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REVIEW ARTICLE

Communicable diseases in rural and remote Australia: the need for improved understanding and action

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ABSTRACT

Introduction: Rural and remote communities of Australia, particularly those including Aboriginal people, experience greater morbidity and mortality across a range of health outcomes compared to urban communities. Previous national data have demonstrated that rural and remote communities experience a disproportionate burden of communicable diseases compared to their urban counterparts. This systematic review was undertaken to describe the types of research that have explored the epidemiology of communicable diseases in rural and remote communities in Australia, with particular reference to the social determinants of health.

Methods: We conducted a keyword search of several databases (EMBASE, MEDLINE/PubMed, RURAL, Aboriginal and Torres Strait Islander Health Database, Web of Science Core Collection, and Google and Google Scholar websites) for peer-reviewed and grey literature that described or analysed the epidemiology of communicable diseases in rural and/or remote communities of Australia from 2004 to 2013. Exclusion criteria were applied to keep the review focused on rural and/or remote communities and the population-level epidemiological analysis of communicable diseases.

Results: From 2287 retrieved articles, a total of 50 remained after applying exclusion criteria. The majority of included articles were descriptive studies (41/50). Seven of the total 50 articles contained analytical studies; one systematic literature review and one experimental study were also identified. Due to the diversity of approaches in measuring disease burden, we performed a narrative synthesis of the articles according to the review objectives. Most of the articles investigated the disease burden in remote (n=37/50) and Aboriginal communities only (n=21/50). The studies highlighted a high prevalence or incidence of skin, eye and respiratory infections for remote Aboriginal communities, particularly children over the past decade. There was emerging evidence to suggest that housing and social conditions play an important role in determining the risk of skin, ear, respiratory and gastrointestinal

infections in children. Other health service and sociocultural factors were also discussed by authors as influencing the epidemiology of communicable diseases in rural and remote communities.

Conclusions: This systematic review identified several communicable diseases that continue to cause considerable morbidity in remote Aboriginal communities, including skin, eye and respiratory infections, particularly for children. Overall there is a substantial amount of descriptive epidemiology published, but few analytical or experimental studies. Despite a lack of empirical investigation into the social determinants of the burden of communicable disease, there is emerging evidence that has demonstrated a significant association between housing conditions and skin, ear, respiratory and gastrointestinal infections in children. There is also growing recognition of other social and environmental factors that can influence the burden of diseases in rural and remote communities. Further investment into higher quality community-based research that addresses the social determinants of communicable diseases in remote communities is warranted. The lack of research investigating zoonoses and tropical diseases was noted.

Key words: Aboriginal and Torres Strait Islander, Australia, communicable disease, epidemiology, infection.

Introduction

Approximately a third of Australia's population lives outside urban cities in regional, rural or remote areas[1] which cover greater than 85% of Australia's land mass[2]. The health inequalities experienced by people living in rural and remote communities are well documented[3-5]. Life expectancy is lower and rates of chronic disease and overall mortality are higher in rural and remote areas[5].

The rural environment itself or the effect of 'place'[6-8] can have negative and positive effects on the health and wellbeing of people. Place consists of economic, physical, social, environmental and sociocultural factors that interact to define health and influence health behaviours[9]. Occupational and environmental hazards are more common in rural and remote areas, and the geographical distance between communities can be challenging in terms of health service provision and access to care[3,6,10]. A review of epidemiological evidence across several developed countries indicated that the impact of 'rural location' likely exacerbated the socioeconomic disadvantage already experienced by many rural communities[6], such as lower incomes, education and employment opportunities, which place rural residents at risk of poor health.

However, there are sociocultural benefits from living in rural communities, such as increased social cohesion, connectedness and wellbeing[11]. Health professionals also report the 'rural lifestyle' and the diversity of rural practice as being important factors that influence them to work and live in rural and remote communities[12,13].

The relationship between health and remoteness is particularly important for Aboriginal peoples. More than 65% of the total Aboriginal population live in regional, rural or remote communities compared to metropolitan cities in Australia[14]. Aboriginal peoples experience significantly poorer health across a range of outcomes than non-Aboriginal people in Australia[15]. For Aboriginal peoples the connection with country is deeply embedded in culture and has inextricable links with individual and community health and the environment.

The state and territory governments of Australia have aimed to ensure that 'people in rural and remote Australia' are as healthy as other Australians[2]. However, this vision of health for rural and remote Australians has yet to be realised. Whilst acknowledging that non-communicable diseases contribute a large proportion of the health burden experienced by rural and remote Australians[5], previous national data has also demonstrated that rates of communicable disease

(eg salmonellosis, pertussis and syphilis) increase with increasing remoteness[4].

In addition to health service factors, it is likely that the social determinants of health[16], including sociocultural factors and environmental factors, contribute to this differential in communicable disease experienced by rural and remote people in Australia. We sought to conduct a systematic review to summarise the types of studies and subjects of recent research into the epidemiology of communicable disease for rural and remote people in Australia. This review has a particular focus on the social determinants of health in an attempt to provide further understanding of their contribution to the burden of communicable diseases in rural and remote communities and to provide recommendations on research in this field.

Methods

Objectives of the review

The review focused on the following questions:

1. What areas of research have been conducted over the last decade focusing on communicable diseases in rural and remote communities in Australia? What were the populations of interest, diseases of interest and type of studies conducted?
2. From this research, what were the overall findings in relation to the epidemiology of communicable diseases in rural and remote communities of Australia?
3. What are the factors that influence the epidemiology of these diseases?
   – *health service factors* – such as surveillance and reporting issues, access to health care, health staffing
   – *social or cultural factors* – such as socioeconomic status, housing and living conditions
   – *environmental issues* – such as contact with animals or contaminated sites.

