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MANATŪ HAUORA
MINISTRY OF HEALTH

Evidence Brief:
Invasive group A streptococcus and skin infections

Office of the Chief Science Advisor,
Te Pou Whakamārama – Evidence Research and Innovation

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This document is an evidence brief and as such, the findings do not reflect government policy. It is intended as background to support health agencies' further work.

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Executive summary

Background and context

Group A streptococcus (GAS) bacteria is a pervasive pathogen, spread through airborne droplets and skin-to-skin contact, that may lead to invasive group A streptococcus (iGAS), post-streptococcal glomerulonephritis (PSGN), acute rheumatic fever (ARF) or rheumatic heart disease (RHD). The onset of iGAS is often sudden, and the disease progresses rapidly. It can result in serious health outcomes such as loss of limbs or severe scarring, brain damage, hearing loss or learning disabilities. Without timely treatment, sepsis can rapidly lead to tissue damage, organ failure and death.

People with socio-economic disadvantage are at greater risk of GAS and iGAS infections; the prevalence of GAS infections is commonly associated with low-quality and inadequate housing. Lack of access to clean water, homelessness and drug injection are other contributing risk factors.

Physiologically, the role of GAS infections in pharyngitis is well understood, likely because of its role in the sequalae of ARF. However, there is increasing recognition of the role of GAS skin infections in the development of iGAS, ARF, RHD and PSGN.

Since 2022, the number of iGAS cases reported has increased internationally, including in New Zealand. Case rates have increased beyond those recorded in 2017 (pre-COVID-19 pandemic), and cases in 2023 showed large ethnic disparities. Pacific peoples had the highest case rates (37.5 per 100,000), followed by Māori (20.1), European and other ethnicities (6.9) and Asian people (5.6). In 2023, the decision was made to start the process to make iGAS a notifiable disease in New Zealand. The Deputy Director of Public Health commissioned this evidence brief in anticipation of iGAS being made a notifiable disease in 2024.

The aim of the brief was to:

1. review national and international research on links between GAS skin infections/impetigo and iGAS disease, PSGN, ARF and RHD
2. report on international evidence on population interventions to treat GAS skin infections and the impact (if any) on iGAS as well as PSGN and ARF/RHD
3. investigate the potential for a retrospective (or prospective) case review/research of iGAS and PSGN cases to look at modifiable risk factors.

Scope of the brief

The brief reports on a systematic review of the prevalence of GAS skin infections in cases of iGAS, ARF, RHD and PSGN. It also reports on a scoping review of the evidence on risk factors and prevention of GAS skin infections and provides an analysis of knowledge gaps within the current evidence to inform future research priorities.

Key findings

Prevalence of skin infections and GAS-mediated diseases and risk factors for GAS skin infections

The review's findings in relation to the prevalence of skin infections and GAS-mediated diseases and risk factors for GAS skin infections were as follows.

- A GAS skin infection (from any cause) is a significant precursor of iGAS, regardless of the geographic location, target population, nature of the health care system or whether the country was a high- or low-income setting.
- Co-existing conditions, particularly diabetes mellitus and alcohol consumption or injecting drug use, increased the likelihood of a GAS skin infection progressing to iGAS.
- Skin infections appear to be a precursor to acute PSGN.
- Evidence directly linking the presence of a GAS skin infections with a ARF and RHD diagnosis is limited; however, evidence is emerging that skin infections play a role in priming the auto-immune response causing these diseases.

Exposure to the GAS pathogen

The review identified a number of risk factors leading to increased exposure to the GAS pathogen. A number of these are associated with social determinants of health: for example, crowded or poor-quality housing; material hardship; living in a low-decile community; and lack of access to adequate laundry, washing and bathroom facilities. Other risk factors included eczema; scabies; head lice; itchy insect bites; wounds; surgery; injecting drug use; delayed diagnosis or misdiagnosis of skin conditions or infections; an age of <5 years or >75 years; Māori or Pacific ethnicity; co-morbidities such as diabetes, chronic kidney disease or long-term mental health conditions or addiction; and limited mobility.

Prevention of GAS skin infections

The review found that key evidence-based strategies for prevention of GAS skin infections were:

- providing high-quality and suitably sized houses
- improving access to potable water, hot water and providing support for maintenance of environmental and personal hygiene
- reducing the stigma attached to skin conditions such as scabies, head lice and impetigo
- implementing culturally supported public health messaging about preventative health behaviours
- tailoring health messaging to at-risk population groups

- increasing clinical training on and improving awareness of treatment pathways for skin infections
- providing community-based clinics and outreach programmes
- implementing targeted eradication and treatment regimens for scabies
- improving surveillance of GAS skin infections in ARF and iGAS case notification systems.

Conclusions

In New Zealand, numbers of iGAS cases have recently increased, and there are large ethnic disparities in case rates. Evidence shows GAS skin infections are a common precursor in cases of iGAS and PSGN and are likely playing a priming role in auto-immune responses leading to ARF and RHD. Prevention of GAS skin infections requires timely appropriate clinical management of a variety of skin conditions and breakages, as well as evidence-informed multi-pronged public health approaches, including immunisation.[1]

[1] The Ministry of Health has supported the funding of a 2021–2025 research project led in the University of Auckland to develop a streptococcus A vaccine.

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Commissioning brief

On 28 November 2023, as part of the process and decision-making for invasive group A streptococcus (iGAS) becoming a notifiable disease, the Deputy Director of Public Health asked the Office of the Chief Science Advisor to:

4. review national and international research on links between group A streptococcus (GAS) skin infections/impetigo and invasive group A streptococcal (iGAS) disease, post-streptococcal glomerulonephritis (PSGN), acute rheumatic fever (ARF) and rheumatic heart disease (RHD).

5. report on international evidence on population interventions to treat GAS skin infections and the impact (if any) on iGAS as well as PSGN and rheumatic fever/RHD.

6. investigate the potential for a retrospective (or prospective) case review/research of iGAS and PSGN cases to look at modifiable risk factors.

The Office of the Chief Science Advisor used several research methods to deliver this project, and has structured the evidence brief around these three components.

Introduction

Since 2022, there has been an increase in the number of invasive group A streptococcal (iGAS) cases reported internationally, including in the United Kingdom, the United States of America, Australia and other countries around Europe Bennett et al. (2023); (World Health Organization, 2022). In the latest surveillance report from the Institute of Environmental Science and Research (ESR) Aotearoa New Zealand has experienced the same trend, with the highest numbers of cases and rates reported in 2023 since at least 2002 (Institute of Environmental Science and Research Limited, 2024).[2] Although iGAS is rare, it can cause serious infections, including necrotising fasciitis, bacteraemia, meningitis, sepsis or streptococcal toxic shock syndrome, which often require hospital care and are associated with significant morbidity and mortality (Bennett et al., 2023; Cannon et al., 2021; Centers for Disease Control and Prevention, 2022a; World Health Organization, 2022). iGAS is a preventable disease, and its burden can be minimised through primordial, primary and secondary prevention approaches, such as targeting risk factors for GAS skin and throat infections.

In response to an increase in the incidence of iGAS, the World Health Organization (2022) released an outbreak update. It recommended enhanced surveillance and vigilance in monitoring case rates of iGAS, advising that countries should report any unexpected increased national or regional incidence. It said that any clusters should be reported to local, regional or national health authorities, to allow them to assess ongoing iGAS risk and keep track of circulating strains, to promptly identify potential outbreaks (Bennett et al., 2023; World Health Organization, 2022). This evidence brief explains the context of iGAS in Aotearoa New Zealand in relation to skin infections and provides current international evidence to support decision-making on additional actions that may help reduce morbidity and mortality.

Invasive group A streptococcal infections are caused by β-haemolytic group A streptococcus (GAS) (also known as *Streptococcus pyogenes*), a highly contagious bacteria (Centers for Disease Control and Prevention, 2023a). Group A streptococcus can be carried in the general population (where people are colonised with the bacteria, but not infected with an associated disease). In the context of GAS skin infections, the role of asymptomatic carriage is still being explored (Lacey et al., 2023). GAS most often causes mild to moderate superficial infections, including of the throat (e.g. pharyngitis, commonly referred to as strep throat, and tonsilitis) and skin (such as impetigo, also known as school sores, and erysipelas, a surface skin infection) (Birrell et al., 2023; Cannon et al., 2021; Centers for Disease Control and Prevention, 2022a). GAS can also cause severe infections when it becomes invasive (Bennett et al., 2023; Birrell et al., 2023).

In Aotearoa New Zealand, iGAS is clinically defined in line with other international definitions as GAS isolation from a normally sterile site (eg, blood or cerebrospinal fluid), with or without evidence of severity, or as isolation of GAS from a non-sterile site, with evidence of severity (e.g. necrosis or meningitis) (Communicable Diseases Network Australia, 2024; Institute of Environmental Science and Research Limited, 2022). GAS can also trigger immune-mediated diseases, including acute rheumatic fever (ARF) and post-streptococcus glomerulonephritis (PSGN), through repeated GAS

[2] See page 15 for case rates and reporting trends

exposure and priming. These diseases can have severe sequalae, such as rheumatic heart disease and renal complications (Bennett et al., 2023; Bennett et al., 2022; Cannon et al., 2021; Hoy et al., 2012).

The intent of this evidence brief is to explain the context of iGAS in Aotearoa New Zealand. The brief builds upon the GAS and ARF evidence synthesis published by the Office of the Prime Minister's Chief Science Advisor (2021), the national Rheumatic Fever Roadmap published in 2022 (Health New Zealand, 2023c) and an evidence brief provided by Intelligence, Surveillance and Knowledge, Public Health Insights (Ministry of Health, 2023b), which outlines the advantages and disadvantages of making iGAS a notifiable disease in Aotearoa, including evidence-based interventions and actions that should be followed after a confirmed case of iGAS has been identified.

The review by the Office of the Prime Minister's Chief Science Advisor highlighted that GAS skin infections were being increasingly recognised in the development of ARF (2021). It was noted, however, that there was 'weaker evidence' with regards to GAS skin infections and the mechanism of the sequalae to ARF is not well understood. Further investigation of GAS skin infections was labelled as 'essential' and 'urgent,' particularly as it may provide new opportunities for ARF intervention (Office of the Prime Minister's Chief Science Advisor, 2021). The national Rheumatic Fever Roadmap highlights this gap in the evidence and it includes plans to support further research about skin infections and interventions (Health New Zealand, 2023c). These observations highlight that there is a gap in evidence on GAS skin infections which also apply to iGAS, as well as ARF.

iGAS and GAS skin infections as a risk factor

iGAS onset is often sudden and rapidly progresses (Australia Central Territory Government. Health, 2023; Bennett et al., 2023). People who develop iGAS need to be immediately treated in hospital and administered antibiotics. However, individual management is dependent on the manifestation of iGAS (Health Direct Australia, 2024). Clinicians may treat household or close contacts of people who develop iGAS with preventative antibiotics to reduce the spread of GAS bacteria and reducing the household risk of iGAS (Health NSW, 2023; UK Health Security Agency, 2023).

There is a substantial research gap on the disabling or other long-term outcomes of iGAS disease and how these contribute to the overall burden of the disease. It is known that the different manifestations of iGAS can result in serious health conditions, but long-term health outcomes from these are less researched. Necrotising fasciitis can result in life-long complications, including loss of limbs or severe scarring (Centers for Disease Control and Prevention, 2022c). Bacterial meningitis can cause serious complications, such as brain damage, hearing loss or learning disabilities (Centers for Disease Control and Prevention, 2021). Without timely treatment, sepsis can rapidly lead to tissue damage, organ failure and death (Centers for Disease Control and Prevention, 2023b), and toxic shock syndrome can be complicated with organ failure, tissue necrosis and loss of extremities (Centers for Disease Control and Prevention, 2022e).

Due to historical and socio-political contexts, some populations experience the burden of iGAS at greater rates than others. Indigenous peoples and people in low-income countries have higher rates than non-Indigenous peoples and people in high-income countries. In 2017, First Nations populations in Alberta, Canada, had a six times higher incidence rate of iGAS compared to the non-First Nations population (Tyrrell et al., 2021). Similarly, in Australia, there is a consistently higher rate of iGAS among Indigenous peoples compared to the rate among non-Indigenous peoples (Abo et al., 2023; Hendrickx, 2017; Wyber et al., 2020). Globally, GAS and iGAS are more prevalent in people with socio-economic disadvantage (Coffey et al., 2018; Loeven et al., 2023), and prevalence of GAS infections is commonly associated with low-quality and inadequate housing (Coffey et al., 2018; End Rheumatic Heart Disease Centre of Research Excellence, 2020; Loeven et al., 2023; Loewen et al., 2017; Romani et al., 2017). There is evidence that links a lack of access to clean running water for use in washing hands, clothes and bedding to higher scabies transmission and GAS infection (Abugrain et al., 2024; Armitage et al., 2019; Bernigaud et al., 2020). It has been reported that iGAS can be more common in people experiencing homelessness (PEH) and people who inject drugs (PWID) compared to the housed and non-drug injecting population (Loeven et al., 2023; Valenciano et al., 2021).

GAS skin infections

GAS bacteria is a pervasive pathogen, spread through airborne droplets and skin-to-skin contact (World Health Organization, 2022). It can also be transferred by contact with inanimate surfaces and has been found to have contaminated fomites (objects/materials likely to carry infections) for up to four months (Nabarro et al., 2022). GAS infections can cause the autoimmune diseases ARF and PSGN (Chong et al., 2023; Dowler & Wilson, 2020; Limm-Chan et al., 2020; Sika-Paotonu et al., 2017). Much of the current literature on GAS infections in Aotearoa New Zealand focuses on pharyngitis, likely because of its role in the sequalae of ARF (Cannon et al., 2021). There is an increasing recognition of the role GAS skin infections play in the trajectory of disease development to iGAS, ARF and PSGN, but limited research nationally examining this (Baker et al., 2023; Barth et al., 2022; Bennett et al., 2022).

