

Housing conditions associated with recurrent gastrointestinal infection in urban Aboriginal children in NSW, Australia: findings from SEARCH

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Gastrointestinal infection is a leading global cause of child mortality and a major public health issue in Australia.^{1,2} While episodes of gastrointestinal infection are usually mild and self-limiting in wealthy nations, some cases result in serious dehydration, hospitalisation and death.³ Gastrointestinal infection can affect child growth and development, school attendance and household productivity,¹ and is associated with serious health sequelae including a range of cardiovascular, rheumatologic, gastrointestinal, neurological, skin and lung conditions.^{3,4}

Gastrointestinal infection is the second most common cause of avoidable hospital admission for Aboriginal children in New South Wales.⁵ Aboriginal children are much more likely than their non-Aboriginal peers to be admitted to hospital with gastrointestinal infection⁵⁻⁷ and, once there, to stay significantly longer and be readmitted for it more quickly.^{6,7} Australian studies indicate that children with recurrent gastroenteritis were more likely to also experience recurrent chest, skin and ear infections.⁸ Moreover, serious health sequelae are significantly more likely after recurrent gastrointestinal infection rather than a single episode, and Aboriginal children are more likely to experience serious health sequelae after recurrent gastrointestinal infection than non-Aboriginal children.^{3,4}

Housing is a well-recognised social determinant of health that is closely linked

Abstract

Objective: To examine the associations between housing and gastrointestinal infection in Aboriginal children in urban New South Wales.

Methods: A total of 1,398 Aboriginal children were recruited through four Aboriginal Community Controlled Health Services. Multilevel regression modelling of survey data estimated associations between housing conditions and recurrent gastrointestinal infection, adjusting for sociodemographic and health factors.

Results: Of the sample, 157 children (11%) had recurrent gastrointestinal infection ever and 37 (2.7%) required treatment for recurrent gastrointestinal infection in the past month. Children in homes with 3+ housing problems were 2.51 (95% CrI 1.10, 2.49) times as likely to have recurrent gastrointestinal infection ever and 6.79 (95% CrI 2.11, 30.17) times as likely to have received recent treatment for it (versus 0–2 problems). For every additional housing problem, the prevalence of recurrent gastrointestinal infection ever increased by a factor of 1.28 (95% CrI 1.14, 1.47) and the prevalence of receiving treatment for gastrointestinal infection in the past month increased by a factor of 1.64 (95% CrI 1.20, 2.48).

Conclusions: Housing problems were independently associated with recurrent gastrointestinal infection in a dose-dependent manner.

Implications for public health: The role of housing as a potential determinant of health in urban Aboriginal children merits further attention in research and policy settings.

Key words: housing, Aboriginal, gastrointestinal infection, urban, child

with social, economic, and geographic factors.⁹⁻¹² Poor housing environments can affect health, beyond other forms of deprivation, through myriad direct and indirect pathways.^{12,13} The absence of functional facilities can impair engagement in healthy living practices, such as washing people and clothes or the hygienic storage and preparation of food.^{13,14} Crowding can affect health by increasing household stress and restricting access to facilities, and through close contact transmission

of infectious disease.¹⁵⁻¹⁷ Multiple forms of housing disadvantage can also co-exist and have a cumulative, detrimental effect on health over time.¹⁸⁻²⁰ Studies conducted outside of Australia have found significant associations between gastroenteritis and housing factors such as crowding and the adequacy of housing facilities in non-indigenous populations^{21,22} and in several remote indigenous communities in Canada.²³⁻²⁶ In Australia, significant associations have been identified between

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poor housing conditions and gastrointestinal infection for Aboriginal children living in remote communities^{16,26} and in one Aboriginal child health cohort study with a relatively small proportion of urban children.²⁷ The majority of Australian Aboriginal children live in urban areas⁹ and, while housing disadvantage is common for urban Aboriginal families,^{9,12,13,28} little is known about possible links between housing conditions and gastrointestinal infection for urban Aboriginal children.^{27,29}

This study examines the relationship between housing conditions and carer report of recurrent gastrointestinal infection among children participating in Phase One of the Study of Environment on Aboriginal Resilience and Child Health (SEARCH), the largest cohort study of urban Aboriginal child health in Australia to date.