Definitions and scope

As there is no commonly accepted international definition of what constitutes rural or remote areas, we classified articles based on the geographical location of the main study population in the article, according to the Australian Statistical Geography Classification of Remoteness Categories[17]. We classified RA 2 (Inner regional) to RA 3 (Outer regional) together as 'rural' and RA 4 (remote) to RA 5 (Very remote) populations together as 'remote' for the purposes of this review[2]. We used the Department of Health and Ageing (DoHA) online tool to determine the eligibility of studies by remoteness categories for inclusion in our review[18]. The review included all communicable diseases or diseases with an infectious cause.

Literature review

Data sources and strategy: Potentially eligible peer-reviewed articles were identified by searching articles published in English between June 2004 and June 2013 inclusive in EMBASE, MEDLINE/PubMed, RURAL (Rural and Remote Health Database) and Aboriginal and Torres Strait Islander-Health. An aggregate search of all databases within the Web of Science Core Collection was conducted. For the grey literature, Google and Google Scholar websites were searched and sorted by relevance according to keyword search terms. The first 20 pages retrieved from each website were included for review.

Search terms:

1. 'Infectious' OR 'infective' OR 'infection' OR 'notifiable' OR 'communicable disease'; AND
2. 'Australia' OR 'Australian'; AND
3. 'Rural' OR 'remote' OR 'regional'.

Selection criteria and classification of articles: Articles were then excluded if they described only:

- the burden of chronic or non-communicable diseases

- the epidemiology of communicable diseases in large population groups without a specific focus on rural and/or remote communities
- other public health issues (eg environmental or social issues)
- public health infection control or case management guidelines
- the burden, prevention or management of communicable diseases in plants or animals
- the epidemiology of communicable diseases in rural or remote communities using secondary data or subset analysis only for these groups
- the microbiological, hospital-based clinical diagnostic or environmental epidemiology of communicable diseases in rural remote communities (eg did not focus on the population-level epidemiology of these diseases).
- commentary pieces or perspectives, editorials and conference abstracts.

A data extraction template was developed and the following items were extracted from each article:

- type of article (eg report, journal article, literature review)
- type of study, such as descriptive (ie ecological or cross-sectional study) analytical (ie case-control or cohort study) or experimental study (randomised study designs, etc.) according to WHO criteria[19]
- study population – rural or remote or both
- type of communicable disease, whether or not it is notifiable and epidemiological trends in diseases studied.

Commentary on the social determinants that were reported in the literature as influencing the epidemiology of the communicable diseases studies were also extracted and a narrative summary is presented in relation to the review questions. Issues over discrepancies concerning analysis of articles were resolved between two authors (EQ and PM) before reporting.

Results

Search strategy results

A total of 2125 articles were retrieved from the five peer-reviewed journal databases and a total of 381 articles were retrieved from the Google website searches (Fig1). After duplicates were excluded, exclusion criteria were applied to the remaining 2287 eligible articles (Table 1); 50 articles[20-69] were included for review (Table 2).

Areas and types of research conducted

A summary of the 50 articles is provided in Table 1. Of the 50 articles, most (37/50) included only remote and not rural communities, 26/50 were conducted in the Northern Territory (NT) and 21/50 included only Aboriginal peoples. No studies identified and discussed in this review specifically examined the burden of communicable diseases in Torres Strait Islander peoples.

The most commonly investigated groups of communicable diseases were skin and ear infections (n=11 articles)[20,22,37,39,48,52,56,57,61,64,66], sexually transmitted infections (n=10 articles)[25,33,36,42,47,51,54,60,65,69] and vaccine-preventable diseases (n=6 articles)[23,29,34,38,43,53]. Other groups of diseases studied included respiratory[24,28,32,63,67], eye infections[45,49,50], gastroenteritis[35,40,41] and zoonoses[30,44,59]. Strongyloidiasis[31] and melioidosis[27,58] were also investigated (Table 3).

Nearly all (41/50) of the articles were descriptive studies[20-26,28-31,33-35,37-39,41-47,49-51,53-57,59-63,65,67-69], 7/50 were analytical studies[27,32,40,48,52,58,66], one article was a systematic literature review on sexually transmitted infections (STIs)[36] and one article contained a randomised controlled trial (RCT)[64]. The area of research related to skin and ear infections and associated diseases contained the only experimental study[64] and the most analytical studies[48,52,66] included in this review (Table 3).

Table 1: Summary of excluded articles

Exclusion criteria	*N*	%
1. Non-communicable diseases or other conditions	583	26
2. No specific focus on rural/remote populations in Australia	924	41
3. Other public health issues (eg environmental or social issues)	201	9
4. Guidelines or policies only	28	1
5. Communicable diseases in plants, insects and animals	83	4
6. Secondary data used/subset analysis only	13	1
7. No population-level epidemiological focus (eg qualitative studies)	222	10
8. Not 2004–2013, in English or relevant article types	183	8
Total	2237	100