It has been hypothesised for some time that GAS skin infection may be a significant risk factor for GAS-mediated diseases, and there is increasing evidence to support this. Studies in Australia have found that Aboriginal and Torres Strait Islander communities with high rates of ARF have shown low rates of GAS throat infection (pharyngitis) but higher rates of GAS skin infection (impetigo) (Currie & Brewster, 2002; McDonald et al., 2004; McDonald et al., 2006). There are also more recent case reports of GAS skin infection leading to ARF in the absence of GAS pharyngitis (O'Sullivan et al., 2017). Aotearoa New Zealand research is building additional evidence that GAS skin infections are playing a role in the risk of developing these serious GAS-mediated diseases.

An in-depth examination of risk factors for ARF found that first-episode ARF cases were significantly more likely than controls to self-report a definite or probable skin infection.[3] The highest risk was seen when a child reported both a skin infection and a sore throat (Baker et al., 2022; Baker et al., 2019). A larger study which included data

[3] This study did not report any laboratory testing of the skin infections to confirm GAS positivity.

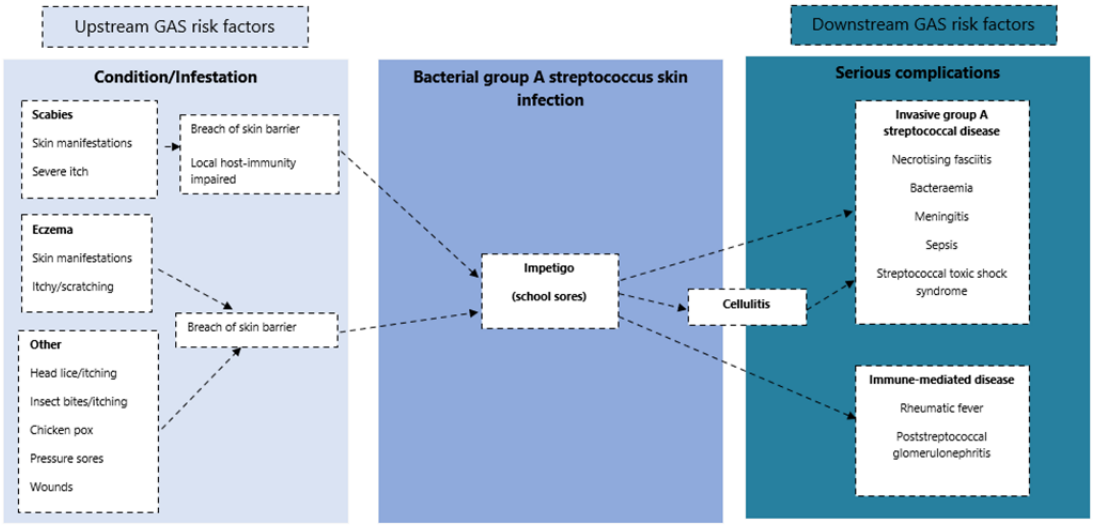
from 436,798 skin swab culture results from the Auckland population over an eight-year period (2010–2017) detected GAS in 12.7% of the skin samples (compared to 14.3% positive throat swabs). The risk of hospitalisation for ARF was highest in the 8–90 days following a GAS-positive skin swab, particularly for children aged 10–14 (Oliver et al., 2021). The role of GAS skin infections in ARF is also being linked through the 'immune priming' hypothesis (Steer et al., 2007). In the study by Lorenz et al. (2021), 33 participants with ARF were shown to have a history of repeated exposure to GAS infections from either throat or skin compared to matched controls. Whitcombe et al. (2022) have also shown that GAS skin infections produce a greater antigen magnitude and breadth in immune response than GAS pharyngitis.

Pathogenesis of iGAS and GAS skin infections

GAS can enter the skin via a wound or break in the skin barrier. Initially, this manifests as a superficial skin infection, called impetigo. Impetigo is most commonly associated with GAS and/or *Staphylococcus aureus* bacteria (Centers for Disease Control and Prevention, 2022b; Linz et al., 2023). It is also known as pyoderma or school sores, and the resulting blisters can form on the body where skin has been damaged and bacteria has entered (Ministry of Health, 2024). Impetigo can also be secondary to itching and skin abrasion caused by other conditions, such as insect bites, scabies, head lice, eczema or varicella (chicken pox), all of which can break the barrier of the skin and allow entry of GAS bacteria (Centers for Disease Control and Prevention, 2022a; Miller et al., 2022). If an initial infection of GAS-associated impetigo is left untreated, the infection can spread to deeper layers of the skin and cause more invasive manifestations of this disease, including abscesses and cellulitis (Centers for Disease Control and Prevention, 2022a). From here, GAS bacteria can further invade the bloodstream and lead to iGAS, which presents as a variety of severe diseases, as noted above (Bennett et al., 2023; Cannon et al., 2021; World Health Organization, 2022).

Eczema or scabies where a secondary GAS skin infection (impetigo) has developed is increasingly accepted as a precursor to iGAS (Aung et al., 2018; Lacey et al., 2023). There is a high incidence of both eczema and scabies in Aotearoa New Zealand, particularly among children (Bennett et al., 2022; Clayton et al., 2013). The most recent New Zealand Health Survey (Ministry of Health, 2023a) found that 18% of children under the age of four had clinically diagnosed eczema. Additionally, in the peak age group of scabies prevalence (15–19 years), there were 665.8 new cases per 100,000 in 2019 (Global Burden of Disease, n.d.).

Figure 1: Theoretical skin infection and iGAS disease pathogenesis/sequence



GAS skin infections, iGAS, ARF, RHD and PSGN

International evidence

To examine the international evidence about the prevalence, incidence and associations between iGAS, ARF, RHD, PGSN, and GAS skin infections (including impetigo and cellulitis, infected eczema and scabies), a systematic review was undertaken following the Joanna Briggs Institute (JBI) method for systematic reviews of prevalence and incidence studies (Munn et al., 2017). The inclusion criteria, quality appraisal instrument and search strategy results are provided in **Supplementary Material 1**. The JBI Critical Appraisal Instrument for Studies Reporting Prevalence Data (Munn et al., 2015) was used to assess each of the 40 studies identified in the initial literature search. A list of these 40 studies, the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flowchart of the selection process and a summary of decision-making for inclusion or exclusion is provided in **Supplementary Material 1**. Two team members independently scored the studies with 12 confirmed for inclusion. A summary of evidence table is provided for theses 12 studies in **Supplementary Material 2**.

The 12 papers were made up of four studies focusing on the prevalence of iGAS (Bocking et al., 2017; Nwosu et al., 2023; Thean et al., 2021; Valenciano et al., 2021); three studies focused on prevalence of GAS and skin infections (Armitage et al., 2019; Chang et al., 2019; Taiaroa et al., 2021); three studies focused on the prevalence of acute post-streptococcal glomerulonephritis (APSGN) (Chong et al., 2023; Dowler & Wilson, 2020; Limm-Chan et al., 2020) and two studies focused on the prevalence of ARF or RHD (Arumugam et al., 2024; Hempenstall et al., 2021). The studies were from Canada (two), the United States (one), Fiji (one), the Gambia (one), Uganda (one), Samoa (one), Australia (four), Hawai'i (one) and India (one).[4]

As the 13 studies were all of diverse population cohorts, a meta-analysis of prevalence was not possible. The main characteristics of the population cohorts were: Indigenous (five), people who inject drugs (PWID) and/or are experiencing homelessness (PEH) (one), rural/remote/island (two), regional hospital catchment (three), peri-urban (one) and school district-based (one). Nine studies focused on children/young people aged under 21. The remaining four were inclusive of all ages, and all were focused on iGAS prevalence. To capture the evidence of these studies in a systematic way, a narrative synthesis has been provided below under each of the diseases of interest. A general summary of the population and variables covered in each study is provided and any specific prevalence findings related to each of the diseases of interest is presented.

[4] Note that some studies assessed reported on incidence, while others reported on prevalence or absolute case numbers. These have not been used interchangeably in this document.

Summary of research quality

Based on the JBI Critical Appraisal Instrument, the quality of the studies was generally high (see **Supplementary Material 3** for individual scoring for each study). The main reduction in scoring related to a lack of adequate reporting on the clinical diagnosis of a skin infection or condition. Only two studies defined and clinically tested for the skin infection in ways that met the inclusion criteria 'infected clinically diagnosed eczema, impetigo, cellulitis or scabies'. Valenciano et al. (2021) differentiated between acute and chronic skin conditions, and Chang et al. (2019) tested for bacterial, fungal or viral skin conditions and ectoparasitic infestation. The remainder classified most lesions as 'skin infections' or impetigo. The absence of accumulative diagnoses is a major weakness as it reduces clinicians' ability to effectively treat root causes and support the prevention of recurring infections.

Other limitations in the 12 papers included small sample sizes and loss of participants to follow-up in two studies (Chong et al., 2023; Dowler & Wilson, 2020). There was minimal incorporation of household/close contact testing: this was only present in one study (Arumugam et al., 2024). Socio-demographic variables outside age, sex and ethnicity were inconsistently included across the studies. Valenciano et al. (2021) examined a cohort of PEH and/or PWID in 10 states in the USA. Two studies included access to water or utilities for washing (Arumugam et al., 2024; Dowler & Wilson, 2020) and two others considered household crowding (Arumugam et al., 2024; Hempenstall et al., 2021). One study included employment status (Hempenstall et al., 2021) and three included seasonal variation (Armitage et al., 2019; Bocking et al., 2017; Taiaroa et al., 2021).

Confounding variables were included in some data collection and analysis, but inconsistently across the studies. Co-morbidities were analysed in terms of incidence in three studies (Bocking et al., 2017; Dowler & Wilson, 2020; Valenciano et al., 2021) and injecting drug use and alcohol dependency in two (Bocking et al., 2017; Valenciano et al., 2021). Some studies featured were *emm*[5] typing (Bocking et al., 2017; Thean et al., 2021; Valenciano et al., 2021) and one study looked at antimicrobial resistance (Armitage et al., 2019). No studies completed any multi-variant statistical analysis to include confounding variables or socio-demographic data.

iGAS

There was no definitive evidence in any of the iGAS studies which estimated the prevalence and/or incidence of GAS-infected eczema, impetigo, cellulitis or scabies as the source of the invasive infection in the cohort. There was evidence which identified cellulitis as the cause in two studies, where 55.0% iGAS cases in Canada (Bocking et al., 2017) and 48–55.0% of iGAS cases in PEH or PWID in the United States (Valenciano et al., 2021) had clinically observed cellulitis. A less specific description, 'skin infection', was also reported in similar proportions in British Columbia by Nwosu et al. (2023), with 47.0% of 101 cases, and 53.3% of 70 cases reported by Thean et al. (2021) in Fiji identified as having a skin infection. Bocking et al. (2017) found underlying chronic

[5] *Emm* typing is based on sequence analysis of the *emm* gene that dictates the M serotype, responsible for at least 100 *Streptococcus pyogenes* (GAS). These serotypes allows different strains of GAS to be distinguished.

unspecified skin conditions in 38.5% of cases, a much higher proportion than in Valenciano et al. (2021), where only 7–11% of cases (depending on sub-group) reported a chronic skin condition (psoriasis, eczema or chronic skin ulcers). Acute skin breakdown was much more prevalent: Valenciano et al. (2021) found that 46% of PWID or PEH admitted with iGAS had an acute wound, burn, varicella or recent surgery. Nwosu et al. (2023) also reported a skin injury or skin damage in 46% of 101 iGAS cases.

The only study to report on seasonal difference found that in North-western Canada the majority of iGAS cases occurred during the autumn-winter months (Bocking et al., 2017). Diabetes mellitus was the most common co-morbidity associated with iGAS cases: Bocking et al. (2017) reported 38.5% of iGAS cases had a diabetes diagnosis, and Thean et al. (2021) reported 46.7% of cases did so. These studies did not report any incidence of skin infections or skin conditions among the people with diabetes.
The 65 iGAS cases reported in Bocking et al. (2017) were more likely to have serotypes associated with skin and generalist *emm*-type strains than throat strains. A similar finding was reported in Thean et al. (2021), where almost all iGAS isolates belonged to *emm* types and *emm* clusters associated with skin infections. Valenciano et al. (2021) found most cases were part of the E *emm* cluster, and these clusters differed substantially from clusters found in the cases who were not homeless or who did not inject drugs, suggesting different strains circulating in different social groups. In the remote Island Health region, in British Columbia in Canada, the dominant 49, 83 and 92 *emm* types had been uncommon in the preceding five years, suggesting a change of circulation in strains in the region which coincided with the highest rates of iGAS reported in the region for the last six years (Nwosu et al., 2023).

GAS skin infections

No studies found evidence of GAS skin infection with source classification by eczema, scabies or other skin conditions or wounds. Impetigo was the most commonly reported skin complaint. In a study of 3,265 skin swabs from Ugandan school-aged young people (Chang et al. (2019), the 25 GAS positive skin swabs were more likely to be clinically diagnosed as impetigo ($p<0.05$). This equated to a prevalence of 0.8%. In Samoa, a much higher prevalence was found for GAS impetigo: 6.0% of active impetigo in a school district was found to be GAS positive (including co-infection with *Staphylococcus aureus* in 22 cases) (Taiaroa et al., 2021). In the Gambia this was higher again for under five-year-old children: 50.8% of impetigised lesions were positive for GAS (Armitage et al., 2019). There was evidence of normalisation of skin infections or sores: 224 of 833 Samoan school children did not report an impetigo lesion when it was clinically observable (Taiaroa et al., 2021). In the Gambia, a history of skin infections was found to increase the likelihood of another infection (Armitage et al., 2019).

Impetigo was significantly associated with scabies infestation by Armitage et al. (2019) and Taiaroa et al. (2021). Other skin conditions, including tinea capitis (scalp ringworm) and scalp folliculitis, were also identified as carrying GAS (Chang et al., 2019). There was little evidence of seasonal change increasing incidence. Only one study reported this variable, finding no change in the proportion of skin-based GAS infections in the Gambia over the rainy season (Armitage et al., 2019). Likewise, only one study tested

anti-microbial resistance, and found that resistance to tetracycline (inhibition zone 15–18 mm) occurred in 29.0% of 21 GAS-positive skin swabs (Chang et al., 2019).