Methods

SEARCH is a partnership between researchers, Aboriginal Community Controlled Health Services (ACCHSs) in urban NSW, and the Aboriginal Health and Medical Research Council of NSW.³⁰ SEARCH aims to investigate the causes of health and illness in urban Aboriginal children attending a participating ACCHS: Mount Druitt (Aboriginal Medical Service Western Sydney); Campbelltown (Tharawal Aboriginal Corporation); Wagga Wagga (Riverina Medical and Dental Aboriginal Corporation), and Newcastle (Awabakal Ltd.).³⁰ The study priorities were established in conjunction with participating Aboriginal community leaders^{30,31} and two of the authors of this paper are Aboriginal.

Carers of eligible Aboriginal children were invited to participate in SEARCH by an Aboriginal research assistant when attending a participating ACCHS. Carers were provided with a participant information sheet and its contents were discussed. Aboriginal children aged 0–17 years were eligible to participate if their parent or caregiver (hereafter carer) was aged 16 years or over and was willing to provide contact information for follow-up interviews. No response rate data was kept. Survey data was collected between 2007 and 2011. Phase Two data collection is underway but is not reported in this study.

Ethics

The study was approved by the ethics committees of the Aboriginal Health and Medical Research Council of New South

Wales (reference 586/06) and the University of Sydney (reference 12-2003/9429). Written consent was provided by all participants.

Measures

SEARCH carers completed a survey about themselves covering a range of demographic, social, lifestyle and environmental factors, along with a comprehensive survey about each child's health and wellbeing.³⁰ In relation to gastrointestinal infection, recurrent infection was examined rather than acute episodes to capture chronic illness associated with higher risk of long-term sequelae.^{3,4,8} Carers were asked if their child had: a) 'ever had a recurring gastro infection' (yes/no) to measure lifetime prevalence; and b) 'a recurring gastro infection treated in the past month' (yes/no) to measure recent occurrence. Evidence from Australia and overseas indicates that relatively few people seek healthcare for gastrointestinal illness; those who do are more likely to have illness of greater severity and duration, thus the measure used is likely to capture relatively serious gastrointestinal infection.^{2,26}

Housing questions were drawn from established sources including the Western Australian Aboriginal Child Health Study, National Aboriginal and Torres Strait Islander Social Survey and Australian Housing Survey or were developed specifically for SEARCH in consultation with Aboriginal community leaders.³¹ For a full description of the SEARCH housing variables, see Andersen et al.³¹ The housing variables related to physical dwelling conditions and crowding were the focus of the current study. Physical dwelling problems were measured by carer's 'yes/no' report of the presence of: major plumbing, electrical or structural problems; damp or mildew; or vermin, and if they are able to make their home warm enough in winter. Crowding is a complex construct to quantify, particularly in cross-cultural contexts;⁹ the measures we used included the number of people who normally sleep in the home (0–5/6 or more), the ratio of people per bedroom (0–2/>2)²⁷ and carer's yes/no response to whether they "felt too crowded where they lived" in the past 12 months. A tally of the total number of physical dwelling and crowding problem domains ("housing problems") was also created and used as both a continuous and binary outcome variable (0–2/3 or more). The control variables used are detailed below.

Statistical methods

Multilevel log-binomial regression was used to estimate recurrent infection prevalence ratios for each housing exposure, adjusting for age, sex, recruiting ACCHS, family (modelled via a random effect), and a range of other socio-demographic and health factors. Regression models were fitted for each exposure separately, first adjusting for age, sex, recruiting ACCHS and family, and then adjusting for all covariates. Additional covariates included in the fully adjusted models for 'ever had recurrent gastrointestinal infection' were household income, carer psychological distress (Kessler 10 score), prenatal maternal smoking, breastfeeding at six months (or current breastfeeding for children aged under six months), ever attended childcare or preschool, daily fruit and vegetable intake and current household smoking. For 'recurrent gastrointestinal infection treated in the past month', we restricted this set of additional covariates to income, breastfeeding at six months and childcare or preschool attendance, due to the small number of cases. These factors were chosen as previous analyses indicate they are strongly associated with gastroenteritis; very similar results were obtained using alternative sets of covariates, e.g. household income, carer psychological distress, fruit and vegetable consumption and household smoking. Children were excluded from regression analyses where they had missing values for one or more explanatory variables. Multiple imputation analyses indicated that this approach to dealing with missing data does not affect our findings (see Supplementary Files 1–3).