Table 2: Summary of articles included in the review

Author/s	Year	Study type	Rural, remote or both?	Population group(s) analysed	State or territory	Disease(s) included
Andrews et al (20)	2009	4	Remote	Aboriginal only	NT	Skin infections
Bailie et al (22)	2005	4	Remote	Aboriginal only	NT	Skin infections
Bailie et al (21)	2010	4	Remote	Aboriginal only	NT	Skin, respiratory, gastrointestinal and ear infections
Bangor-Jones et al (23)	2009	4	Remote	Aboriginal and non-Aboriginal	WA	Mumps
Bolisetty et al (24)	2005	4	Remote	Aboriginal and non-Aboriginal	NT	Respiratory syncytial virus and bronchiolitis
Brazzale et al (25)	2010	4	Remote	Aboriginal only	Qld	Herpes simplex virus
Clucas et al (26)	2008	4	Remote	Aboriginal only	NT	Skin, respiratory, gastrointestinal, ear infections etc.
Currie et al (27)	2004	3	Remote	All cases/people	NT	Melioidosis
Dede et al (28)	2010	4	Remote	Aboriginal and non-Aboriginal	NT	Respiratory syncytial virus
Dent et al (29)	2010	4	Remote	Aboriginal and non-Aboriginal	NT	Hepatitis B
Eales et al (30)	2010	4	Both	All cases/people	Qld	Brucellosis
Einsiedel et al (31)	2008	4	Remote	All cases/people	NT	Strongyloides
Einsiedel et al (32)	2011	3	Remote	Aboriginal and non-Aboriginal	NT	Bronchiectasis
Fagan et al (33)	2007	4	Remote	Aboriginal and non-Aboriginal	Qld	Syphilis
Fitzgerald et al (34)	2012	4	Both	All cases/people	NSW	Invasive pneumococcal disease
Franklin et al (35)	2009	4	Rural	All cases/people	Vic	Gastroenteritis
Guy et al (36)	2012	1	Remote	Aboriginal only	SA, NT, WA	Chlamydia, gonorrhoea and syphilis
Hanna et al (37)	2010	4	Both	Aboriginal only	Qld	Acute rheumatic fever
Hanna et al (38)	2010	4	Both	non-Aboriginal only	Qld	Invasive pneumococcal disease
Hewagama et al (39)	2012	4	Remote	All cases/people	NT	*Staphylococcus aureus* bacteraemia
Heyworth et al (40)	2006	3	Both	All cases/people	SA	Gastroenteritis
Heyworth et al (41)	2006	4	Both	All cases/people	SA	Gastroenteritis
Huang et al (42)	2008	4	Remote	Aboriginal only	SA	Chlamydia, gonorrhoea and syphilis
Hunt et al (43)	2004	4	Remote	Aboriginal and non-Aboriginal	NT	Rubella
Islam et al (44)	2011	4	Both	All cases/people	NSW	Q-fever
Kain et al (45)	2007	4	Remote	Aboriginal only	WA	Trachoma
Kearns et al (46)	2013	4	Remote	Aboriginal only	NT	Any communicable disease
Kong et al (47)	2009	4	Rural	All cases/people	Vic	Chlamydia
La Vincente et al (48)	2009	3	Remote	Aboriginal only	NT	Skin infections
Landers et al (50)	2005	4	Remote	Aboriginal only	NT	Trachoma
Landers et al (49)	2010	4	Remote	Aboriginal only	NT	Trachoma
Lenton et al (51)	2007	4	Remote	Aboriginal and non-Aboriginal	NSW	Chlamydia
Mackenzie et al (52)	2009	3	Remote	Aboriginal only	NT	Skin and ear infections
Mak (53)	2004	4	Remote	Aboriginal only	WA	Invasive pneumococcal disease
Mak et al (54)	2004	4	Remote	Aboriginal only	WA	Syphilis
Mak et al (55)	2006	4	Remote	Aboriginal only	All	Trachoma
Marshall et al (56)	2011	4	Remote	Aboriginal and non-Aboriginal	NT	Acute post-streptococcal glomuleronephritis

Table 2: Cont'd

Author/s	Year	Study type	Rural, remote or both?	Population group(s) analysed	State or territory	Disease(s) included
McMeniman et al (57)	2011	4	Remote	Aboriginal only	NT	Skin infections
Parameswaran et al (58)	2012	3	Both	Aboriginal and non-Aboriginal	NT	Melioidosis
Parker et al (59)	2010	4	Rural	All cases/people	Qld	Q-fever
Ryder et al (60)	2012	4	Both	All cases/people	NSW	*Trichomonas vaginalis*
Scrace et al (61)	2006	4	Remote	Aboriginal only	Qld	Acute post-streptococcal glomuleronephritis
Silva et al (62)	2008	4	Remote	Aboriginal only	WA	Skin, ear and respiratory infections
Steinfort et al (63)	2008	4	Remote	All cases/people	NT	Bronchiectasis
Stephen et al (64)	2013	2	Remote	Aboriginal only	NT	Ear infections
Su et al (65)	2012	4	Remote	All cases/people	NT	Gonorrhoea
Tong et al (66)	2009	3	Remote	Aboriginal and non-Aboriginal	NT	Methicillin resistant *Staphylococcus aureus*
Trauer et al (67)	2011	4	Remote	Aboriginal and non-Aboriginal	NT	Pandemic influenza
Vally et al (68)	2004	4	Rural	All cases/people	WA	Aeromonas hydrophila
Wilkey et al (69)	2006	4	Remote	All cases/people	NT	Syphilis, herpes simplex virus and donovanosis

1 – systematic review. 2 – experimental study/randomised controlled trial, 3 – analytical study (ie case control or cohort study). 4 – descriptive study (ie case series, audit, outbreak investigation, ecological study or cross-sectional study)

NSW, New South Wales. NT, Northern Territory. Qld, Queensland. SA, South Australia. Vic, Victoria. WA, Western Australia.