Only one study carried out genome sequencing to generate phylogenetic linkages and give a sense of the spread of infection. It found that from 52 GAS isolates originating from one island in Samoa, a total of 22 *emm* types were present, the most common being emm 101 (7/52; 13.5%), *emm* 100 (5/52; 9.6%) and *emm* 225 (5/52; 9.6%). The most common cluster types were D4 (20/52; 38.5%), E3 (10/52; 19.2%) and E6 (7/52; 13.5%). These types have been isolated from skin and soft tissue infections in other South Pacific nations, including New Zealand and Australia (Taiaroa et al., 2021).

APSGN and PSGN

Evidence of a prevalence linkage between APSGN and GAS skin infections was limited. Chong et al. (2023) reported a history of preceding skin infections in 65.6% of 96 APSGN cases, of which 23.8% had active skin lesions positive for GAS on admission to hospital. Similarly, in an Australian study of 69 APSGN admissions, 65.2% were identified as being from a GAS skin infection (Dowler & Wilson, 2020). In Hawai'i, a smaller proportion of 106 APSGN cases was attributed to a GAS skin infection: 41% were linked (Limm-Chan et al., 2020).

ARF and RHD

There was very little evidence in the studies connecting ARF and RHD with GAS skin infections. In the study of 30 RHD or ARF cases in India, only two swabs, of 915 taken, were from active impetigo: the rest were throat swabs (Arumugam et al., 2024). In the Australian study, a higher number of cases had skin infections: 16 of 25 cases of newly diagnosed RHD had a GAS-positive skin swab, and there was a history of skin infections in 18 of 25 of the cases (Hempenstall et al., 2021).

Conclusion and research gaps

There remains limited evidence about originating skin conditions/infections and their connections to iGAS, ARF, RHD or APSGN. There is evidence that GAS skin infection (from any cause) is a significant precursor of iGAS, regardless of the geographic location, the target population, the nature of the health care system or whether the country was a high- or low-income setting. There is evidence that co-existing conditions, particularly diabetes mellitus and alcohol or injecting drug use, increased the likelihood of a GAS skin infection progressing to iGAS. There is evidence showing skin infections are a precursor to APSGN. There is limited evidence directly linking GAS skin infections and the prevalence of ARF and RHD.

The main knowledge gaps this systematic review identified were as follows:

- The identification of source skin conditions (eg, eczema, cellulitis, impetigo, scabies or ringworm) and causes of infection (bacterial, viral or fungal) is a significant gap in knowledge. Without this information, the ability to provide appropriate clinical

interventions to prevent these conditions progressing to the serious outcomes of iGAS, ARF, RHD and APSGN is reduced.

- Information on the baseline population-level prevalence of the above skin conditions in high-risk localities or regions is very limited.
- Many of the studies entailed little incorporation of variables such as household contacts, housing conditions, socio-cultural environments, access to appropriate health services, age and presence of co-existing medical conditions. These are important factors in effective management of skin conditions and are likely to influence prevalence rates. This information is also highly relevant for tailoring and targeting clinical advice, public messaging and anti-stigma action.
- There is little knowledge about the influence of seasonal and climatic conditions on the prevalence of skin conditions/infections and/or iGAS. As the climate changes and extreme weather (such as high rainfall and higher temperatures) becomes more common, conditions may arise that increase the risk for exacerbation of some or all of the precursor skin conditions.
- Genotyping of GAS strains isolated from skin infection is still emerging as a surveillance tool. Little is currently known about global, regional and local patterns of the circulation of more invasive strains.

Aotearoa New Zealand evidence

To gather evidence for the Aotearoa New Zealand context, we undertook a scoping review methodology. Scoping reviews identify, characterise and summarise evidence on a topic, including by identifying research gaps. 'Evidence' includes published, peer-reviewed research, evaluations and grey literature.[6] To manage the volume of literature, our search was limited to iGAS and GAS skin infections. We designed the scoping review was designed to answer the following questions:

- What Aotearoa New Zealand-specific research exists that examines the relationship between GAS skin infections and iGAS, and what does this evidence say?
- What is the epidemiology of iGAS, impetigo, cellulitis, eczema and scabies in Aotearoa New Zealand?
- What primordial, primary and secondary preventative measures,[7] treatment guidelines or interventions exist in Aotearoa New Zealand for managing the risk of GAS skin infections and subsequentially reducing the burden of iGAS?

[6] Grey literature included clinical guidance and guidelines, public health directives and other official information related to health

[7] Primordial prevention aims to modify determinants of health at a population level, by targeting the environmental, economic, social or behavioural conditions that are known to increase the future risk of a disease Public Health Educator's Network. (2024). Basic Concepts in Prevention and Health Promotion. In I. McDowell (Ed.), *Association of Faculties of Medicine of Canada Primer on Population Health* (3 ed.). **https://phprimer.afmc.ca/en/part-i/chapter-4/** . Primary prevention aims to prevent the onset of disease via risk reduction strategies ibid.. Secondary prevention of iGAS involves reducing the risk of the disease and/or infection spreading to close contacts of the case Armstrong, A., Hahn-Pedersen, J., Bartlett, C., Glanville, J., & Thyssen, J. P. (2022). Economic Burden of Chronic Hand Eczema: A Review. *American journal of clinical dermatology*, *23*(3), 287-300. **https://doi.org/https://dx.doi.org/10.1007/s40257-021-00669-6** . Tertiary prevention aims to reduce the burden of ongoing health impacts for the individual.

- What research protocols or projects are currently under way on GAS skin infections and iGAS in Aotearoa New Zealand and the wider Pacific?

Methods

Our data collection for the scoping review involved three methods:

1. scoping the literature published in Aotearoa New Zealand over the last 10 years
2. engagement with hauora Māori leadership, subject matter and equity experts and the project leads of related national work programmes
3. a focused wānanga with hauora Māori and equity experts to discuss key design features for future research.

We identified published national evidence from 2013–2023, including grey literature, with support from a senior librarian at Manatū Hauora – the Ministry of Health (the Ministry). We conducted a search strategy (**Supplementary Material 4**) involving three discrete searches:

- research protocols and skin infections – New Zealand, Australia, Pacific Islands and other Indigenous populations (eight publications);
- treatment of GAS skin infections (25 publications)
- qualitative studies on skin infection programmes (four publications).

We reviewed all 37 publications we found through these searches. We sourced additional literature from citing references and from peer review.

We engaged with community, Health New Zealand I Te Whatu Ora (HNZ) and the Ministry subject-matter experts on the rheumatic fever and RHD research, prevention of Strep A and epidemiologists and public health doctors specialising in skin infections, particularly scabies. Our key informants were from Moana Research, Rapua te mea ngaro ka tau, the Strep A Vaccine Development project and the Rheumatic Fever Care Co-ordination system project leads.[8]

We discussed concurrent work programmes and equity issues with representatives from Te Aka Whai Ora – the Māori Health Authority,[9] the Equity and Population Health team and Hauora Māori Tūmatanui team from the Public Health Agency, and the Mental Health and Addictions clinical leads and the Health of Disabled People Policy team within the Ministry. This latter group of internal stakeholders also attended the research design wānanga.

[8] Moana Research is a community based research organisation which leads research for and by Pacific Peoples including for RF and scabies; Rapua te mea ngaro ka tau, the Strep A Vaccine Development project is hosted by University of Auckland and has a multi-disciplinary research programme over a five year period (2021-2025) and; the Rheumatic Fever Care Co-ordination system project is building a national register of all rheumatic fever cases and the care and treatment they receive.

[9] Te Aka Whai Ora – the Māori Health Authority has since been disestablished

Analytical approach

We undertook a content analysis to combine our three data collection methods. We have presented this here with a primary focus on iGAS, skin conditions and infections. As there were many gaps in this knowledge base, we have, at times, referred to evidence within the rheumatic fever and skin infection/disease domains: particularly those entailing cases which had the same precursory GAS infection. We have analysed content in the context of existing interventions and different levels of prevention and/or modifiable risk factors.

To structure the complex information we present this information beginning with iGAS, followed by GAS skin infections, then scabies and eczema. We have used a strengths-based approach to analyse proximate risk factors of iGAS. These risk factors are divided into sections: primordial, primary and secondary prevention strategies. We present these approaches in an order that reflects the breadth of the potential impact on the population.

iGAS

The Institute of Environmental Science and Research Limited (ESR) currently provides surveillance and five-yearly reports on iGAS trends across the 20 regions previously defined as district health boards (DHBs). In addition to this, ESR has recently published an update to include rates for 2023. The rate for iGAS infections in 2023 was 10.9 per 100,000 compared with 9.4 per 100,000 in 2018 (Institute of Environmental Science and Research Limited, 2022, 2024).

As referred to above, the most recent five-yearly ESR report covers the years 2017–2022. This report showed a decline of iGAS cases: from 7.2 per 100,000 in 2017 to 4.8 per 100,000 in 2022[10] (Institute of Environmental Science and Research Limited, 2022). This reduction was not consistent across the health districts with Northland (9.9 cases per 100,000), Whanganui (12.9 cases per 100,000), Bay of Plenty (8.7 cases per 100,000) and Counties Manukau (7.3 cases per 100,000) reporting higher rates (Institute of Environmental Science and Research Limited, 2022). In 2023 rates have increased markedly from 2022 in some regions with Lakes (19.2 per 100,00), Tairāwhiti (19.0 per 100,000) and Counties Manukau (18.9 per 100,000) districts reporting the highest number of cases per head of population (Institute of Environmental Science and Research Limited, 2024).

As iGAS is associated with high mortality rates, it disproportionately contributes to the overall burden of GAS as a disease in Aotearoa New Zealand (Cannon et al., 2021). Mortality between 2005-2014 due to GAS infections in Aotearoa New Zealand has been estimated as 34 cases per year, equivalent to an annual mortality rate of 0.8 deaths per 100,000 population (Cannon et al., 2021). Of these deaths, 91.2–94.1% were due to iGAS, 5.9–8.8% to RHD and 0–2.9% due to chronic kidney disease (including PSGN). Cellulitis and iGAS placed the highest health burden in adults, but for children aged 0-9 years all GAS diseases contribute in similar ways to total health burden (Cannon et al., 2021). In Aotearoa New Zealand, the direct connection between skin

[10] This reporting period includes the COVID-19 pandemic and likely reflects the impact of public health measures on infectious disease transmission

infections like impetigo, and iGAS infections, including bacteraemia, has not been explored.

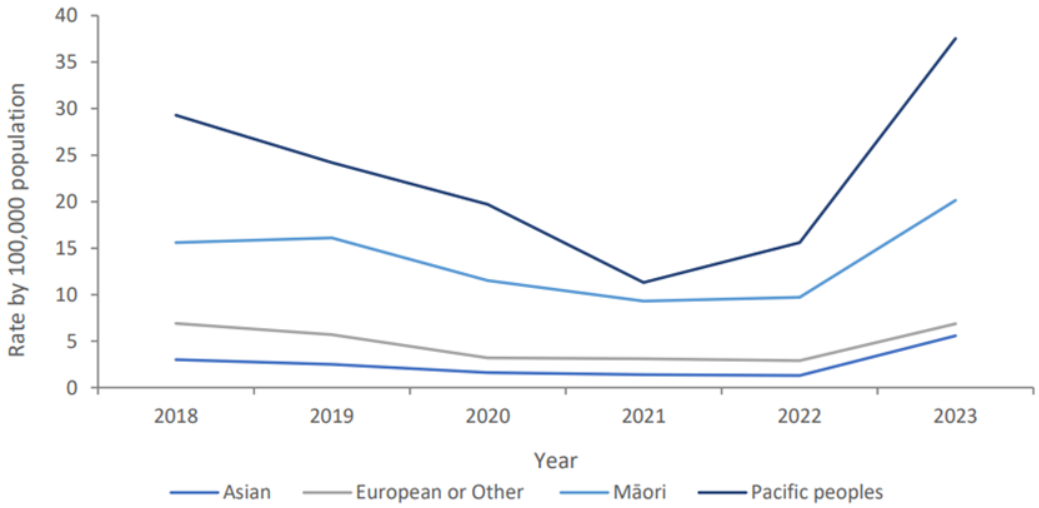
There appears to be no clear seasonal pattern for iGAS infection in Aoteroa New Zealand in the five years to 2022, but when there is a peak in cases, this has tended to be over the summer months (Institute of Environmental Science and Research Limited, 2022). ESR undertakes whole genome sequencing, as surveillance of the circulating iGAS strains in the community (Institute of Environmental Science and Research Limited, 2022). There were 104 *emm* types associated with iGAS infections in New Zealand between 2017 and 2022. Prior to 2019, *emm* 1 was the most common *emm* type, but this strain has steadily decreased since 2018. Since 2020, an increase in *emm* types 92 and 41 has been seen. In 2022, these accounted for 9.4% and 8.1% respectively of all iGAS isolates. In 2022, the most prevalent *emm* types were *emm* 114, *emm* 92 and *emm* 41 (Institute of Environmental Science and Research Limited, 2022).

iGAS inequities

The burden of iGAS disease is not distributed equitably across the population: there are substantial differences depending on age and ethnicity. Despite the decreasing trend in iGAS infections in the reporting period 2017-2022, large disparities in case rates between ethnicities remained at the end of 2022. Pacific peoples were the only ethnicity to report an increase in cases during 2022, with a case rate of 15.6 per 100,000 up from 11.3 in 2021 (Institute of Environmental Science and Research Limited, 2022). In comparison there were 9.7 cases per 100,000 in people who identified as Māori in 2022 (down from 7.9 in 2021) and 2.9 and 1.3 cases per 100,000 respectively in people who identified as European/other ethnicities or Asian in 2022 (compared to 3.1 and 1.4 in 2021). The rates for Pacific peoples and Māori were 5.5 and 3.4 times higher respectively than the rates for European/Other (Institute of Environmental Science and Research Limited, 2022).

In the latest surveillance report for the year 2023, (Institute of Environmental Science and Research Limited, 2022) all ethnic groups reported a substantial increase in case rates since 2022. Case rates in people who identify as a Pacific ethnicity more than doubled at 37.5 per 100,000 as did cases in people who identify as Asian at 5.6 cases per 100,000. Case rates in people who identify as Māori ethnicity doubled to 20.1 per 100,000 as did cases in people who identify as European and other ethnic groups at 6.9 cases (Institute of Environmental Science and Research Limited, 2024).

