
Low	353 (49.0)	44 (47.3)	27 (36.0)	
Moderate	94 (13.0)	18 (19.4)	13 (17.3)	
High/extreme	71 (9.8)	8 (8.6)	13 (17.3)	
2006 IRISEO				
Lowest	131 (18.1)	31 (33.3)	20 (26.3)	0.003
Middle	434 (59.9)	49 (52.7)	45 (59.2)	
Highest	160 (22.1)	13 (14.0)	11 (14.5)	

IRISEO, Index of Relative Indigenous Socioeconomic Outcomes; OM, otitis media; P1, primary caregiver; SC, study child.

^a Covariates that were imputed. Body mass index not included due to 42% values missing. See [Supplementary Table S3](#) for the frequency of missing observations. Percentages are from the imputed analysis. [Supplementary Table S5](#) has the complete case analysis.

Indigenous children from birth (0.5–2 years) to 10.5–12 years of age, namely, non-severe OM prone, early/persistent severe OM, and late-onset severe OM. Around 21% of study children had either early/persistent (11.4%) or late-onset severe OM (9.8%) over the 11-year study period. Children with middle and highest socio-economic outcomes compared to lowest socio-economic advantage; high/extreme LORI compared to none had lower risk of early/persistent severe OM; while children living with more than two adults compared to less adults had higher risk of early/persistent severe OM. Children with low vs no isolation, living with more than

two vs less adults, and having primary caregiver currently employed vs not employed had lower risk of late-onset severe OM.

Comparison of OM trajectories with other national and international studies

A prospective study of children in the Netherlands with acute OM identified three groups of acute OM-related trajectory (“non-otitis prone,” “early acute OM” and “persistent acute OM”) among children in their first 10 years of life.³⁷ They found that the early

Table 3
Univariable multinomial logistic regression of the association between determinant and the membership of the different OM trajectories.

Study characteristics	Early and persistent severe OM (2)		Late-onset severe OM (3)		Overall effect <i>P</i> -value ^a
	RRR (95% CI)	<i>P</i> -value	RRR (95% CI)	<i>P</i> -value	
Gender					0.53
Male	1.00		1.00		
Female	0.94 (0.61, 1.45)	0.78	1.29 (0.81, 2.08)	0.29	
Still being breastfed					0.57
No	1.00		1.00		
Yes	1.28 (0.80, 2.05)	0.31	1.08 (0.65, 1.81)	0.77	
Ever breastfed					0.19
No	1.00		1.00		
Yes	1.80 (0.94, 3.45)	0.08	0.92 (0.52, 1.65)	0.78	
Birth weight category					0.89
Low <2500 g	0.74 (0.27, 2.01)	0.55	1.32 (0.60, 2.92)	0.49	
Normal	1.00		1.00		
High >4000 g	1.17 (0.54, 2.51)	0.69	1.16 (0.49, 2.76)	0.73	
Gestational age at birth					0.90
Preterm (<37 wk gestation)	1.34 (0.71, 2.51)	0.37	1.12 (0.54, 2.36)	0.76	
Term (>37 and < 42wk gestation)	1.00		1.00		
Post-term (≥42 wk gestation)	0.87 (0.36, 2.12)	0.76	0.90 (0.36, 2.28)	0.83	
P1 currently employed					0.07
No	1.00		1.00		
Yes	1.17 (0.74, 1.86)	0.51	0.51 (0.27, 0.94)	0.03	
Anyone smokes in the house					0.44
No	1.00		1.00		
Yes	1.02 (0.61, 1.71)	0.95	1.41 (0.84, 2.39)	0.20	
Number of children in household					0.69
≤2	1.00		1.00		
3–14	1.33 (0.86, 2.05)	0.20	1.03 (0.65, 1.67)	0.87	
Number of adults in household					0.02
≤2	1.00		1.00		
3–19	1.75 (1.10, 2.78)	0.02	0.63 (0.33, 1.19)	0.15	
P1 had any ear problem					0.31
No	1.00		1.00		
Yes	1.80 (0.84, 3.84)	0.13	1.17 (0.45, 3.05)	0.75	
P1 global health measure					0.74
Fair-to-poor	1.00		1.00		
Good	1.20 (0.56, 2.58)	0.64	1.30 (0.56, 3.05)	0.54	
Very good-to-excellent	0.98 (0.46, 2.10)	0.96	0.97 (0.42, 2.28)	0.95	
Net income per fortnight					0.36
<\$300–\$499	1.00		1.00		
\$500–\$1199	1.12 (0.62, 2.03)	0.71	1.32 (0.72, 2.42)	0.36	
\$1200–\$1999	1.13 (0.59, 2.18)	0.71	0.53 (0.23, 1.23)	0.14	
≥\$2000	1.30 (0.60, 2.83)	0.51	0.95 (0.39, 2.35)	0.92	
Level of Relative Isolation					0.14
None	1.00		1.00		
Low	1.10 (0.65, 1.87)	0.73	0.70 (0.39, 1.27)	0.24	
Moderate	1.69 (0.87, 3.28)	0.12	1.31 (0.63, 2.72)	0.47	
High/extreme	1.00 (0.43, 2.33)	0.99	1.69 (0.81, 3.54)	0.16	
IRISEO					0.004
Lowest	1.00		1.00		
Middle	0.48 (0.29, 0.78)	0.003	0.68 (0.39, 1.19)	0.18	
Highest	0.34 (0.17, 0.68)	0.002	0.45 (0.21, 0.97)	0.04	

IRISEO, Index of Relative Indigenous Socioeconomic Outcomes; OM, otitis media; P1, primary caregiver.