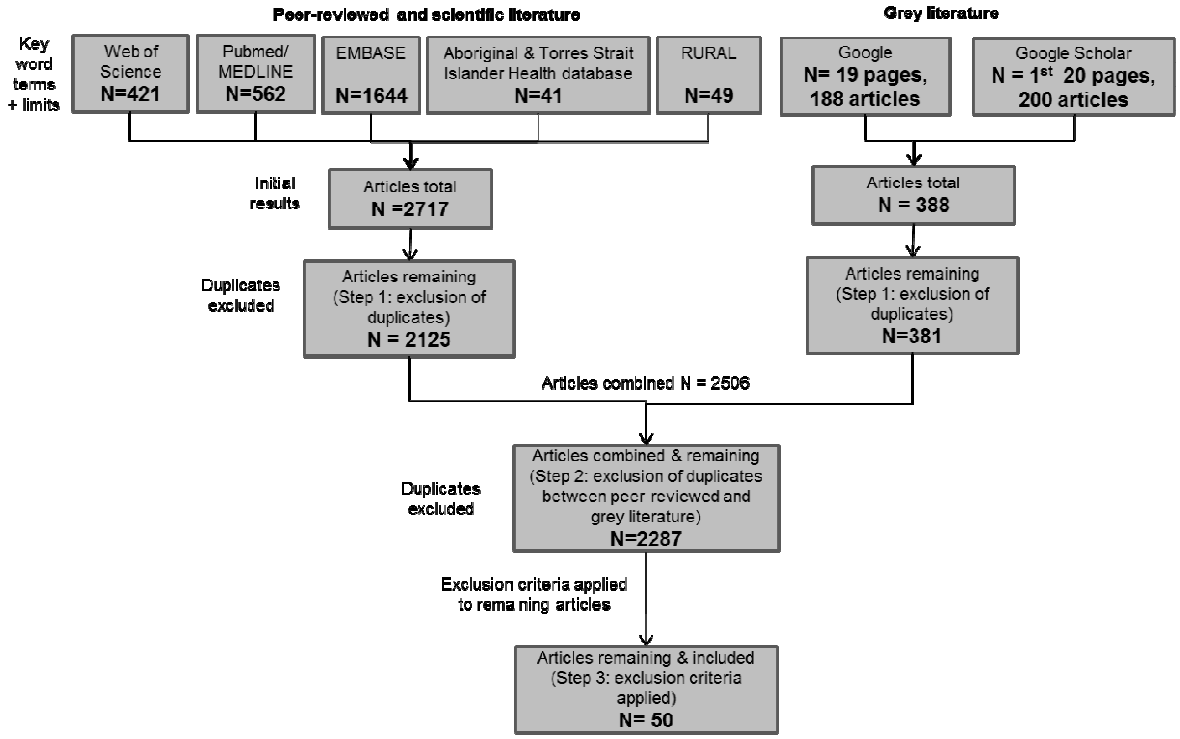

Figure 1: Search strategy algorithm and results.

Quality of studies included

Due to the lack of a singular checklist for assessing the quality of individual studies included in mixed studies reviews[70,71], we focused on assessing the reporting quality of the analytical[27,32,40,48,52,58,66], RCT[64] and systematic review[36] articles using separate and commonly used checklists. All seven analytical studies[27,32,40,48,52,58,66] included in this review meet all 25 major items of the STROBE[72] checklist. The RCT included in this study met 23/25 quality assessment items as listed in the CONSORT checklist[73]; notable exceptions included specifying who randomised, allocated and followed up on study participants, as well as exact dates defining recruitment and follow-up periods. The systematic review article met 9/11 criteria as included in the AMSTAR checklist[74], with improvements warranted for describing the studies excluded as part of the search strategy process. Of the 41 descriptive studies included in this review, 54% (n=28) were ecological or cross-sectional studies (Table 3) with various methods (eg prospective vs retrospective surveys or surveillance reviews), sample sizes (ranging from approximately 40 to >7000) and follow-up periods (ranging from several months to more than a decade). Study type is also noted below to provide an indication of the quality of evidence for each disease area discussed.

Epidemiology of communicable diseases in rural and remote areas

Due to the diversity in the measurement and reporting of the epidemiology of communicable diseases, a quantitative synthesis of the articles was not possible. A narrative synthesis of the 48/50 studies is presented below, where the primary objective of the study was to report on the incidence, prevalence, clinical presentation or severity of communicable diseases in rural and/or remote communities.

Multiple disease types: Three descriptive studies reported the epidemiology of multiple disease types (ie skin, respiratory, gastrointestinal and ear infections) in remote Aboriginal children (Table 3). Kearns et al[46] reported Aboriginal children presented to health care a median of 21 times in their first year of life (n=320 children), with the vast majority of presentations due to respiratory infections for the period 2001 to 2006. Similarly, Clucas et al[26] reported the median number of presentations in a child's first year of life (n=174 children) to be 23; again, respiratory infections were the most common (32%) reason for attending healthcare clinics between 2001 and 2005. The study by Silva et al[62] followed up 259 Aboriginal children for the period 1999 to 2005, to determine the impact of the use of a swimming pool on rates of healthcare attendance for common childhood infections (ie skin, ear, respiratory and gastrointestinal infections). The study[62] found significant reductions in the rate ratios of skin (–68%), ear (–61%) and respiratory (–52%) infections in one community.

Skin and ear infections and associated diseases: Two descriptive studies[20,57], one analytical study[48] and one RCT[64] examined the epidemiology of skin infections for Aboriginal peoples, predominantly children, living in remote communities (Table 3). Two descriptive studies reported a high prevalence of skin infections in Aboriginal children aged <1 year (>68%)[57] and children aged <15 years (greater than 45%)[20] in remote communities. The analytical study by La Vincente et al[48] examined the effectiveness of scabies treatment in remote Aboriginal households (n=40) from December 2006 to June 2007, revealing that households with complete treatment uptake had a significant five- to six-fold reduction in scabies prevalence.