All models were fitted using the MCMC procedure in SAS ver. 9.3 (SAS Institute, Cary, NC, USA), specifying diffuse normal priors for all regression coefficients, and a non-informative uniform prior for the standard deviation of the family-level errors. The regression models and analytical methods used are described in greater detail in Supplementary File 1.

Results

Phase One survey data were available for 1,467 children from 620 families, of which 1,398 children from 602 families had non-missing data for recurrent gastrointestinal infection ever and 1,367 children from 595 families had non-missing data for recurrent gastrointestinal infection treated in the past

month. One hundred and fifty-seven (11%) SEARCH children had ever had recurrent gastrointestinal infection and 37 (2.7%) had been treated for recurrent gastrointestinal infection in the past month (Table 1).

Individual housing factors associated with recurrent gastrointestinal infection

In models adjusted for all sociodemographic and health factors, recurrent gastrointestinal infection ever was associated with major structural problems (aPR 2.42, 95%CrI 1.56, 3.86), major plumbing problems (aPR 1.95, 95%CrI 1.10, 3.50), damp or mildew (aPR 1.82, 95%CrI 1.13, 2.94) and carer report of feeling crowded (aPR 1.63, 95%CrI 1.03, 2.67), see Table 2. Having six or more people who normally slept in the home was associated with reduced likelihood of child recurrent gastrointestinal infection ever (aPR 0.56, 95%CrI 0.31, 0.98), compared to 0–5 people. Living in a home with major structural problems (aPR 3.72, 95%CrI 1.34, 13.27), vermin problems (aPR 5.06, 95%CrI 1.68, 23.76) or that could not be kept warm enough in winter (aPR 3.88, 95%CrI 1.10, 19.99) was associated with recurrent gastrointestinal infection treated in the past month (Table 2).

Cumulative housing disrepair and trend analysis

Children in homes with three or more housing problems were more than twice as likely to have ever had recurrent gastrointestinal infection as those in homes with 0–2 housing problems (aPR 2.51, 95%CrI 1.57, 4.21). They were also more than six times as likely to have had treatment for recurrent gastrointestinal infection in the past month as those in homes with 0–2 problems (aPR 6.79, 95%CrI 2.11, 30.17). When analysed as a continuous variable, the number of housing problems was significantly associated with the prevalence of recurrent gastrointestinal infection ever and treated in the past month, after adjustment for demographic and child health factors (posterior probabilities of an increasing trend >0.99), see Figure 1. For every additional housing problem, the prevalence of recurrent gastrointestinal infection ever increased by a factor of 1.28 (95%CrI 1.14, 1.47) and the prevalence of recurrent gastrointestinal infection treated in the past month increased by a factor of 1.64 (95%CrI 1.20, 2.48), see Figure 1.

Table 1: Socio-demographic and health-related patterns of recurrent gastrointestinal infection among urban Aboriginal children in the SEARCH cohort.