Figure 2: iGAS infection rates by prioritised ethnicity, 2018-2023



(Institute of Environmental Science and Research Limited, 2024)

Nationally, the age distribution of iGAS cases has continued trends of previous years, following a U-shaped curve; in 2023 the highest rates were in the youngest (25.0 cases per 100,000 for <1 year) and the oldest (35.9 cases per 100,000 for> 80 years) age groups (Institute of Environmental Science and Research Limited, 2024).

There is no iGAS surveillance data pertaining to disabled people or people with lived experience of serious long-term mental distress. The over-representation of disabled people experiencing chronic high-risk diseases and lack of prevention and knowledge of secondary conditions (such as skin infections) in this population has been well documented (Environmental Health Intelligence New Zealand, n.d.; Lockett et al., 2021). It is also well documented that people with long-term mental health conditions and long-term substance-injecting users have a significantly increased incidence of physical co-morbidities affecting their health and shortening their life span (Halstead et al., 2023; Rodrigues et al., 2021).

The higher risks associated with multi-morbidities is supported by a retrospective study of all iGAS cases admitted to hospital in Hawkes Bay from 2016 to 2021. Among these cases, 59% had medical co-morbidities, including diabetes (31%), chronic kidney disease (29%), diabetes and chronic kidney disease (18%), injecting drug use and surgery in the past 30 days (1% each) and having recently given birth (4%); 8% were on immunosuppressing medication (Birrell et al., 2023). Although there is no high-quality data indicating that iGAS is more common among populations with unmet primary care needs in Aotearoa New Zealand, based on known existing risk factors, it is likely that groups who have long-term disabilities, mental health conditions, addiction or chronic health conditions carry a disproportionate disease burden from iGAS infection.

GAS skin infections

Many pathogens can cause infections of the skin. These can be bacterial, ectoparasitic, fungal or viral in origin, and prevention of skin conditions caused by GAS is a modifiable risk factor for iGAS. In Auckland between 2018 and 2019, a study examining the different immune responses from GAS pharyngitis or skin infection in ARF cases

found that GAS skin infections induced greater magnitude and breadth in antibody reactivity compared to pharyngitis (Whitcombe et al., 2022), strengthening the evidence that GAS skin infections are priming the auto-immune system to be more susceptible for ARF and/or PSGN and are a risk factor for iGAS.

An Aotearoa New Zealand-based case control study from 2022 found that children who had GAS skin infections were three times more likely to report having poor or fair general health, in comparison to groups of children with GAS throat infections, GAS carriers and healthy controls (Bennett et al., 2022). Furthermore, children with GAS skin infections were 4.4 times as likely to have been diagnosed with eczema by a doctor (Bennett et al., 2022). In 2010–2016, skin swabs taken in Auckland showed significantly higher GAS positivity in autumn and an increase parallel to higher levels of socio-economic deprivation (Thomas et al., 2021a).

GAS impetigo

Cannon et al. (2021) found that hospital presentations for impetigo decreased with age (with exception of the 80+-year-old age bracket, where they increased slightly) from 97.8 cases per 100,000 for children under four to 3.2 per 100,000 for those over 80. Complications of impetigo can include cellulitis, a bacterial skin infection that invades into the deeper layers of skin tissue (Stevens & Bryant, 2016). Cellulitis can be an intermediary between impetigo and iGAS (Cannon et al., 2021) and contributed the most to the total economic and health burdens of GAS-mediated diseases in this detailed analysis. The highest incidence of hospitalised cases of cellulitis was in those over 80 years, at 582.3 per 100,000. Rates for 0–4-year-olds were the next highest, at 165.8 cases per 100,000 (Cannon et al., 2021).

GAS skin infection diagnosis and treatment

Treatment options for GAS are multi-pronged. They can include hygiene regimes and topical or systematic therapies (Bennett et al., 2021). There are currently no standard national diagnostic or treatment guidelines in Aotearoa New Zealand specifically for the management and treatment of GAS skin infections. Swabbing and diagnosis of GAS is generally recommended for serious or repeated impetigo and cellulitis. Several clinical guidance websites provide information about impetigo and cellulitis and mention *Staphylococcus aureus* and *Streptococcus pyogenes* as the most common causes. The Best Practice Advocacy Centre New Zealand (BPAC) webpage for impetigo recommends swabbing lesions to clinically diagnose the infection type for people with recurrent impetigo or treatment failure with oral antibiotics, or where there is a community outbreak and the cause needs to be identified (Best Practice Advocacy Centre New Zealand, 2021). Community HealthPathways, a platform for distribution of guidance for primary care clinicians to refer to during a primary care consultation, also gives detailed advice for clinical treatment of impetigo and cellulitis which includes swabbing to guide appropriate antibiotic choice (Community HealthPathways, 2024).

For the public, Healthify, a charitable organisation which is endorsed by HealthPathways and HNZ, provides trusted easy-to-understand health information and self-help resources and provides clinical guidance for managing impetigo and cellulitis. The Healthify website does not mention causes of impetigo, swabbing or testing; rather it recommends seeking medical advice for treatment (Health Navigator Charitable Trust, 2022; Health New Zealand, 2024b). Kids Health is another public-

facing website which provides clinical advice for impetigo. This site also does not mention testing for cause bacteria (The Paediatric Society of New Zealand and Starship Foundation, 2024). None of the websites we have mentioned here provided clinical guidance for GAS skin infections as a discrete condition.

GAS skin infection inequities

A large number of intersecting factors increase the risk of GAS transmission and the incidence of skin conditions. The increased risk of developing a GAS skin infection can occur when a person has weakened body defences, lessened mobility, heightened exposure to risk due to living in shared accommodation, inadequate housing and difficulties in physically managing skin infections or infectious disease including a lack of appropriate support to do so (Environmental Health Intelligence New Zealand, n.d.). Unmet primary and secondary health needs are often exacerbated when a person falls into more than one of the population groups known to be less likely to receive the health care they need. People with intellectual disabilities, particularly those with high and complex needs, wheelchair users, older disabled children in state care and people with Down syndrome, often have the most unmet need with regards to diagnosis and management of secondary skin infections (Beltran-Castillon, 2023; Don Beasley Institute, 2013; Faasen, 2023). Other groups likely to have unmet health needs include Indigenous peoples, Rainbow communities, women, people with a disability, those living in material hardship and people experiencing long-term mental health conditions or addiction (Environmental Health Intelligence New Zealand, n.d.; Lockett et al., 2021).

Scabies and GAS skin infections

Scabies is a predisposing factor for impetigo and is an upstream risk factor for invasive GAS infection (Thean et al., 2022). Emerging research has linked scabies prevalence to ARF and RHD (Thornley et al., 2020; Thornley et al., 2018; Thornley & Sundborn, in press-a, in press-b). Scabies is a skin disease caused by infestation by the mite *Sarcoptes scabiei* var. *hominis*. The symptoms of scabies are typically an intense itch and associated rash. Consequential scratching can lead to breaks of the skin, so secondary infections, often of a *Streptococcus* or *Staphylococcus* organism, are common (Lake et al., 2022). Additionally, scabies mites secrete proteins that interfere with a part of the innate immune system (complement), which further allows for the proliferation of bacteria such as GAS (Swe et al., 2014). Over the last two decades, when research has been carried out in communities where GAS skin infections (or impetigo) have been endemic, skin sores and scabies infection have consistently been reported as major drivers of invasive *Streptococci* infection (Carapetis et al., 1999; Mika et al., 2012). In African countries, there have been nation-wide and regional-wide attempts to manage scabies and impetigo, to reduce the upstream impacts of these diseases (Enbiale et al., 2020; Gezmu et al., 2020). Samoa and Fiji have attempted similar prevention strategies due to their high rates of impetigo and RHD (Thean et al., 2022; Willis et al., 2023).

Scabies is frequently misdiagnosed due to its symptomatic similarities to insect bites and eczema (Lake et al., 2022; Thornley et al., 2023). It is often complicated by bacterial infections, such as of GAS, due to abrasion of the epidermis. Additionally, proteins

released by burrowing mites allow for the proliferation of GAS bacteria and evasion of the immune system (Murray & Crane JS, 2023). Scabies spreads through skin-to-skin contact or by sharing clothes and bedding. Therefore, it tends to be more common when people are living in close proximity to one another or in institutions such as schools, aged residential care facilities and prisons (Centers for Disease Control and Prevention, 2010; Health New Zealand, 2024c; Lake et al., 2022). Scabies infestations are increasingly linked to GAS skin infections (Baker et al., 2022; Lake et al., 2022; Thean et al., 2022).

In 2019, the peak age group for scabies in Aotearoa New Zealand was the 15–19-year-old age group (665.8 new cases per 100,000) (Global Burden of Disease, n.d.). The incidence rate was high from ages 1 to 24 years (to a peak of 665.8 new cases per 100,000 in those aged 15–19 years) and decreased thereafter (to a minimum rate of 230.8 cases per 100,000 in those aged 65–69 years). Cases rose again among those older than 70 years (to a maximum of 486.5 cases per 100,000 among those aged 95 years and older) (Global Burden of Disease, n.d.).

Administration of a topical insecticide, permethrin, is the recommended treatment for scabies in Aotearoa New Zealand. Permethrin is available over the counter at pharmacies (Health New Zealand, 2024f). Oral ivermectin, an antiparasitic, is used occasionally if other treatment has not worked or in severe cases of scabies; it requires a medical consultation and prescription (Medsafe, 2023). An entire household should be treated for scabies. Treatment regimens need to be repeated after a week to prevent reinfestation. It is also crucial that all bedding and clothes are decontaminated by being washed, dried and/or sealed at the same time that treatment is applied (DermNet, 2022; Health New Zealand, 2024f).

Eczema and GAS skin infections

Eczema, increasingly called atopic dermatitis or atopic eczema (Kantor et al., 2016), is a chronic inflammatory skin condition characterised by itching, scratching and dry/scaly lesions (Starship, 2022). Eczema can be complicated by bacteria entry through cracks or skin tears that may be worsened by scratching. This can result in skin infections (Eyerich & Ring, 2023). These infections are most often due to *Staphylococcus aureus* or GAS bacterial colonisation, and result in infected (impetigised) eczema (Aung et al., 2018; Lacey et al., 2023). Eczema is most commonly seen in infants and children under five years of age. However, 20–40% of those affected in childhood will continue to experience eczema as adults (Clayton et al., 2013; Eyerich & Ring, 2023). Eczema cannot be spread from person to person. The exact cause of the condition is unknown (National Eczema Association, 2024).

A comprehensive eczema prevalence study in 2001–2003 undertaken by Clayton et al. (2013) found that the prevalence of eczema in Aotearoa New Zealand was consistently lower among people who identified as non-Māori and non-Pacific than those who identified as Māori or Pacific. The study found current symptoms of eczema prevalence in 17.2% of tāmariki Māori and in 20.8% of Pacific children aged six to seven years. In comparison, 13.8% of European/Pakeha children of that age had current eczema symptoms. This trend continues; the 2022/23 New Zealand Health Survey reported that the prevalence of atopic dermatitis among children aged 0–14 years was 17.8% for tamariki Māori, 19.3% for Pacific children and 13.3% for non-Pacific, non-Māori

children (Ministry of Health, 2023c). The New Zealand Health Survey also found a greater prevalence of diagnosed eczema among those aged zero to four (18.0%) compared to those aged five to nine (13.0%) and ten to fourteen (13.8%) (Ministry of Health, 2023c).

Eczema can be controlled with optimal everyday management and treatment of flare-ups. This often involves rigorous adherence to regimes, including bathing daily, moisturising several times a day, taking bleach baths,[11] avoiding environmental triggers or irritants and using corticosteroids in flare-ups (Health New Zealand, 2024e; Stanway, 2022). Over-the-counter management treatments for eczema include emollients and moisturisers (Stanway, 2022; The Royal Children's Hospital, n.d.). Medical prescriptions and clinical oversight are required to manage severe eczema. Topical or systemic steroids may help, and oral antibiotics or bleach baths are recommended if sites show concerning signs of skin infections (Community HealthPathways, 2024; Health New Zealand, 2024e; Stanway, 2022; The Royal Children's Hospital, n.d.). Treatment of eczema is multifaceted; education has been highlighted as an important factor to help families and individuals fully understand the disorder and its personal environmental, food or psychological triggers and irritants (Stanway, 2022).

[11] The addition of a small amount of bleach to the bath is recommended for conditions such as eczema to reduce bacteria on the skin (Community HealthPathways. (2024). *Children and Young Person Health - Skin*. **https://3d.communityhealthpathways.org/13454.htm**; The Paediatric Society of New Zealand and Starship Foundation. (2024). *School Sores In Children*. https://www.kidshealth.org.nz/school-sores-children, The Royal Children's Hospital. (n.d.). Clinical guide index eczema. **https://www.rch.org.au/clinicalguide/guideline_index/eczema/**

Population interventions for GAS skin infections

We undertook a stocktake of interventions through a targeted literature search (**Supplementary Material 5**), a review of literature excluded from the systematic review and of programmes referred to within cited literature. **Supplementary Material 6** presents the studies we included, summarised in terms of primordial, primary and secondary interventions. In Aotearoa New Zealand, (Tu'akoi et al., 2023) undertook a stocktake of preventative interventions for rheumatic fever, including skin infections.

International evidence

Primordial prevention of iGAS

There is limited international evidence of primordial prevention strategies that successfully reduce the burden of iGAS. The interventions we classified as primordial preventative approaches were not necessarily disseminated at a population level, despite this being their intent. This is typical of many primordial prevention approaches. The benefits of such interventions may not be realised when they are not initiated at a population level. A lack of inter-agency collaboration, a lack of sustainability within the target populations and unclear stakeholder communication were identified as key barriers to implementation of these approaches (McRae, Walker, et al., 2023; Phillips et al., 2021). The tables in **Supplementary Material 6** provide further detail of these barriers. The primordial prevention strategies presented below targeted skin infections and skin conditions through interventions focused on personal hygiene and culturally supported public health messaging.