Stephen et al[64] conducted an RCT in 2009 to examine whether 4 weeks of attendance at swimming pools could significantly reduce the prevalence of skin infections in Aboriginal children (n=89) in remote communities and found no significant difference in skin infection or carriage of streptococci for these children.

The analytical study by MacKenzie et al[52] investigated differences in age-adjusted incidence of ear infections and ear perforations between two birth cohorts of remote Aboriginal children prior to (1996–2001) and after introduction of pneumococcal vaccination (2001–2004). The study found no significant reduction in odds of ear infections or microbiological ear carriage of *Streptococcus pneumoniae* vaccine serotypes[52].

Table 3: Summary of articles included in the review – by disease of interest and study type

Disease type	Type of study (article reference number)						
	Descriptive			Analytical	Experimental	Review	
	CA	OI	ES or CS	OS	RCT	SR	Total *n*(%)
Multiple disease types (eg skin, ear and respiratory infection)			(21, 26, 46, 62)				4 (8%)
Skin and ear infections and associated diseases (eg APSGN, ARF, MRSA)	(39, 57)	(61)	(20, 22, 37, 56)	(48, 52, 66)	(64)		11 (22%)
Eye infections (eg trachoma)			(45, 49, 50, 55)				4 (8%)
Respiratory infections and associated diseases (eg respiratory syncytial virus, influenza, bronchiectasis)	(28, 63)		(24, 67)	(32)			5 (10%)
Gastrointestinal (eg salmonella)		(35)	(41)	(40)			3 (6%)
Sexually transmitted infections (eg chlamydia, syphilis, gonorrhoea)	(69)	(54)	(25, 33, 42, 47, 51, 60, 65)			(36)	10 (20%)
Vaccine-preventable (eg mumps, invasive pneumococcal disease, hepatitis B)	(43)	(23)	(29, 34, 38, 53)				6 (12%)
Zoonoses (eg brucellosis, Q-fever)	(30)		(44, 59)				3 (6%)
Other diseases (eg melioidosis, strongyloides)	(31)	(68)		(27, 58)			4 (8%)
Total *n*(%)	**8 (16%)**	**5 (10%)**	**28 (54%)**	**7 (14%)**	**1 (2.0%)**	**1 (2.0%)**	**50 (100%)**

APSGN, acute post-streptococcal glomuleronephritis. ARF, acute rheumatic fever. CA, case audit or series. CS, cross-sectional study. ES, ecological study. MRSA, methicillin-resistant *Staphylococcus aureus*. OI, outbreak investigation. OS, observational study (including case-control and cohort studies). RCT, randomised controlled trial. SR, systematic review

Three descriptive studies examined the burden of acute post-streptococcal glomerulonephritis[56,61] and acute rheumatic fever[37] in remote communities, noting the causal links with streptococcal skin or pharyngeal infections. Scrace et al[61] conducted an outbreak investigation of acute post-streptococcal glomerulonephritis in children aged <12 years of remote communities of far north Queensland (Qld) during the period February to March 2005 and found that of the 11 confirmed acute post-streptococcal glomerulonephritis cases, 65% were preceded by infected scabies. Acute rheumatic fever became a notifiable disease in Qld during 2004 and although the study by Hanna et al[37] revealed an upward trend in the incidence of acute rheumatic fever from 2004 to 2009 for remote Aboriginal peoples, the number of recurrent acute rheumatic fever episodes decreased significantly during this period.

One case audit[39] and one analytical study[66] examined the epidemiology and clinical presentation of *Staphylococcus aureus* bacteraemia cases in remote communities of the NT. Hewagama et al[39] found an extremely high annual incidence rate of bacteraemia for Aboriginal peoples (160.7/100 000) compared to non-Aboriginal people (8.1/100 000) between 2003 and 2006. Similarly, the prospective matched case-control study by Tong et al[66] found a higher incidence of *S. aureus* bacteraemia (172 cases/100 000 population) in remote Aboriginal peoples compared to the rest of the remote population in the NT from 2006 to 2007 (65 cases/100 000 population).

Eye infections: Four descriptive studies[45,49,50,55] analysed the epidemiology of eye infections in remote Aboriginal communities. Two studies[49,50] investigated the prevalence of trachoma trichiasis and corneal opacity as complications of recurrent trachoma in remote Aboriginal communities of the NT.

The survey published by Landers et al[50] revealed an 8% prevalence of trachoma trichiasis and 3% prevalence of corneal opacity in remote Aboriginal residents (*n*=181) of the NT in 2003. A similar survey conducted between 2005 and 2008 found that the prevalence of trachoma trichiasis (6.1%)

and corneal opacity (3.3%) did not reduce significantly in remote Aboriginal peoples (n=1884) of the NT[49], suggesting endemicity of trachoma and its complications in this region.

The study by Kain et al[45] measured the prevalence of 'active trachoma'[75] in children aged >12 years (n=2975) in remote communities of Western Australia (WA) from 1992 to 2003 and found the prevalence varied widely across these years, but with a significant decline in severe trachoma over time (5% in 1993 to 1% in 2001). Aboriginal children were also greater than 12 times more likely to have active trachoma compared to non-Aboriginal children in this study[45]. Mak et al[55] also found a highly variable but ongoing prevalence of active trachoma (0–40%) in children in remote communities of WA, NT and South Australia (SA) from 1993 to 2007.

Respiratory infections and associated diseases: Two descriptive studies[24,28] examined the epidemiology of respiratory syncytial virus in remote communities of the NT. Dede et al[28] found significantly higher rates of respiratory syncytial virus in Aboriginal children (29.6/100 000) compared to non-Aboriginal children (10.9/100 000) from 2000 to 2004. Bolisetty et al[24] found a very high incidence of respiratory syncytial virus-related hospitalisation during 1998–2000 in children living in remote communities of the NT. A cross-sectional serological survey by Trauer et al[67] of residents in the NT revealed a significantly disproportionate infection rate of pandemic H1N1 influenza for Aboriginal people compared to non-Aboriginal people.