	Ever had a recurrent gastrointestinal infection			Recurrent gastrointestinal infection treated in the past month		
	Total ^a	% ever had (n)	PR ^c (95% int.) ^b	Total ^a	% treated (n)	PR ^c (95% int.) ^b
Total	1,398	11.23 (157)		1,367	2.71 (37)	
Age at survey (years)						
Less than 1	69	7.25 (5)	1	68	4.41 (3)	1
1–4	515	16.50 (85)	2.54 (1.24–7.34)	501	4.39 (22)	1.41 (0.56–5.37)
5–11	629	8.59 (54)	1.50 (0.71–4.30)	616	1.62 (10)	0.58 (0.18–2.40)
12–17	185	7.03 (13)	1.27 (0.49–3.91)	182	1.10 (2)	0.33 (0.04–1.97)
Sex						
Female	672	8.63 (58)	1	663	1.51 (10)	1
Male	726	13.64 (99)	1.39 (1.04–1.90)	704	3.84 (27)	2.18 (1.06–4.83)
Household income per fortnight						
\$0–\$799	533	11.26 (60)	1	520	2.12 (11)	1
\$800–\$1999	570	12.11 (69)	1.06 (0.70–1.63)	561	3.74 (21)	1.65 (0.70–4.14)
\$2000 or more	119	8.40 (10)	0.76 (0.35–1.54)	118	4.24 (5)	2.22 (0.53–8.00)
Carer Kessler 10 score						
Less than 22	1,015	11.03 (112)	1	990	2.63 (26)	1
22 or more	256	12.11 (31)	0.99 (0.59–1.60)	255	3.92 (10)	1.37 (0.51–3.46)
Prenatal maternal smoking						
No	628	12.58 (79)	1	617	3.40 (21)	1
Yes	706	10.20 (72)	0.87 (0.62–1.17)	688	1.89 (13)	0.64 (0.28–1.27)
Breastfed for six months or more						
No	918	11.55 (106)	1	898	2.45 (22)	1
Yes	300	11.00 (33)	0.97 (0.67–1.35)	291	2.41 (7)	1.06 (0.45–2.43)
Serves of vegetables per day						
0–1	192	9.38 (18)	1	186	1.61 (3)	1
2 or more	1,169	11.72 (137)	1.35 (0.86–2.27)	1,144	2.97 (34)	1.95 (0.67–8.93)
Serves of fruit per day						
0–1	127	10.24 (13)	1	126	3.97 (5)	1
2 or more	1,226	11.50 (141)	1.27 (0.77–2.34)	1,197	2.67 (32)	0.76 (0.31–2.32)
Ever attended childcare or preschool						
No	360	10.56 (38)	1	352	2.56 (9)	1
Yes	1,014	11.64 (118)	1.10 (0.84–1.57)	991	2.72 (27)	1.17 (0.60–2.67)
Any household smoking						
No	685	10.95 (75)	1	673	3.27 (22)	1
Yes	548	10.58 (58)	1.01 (0.66–1.54)	537	2.61 (14)	0.86 (0.37–2.00)
Tenure type						
Mortgage or own	223	7.62 (17)	1	219	1.83 (4)	1
Renting	256	12.11 (31)	1.64 (0.85–3.26)	252	1.59 (4)	0.98 (0.18–5.69)
Social housing	837	11.95 (100)	1.69 (0.97–3.07)	819	3.54 (29)	2.41 (0.70–10.83)
Housing affordability problem						
No	863	10.31 (89)	1	849	2.24 (19)	1
Yes	444	13.51 (60)	1.31 (0.87–1.94)	431	4.18 (18)	1.91 (0.85–4.31)
Evicted in past 12 months						
No	1,144	10.93 (125)	1	1,120	2.86 (32)	1
Yes	174	14.94 (26)	1.34 (0.79–2.24)	170	2.94 (5)	0.81 (0.20–2.58)
Duration of tenure						
Less than 12 months	292	13.70 (40)	1	286	2.45 (7)	1
12 months or more	1,038	10.50 (109)	0.81 (0.53–1.28)	1,018	2.95 (30)	1.47 (0.55–4.72)
Number of houses lived in						
0–3	928	10.88 (101)	1	907	2.65 (24)	1
4 or more	362	13.26 (48)	1.14 (0.85–1.57)	354	2.54 (9)	0.99 (0.45–2.03)

Notes:

a: Number of children with non-missing data on recurrent gastrointestinal infections.

b: Unadjusted prevalence ratios and 95% credible intervals derived from multilevel log-binomial regression models fitted for each explanatory factor separately.

c: Prevalence Ratio

Discussion

This is the first study to our knowledge to examine associations between housing and gastrointestinal infection in an exclusively urban cohort of Aboriginal children. Our results show that the more housing problems a child is exposed to, the greater their risk of recurrent gastrointestinal infection. These relationships existed over and above socioeconomic and other risk factors.