Culturally supported public health messaging

Culturally supported and tailored public health messaging programmes have provided evidence of effective, stigma-reducing, primordial approaches. See, Treat, Prevent Skin Sores and Scabies (SToP) is an emerging initiative tailored for remote Aboriginal children and communities living in the Kimberly region of Western Australia. It aims to reduce the prevalence and consequences of skin infections using a holistic, strengths-based approach that aligns with Aboriginal worldviews of wellness.

A qualitative evaluation of the SToP programme noted that there was a strong knowledge base in the communities in regard to the recognition, treatment and prevention of skin infections (McRae, Leaversuch, et al., 2023). However, this understanding did not extend to the role that skin infections play in causing ARF, RHD and APSGN. This finding may be relevant to iGAS also. Community members demonstrated a reliance on traditional remedies to manage skin infections.

HipHop2SToP was one of the community and youth-led health promotion initiatives under the SToP intervention programme that tailored public messaging to a target audience. The programme involved youth producing a hip hop music video about healthy skin and lifestyle practices. McRae, Walker, et al. (2023) undertook a qualitative process evaluation of HipHop2SToP and found that youth across the community actively engaged in with these videos, validating this Indigenous and community-led approach.

Public health messaging tailored to people who inject drugs

Another example of evidence of intervention at the primordial level addressing skin infections was that of a skin and needle hygiene behavioural intervention called SKIN, which aimed to reduce skin and soft-tissue infections among PWID in Boston. SKIN included two sessions of psychoeducation, demonstrations of positive skin care behaviours and deployed motivational interviewing techniques. The programme was delivered over four years to 128 people (Phillips et al., 2021). In a randomised controlled trial studying the programme 35.0% of participants had a lower rate of skin or soft-tissue infections after completion when compared to those in the control arm. SKIN is an example of a public health messaging intervention addressing stigma. The programme was tailored to a population group already facing social stigma and having historically experienced poor access to health care. It lifted recognition of the health needs of this population group into normalised health care practice.

Primary prevention of iGAS

There is a substantial evidence base regarding that stopping the clinical progression of skin infections occurring in specific skin conditions is a primary prevention of iGAS. In the sections that follow, we summarise the evidence by skin condition and/or approach. A key consideration in primary prevention is the phenomena of normalisation of skin conditions and infections (such a school sores) in primary health care settings (Wyber et al., 2021). Preventative approaches need to address normalisation within communities to ensure timely access to treatment before an infection progresses to serious stages. Additional considerations are noted in the **Supplementary Material 6**.

GAS skin infection management and diagnosis

Two systematic reviews examined pharmaceutical and non-pharmaceutical treatments for GAS skin infections. Gahlawat et al. (2021) reported that in non-endemic settings, ozenoxacin cream (a topical antibiotic) had the strongest evidence of effectiveness. In endemic settings, the strongest performers were oral cotrimoxazole (a systemic antibiotic) and regular intramuscular benzathine penicillin G injections. The second systematic review by Nepal et al. (2018) had a specific focus on strategies to reduce skin infections among Indigenous youth from Canada, Australia and New Zealand. This study found that effective strategies for treatment and prevention of bacterial skin infections included appropriate clinical management of active infections and lesions, improving environmental and personal hygiene and providing access to swimming pools. The role of community swimming pools in the management of skin infections was also noted in a systematic review by Hendrickx et al. (2016). Prospective studies included in this review found that access to swimming pools was associated with a drop in skin sore prevalence and severity, due to the chlorination of the water.

Scabies management and diagnosis

Mass drug administration

Mass drug administration (MDA) is an internationally well-established and researched intervention method to manage endemic scabies. A systematic review in 2021 found that the average absolute reduction in scabies prevalence following MDA was 22%; the average relative reduction was 73.4% (Rinaldi & Porter, 2021). In reducing the prevalence of scabies, MDA can also reduce the likelihood of bacterial complications, including impetigo (GAS skin infections). There is clear evidence of the success of MDA as a scabies treatment option in the Solomon Islands, Fiji and Ethiopia. An MDA campaign based in the Amhara region of Ethiopia aimed to control an endemic outbreak within a population of over 9 million people. Enbiale et al. (2020) outlined a campaign process which included community and health care mobilisation and advocacy, engagement of local leaders, and field implementation and monitoring. A before and after trial in the Northern Division of Fiji aimed to assess the impact of MDA on bacterial complications of scabies within a population of 131,914 (Thean et al., 2022). This study found that the incidence in hospitalisations with skin infections was 17% lower after interventions, and primary health care presentations with scabies and skin infections were 21% lower. Community prevalence of scabies declined from 14.2% to 7.7%, and prevalence of impetigo reduced from 15.3% to 6.1%. There was no evidence of MDA affecting the incidence of childhood iGAS rates and post-streptococcal sequalae (including PSGN), although hospitalisations of these diseases were infrequent in the area.

Studies have demonstrated that MDA as a treatment strategy for scabies and prevention method for skin infections has a long-term impact. Studies in the Solomon Islands and Fiji have revealed a sustained reduction in scabies and impetigo prevalence three and two years respectively after intervention (Marks et al., 2020; Romani et al., 2020). Trials and systematic reviews have found oral ivermectin treatment to be the most effective form of treatment. However, this may not be an option for some groups (eg, for pregnant or lactating people) (Enbiale et al., 2020; Rinaldi & Porter, 2021; Romani et al., 2020). Additional drivers for MDA success include low levels of migration, high levels of uptake and repeated treatment for those diagnosed with scabies at the baseline (Rinaldi & Porter, 2021). One study suggested that MDA should not act as a substitute to tackling the socio-economic factors which contribute to endemic scabies disease, including poor sanitation and hygiene (Rinaldi & Porter, 2021). The authors in Nepal et al. (2018) concluded that until underlying socio-economic conditions were addressed, skin infections would continue to be a burden in some communities.

Much of the evidence base for the treatment and management of scabies in international settings points to MDA as an effective intervention strategy. There is, however, evidence of innovative interventions emerging, including the use of artificial intelligence (AI), tele-dermatology and remote community health providers to enhance diagnosis and management.

Health education interventions

In Nigeria, a school-based educational intervention targeting scabies, including aetiology, risk factors, clinical features, treatment and prevention was introduced into

the curriculum of junior secondary school students. A pre- and post-intervention evaluation (Ibekwe et al., 2020) highlighted that the frequent health talks the intervention entailed increased students' awareness and knowledge of scabies transmission and prevention. Researchers noted that the intervention may have reduced apprehension and stigma with regard to accessing scabies treatment and diagnosis.

A similar health education-based intervention was carried out in rural Ethiopia targeted to health extension workers, who were trained in the identification and reporting of scabies. A comparative cross-sectional study of this intervention revealed that the introduction of trained and educated health extension workers resulted in a reduction in the community load of scabies and secondary skin infection (Gezmu et al., 2020).

E-health platforms and artificial intelligence

eSkinHealth is a novel and innovative health app introduced in sub-Saharan Africa to help with the detection and management of skin diseases in resource-limited settings. This field-adapted platform serves as a portable electronic patient chart including tele-dermatology. Users input data into a computerised system to be analysed alongside an international database related to neglected tropical skin diseases (including scabies). The app was used as a comparative intervention to study the utility of AI as an effective and feasible way to diagnose neglected tropical diseases (including scabies). A mixed-methods pilot study revealed that all participants were satisfied with the app, and community health care providers felt empowered being equipped with this tool (Yotsu, Almamy, et al., 2023). In the intervention arm, AI accurately diagnosed 72.9% of cases through photos and videos within the eSkinHealth app. In comparison in the control arm, of the cases assessed by humans without the use of the tele-dermatology function, 66% were not diagnosed with any specific condition.

The study noted that internet connection was required for certain functions, which may hinder the use of this tool in particular settings. A follow-up pilot study has added to the AI arm of this work by using the data and images collected to examine the diagnostic abilities and feasibility of two neural network models (Yotsu, Ding, et al., 2023). This study found that these models had an accurate prediction rate of 70% when diagnosing neglected tropical diseases[12] including scabies (Yotsu, Ding, et al., 2023).

Eczema management and diagnosis

Caregiver education

A consistent theme in eczema interventions is the education and inclusion of caregivers, to enhance management and treatment of atopic dermatitis among children. A randomised controlled trial in the United Kingdom (Pickett et al., 2016) found that group-based education for children with eczema and their parents resulted in a greater improvement in health-related quality of life and disease severity. The Promotora de Salud programme in Dallas, in the United States, provides an example of a novel culturally tailored caregiver-based intervention. Promotora de Salud is a

[12] Neglected tropical diseases (NTDs) are a diverse group of conditions caused by a variety of pathogens (including viruses, bacteria, parasites, fungi and toxins) and are associated with devastating health, social and economic consequences. They are mainly prevalent among impoverished communities in tropical areas. See **https://www.who.int/health-topics/neglected-tropical-diseases#tab=tab_1**

community health worker programme tailored to Spanish-Speaking Latin American caregivers of paediatric eczema patients. An evaluation by (Joseph et al., 2022) found that culturally competent and language-concordant education interventions can improve confidence in eczema management skills and medication adherence among Latin-American caregivers of children with atopic dermatitis. Caregivers in the Promotora group demonstrated greater self-efficacy and were more confident in the application of wet wraps and the use of bleach baths when compared to the control group. School-based eczema care programmes in Seoul, South Korea, were also found to increase caregivers' knowledge of atopic dermatitis and promote a greater sense of parental efficacy (Ryu & Lee, 2015; Yoo et al., 2018).

Enhancement of health services/providers

Medical-based eczema interventions included an innovative guided practice model called ECHO (Extension for Community Healthcare Outcomes), based in Argentina. The ECHO project is an innovative strategy that aims to support health providers in the management of patients with atopic dermatitis: particularly those living in areas underserved by the health system. ECHO takes place through knowledge-sharing teleconferences between physicians and specialist mentors. An evaluation of the programme one year after establishment revealed a significant improvement in the management of patients with eczema (Luna et al., 2022). Feedback revealed that ECHO had contributed to health care providers' interpretation and use of eczema severity scores, use of phototherapy, and management and prescription of classic and innovative topical and systemic treatments.

Secondary prevention of iGAS

Core to secondary prevention of iGAS are case surveillance, case management, contact tracing and close contact management. Guidelines for these interventions are usually provided as part of the notification system initiated when a disease is publicly notifiable by law. iGAS is notifiable in many countries but is currently not notifiable in New Zealand.[13] Guidelines provided by jurisdictions which where iGAS is notifiable and are in English are provided in **Supplementary Material 6** presents guidelines relevant to jurisdictions where iGAS is notifiable, where those guidelines are published in English.[14]

Across these guidelines, the management of iGAS is not uniform; the guidelines differ in several respects, including:

- mandatory surveillance reporting requirements
- whole genome sequencing of collected isolates
- identification/definition of a high-risk close contact
- recommendations for antibiotic chemoprophylaxis

[13] iGAS is notifiable in the United Kingdom (since 2010), Ireland (since 2003), Canada (since 2000), Australia (earliest state in 2005, most recent in 2022), the United States (since 1995), Spain (since 2022), Switzerland (since 2022), Greece (since 2022), Germany (since 2018), Belgium (since 2016), France (since 2005), the Netherlands and Sweden (since 2004).

[14] Guidelines not published in English include those published by the European Society for Paediatric Infectious Diseases. (2022). *ESPID Committee for Guidelines - Existing guidelines on the management of children with Group A streptococcal infection*. **https://www.espid.org/data/files/Guideline%20Sub-Committee/ESPID%20CfG%20Collection%20of%20GAS%20Guidelines%20Dec%202022.pdf**

- level of recommended intervention strategy (ie, primordial vs primary)
- nation-wide consistency: in some countries this differs considerably due to federal governing structures and how recently guidelines were updated.

The international clinical guidelines that accompany iGAS being notifiable tended to give little information regarding primordial and primary prevention strategies. Most of their recommendations were secondary interventions, to stop the further spread of GAS infections and iGAS.

Surveillance reporting

All countries expected iGAS isolates to be sent to a designated laboratory. There was limited information on mandated reporting of clinical, demographic and risk-factor details entered into central data collections, including whether a root diagnosis of the source of infection was identified.

Whole genome sequencing

Whole genome sequencing is not mandatory for iGAS in the United Kingdom or Australia but has been used in outbreak situations. It is unclear if Canada or the United States routinely conduct whole genome sequencing for iGAS cases.

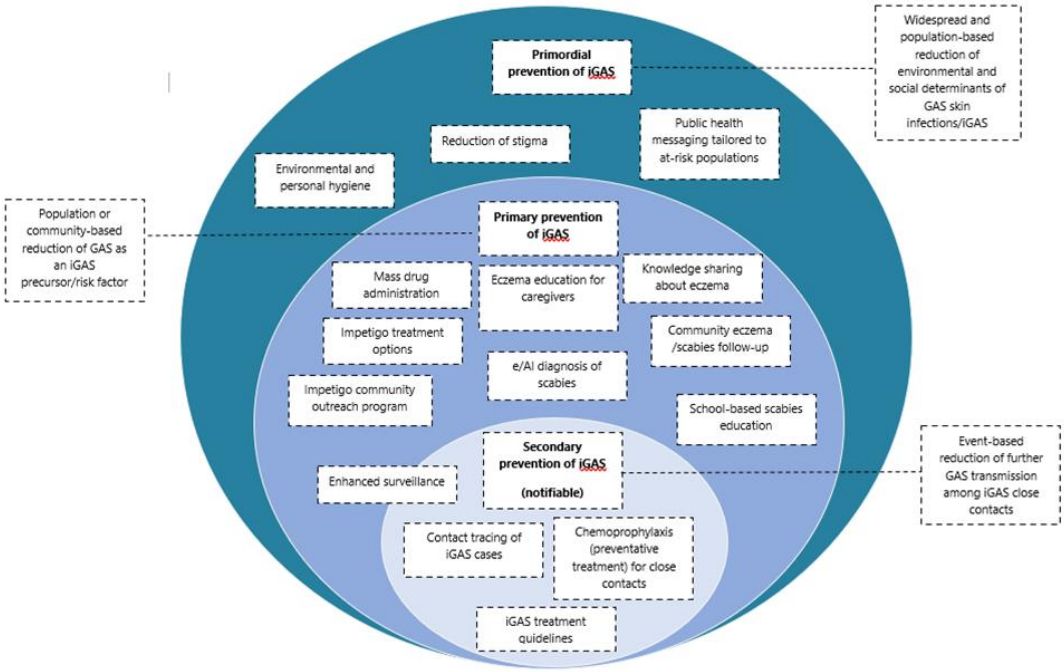
Close contacts

The guidelines varied in their definitions of high-risk close contacts. All iGAS guidelines reviewed identified older close contacts (usually older than 65) and younger close contacts (usually younger than five) to those at higher risk, particularly in institutional settings such as aged residential care facilities and schools. Some national guidelines were more comprehensive in their definition of high-risk close contacts: they included people who were injecting drug users, Indigenous populations, neonate pairs, people with chronic illnesses and people with recent skin injury or breakdown. Recommendations for antibiotic chemoprophylaxis for high-risk close contacts differed. Some guidelines recommended commencement within 24 hours of an index date; others suggested a pragmatic approach, due to a lack of evidence to support proactive chemoprophylaxis.