The reference category is the non-severe OM prone class;

^a The overall effect was used for the univariable filtering of candidate variables for the multivariable model.

acute OM group consisted of 20.5% of children who had acute OM before their fourth year of life.³⁷ Our findings, although on children with reported runny ears/perforated eardrums (severe OM), show that 11.4% of the children had early severe OM since birth which persisted till their 7.5–9th birthday. This could be the case of recurrent acute infection that have persisted and or progressed to the more chronic OM disease conditions. Persistent OM and its hearing loss and developmental delay sequelae often require services of primary healthcare providers, audiologists and speech pathologists or surgeons. This generates long wait times and multiple consultations with associated cost, thereby leading to stress and frustration on the whole family.³⁸ Therefore, early and improved quality of ear health assessment and management of OM is needed to minimise the risk of long-term hearing loss, poor

developmental and educational outcomes, and socio-economic consequences.^{5,39}

A study that used the longitudinal study of Australian children (LSAC) data with more than 90% of non-Indigenous study children identified four groups of OM trajectory that include “consistently low,” “moderate to low,” “low to moderate,” and “consistently high.”⁴⁰ Children with increased risk of OM trajectory showed two different trajectories in the LSAC study consisting of consistently high probability of OM from birth and “low to moderate” group with increasing probability from three years onwards. The low-moderate group in the LSAC study is consistent with our late-onset severe OM trajectory group, where the probability of severe OM increased from age 3.5 to five years. The overall probability to follow “early/persistent severe OM” trajectory was higher among

Table 4
Multivariable multinomial logistic regression of the association between determinant and the membership of the different OM trajectories.

Study characteristics	Early and persistent severe OM (2)		Late-onset severe OM (3)	
	RRR (95% CI)	P-value	RRR (95% CI)	P-value
Ever breastfed				
No	1.00		1.00	
Yes	0.50 (0.26, 0.99)	0.05	1.14 (0.61, 2.13)	0.67
P1 currently employed				
No	1.00		1.00	
Yes	1.33 (0.82, 2.15)	0.25	0.49 (0.26, 0.91)	0.03
Number of adults in household				
≤2	1.00		1.00	
3–19	1.76 (1.08, 2.86)	0.02	0.49 (0.25, 0.95)	0.04
Level Of Relative Isolation				
None	1.00		1.00	
Low	0.83 (0.45, 1.53)	0.55	0.51 (0.26, 0.99)	0.05
Moderate	0.62 (0.27, 1.41)	0.26	1.05 (0.43, 2.57)	0.91
High/extreme	0.33 (0.12, 0.88)	0.03	1.51 (0.59, 3.84)	0.39
IRISEO				
Lowest	1.00		1.00	
Middle	0.39 (0.22, 0.70)	0.002	0.95 (0.48, 1.89)	0.89
Highest	0.22 (0.09, 0.52)	0.001	0.54 (0.20, 1.47)	0.23

IRISEO, Index of Relative Indigenous Socioeconomic Outcomes; OM, otitis media; P1, primary caregiver. The reference category is the non-severe OM prone class.

Indigenous children in our study compared to the overall Australian children in the LSAC population (11.4% vs 1.4%),⁴⁰ which highlights the continued disproportionate burden of OM among Indigenous children compared to the children from non-Indigenous background.

Individual-level determinants

Our study is the first to report factors associated with trajectories of severe OM among Indigenous children in Australia. Some host-related factors assessed in this study that are known to be associated with OM include age, sex and premature birth.⁴ However, our findings show no statistically significant association between sex and preterm birth with the OM trajectories, although the relative risk was higher in children born preterm compared to those born at term for late-onset severe OM and early/persistent severe OM relative to the non-severe OM group. The Australian National Health and Medical Research Council classifies the level of evidence for these host factors to be relevant to support recommendation for practice but emphasises that care should be taken in their application in practice,⁴ given inconsistencies in direction and magnitude of effect, and given the burden of OM among Indigenous people is more related to and amplified by structural and social factors that propagate the health inequities. A study that assessed risk factors for recurrent acute OM found that gender was not a strong predictor.⁴¹ Although our crude analysis shows that the risk of early/persistent severe OM risk was somewhat higher with smoking exposure, maternal history of ear problems, and high birth weight, these were not statistically significant. Similarly, Santos-Cortez et al.⁴² assessed the host and environmental determinants of OM among a group of Indigenous Filipino children and found that OM was not significantly associated with sex, body mass index, breastfeeding, and tobacco exposure, although 50% of the study population had OM.