Two studies[32,63] examined the burden of bronchiectasis in remote residents of the NT. The case audit by Steinfort et al[63] of 61 patients presenting to Alice Springs Hospital in the NT for respiratory infections between 2004 and 2005 found that at least 70% of patients had previous recurrent respiratory infections, and human t-cell lymphotropic virus was implicated in 72% of those patients. The retrospective cohort study by Einsiedel et al[32] of bronchiectasis admissions to Alice Springs Hospital during 2000–2006 in Aboriginal remote peoples revealed that 60% of cases (n=89) were human t-cell lymphotropic virus-1 seropositive and these adults experienced a significantly higher mortality rate.

Gastrointestinal infections: Three studies analysed the epidemiology of gastroenteritis in children in rural areas of Victoria(Vic)[35] and SA[40,41]. The outbreak investigation of gastroenteritis reported by Franklin et al[35] in school children in rural Vic revealed that consumption of untreated private drinking water was the likely source of infection, with microbiological confirmation of *Salmonella enterica* Typhimurium DT9 in this water supply. In contrast, a cohort study conducted by Heyworth et al[40] surveying children 4–6 years (n=1016) about water consumption in rural areas of SA revealed no increased odds of gastroenteritis for children who drank rainwater compared to treated mains water during 6 weeks in the autumn of 1999.

Sexually transmitted infections (STIs): Ten studies[25,33,36,42,47,51,54,60,65,69] examined the epidemiology of STIs in a variety of rural and remote settings across a number of states and territories (NT, Qld, NSW, Vic) for different infections (eg syphilis, chlamydia, gonorrhoea, herpes simplex virus). Two descriptive studies[33,54] reported a high prevalence of syphilis for remote Aboriginal people. The outbreak investigation by Mak et al[54] reported rates of syphilis for young Aboriginal peoples in the Kimberley region to be 439–583/100 000 person years during 2000–2002. A review of notification data from 2001 to 2005 in north Qld by Fagan et al[33] found that although the rate of syphilis for Aboriginal peoples decreased significantly from 97/100 000 to 52/100 000, it was still more than 10 times higher than that for non-Aboriginal people.

Two descriptive studies investigated the prevalence of chlamydia in rural Vic[47] and remote NSW[51]. Kong et al[47] demonstrated the feasibility of community screening for chlamydia within sporting clubs during 2007, with 709 young adults participating in the program and 5.1% detected as having chlamydia. Lenton et al[51] conducted a cross-sectional survey of pregnant women in far west NSW (n=218) between 2004 and 2006 and found that pregnant Aboriginal women were three times more likely to have chlamydia compared to all pregnant women.

Five other descriptive studies investigated the epidemiology of various STIs in remote communities of Qld[25], NSW[60] and NT[42,65,69]. Brazzale et al[25] found a very high seroprevalence of herpes simplex virus-1 and -2 infection{58-97%) in Aboriginal adults (*n*=270) in remote areas of the NT between 2007 and 2008. Ryder et al[60] found that of the 356 adult women attending a sexual health service in far-west NSW during 2009–2010, 8% were positive for *Trichomonas vaginalis*. Su et al[65] reviewed routine notification data in the NT and found the prevalence of gonorrhoea decreased significantly from 2005 to 2008 in remote adult residents. Wilkey et al[69] found that herpes simplex virus-2 was implicated in over half of all cases of genital ulcer disease in remote Aboriginal adults of the NT. The cross-sectional annual prevalence study by Huang et al[42] found a significant decrease in the prevalence of chlamydia (67%) and gonorrhoea (58%) from 1996 to 2003.

A recent systematic review by Guy et al[36] of STI control programs in the primary healthcare setting in remote Aboriginal communities of Australia demonstrated that well-coordinated and evidence-based programs in SA, NT and WA had significantly decreased rates of STIs (predominantly chlamydia and gonorrhoea) for the review period 1996–2005.

Vaccine-preventable diseases: Six studies examined the epidemiology of vaccine-preventable diseases, such as rubella[43], mumps[23], hepatitis B[29] and invasive pneumococcal disease[34,38,53] in remote communities of NT[29,43], WA[23,53], Qld[38] and NSW[34]. A case audit conducted by Hunt et al[43], revealed that antenatal rubella immunity levels were lower for Aboriginal mothers in remote areas of the NT in 1999, leaving women susceptible to this disease during pregnancy.

An outbreak investigation[23] of mumps in remote communities of WA from 2007 to 2008 revealed that 92% of all notified cases were Aboriginal people, revealing low vaccination coverage for this group. A serological study by Dent et al[29] examining hepatitis B serology of adolescents (*n*=37) from 1989 to 1990 in remote communities of the NT revealed four had evidence of active infection and under half also had low levels of immunity.

Three studies examined the epidemiology of invasive pneumococcal disease in rural and remote residents of NSW[34], Qld[38] and WA[53]. The case series by Mak[53] investigated the impact of the 23-valent pneumococcal vaccination program on invasive pneumococcal disease notification rates in Aboriginal and non-Aboriginal remote residents of WA from 2001 to 2005. Invasive pneumococcal disease incidence in Aboriginal peoples significantly declined from 97.8/100 000 person years in 1997 to 38.1/100 000 person years in 2001[53]. Fitzgerald et al[34] analysed routine notification data in NSW and found that the annualised rate of invasive pneumococcal disease for all age groups decreased after introduction of the 7-valent invasive pneumococcal disease vaccine in 2005 (from 13.7/100 000 to 8.3/100 000) and that the largest reduction was observed in vaccine serotypes and for children aged <4 years. A similar study conducted by Hanna et al[38] in Qld also found significant declines for all ages and vaccine serotypes.