Recurrent gastrointestinal infection was reported for a relatively substantial proportion of children in this urban cohort, although differing case definitions and recruitment strategies between different studies make prevalence comparisons difficult.² The only other study to our

knowledge to have gathered data about the community prevalence of recurrent gastrointestinal infection was the Western Australian Aboriginal Child Health Survey, where 5.6% of children were reported by their carer to have recurrent gastrointestinal infection.⁸ The prevalence of housing problems reported by SEARCH carers was notably higher than those reported in studies of non-Aboriginal Australian households, as discussed in detail elsewhere.^{31,32}

Each of the specific housing problems significantly associated with recurrent gastrointestinal infection in this study have been previously associated with human health issues.³³ Factors such as vermin and major plumbing problems have relatively obvious plausible biological pathways to

gastrointestinal infection.¹⁴ However, it is less intuitively clear how other problems like mildew, temperature control or major structural problems may increase the risk of recurrent gastrointestinal infection. There is little existing evidence about these specific associations, although inadequate temperature control was associated with skin infection in remote communities.¹⁶ There is evidence, however, that homes with damp and mildew are more likely to be older, in poor condition and uninsulated, suggesting this may be a proxy for an old or poorly maintained home.³³

However, the major finding of this study is the trend association between the *number* of housing problems and risk of recurrent gastrointestinal infection. It seems that

Table 2: Associations between recurrent gastrointestinal infection and housing problems (housing exposures examined separately).

Housing exposure	Ever had a recurrent gastrointestinal infection				Recurrent gastrointestinal infection treated in the past month			
	Total ^a	% ever had (n)	PR ^c (95% int.) adjusted for age, sex, ACCHS	PR ^c (95% int.) adjusted for all covariates ^b	Total ^a	% treated (n)	PR ^c (95% int.) adjusted for age, sex, ACCHS	PR ^c (95% int.) adjusted for all covariates ^d
Major plumbing problems								
No	1,114	10.50 (117)	1	1	1,093	2.65 (29)	1	1
Yes	194	17.01 (33)	1.70 (1.09–2.65)*	1.95 (1.10–3.50)*	187	3.74 (7)	1.82 (0.61–4.72)	2.58 (0.69–11.59)
Major structural problems								
No	791	9.48 (75)	1	1	780	1.92 (15)	1	1
Yes	528	14.58 (77)	1.60 (1.11–2.26)*	2.42 (1.56–3.86)*	510	4.31 (22)	2.58 (1.26–5.76)*	3.72 (1.34–13.27)*
Major electrical problems								
No	1,118	11.63 (130)	1	1	1,095	2.92 (32)	1	1
Yes	177	10.17 (18)	1.00 (0.56–1.75)	1.67 (0.89–3.17)	175	2.86 (5)	1.40 (0.40–4.10)	2.29 (0.56–10.59)
Mould or damp								
No	846	9.93 (84)	1	1	830	2.29 (19)	1	1
Yes	479	13.57 (65)	1.48 (1.02–2.17)*	1.82 (1.13–2.94)*	467	3.85 (18)	2.06 (0.97–4.79)	2.26 (0.79–7.31)
Vermin								
No	755	12.05 (91)	1	1	736	1.77 (13)	1	1
Yes	574	10.63 (61)	0.97 (0.68–1.41)	1.29 (0.80–2.08)	565	4.25 (24)	2.71 (1.27–6.55)*	5.06 (1.68–23.76)*
Unable to keep home warm in winter								
No	1,079	10.94 (118)	1	1	1,054	2.28 (24)	1	1
Yes	235	12.77 (30)	1.19 (0.73–1.88)	1.73 (0.96–3.08)	232	5.17 (12)	2.36 (0.98–6.08)	3.88 (1.10–19.99)*
Number of people sleeping in home								
0–5	805	13.54 (109)	1	1	784	3.19 (25)	1	1
6 or more	515	7.57 (39)	0.64 (0.42–0.97)*	0.56 (0.31–0.98)*	510	2.16 (11)	0.66 (0.27–1.46)	0.53 (0.11–1.85)
Felt crowded in past 12 months								
No	910	9.89 (90)	1	1	891	2.36 (21)	1	1
Yes	413	15.01 (62)	1.56 (1.07–2.28)*	1.63 (1.03–2.67)*	404	3.96 (16)	1.53 (0.67–3.40)	1.03 (0.28–3.12)
People per bedroom								
0–2	1,144	10.75 (123)	1	1	1,121	2.68 (30)	1	1
3 or more	175	13.71 (24)	1.65 (0.94–2.79)	1.27 (0.60–2.63)	172	3.49 (6)	1.32 (0.38–4.00)	0.93 (0.13–5.10)
Number of housing problems								
0–2	748	9.49 (71)	1	1	736	1.63 (12)	1	1
3 or more	423	14.18 (60)	1.64 (1.10–2.49)*	2.51 (1.57–4.21)*	416	5.29 (22)	3.61 (1.62–8.37)*	6.79 (2.11–30.17)*