Household-level determinants

The clustering pattern of OM infection and the observed difference in child ear health outcomes across the trajectory groups indicates that children belonging to the early/persistent and late-onset severe OM trajectory groups carry different household/community-level social determinants of disease than children

belonging to the non-severe OM prone trajectory group. Household-related factors, such as overcrowded family home and living with individuals with acute OM, have been implicated as important factors propagating the burden of OM among Indigenous populations in Australia and globally who continue to experience inequities in housing and resource allocation.^{17,43} Our findings show that households with more than two adults had higher relative risk of having early/persistent severe OM relative to the non-severe OM prone. Studies have found household crowding a strong predictor of upper respiratory tract carriage of OM-related bacteria in both Australian Indigenous and non-Indigenous children.¹⁷ This evidence highlights the importance of household transmission of OM bacteria, underscoring the need to reduce crowding in households. The Indigenous leadership, through the Aboriginal and Torres Strait Islander Justice Commissioner, for decades, have been advocating for improvements in the living conditions of Indigenous communities across Australia.^{44–46} The WHO through the global assessment of the burden of disease from environmental risk is now strongly advocating for the creation and maintenance of healthful environments as a priority for primary prevention of diseases.^{25,26}

Community-level determinants

Community-level socio-economic disadvantage has been emphasised as significant contributing factor to poor health outcomes.⁴⁷ Our findings show that children in communities with the highest socio-economic advantage category had the lowest risk of early/persistent and late-onset severe OM. The definition of socio-economic position used in our study is a composite index of income, housing, employment, and educational opportunities. The National Agreement on Closing the Gap⁴⁸ has outlined 17 targets, including a range of health outcome measures (education, housing, employment, etc) and related determinants to address the entrenched inequity faced by Indigenous Australians so that life outcomes are equal to all Australians. It is known that an individual's education can influence health outcomes, where higher levels of education can directly influence greater understanding and application of health information, better prospects for employment and income, which can translate to access to quality housing, healthy food, and healthcare services.⁴⁹

A recent systematic review²¹ of OM intervention studies found few studies focussing on social risk factors as a pathway to reduce OM among Indigenous children. Interventions targeting the reduction in social risk factors of OM among Indigenous children were outnumbered by biomedical approaches to prevent and treat OM. These studies found that crowding, smoke exposure and maternal education were not significant predictors of OM.^{7,17} Whilst very important, they do not provide a holistic improvement in the quality of life in general.²¹ Therefore, integrated approaches involving systems interventions targeting the social and structural determinants of OM, such as quality housing and access to quality primary health care are needed for effective reduction of OM burden among Indigenous children.

Strength and limitations

A strength of our study is the use of a decade-long longitudinal data of Indigenous children and families to unpack the different trajectories of OM that exist in the complex process of OM disease development among Indigenous children in their first 10.5–12 years of life. Each group trajectory comprises more than 5% of the population, and the average posterior probability for each group membership was above 0.80, which is 10% higher than the recommended threshold for good model.³² This implies that the model presented had very good group assignment probability as evidenced by the entropy value.

Nonetheless, a limitation is the lack of representativeness of the data because it covers fractions of population of Indigenous children from five states and the Northern Territory. This informed our avoidance of overinterpreting any estimate of prevalence because such is unlikely to be extrapolated to represent all Indigenous children in Australia, which is a common feature of cohort studies. Also, height and weight were the only physical measures taken in LSIC study (a response to community consultations and consideration of participant's comfort and willingness to participate); therefore, the potential of recall bias, which can lead to underreporting, cannot be exempted from other self-reported measures, such as primary caregivers' report of OM. Considering that no clinical diagnosis of OM was made, the loosely defined parent/carer reported runny ears or perforated eardrum may not be definite. Our study could not draw any relationship between genetics and the burden of OM in this population due to lack of genetic data in the LSIC survey. However, existing study did not show family history to be a strong predictor of OM.^{13,50}

In conclusion, this study documents three distinct trajectories of OM among Indigenous children in their first 10–12 years of life. The finding that children living in a household with more than two adults and those from communities with socio-economic disadvantage had greater relative risk of early/persistent severe OM highlight the importance of addressing socio-economic disadvantage in communities. It points to the need for interventions tackling social determinants of health to prevent OM and its impact on quality of life, hearing and learning outcomes of children. Such strategies should aim to improving the underlying living standards, healthcare access and health literacy for early, and improved ear health assessment and management of OM. This will be pivotal in minimising the tendency for long-term consequences for children with existing OM, such as hearing loss, poor developmental and educational outcomes and socio-economic consequences.

Author statements

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Nothing to declare.

Author contributions

V.M.O. conceptualised the study, obtained ethical approval, and implemented the data analysis. V.M.O. and F.B. contributed to the methodology. V.M.O., S.M. and T.B. wrote the original draft. V.M.O., S.M., T.B., E.D., J.W., A.J.L. and F.B. revised and edited the draft. All authors contributed to revisions of the manuscript and approved the final version.

Data sharing

The LSIC data are available from the Australian Government Department of Social Services at <https://dataverse.ada.edu.au/dataverse/lxic>.

Competing interests

The authors have no competing interests to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.puhe.2023.09.010>.

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