Zoonoses: Three descriptive studies analysed the epidemiology of zoonoses (as listed by the National Notifiable Diseases Surveillance System) in rural and remote communities in NSW[44] and Qld[30,59]. Two studies examined the seroprevalence of Q-fever and found a prevalence of 7%[44] and 6.5%[59] in rural and remote communities of NSW and Qld respectively. A case audit by Eales et al[30] (*n*=32) for the period 1996–2009 examined the risk factors and clinical presentation of brucellosis and reported that feral pig hunting was indicated as an exposure risk in all cases.

Other diseases: Two studies examined the epidemiology of melioidosis in rural and remote communities of the NT[27,58]. The prospective cohort study conducted by Currie et al[27] from 1989 to 2003 included analysis of 364 cases of melioidosis and found the adjusted relative risk for melioidosis to be three times greater for Aboriginal peoples. The outbreak investigation reported by Parameswaran et al[58] of melioidosis cases in the NT between 2009 and 2010 found twice the rate of melioidosis in Aboriginal peoples

(102.4/100 000) compared to the overall NT population (50.2/100,000).

Einsiedel[31] conducted a case audit of complicated *Strongyloides* cases in Aboriginal peoples (n=18) in remote communities of the NT and found concurrent human T-lymphotropic virus-1 infection was common and nearly all of the patients died due to sepsis. An outbreak investigation by Vally et al[68] revealed cases of *Aeromonas* were most likely associated with contaminated water, which players were exposed to during a game of mud football.

Factors influencing the epidemiology of communicable diseases in rural and remote areas

Two[21,22] of the 50 studies included in this review empirically examined the association between social and environmental factors and rates of communicable diseases in remote Aboriginal communities. The first pilot study by Bailie et al[22] prior to 2005 measured the association between poor housing conditions, social conditions and incidence of skin infections in Aboriginal children living in remote communities of the NT. Multivariate analysis of household surveys and primary health care records of 138 children revealed that the most important 'household living practices' influencing the rate of skin infections included a lack of sanitation facilities, four or more children younger than 7 years in the household and low family income[22].

The cross-sectional follow-up survey by Bailie et al[21] measured the association between housing conditions and social factors and common childhood infections, such as skin, respiratory, ear and gastrointestinal infections, in 328 households in the NT. This study found a strong independent association on multivariate analysis between overall household conditions and respiratory infections[21]. Significant associations between childhood infections and secondary explanatory variables were also found for skin infections and lack of facilities for household temperature control, gastrointestinal infections and hygienic state of food preparation and storage areas, and ear infections and childcare attendance[21]. Around half of all the remaining papers discussed multiple factors that could influence the epidemiology of communicable diseases in rural and remote communities (Table 4).

Health service factors: Health service factors were discussed in 26 articles[20,23,26,29,31-34,36-39,41-45,48,54,60-62,65,66,69] as influencing the epidemiology of communicable diseases in rural and remote areas. Increased or enhanced screening and surveillance were discussed in eight articles[20,33,34,39,42,61,65,69] as being important to ensure cases are detected early and treatment programs remain targeted. Other factors included difficulties with health service delivery due to lack of staff in remote areas[26,39,54,62] and the need for continued medical education of the presentation and treatment for some infectious diseases[31,37,44,54,66,68].

Sociocultural factors: Sociocultural factors were discussed in 21 articles[20,23,25,27,30-32,36,42,43,48,54,56,57,61,62,66-69], including the population mobility of Aboriginal people[23,36,42,43,48,57,62,69] along with socioeconomic disadvantage[25,32,66,67]. It is worth highlighting that only two articles[20,67] explicitly discussed the importance of community partnerships in designing and/or implementing epidemiological or research studies designed to reduce the burden of communicable diseases.

Environmental factors: Environmental factors were discussed in 18 articles[23,27,28,31,32,35,39,40,43-45,48,56,58,61,66-68], in particular household overcrowding[23,31,32,39,48,56,61,66,67] and poor housing conditions[23,31,32,39,48,56,61,66,67]. The climate[28,43,45,58,68] was also discussed by several authors as being an important factor determining the incidence of some communicable diseases with seasonal patterns or in relation to the logistics of vaccine delivery being difficult in remote communities of Australia.

Discussion

This systematic review of the published literature over the last decade showed a substantial increased burden of

communicable diseases in remote Aboriginal communities of Australia, in particular skin, eye and respiratory infections in children. Rates of skin pathogen-associated diseases (eg acute post-streptococcal glomerulonephritis, acute rheumatic fever and bacteraemia) were high amongst Aboriginal peoples compared to non-Aboriginal people in remote communities. Evidence suggests that improvements have been made in reducing the burden of STIs in remote Aboriginal communities. Evidence has been emerging to demonstrate that poor housing conditions are associated with an increased risk of skin, ear, respiratory and gastrointestinal infections in children. There is also growing recognition of the role of sociocultural and environmental factors in influencing the epidemiology of communicable diseases in rural and remote communities. However, further investment into higher quality community-based research that addresses the social determinants of the burden of communicable diseases in remote communities of Australia is needed.

Our review of the literature identified mostly descriptive studies examining the epidemiology of diseases in remote areas of Australia, predominantly for Aboriginal peoples. Very few studies reported on the epidemiology of communicable diseases in rural communities only or for non-Aboriginal populations in general. There was also a lack of research investigating the epidemiology of zoonoses (in the narrow sense) and tropical diseases despite the evidence suggesting an increased risk for rural and remote residents.