Notes:

a: Number of children with non-missing data on recurrent gastrointestinal infection. Numbers may not add up to total due to missing data.

b: Adjusted for age, sex, recruiting ACCHS, household income, carer Kessler 10 score, prenatal maternal smoking, breastfed for 6 months or more, serves of vegetables per day, serves of fruit per day, ever attended childcare or preschool, any household smoking.

c: Prevalence Ratio

d: Adjusted for age, sex, recruiting ACCHS, household income, breastfed for 6 months or more, ever attended childcare or preschool.

* 95% credible interval excludes 1

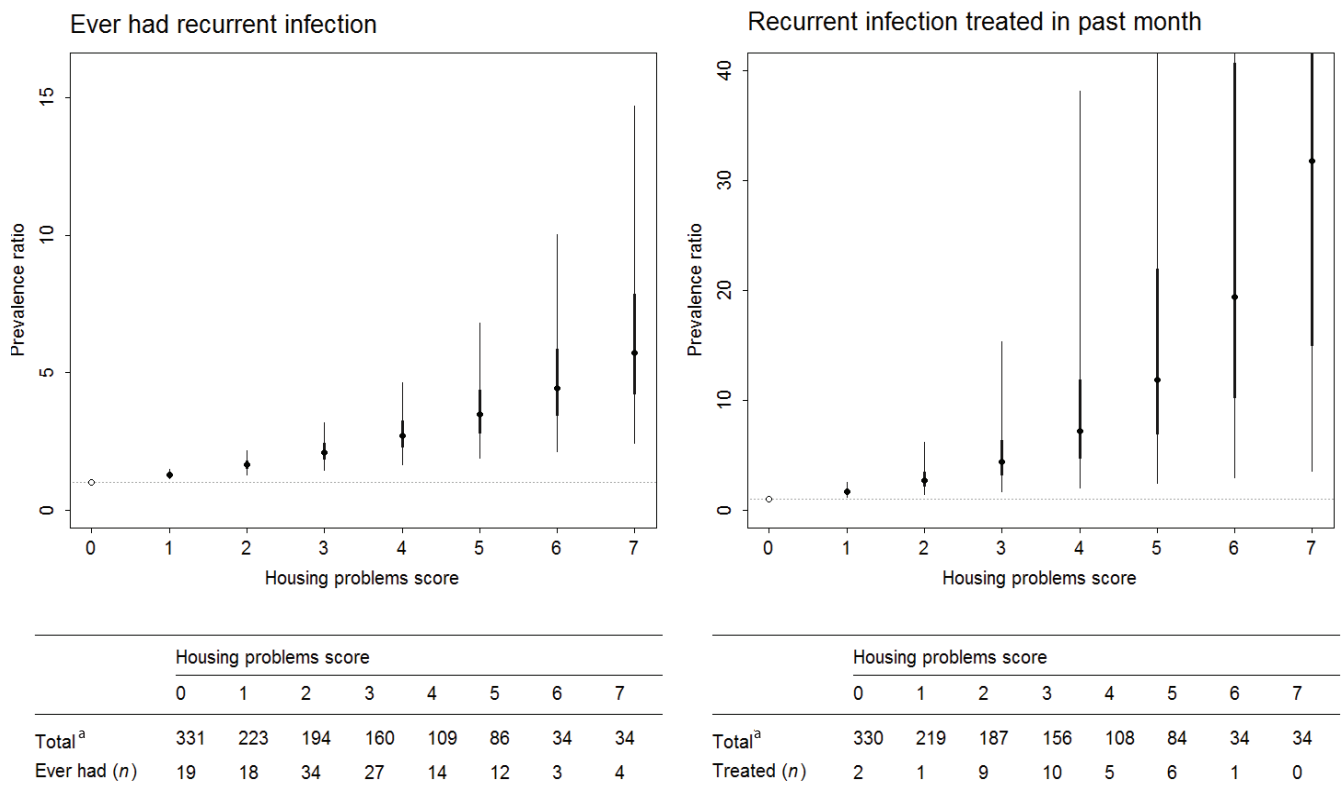
housing conditions overall matter more than any one specific housing problem. Multiple housing problems may compound a child's risk of gastrointestinal infection in many ways; each additional problem may present an increased risk of pathogen exposure, impair residents' abilities to perform healthy living practices, or be linked to other health and wellbeing issues that may then make a child more vulnerable to infectious disease. The challenges presented to residents attempting to perform their daily tasks in a crowded home are, for instance, potentially greatly exacerbated if the dwelling also has major problems with plumbing, electricity and vermin infestation. Cumulative housing disadvantage may be a particularly useful way to conceptualise and measure the severity and impact of poor housing on health and wellbeing.^{18,19} In remote communities, the overall score of housing dysfunction has been associated with respiratory infection, although not with gastroenteritis.¹⁶ Exposure to cumulative housing disadvantage in childhood has been shown elsewhere to relate to poor health outcomes in adulthood, irrespective of adult socioeconomic and housing conditions.¹⁸