Conclusion

Primordial, primary and secondary prevention strategies are all required to prevent iGAS. Many of the studies we reviewed for this stocktake suggest that the lack of progress in addressing the burden of skin infections and associated serious health outcomes is due to poor coordination of interventions and a focus on only one level of prevention, as opposed to the incorporation of a combined approach of primordial, primary and secondary prevention in a strategy. Figure 3 illustrates population impacts of iGAS interventions, as described above, by each level of prevention.

Figure 3: Population impacts of iGAS prevention measures



Aotearoa New Zealand evidence

We have analysed the existing prevention strategies that are appropriate for iGAS and associated precursory conditions (GAS skin infections) to better understand the modifiable risk factors of this disease. Currently there is little evidence regarding the minimisation of harm following an iGAS infection at the tertiary level; this brief does not further examine this.

Primordial prevention of iGAS

In the academic iGAS literature and clinical guidelines, advice for primordial prevention of iGAS was often absent. A primordial prevention approach to iGAS would target health determinants that increase the risk of GAS disease and the conditions in which a GAS infection is more likely to become invasive. Primordial prevention strategies for GAS skin infections (including impetigo and infected scabies or eczema) would address the environmental and social factors that significantly affect the likelihood of escalation to more severe infections or repeat infections. In Aotearoa New Zealand, some strategies are already in place; for example, addressing inadequate housing conditions, which may be already affecting the incidence of GAS skin infections (Howden-Chapman et al., 2021; Su & Wu, 2020). Further opportunities include enabling people to maintain personal and domestic hygiene, and addressing the socio-cultural environment; for example, attitudes towards GAS skin infections (Anderson et al., 2023; Curtis et al., 2019; Sylvester et al., 2023).

Housing initiatives as primordial prevention of iGAS

Living conditions are recognised as an important factor for GAS transmission and subsequent disease progression. Inadequate housing factors include crowded living conditions (either due to a lack of rooms or needing to share rooms – 'functional crowding'), a lack of insulation and/or ventilation and inadequate heating (which makes homes cold, damp and mouldy). Another factor is material and financial hardship, which may limit access to clean water, heating, laundry facilities or injury prevention measures (such as rails, smoke alarms or safe hot water temperatures) (Howden-Chapman et al., 2021).

In homes which people live in closer proximity with one another, there is an increased risk of infectious disease transmission (Baker et al., 2013; Trace, 2022). Additionally, where people are exposed to damp, cold or mouldy conditions at home, their general health is likely to be poorer; this can put people at an increased risk of disease progression (Bennett et al., 2022; Howden-Chapman et al., 2021). Bennett et al. (2022) quantified these associations in a case study of 733 children from Auckland in 2018–2019 who had a GAS skin infection. These children were 2.4 times more likely than controls to have experienced household crowding and 1.3 times as likely to have been exposed to dampness or mould in the home (Bennett et al., 2022).

A range of national initiatives across different sectors aim to improve housing conditions in Aotearoa New Zealand. Key initiatives and agencies include the Healthy Homes Initiative (HHI), Housing First, Kāinga Ora – Homes and Communities and Te Tūāpapa Kura Kāinga – Ministry of Housing and Urban Development.

Publicly funded housing

Kāinga Ora and the Ministry of Housing and Urban Development have complementary roles in supporting publicly funded housing and urban development. The Ministry is responsible for leadership in the housing and urban development system, policy, monitoring and advising the Government on strategic direction. Kāinga Ora is focused on providing public housing, providing home-related financial assistance, initiating or undertaking urban development on its own or on behalf of others and delivering aspects of the Government's KiwiBuild programme.

Kāinga Ora is responsible for placing people from the Housing Register into homes, providing tenancy services to public housing tenants, and maintaining and developing public housing. Currently Kāinga Ora provides tenancy services to nearly 200,000 customers and owns and maintains nearly 69,000 public houses. To be considered for Kāinga Ora public housing, people and whānau must go through an application process within the Ministry of Social Development. The application is relatively non-specific with respect to health conditions (Work and Income NZ, n.d.). While Ministry of Social Development assessors are trained to be aware that a family may have changing housing needs because of different medical or disability requirements, this is not a primary focus of the referral process (Ministry of Social Development, 2022).

The Healthy Homes Initiative

The Ministry of Health introduced the HHI in 2013, as a part of the Rheumatic Fever Prevention Programme (Health New Zealand, 2024a). Kāinga Ora and the Ministry of Housing and Urban Development support the HHI. The initiative focuses on the

material conditions of existing houses, aiming to upgrade them to be warm, dry and ventilated healthy homes. The HHI aims to provide healthy housing for pregnant people, low-income families with children at risk of rheumatic fever or aged between 0 and 5 who have been hospitalised with a specified housing-related conditions, and families to whom at least two of eleven defined social investment risk factors apply (these factors relate to crime, deprivation, socio-economic position, mental health, standard of living, access to facilities and physical health) (Health New Zealand, 2024a). In May 2023, it became a nationwide service. At a regional level, different providers implement the HHI. A range of organisations, charities and health care providers are partners (Health New Zealand, 2024a).

An interim evaluation of the programme up to 2019, while not referring to GAS or iGAS specifically, found that the HHI had led to a significant reduction in reported GP visits and pharmaceutical dispensing (Pierse et al., 2019). A similar report in 2022 confirmed these findings and reported fewer hospitalisations in both referred children and wider whānau (Pierse et al., 2022). Additionally, evidence suggests that the HHI is an effective way to address housing inequities. As at 2022, the HHI cohort was made up of 48.7% who identified as Māori and 46.1% who identified as Pacific peoples; therefore, the positive effects of this programme are concentrated within these groups (Pierse et al., 2022).

Housing First

Housing First is supported by the Ministry of Housing and Urban Development. It is a model particularly targeted at people experiencing homelessness, with the primary aim to help people and whānau stay housed and achieve their life goals. A core premise of the model is that it is easier for people to deal with complex issues affecting their lives, such as chronic health conditions and addiction, if they have a stable place to live. Once people are in stable housing, a team, generally including a health professional, provides ongoing wrap-around support to help address underlying issues that may have led to their homelessness. There are Housing First providers in Mid-Far North, Whangārei, Auckland, Hamilton, Tauranga, Rotorua, Hawke's Bay, Wellington, Nelson, Blenheim and Christchurch (Ministry of Housing and Urban Development, 2024a). In 2022, individuals and whānau in the programme reported improved physical and mental health wellbeing, enhanced social relationships, steps toward their aspirations and personal growth (Ministry of Housing and Urban Development, 2023).

The Ministry of Housing and Urban Development and Māori and Pacific housing models

The Ministry of Housing and Urban Development sets the direction of urban development. Its National Māori Housing Strategy, the Māori and Iwi Housing Innovation (MAIHI Ka Ora) framework, acts to shape locational planning, including that of Kāinga Ora's public housing development. MAIHI Ka Ora encourages Māori-led local solutions to housing, through the provision of guidelines and financial support for whānau papakāinga development, which involves 'development of a communal nature on ancestral land owned by Māori' (Ministry of Housing and Urban Development, 2024b). Support for housing alternatives such as these exists as an integral pathway for tangata whenua to live in a way that enhances their cultural, whānau and whenua connections (Tupu.nz, 2024). Such initiatives also allow whānau the autonomy to develop communities and homes which are fit for purpose (Trace, 2022).

Modifiable risk factor: ***Housing***

- There is an opportunity to increase the impact of the HHI, particularly in the context of iGAS prevention, by expanding the eligibility criteria and reinforcing the assessment process. The rheumatic fever eligibility element of the HHI currently includes those aged 0 to 19 years who have had three or more episodes of GAS throat infections (Health New Zealand, 2024a). This could be extended to include serious skin infections and/or repeated incidences within a whānau.
- Initiatives aiming to increase knowledge about skin infections across the HHI network need to address how and where providers can access information, including where to refer for assessment and treatment for skin infections. A nationally consistent referral pathway for HHI and other community housing providers would support this.
- Due to the complexity of diagnosis, treatment regimens and environmental factors for skin infections, further strengthening of connections between HHI and health professionals may be a way to raise awareness of skin infections among community-based workers in the context of the HHI and other housing programmes, such as Housing First.

In a thesis for the University of Auckland, Gemma Malungahu developed a similar housing model, Lolo Na'ati (Malungahu, 2020), based upon Tongan kāinga (temporary home) experiences in Aotearoa New Zealand. Lolo Na'ati aims to provide a strengths-based policy alternative to public housing policies that place Pacific families in a deficit framework (Malungahu, 2020). A housing initiative which looked to include this model would enhance positive health outcomes for Pacific people in Aotearoa New Zealand.

Modifiable risk factor: ***Housing***

Options following Pacific and Māori models for housing design support intergenerational and culturally aligned ways of living. They are designed to provide space for large numbers of whānau to live together in separate and un-crowded dwellings. These models offer an opportunity to reduce GAS and iGAS disease transmission conditions through the design process.

Personal and environmental hygiene as primordial prevention of iGAS

Aotearoa New Zealand researchers have proposed that personal and domestic hygiene comprises one avenue by which GAS infection transmission could be halted (Bennett et al., 2023). As for many infectious diseases, handwashing and personal hygiene can act as a prevention technique for GAS (Centers for Disease Control and Prevention, 2022d). Regular washing of clothing, bedding, surfaces and communal spaces within a house can reduce the transmission of skin infections and the management of skin conditions (Centers for Disease Control and Prevention, 2010, 2022a, 2022d). These preventative measures require unhindered and easy access to water and washing facilities and the

financial means to pay for the necessary electricity, water charges and cleaning products (or a laundromat), as well as the time and ability to carry out the physical labour required (Anderson et al., 2023). Water poverty, access to water and social injustices due to water availability are increasingly recognised as a significant issue in other developed countries (Cooper, 2017; Sylvester et al., 2023; Yoon et al., 2021). In England and Wales, local councils are implementing programmes to address this (Sylvester et al., 2023).

Prevention measures for disabled people and people who reside in shared care settings need special consideration and action (Faasen, 2023). Poor hygiene can lead to skin conditions such as scabies, impetigo or eczema where infections such as GAS can easily arise and be transmitted between residents and carers (Nabarro et al., 2022).

In the context of GAS skin infections, no existing population-level hygiene interventions take into account water accessibility, material conditions and shared residences.

> *Modifiable risk factor:* ***Sanitation, water and hygiene***
>
> There is a need for public health initiatives focused on equitable access to sanitation, water and hygiene to prevent the spread of scabies and assist in the management of severe eczema. Agencies should not assume that everybody has an equal ability to carry out hygiene and sanitation actions. The necessity for appropriately targeted interventions may assist prevention of GAS infections and risks of iGAS.

Reduction of stigma as primordial prevention of iGAS

Skin conditions such as impetigo (GAS skin infection), eczema and scabies can have a significant influence on individuals' psychosocial wellbeing (Horne & Oakley, 2015). People who have neglected tropical diseases, many of which are skin conditions, are known to experience stigmatisation and discrimination within their communities (Dean et al., 2022; Kuper, 2019). Stigmatisation can reinforce feelings of shame and create negative public perceptions (Horne & Oakley, 2015), which, in turn, can prevent people from accessing the health care they require (Trace, 2022). Stigma can be amplified by public health messaging (and education) interventions or through experiences within the health care system (Trace, 2022).

Public health messaging

In light of rising levels of iGAS, the World Health Organization and the European Centre for Disease Prevention and Control recommend public health communication campaigns to educate people about the risks associated with iGAS, as well as symptoms of GAS infections and recommended actions (UK Health Security Agency, 2023; World Health Organization, 2022). This is an important primordial prevention approach, but caution should be exercised in applying it, due to the risks associated with further exacerbating the existing stigma attached to skin infections.

In Aotearoa New Zealand, the rheumatic fever public health messaging campaigns that ran in 2014 and 2015 were effective in recall of information. However, evidence

suggests that the campaign may have had the effect of implying that identifying as Māori or Pacific ethnicity was a cause of getting rheumatic fever. Public health messaging can risk internalisation of blame, guilt and stigma among whānau (Office of the Prime Minister's Chief Science Advisor, 2021). Such approaches can assume whānau are able to prevent disease and fail to consider the broader determinants of health which are caused by societal problems significant drivers of diseases such as GAS, iGAS and ARF (Trace, 2022).

Tu'akoi, Ofanoa, Ofanoa, Lutui, Heather, Jansen, van der Werf, et al. (2022) have highlighted that educational and awareness initiatives that are led by Pacific and Māori communities and target prevention of ARF, including skin infections, have the potential to be more focused, effective and avoid stigmatisation. Communication campaigns need to take particular care with the use of Indigenous languages and be guided by cultural experts to ensure there is not hidden, historical, stigmatising shame attached to the language and terminology chosen (Moana Research, personal communication, 7 December 2023).

> *Modifiable risk factor:* ***Communication and messaging***
>
> Public health communication campaigns can be used as a primordial preventative strategy of iGAS. However, caution should be exercised to ensure that they reduce, and do not unintentionally exacerbate, stigma and inequities. Community-led and locally tailored messaging informed by whānau with lived experience is required to ensure positive messaging about eczema, scabies, impetigo and iGAS care.