The focus in the published literature on the disease burden for Aboriginal peoples in remote communities is particularly relevant and important given the need to address the health gap between Aboriginal peoples and non-Aboriginal people[15] and the increasing differential in health status associated with remoteness in Australia[3]. This review has also identified a substantial burden of non-notifiable communicable diseases for remote Aboriginal peoples over the past 10 years, particularly skin, eye and respiratory infections for Aboriginal children in remote communities.

Whilst health service factors were the most commonly discussed factors identified in this review there was also clear recognition that overcrowding in households, poor housing conditions in remote Aboriginal communities in particular, and other socioeconomic detriments, can place people at increased risk for communicable diseases. Only two empirical studies were identified in this review. Both demonstrated an association between housing and living conditions and rates of common childhood infections (eg skin, ear and respiratory infections)[21,22]. The Housing for Health program, which now operates in many parts of Australia, is a practical example of how surveying and then fixing and maintaining adequate housing conditions for remote communities can reduce the rates of common infectious diseases[76]. The evaluation of the program in NSW revealed an overall 38% reduction in hospitalisation for infectious diseases in Aboriginal communities participating in the program, compared to the rest of the rural NSW Aboriginal population without the program[76].

There is increasing acknowledgement of the need to take a social determinants approach to designing interventions and strategies that reduce the burden of communicable diseases[77-79]. Significant advances in the past century have reduced the burden of communicable diseases for most groups in the population, for example through vaccination, enhanced surveillance systems for improved detection and a more timely response, as well as more effective treatments to reduce morbidity and mortality from communicable diseases. However, as detected in this review, some population groups, such as remote Aboriginal children, remain vulnerable to communicable diseases through a combination of health service and social and environmental factors.

The findings from this review suggest that there may still be room for improvement in non-experimental epidemiological studies describing the communicable disease burden in rural and remote areas. Examples include recruiting and analysing larger samples over longer time periods and including analysis of risk factors that may help explain any changes in disease incidence or prevalence over time.

Table 4: Summary of reported factors influencing the epidemiology of communicable diseases in rural and remote communities

Factor	References
Environmental	
Geographical isolation of communities	(23)
Household overcrowding	(23), (31), (32), (39), (48), (56), (61), (66), (67)
Poor housing conditions (eg utilities not working)	(23), (31), (32), (39), (48), (56), (61), (66)
Occupational exposure	(27), (44)
Climate eg seasonality and/or control of vectors	(28), (43), (45), (58), (68)
Management of water supplies (eg private water supplies)	(35), (40)
Sociocultural	
Partnership with communities	(20), (67)
Population mobility of Indigenous people	(23), (36), (42), (43), (45), (48), (57), (62), (69)
Socioeconomic disadvantage (eg low household incomes)	(25), (32), (66), (67)
Lifestyle exposure (eg health behaviours or leisure activity)	(27), (30), (31)
Improving community education	(54), (56), (61), (68)
Stigma and marginalisation	(54)
Healthcare service	
Culturally appropriate care	(26), (39)
Increased screening and/or surveillance	(20), (33), (39), (42), (61), (69), (34)
Logistics of vaccine delivery and laboratory testing	(23), (29), (36)
Lack of healthcare staff	(26), (39), (54), (62)
Community-level vs individual screening and treatment	(26), (36), (45), (48)
Awareness of signs, symptoms and appropriate treatment	(31), (37), (44), (54)
Effectiveness of immunisation programs	(34), (38)
Healthcare costs	(41)
Data management	(43)
Lack of access to healthcare services	(36), (60)

This review also highlighted that more analytical or experimental evidence is required to better demonstrate which strategies or interventions targeting the social determinants of health might be effective at reducing the burden of communicable diseases for rural and remote communities. However, the challenges with conducting this type of research cannot be underestimated[80]. Some of these challenges may include the need to select the best correlates or indicators of the social determinants and health outcomes to monitor over time and the number or type of intervening variables that can ultimately affect the dose relationship between intervention strategy and health outcomes. In addition, the difficulties with smaller populations in having sufficient power for intervention studies, the vast distances between communities, as well as issues with conducting large studies over a long timeframe, make the design of these intervention studies challenging in terms of trying to demonstrate impact.

Despite the methodological difficulties mentioned above, addressing the social determinants of communicable diseases in rural and remote communities of Australia is a public health priority that will require intersectoral action and multicomponent public health programs. Frameworks[81] or tools[82] that assist public health practitioners with the design or conduct of these studies will help promulgate this type of research. Epidemiological or research studies that include community-based partnerships[83] can also be an important way to empower local communities to address locally relevant public health issues (eg including community-based views in the design of services or programs or training local

community members and/or health staff to help deliver enhanced services).

Limitations

Given the difficulties associated with keyword searching and comprehensively searching the grey literature, we will not have identified every eligible article for review; however, our review process was systematic and covered a decade. The possible pathogen-related cause or development of some non-communicable diseases was not a focus of this review. Also, the published literature only provides an insight into the true burden of communicable diseases experienced by rural and remote communities of Australia.

Conclusions

Communicable diseases remain an , important cont, ributor to preventable morbidity in rural and remote communities of Australia, particularly for Aboriginal peoples. There is growing recognition of the role of sociocultural and environmental factors in contributing to this burden of disease. Overall, there is a lack of high-level evidence demonstrating which strategies or interventions might be the most effective at alleviating the social determinants of the communicable disease burden experienced by rural and remote communities. Further investment into higher quality community-based research that aims to provide an epidemiological and social understanding of the burden of disease in order to develop evidence-based prevention and control strategies is needed.

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