With regard to crowding, carer report of feeling crowded was significantly associated with ever having recurrent gastrointestinal infection, whereas the objective crowding measure (>2 persons per bedroom) was not. This may indicate that the subjective crowding question captures issues relevant to health not measured in customary person-per-bedroom ratios, such as dwelling size, design, bathroom facilities, family composition and cultural factors.^{34,35} In existing Aboriginal child health studies in remote and mixed settings, objective measures of crowding were likewise not significantly associated with gastroenteritis.^{16,27} The finding that having six or more usual residents was protective against having ever had recurrent gastrointestinal infection (though not in the past month) was somewhat unexpected, as exposure to more household members has been associated with increased risk of exposure to infectious disease pathogens, although evidence exists that this risk is moderated by dwelling size.¹⁵ This finding may be due to chance association or it may reflect existing suggestions that large households are not inherently problematic for health, provided housing facilities afford

adequate space and amenity to meet the needs of the people in the home.³⁶ Some research suggests larger households may be beneficial for Aboriginal people,⁹ for instance, by enabling resources and the care of children to be shared.³⁶

Given that most Aboriginal people live in urban areas,⁹ that housing disadvantage is common among urban Aboriginal people^{12,13} and that the majority of the health gap is attributable to Aboriginal people living in non-remote areas,³⁷ more information is urgently needed about what works to improve the housing situations of urban Aboriginal communities and whether improved housing conditions result in better health outcomes. While no housing intervention studies have been conducted in urban Aboriginal communities, some have been conducted with Aboriginal people in rural and remote areas. A prospective study of 418 children from 10 remote Aboriginal communities in the Northern Territory that received government housing improvement programs did not find that improved housing conditions alone resulted in significant improvement in carer-reported child health outcomes, including gastroenteritis.³⁸ Study authors suggested that housing interventions

Figure 1: Relationship between number of housing problems and recurrent gastrointestinal infection.



^a Number of children with non-missing data on recurrent gastrointestinal infections.

in remote communities must also do more to address crowding and encompass a broader ecological approach, incorporating hygiene promotion programs and addressing broader community-level environmental health factors in order to maximise improvements to health.^{38,39} However, an evaluation of a targeted, health and safety focussed housing repair and maintenance program provided to 9,528 people from 71 rural and remote Aboriginal communities across NSW found significant reductions in hospital separations for infectious disease in the intervention group compared to matched communities who did not receive the program.¹⁰ The largest improvements were observed for hospital separations for intestinal infection, which dropped by 43% in the intervention group and increased by 3% in the control group (3%).¹⁰ The differences in study findings may suggest that geographic factors or the type of housing improvements conducted influence the effectiveness of housing intervention programs. Regardless, findings from these studies are unlikely to be directly applicable to Aboriginal people living in urban communities, given the considerable differences in social and environmental circumstances between these settings, and specific studies in urban areas are required. The following caveats should be noted in regard to this study. Associations between housing and gastrointestinal infection are complex and closely linked to a range of other social, environmental and other mediating factors. While this study has used modelling techniques to control for confounding by variables available in the SEARCH survey, many other factors not measured in this study may also be associated with gastrointestinal infection, including but not limited to vaccination against rotavirus, the presence of younger siblings, household hygiene practices and other health behaviours.^{16,38–40} As with all studies examining multiple variables, chance associations may occur. Also, causal inference cannot be asserted from cross sectional studies. Once longitudinal SEARCH data becomes available, examination of the direction of influence between housing and health over time will be possible. SEARCH is not a representative sample and our results may not be generalisable to other populations. Recruitment through ACCHSs may increase the likelihood of recruiting participants with recent health problems. That said, participants attending ACCHSs are not necessarily unwell, as ACCHSs