Systemic stigmatisation

Systemic processes, functions and operations can exacerbate inequities and internalised stigma by placing blame on Māori and Pacific whānau in both subtle and overt ways (Trace, 2022). Structural complexities (Trace, 2022), racism and a lack of cultural safety (Curtis et al., 2019) already act as barriers to whānau presenting to health care services. Potentially stigmatising conditions may strengthen these barriers further, reducing the likelihood early presentation for health care. Prompt treatment and ongoing support for whānau-centred, culturally appropriate management will help ensure that GAS skin infections do not progress to more invasive conditions.

Communication campaigns need to be targeted to medical practitioners and providers in ways that highlight the impact of stigma and negative perceptions associated with skin conditions. A 2018 qualitative study of Māori and Pacific whānau experiences of ARF found that many participants experienced a dismissal of their concerns about symptoms, resulting in GAS diagnosis being missed (Anderson et al., 2018). Protective factors in health service delivery that reduced a recurrence of rheumatic fever and RHD have been found to include whānau advocacy and support, positive rapport and communication between whānau and health care professionals, and effective communication and referral pathways between health care practitioners (Anderson et al., 2018).

Modifiable risk factor: ***Education and training***

Increasing awareness among health service providers to promote whānau-centric and culturally appropriate skin management may support the reduction of stigma associated with skin conditions and infectious diseases. This may improve our provision of and access to the prompt diagnosis and treatment of skin conditions.

Primary prevention of iGAS

A primary prevention approach to iGAS involves strategies to promptly and effectively diagnose, manage and treat GAS skin infections along with precursory downstream and upstream conditions including impetigo, eczema and scabies. It may also improve health literacy for the treatment of minor skin injuries such as cuts, scrapes and burns. Timely diagnosis and access to community-based local health services were the main primary prevention strategies referred to in the literature.

Diagnosis of skin conditions as primary prevention of iGAS

Prompt and accurate diagnosis of GAS skin infections and eczema or scabies infections is crucial as a prevention of iGAS development (Bennett et al., 2023), to ensure health practitioners with prescribing authority can start primary treatment of GAS skin infections before the disease becomes invasive (Wyber et al., 2020). In recent times, there has been an increasing amount of public and clinical attention on GAS throat infections as a precursor to rheumatic fever (Health New Zealand, 2023c; Office of the Prime Minister's Chief Science Advisor, 2021; Tu'akoi et al., 2023). However, the risks of GAS skin infections are less broadly known, due to a general neglect of attention to skin in primary interventions and causal research. There appears to be a lack of knowledge in the health workforce about the connection between a skin infection or infected eczema/scabies and the development of a severe and invasive disease such as iGAS (Office of the Prime Minister's Chief Science Advisor, 2021; Trace, 2022).

A 2021 structured review of primary interventions to reduce GAS infections noted that it is important for clinicians to identify a GAS infection (particularly strep throat) by proactive swabbing and lab testing (Bennett et al., 2021). Clinical guidelines need to be expanded to include this. Updating clinical guidance for accurate diagnosis of GAS is one of the actions in the Rheumatic Fever Roadmap planned for release in mid-2024 (Health New Zealand, 2023b, 2023c). Prioritising accurate diagnosis of impetigo, eczema and scabies is essential to support the clinical guidance for preventing GAS infections. As noted above, scabies is frequently mistaken for eczema or insect bites (Thornley et al., 2023), and eczema can be misdiagnosed for other dermatological conditions, due to clinicians' overreliance on visual presentation and personal history (Withana & Fernando, 2017). Prompt and accessible diagnosis of GAS skin infections, infected scabies and eczema is crucial to prevent upstream disease escalation to iGAS. Prevention of GAS infections which require antibiotic treatment is a priority related to wider management of the pressing global issues concerning antimicrobial resistance (Bennett et al., 2021).

Along with the difficulty with diagnosis, access to health care services is another common barrier to the prompt diagnosis of GAS skin infections, infected eczema or scabies. Issues such as not having transport, living rurally, lack of parking and inaccessible buildings prevent engagement with health services (Ministry of Health, 2023a; Whitehead et al., 2023). Other common factors include inability to meet the costs of health care, people/caregivers having other commitments (such as work or caregiving responsibilities) and an increasing lack of appointment availability (Ministry of Health, 2023a). 'Time taken to get an appointment was too long' was the most commonly reported barrier to visiting a general practitioner in the 2022/2023 New Zealand Health Survey (Ministry of Health, 2023c). This concern has increased since the 2021/2022 New Zealand Health Survey, having almost doubled for children (14.8% compared to 8.0%) and adults (21.2% compared to 11.6%) (Ministry of Health, 2023c). Disabled people with limited mobility; people with intellectual disabilities; and people dependent on others (such as children in state care, who depend on residential staff to support and facilitate access) are more likely to experience barriers to accessing an accurate diagnosis (Faasen, 2023).

Community clinics as primary prevention of iGAS

Several community initiatives addressing iGAS have been documented in the last 20 years, including school-based, community-based and pharmacy-based clinics. After the introduction of the national Rheumatic Fever Prevention Programme in 2011, sore throat clinics were introduced in 11 high-incidence regions across the North Island as local community-led initiatives to reduce barriers to GAS infection diagnosis (Tu'akoi et al., 2023). These clinics have outlived the formal timespan of the prevention programme and continue to be offered in a few schools around the country and within the broader community. Their purpose is to provide rapid and accessible GAS infection diagnosis, awareness and management (Tu'akoi, Ofanoa, Ofanoa, Lutui, Heather, Jansen, van der Werf, et al., 2022).

Mana Kidz is a kaupapa Māori version of this initiative. It has been the driver behind the continuation of school-based clinics in 88 low-equity index school zones within Counties Manukau (National Hauora Coalition, 2024). Mana Kidz was established as an ARF prevention programme, but also provides comprehensive health care, including vision and hearing checks, skin infection treatment and general health assessments (National Hauora Coalition, 2024). The way Mana Kidz has expanded and continued this service is an example of how culturally appropriate diagnosis of skin infections can be included into already existing school-based or community sore throat clinics (Tu'akoi, Ofanoa, Ofanoa, Lutui, Heather, Jansen, & Goodyear-Smith, 2022).

School-based nursing has been promoted as another community-based model for delivery of primary health care to young people in Aotearoa New Zealand. It has been demonstrated that school-based nursing achieves reductions in risk of skin infections and ARF incidence (Lambe & Hoare, 2016; Lennon et al., 2009), but there is no nationally consistent approach to service delivery. At present, publicly funded school-based health services which include nurses are available to secondary schools scoring low on the equity index, teen parent units, activity centres and alternative education sites nationally. This means they are available to around 115,000 secondary students across approximately 300 schools. There are also school-based health services in other schools where schools pay for their own nurse or where a district or primary health organisation has chosen to supplement services in a school. A school-based health

service enhancement programme is under way which supports workforce development; this includes a formal evaluation programme (Health New Zealand, 2024d). The first formative evaluation of the programme found that the most comon health care sought from school-based health care services was for acute and chronic physical health conditions, mental health and wellbeing, sexual health, alcohol and other drug abuse, school engagement, teenage pregnancy and accident and emergency presentations (Malatest International, 2022).

In Aotearoa New Zealand, a programme providing funded pharmacist minor ailment services ran as a pilot for six months, until September 2023. It aimed to provide accessible pharmaceutical services for conditions including scabies, eczema and skin infections (Health New Zealand, 2023a; Hikaka et al., 2023). There is no data related to the outcome of this service or the impact on skin infection reduction, GAS diagnosis or prevention of other more serious health concerns. Development of such interventions should involve communities and populations of interest throughout the processes of planning, implementation and evaluation to ensure they are culturally and clinically appropriate (Hikaka et al., 2023).

Management and treatment of skin conditions (GAS skin infections, eczema and scabies) as primary prevention of iGAS

Prompt treatment of GAS skin infections or infected scabies and eczema is crucial to avoid disease progression to iGAS (Bennett et al., 2023). Treatment options for these conditions varies, but it often involves complex regimes and ongoing monitoring.

iGAS treatment

Serious iGAS infections require immediate hospitalisation (Health Direct Australia, 2024). Management usually includes antibiotic and surgical intervention. However, treatment is dependent on a patient's specific iGAS presentation (Health Direct Australia, 2024).

GAS skin infection treatment

There is currently a variety of treatment options for GAS skin infections, including topical and systemic therapies (Bennett et al., 2021). Care is required to ensure best practice is followed, due to the risk of overuse of antibiotics and multi-drug resistance. Due to the reliance on clinical knowledge and skills in diagnosis and treatment regimes, there can be inconsistencies in the clinical management of skin infections, as highlighted in studies examining school nurse practices managing skin infections and decision-making when drug resistance occurs (Lambe & Hoare, 2016; Vogel et al., 2016; Vogel et al., 2013). Decisions related to optimal choice, dosage and the duration of antibiotic therapies for skin infections are required and clinicians often tend to take a pragmatic approach to care rather than strict adherence to regimes (Vogel et al., 2013). The necessity for clear guidelines to support community-based clinical intervention for families was also indicated in a 2013 qualitative study of Pacific children's experiences prior to hospital admission for skin infections. All participating families had unsuccessfully attempted home interventions to manage the infection prior to admission, suggesting that additional clinical guidance and/or support was required (Ete-Rasch & Nelson, 2013).

With antibiotic treatment there is a threat of antimicrobial resistance. As such, intervention relies on strict adherence to regimen plans and accurate diagnosis (Bennett et al., 2021; Primhak et al., 2022; Tu'akoi, Ofanoa, Ofanoa, Lutui, Heather, Jansen, & Goodyear-Smith, 2022; Vogel et al., 2016) and there is limited evidence for effective alternative treatment strategies (Primhak et al., 2022; Vogel et al., 2016). An antiseptic alternative has been proposed. There is currently a single blinded randomised control trial under way in Aotearoa New Zealand to assess the effectiveness of antiseptics to treat skin infections (Primhak et al., 2022).

> *Modifiable risk factor:* ***Impetigo***
>
> Guidelines for impetigo treatment could be updated to include an agreed approach to routine testing for GAS. These guidelines could streamline best clinical practices within community-based initiatives, and should draw on knowledge and experiences of community care providers, to be locationally and culturally appropriate.

Scabies treatment

The clinically recommended first-line scabies treatment in Aotearoa New Zealand is a topical insecticide, permethrin, and the recommended second-line treatment is an oral agent, ivermectin (Best Practice Advocacy Centre, 2022; Lake et al., 2022). The American Centers for Disease Control (CDC) guidelines also recommend treatment for household contacts (Centers for Disease Control and Prevention, 2010; Lake et al., 2022) and as discussed earlier in high-prevalence settings, mass drug administration is used as an infectious disease control strategy that involves the treatment of everyone in a particular population (Lake et al., 2022).

Scabies can be spread to household contacts via shared bedding or clothes or through prolonged skin-to-skin contact (Centers for Disease Control and Prevention, 2010) making it crucial that all bedding and clothes are washed, dried and/or sealed at the same time that treatment is applied (DermNet, 2022; Health New Zealand, 2024f). This recommendation assumes that people can access facilities to wash their personal belongings. Water poverty and material hardship in Aotearoa New Zealand can act as a barrier to families' ability to effectively eradicate scabies within a household (Perry, 2021).

> *Modifiable risk factor:* ***Scabies***
>
> There is an opportunity to explore MDA for scabies as an option for treatment in areas with high scabies prevalence in Aotearoa New Zealand. Recognition and remediation of material conditions that may hinder abilities to effectively carry out treatment regimens (such as access to water) is essential.

Eczema management and treatment

Eczema treatment is multifaceted and often product and time-intensive (Mooney et al., 2015). Eczema does not have a defined cause, but it can be triggered by environmental, psychological or genetic factors (Stanway, 2022). Comprehensive clinical assessments are necessary to understand triggers and to recognise and react to flare-ups or infections (Stanway, 2022). In their 2020 literature review of national clinical guidelines and expert opinions (Rademaker et al., 2020) noted that specific, practical advice on the use of systemic therapies for patients with severe eczema was lacking.

A core component of eczema therapy is management of inflammation with topical corticosteroids (Mooney et al., 2015). Despite this, topical corticosteroids can often be underutilised due to parental and individual concern about corticosteroids and their adverse effects (Mooney et al., 2015). The safety profile of topical corticosteroids is robust when used appropriately (one or two applications per day until active eczema is controlled) (Mooney et al., 2015). Alternative therapies are emerging as options for eczema management and therapy (Rademaker et al., 2022). These may be more acceptable for some people and provide options for clinicians to offer. In Aotearoa New Zealand one such alternative therapy is kānuka oil cream, developed from Indigenous knowledge and the healing systems of rongoā Māori. The cream was recently investigated in a randomised control trial and found to produce a statistically significant improvement in adult eczema (Shortt et al., 2022*)*. Additionally, an observational study has suggested that a mamaku (New Zealand black tree fern) extract may be another effective treatment option for a variety of inflammatory skin conditions including eczema (Rademaker et al., 2022). This therapy has long been used in rongoā Māori for rejuvenating, cooling and hydrating the skin, and was found by 30 participants to be favourable to previous eczema therapy options (Rademaker et al., 2022).

> *Modifiable risk factor:* ***Eczema***
>
> To increase community surveillance of GAS, clinical guidance and training for the diagnosis and management of infected eczema needs to cover when to test for GAS, with attention to repeated infections, priming for diseases such as RHD and transmission risks. Adherence to a treatment regime may require substantial support and a range of acceptable options for medical management and prevention of flare-ups and repeat infections.

Strep A vaccine development as primary prevention of iGAS

In 2021, the New Zealand Government announced a $10 million investment in development of a vaccine to prevent GAS-related diseases and commissioned University of Auckland for a four-year project accordingly (The New Zealand Government, 2021). The objectives of the research include:

- laying the foundation for and contributing to the development of a strep A vaccine
- growing strategic trans-Tasman partnerships in vaccine development and innovation

- to improve the health and wellbeing of Indigenous populations
- Building capability and capacity in vaccine development with Māori and Pacific communities, who sit at the heart of this research
- strengthening community engagement by viewing vaccine development issues holistically and embedding Māori and Pacific partnerships in every aspect of this work (Rapua te mea ngaro ka tau, 2023).