provide a broad range of preventative health and wellbeing programs and a range of other community services.⁴¹ Participants in SEARCH are a relatively a relatively disadvantaged urban Aboriginal sample in terms of socioeconomic status, with lower average household incomes and lower rates of home ownership than the broader Aboriginal population of NSW.⁴² This limits the generalisability of findings about the prevalence of housing problems, but does not affect the validity of the internal associations noted between housing problems and gastrointestinal illness, as the models used controlled for socioeconomic status. Carer self-report data may not be as accurate as objectively measured data. However, as carers completed questions about a wide range of environmental, cultural and behavioural exposures and many child health outcomes, they were not conscious of the particular relationship being examined in the current study at the time of completion; hence, it is unlikely that any inaccuracies were differential with regard to associations between housing and gastrointestinal infection. The data available relates to current housing conditions, not a full history of all homes lived in, a common difficulty in housing research.¹⁸ There are obvious temporal issues with studying the health effects of housing exposures, including time lag effects as both current and previous housing exposures may be associated with ill health.^{13,18} Given that clear associations were observed between recurrent gastrointestinal infection ever and current housing conditions, even after controlling for socioeconomic status, we hypothesise that for those who have moved, current housing conditions may be indicative of previous housing conditions.

These caveats notwithstanding, SEARCH is the largest urban Aboriginal child health cohort in Australia to date and this study contributes new information about the links between housing and gastrointestinal infection for urban Aboriginal children – an under-researched field. The associations found are biologically plausible, substantial, significant and largely consistent with existing knowledge.^{10,27,29} The findings also support recent qualitative research conducted with Aboriginal people in Western Sydney, who asserted that poor housing conditions were negatively affecting the health of urban Aboriginal children, including through gastrointestinal infection.²⁹ Research examining associations between housing

and other health outcomes for urban Aboriginal children and adults is indicated, along with high quality housing intervention studies to examine whether improved housing conditions result in improved health outcomes for urban Aboriginal people.

Conclusion and implications

While most Australians enjoy high-quality housing, a sizeable portion of urban Aboriginal people do not,^{9,12} and this study suggests that housing problems may be contributing to the health gap experienced by urban Aboriginal children. Treatment for most infectious diseases are readily available in Australian cities,¹⁰ but infectious disease disparity for Aboriginal people remains.^{5,37} Unless the underlying drivers of infection are addressed, children who receive treatment simply return to the same conditions that contributed to their illness.^{10,11} Along with social justice arguments, economic arguments can be made for more action to improve the availability of affordable, decent quality housing as a preventative health measure.^{10,11,43} This is not to suggest that improved housing is enough in itself to close the urban Aboriginal health gap.⁴⁴ Rather, housing should be a key part of a broader suite of multi-faceted initiatives that involve governments working with Aboriginal organisations and communities to address underlying social, economic and environmental determinants of health.⁴⁴ Importantly, housing needs to be on the agenda as a potential health issue for Aboriginal people in all parts of Australia.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Supplementary File 1: Further detail on statistical methods.

Supplementary File 2: Table S1. Associations between recurrent gastrointestinal infection and housing conditions estimated in the multiple imputation analyses

(housing exposures examined separately).

Supplementary File 3: Figure S1.

Relationship between recurrent gastrointestinal infection and number of housing problems estimated in the multiple imputation analyses.