The Government had prioritised this project due to the ongoing national inequities of GAS health burdens, the economic costs of GAS disease in Aotearoa New Zealand (estimated at almost $30 million per annum) and the opportunity of a renewed collaboration with the Australian Government as part of the Coalition to Advance New Vaccines for Group A Streptococcus (CANVAS) (Cannon et al., 2016). The three main objectives of the CANVAS programme are:

- obtaining a selection of the most common GAS strains
- testing potential vaccines against these strains
- undertaking an economic analysis to evaluate if vaccination is cost-effective (Telethon Kids Institute, 2024).

While a GAS vaccine represents an opportunity to reduce the likelihood of GAS infections within Aotearoa New Zealand, it is only one primary prevention approach. A GAS vaccination would need to be complemented by additional clinical and socio-cultural interventions to address broader determinants of health that create risk factors for GAS and iGAS (Baker et al., 2019; Trace, 2022). Over emphasis on vaccination as the main prevention strategy for a disease which is primarily caused by social inequities could imply that a Western medical approach is the only solution (Trace, 2022). Primordial prevention at the population level to address societal inequities in housing, access to water, material poverty, stigma, clinical education and public awareness campaigns are also likely to have a significant impact on GAS and iGAS prevalence.

Vaccine hesitancy became more pronounced globally during the COVID-19 pandemic (Wiysonge et al., 2022). More research is required to examine the cultural nuances of vaccine uptake, acceptance and hesitancy in the Aotearoa New Zealand context. The Ministry of Health has commissioned several research projects to specifically fill this gap. Recent research into COVID-19 vaccination investigated perceptions of national scheduled childhood vaccines among Māori and Pacific caregivers and health care professionals (Charania et al., 2024). This study highlighted that although there was high acceptance of routine childhood immunisation, when a new vaccine was developed at a pace, participants felt as though their agency to decline vaccination and their rights to culturally specific information and vaccination programmes were hindered. Māori caregivers described feeling coerced to vaccinate in ways which had undertones of colonisation and systemic racism. On the other hand, Pacific participants expressed higher degrees of trust of health practitioners' expertise and recommendations to vaccinate (Charania et al., 2024). Several publications related to the COVID-19 vaccination process are due to be published in 2024. Part of the commissioning of GAS vaccine development in Aotearoa New Zealand includes undertaking research about community perceptions, which may help to fill remaining gaps (Rapua te mea ngaro ka tau, 2023).

Modifiable risk factor: ***Immunisation***

GAS immunisation programmes which are acceptable for Māori and Pacific peoples need to build on the COVID-19 vaccination experience. To be successful, such programmes will require community governance and leadership, culturally responsive delivery, resourcing of trusted providers and support for access.

iGAS and GAS surveillance as primary and secondary prevention of iGAS

Making iGAS notifiable will provide a robust basis for effective surveillance (Bennett et al., 2023). Notification will also support more complete iGAS epidemiological monitoring and the ability to conduct genomic sequencing. Such surveillance activities help track strains circulating in the community and identify potential outbreaks (Bennett et al., 2023; Lacey et al., 2023). An ESR audit undertaken in 2022 noted that the existing iGAS surveillance system is based on voluntary, non-systemised laboratory reporting and may underestimate the burden of disease in Aotearoa New Zealand (Institute of Environmental Science and Research Limited, 2022). This existing iGAS surveillance does not report on possible sources of disease. Precursory skin infections and conditions is important to understand the upstream pathway of iGAS. Better identification of co-morbidities (including long-term mental health conditions, addiction and disability) will help to understand and mitigate for the intersectional risk factors contributing to iGAS incidence.

An important parallel piece of work is the Rheumatic Fever Care Coordination Programme, which aims to implement a national system (including a central register) to improve the delivery of rheumatic fever and RHD prevention activities (Health New Zealand, 2023b). This centralised database could supplement iGAS surveillance and prevention activities due to the close ties these programmes of work have.

Secondary prevention of iGAS

Antibiotic chemoprophylaxis (medication to prevent infection) may be used to decrease the risk of close contacts contracting iGAS. The iGAS guidelines in some states in Australia and the United Kingdom recommend this (Health NSW, 2023; UK Health Security Agency, 2023). Those guidelines advise that antibiotic treatment of close contacts should be at the discretion and advice of assessing clinicians, but should be strongly recommended to those at a high risk of infection and those showing GAS symptoms/signs (Health NSW, 2023; UK Health Security Agency, 2023). Non-pharmaceutical actions in the United Kingdom include communication of risk to household contacts and assessment to see if environmental cleaning is required (UK Health Security Agency, 2023).

Research to examine modifiable risk factors

The research and evidence drawn upon for this brief provides a baseline to build upon for future research projects. The range of methodologies and quality of the evidence reviewed was wide; many sectors and researchers are contributing to building the evidence base for Aotearoa New Zealand. We found gaps in the evidence related to skin infections, GAS and iGAS, but we also identified current projects and work programmes that are aligned and provide opportunities for identifying and addressing modifiable risk factors in future research. Several current or recently completed research projects from Aotearoa New Zealand, Australia or the Pacific are focused on understanding skin infections and/or GAS.

Most of the current or recent projects are focused on children, with the exception of Lydeamore et al. (2020) and Tu'akoi, Ofanoa, Ofanoa, Lutui, Heather, Jansen, van der Werf, et al. (2022), which looked at all ages. Several projects incorporated surveillance and collection of epidemiological data (Barth et al., 2022; Taiaroa et al., 2021; Thornley et al., 2023; Tu'akoi, Ofanoa, Ofanoa, Lutui, Heather, Jansen, van der Werf, et al., 2022). Four studies included treatments and management (Bennett et al., 2019; Lokuge et al., 2014; Mullane et al., 2019; Primhak et al., 2022), one involved modelling infectiousness of skin sores (Lydeamore et al., 2020) and one involved genomic analysis of circulating GAS strains in Auckland (Lacey et al., 2024). Two from Tonga are yet to be published (Thornley & Sundborn, in press-a, in press-b).

As well as these research projects, current surveillance and clinical activities are contributing to the knowledge base of iGAS, GAS, interventions and prevention. The University of Auckland is an international research partner for the development of the strep A vaccine. This research includes surveillance and genomic and epidemiological analysis of hospital admissions of iGAS in the greater Auckland region. Publications of this research are forthcoming. ESR undertakes routine surveillance of iGAS. While at present this is reported in five-year cycles, annual updates are available. ESR has also recently audited the surveillance and laboratory processes involved for reporting iGAS and is working on improving and increasing these (Institute of Environmental Science and Research Limited, 2023). The goals of the Rheumatic Fever Roadmap 2023–2028 include 'improving surveillance and good-quality data collection and analysis' and 'supporting research and development, including epidemiology and pathogenesis of rheumatic fever and rheumatic heart disease' (Health New Zealand, 2023c, p. 15). Part of the rheumatic fever work programme includes a national, centralised digital care-coordination platform for active management of rheumatic fever which aligns closely with interventions for and prevention of iGAS (Health New Zealand, 2023b). A list of these projects has been provided in **Supplementary Material 7** as a snapshot of these current research activities, to help identify gaps that need to be filled.

Research priorities from equity wānanga (January 2024)

Ministry participants who attended the research design equity wānanga recommended research focused on the following questions, to help ensure research objectives meet Te Tiriti o Waitangi and equity responsibilities as well as centre community voice and leadership in iGAS research.

- How prevalent are pre-existing skin conditions in iGAS cases, and which groups in the population are most at risk for contracting iGAS?
- What individual risk and protective factors make someone more or less susceptible to GAS skin infection escalation to iGAS?
- What community factors make a community more likely to experience ongoing GAS transmission and a higher risk of iGAS? What community-based programmes and/or community strengths can be resourced to address GAS circulating?
- What population-based risk and protective factors exist along the skin infection – iGAS disease progression that may provide an opportunity to reduce iGAS burden?
- What is the best approach to upskill the health workforce to proactively and effectively manage the diversity of skin conditions at the community level and prevent GAS infections?

Key principles to ensure equity in future research

Any proposed research is planned with a Tangata Whenua: Tangata Moana (Pacific Peoples) partnership leading all stages of the project. Ideally, the contract holder and lead investigators will be Māori or Pacific researchers/research organisations.

The disaggregation and analysis of any cohort studies, case reviews or survey or surveillance activities researchers undertake needs to take into account disabled people, who are at higher risk of skin infections and skin conditions, as well as people with long-term mental illness and addictions.

Research design should include interventions which incorporate whānau- and community-centred follow-up and support. Research focused on population-level interventions needs to take into account poverty, material conditions and water insecurity as key factors.

Multiple strands of research are required, which are likely to need different methodologies and approaches. Researchers will need to build on current research activities to create national collaborations.

The quality of health data is generally poor for high-risk population groups. This needs to be factored into any design for accuracy.

Research design and gaps

The research we reviewed entailed many different methodologies and approaches. These provided insight into design features, missing pieces and limitations for future research in Aotearoa New Zealand. The wide range of methodologies demonstrates the complexity of modifiable risk factors for iGAS.

In the systematic review, we found that the predominant methodology deployed was a retrospective descriptive study. These studies were generally linked to a specific hospital and used health data collected in medical notes and/or through routinely collected surveillance data (Bocking et al., 2017; Chong et al., 2023; Dowler & Wilson, 2020; Limm-Chan et al., 2020; Nwosu et al., 2023; Valenciano et al., 2021). One study used a case control sample as part of the retrospective case review (Hempenstall et al., 2021). Studies which specifically focused on skin conditions and GAS tended to be cross-sectional (Armitage et al., 2019; Chang et al., 2019; Taiaroa et al., 2021) or prospective (Arumugam et al., 2024; Thean et al., 2021).

In the scoping review, we found a range of methodologies in the research and evaluation publications, which added depth and breadth to the review. Retrospective descriptive studies were most common (Bennett et al., 2022; Birrell et al., 2023; Cannon et al., 2021; Lacey et al., 2024; Oliver et al., 2020; Thomas et al., 2021b; Thornley et al., 2023). There was one randomised control trial (Primhak et al., 2022), two involving mixed methods (Baker et al., 2013; Tu'akoi, Ofanoa, Ofanoa, Lutui, Heather, Jansen, van der Werf, et al., 2022), one prospective cohort study (Bennett et al., 2019) and several qualitative studies that used a variety of methodologies to examine the lived experience and outcomes of intervention/prevention initiatives (Ete-Rasch & Nelson, 2013; Hikaka et al., 2023; Lambe & Hoare, 2016; Malungahu, 2020; Trace, 2022). As well as these research projects, there were several mixed-method evaluations, which provide another source of knowledge and evidence. These included evaluations of the HHI (Pierse et al., 2022), of school-based health services (Malatest International, 2022) and of community outreach programmes specifically for treatment of skin infections (Wyber et al., 2021).

Our summary of the key gaps and limitations future research designers and planners should consider is as follows.

- Clinical diagnosis to correctly identify a wide variety of skin conditions and infections was often absent; assessments were often conducted by the health practitioner who was managing the person at the time, who may not have been adequately skilled in skin conditions or infections.
- Variables likely to add important information for interventions and prevention were often missing in data collections. These included sources of skin breakage (eg, insect bites or wounds), the proportion of other skin conditions (eg, bacterial (particularly *Staphylococcus aureus*), fungal or viral pathogens) and the site of skin swabs (eg, lower limb, head, or hands).
- Follow-up after admission for iGAS and/or treatment for GAS-infected skin infections was often missing due to loss of participants, limiting understanding of the effectiveness of intervention and prevention measures.
- High-quality national denominators and the baseline prevalence of ARF, RFD, PSGN, GAS and iGAS were generally absent in data analysis.

- Analysis for higher-risk sub-population groups within a study cohort was generally not possible due to small sample sizes.
- Small population and reported case numbers prevented statistical analysis.
- Age ranges were highly varied. Some studies focused on younger children, some included adolescents and others focused on all ages.
- There was very little household- or whānau-based analysis of close contacts and household movements in any of the studies.
- The impact of historical community interventions such as MDA for scabies or impetigo was referred to in cohort studies but this was not included in any statistical analysis as a confounding variable.
- There was very little analysis of demographic information outside individually collected health data on age, gender, ethnicity (limited in most studies) and co-morbidities. Studies which did conduct interviews or entailed more in-depth data collection of personal circumstances often did not analyse these or include or integrate this information with other findings.
- The studies generally did not examine key social elements which impact skin conditions and infectious disease transmission, such as housing conditions, household membership, access to water, socio-economic status, level of education and access to primary health care or data collection methods for these elements were very superficial.

Surveillance and case review

The key limitations listed above relate to the Aotearoa New Zealand context in the following ways.

- Existing national surveillance or epidemiological case data related to iGAS does not identify GAS infection sources (ie, skin as opposed to throat; where the lesion was; and, for skin lesions, what the originating condition was (eg, wound, post-surgical, chickenpox, eczema, scabies or head lice).
- The community prevalence and epidemiology of GAS skin infections in comparison to other skin infections is unknown.
- Existing national surveillance or epidemiological iGAS case evidence does not disaggregate demographic data in ways which enable prevalence and incidence rates in high-risk groups to be monitored in meaningful ways. For example:
  - appropriate iwi, hapu or whānau affiliation and level two classification of Pacific ethnicities (level four for Indigenous Fijians and Fijian Indians)[15] to support effective community leadership in Māori and Pacific communities
  - identification of disability type and skin-related risks
  - presence of co-existing long-term health conditions; particularly diabetes
  - presence of long-term mental health conditions or addictions; particularly injecting drug users and alcoholism
  - post-partum mother and neonate pairs and pregnancy-related surgical procedures

[15] See Ethnicity Data protocols and advice for reporting specific ethnic sub-groups in the population **https://www.tewhatuora.govt.nz/health-services-and-programmes/digital-health/data-and-digital-standards/approved-standards/identity-standards/**

  - community level case-cluster analysis.
- Little is known about the causal pathway of disease escalation, including circulation patterns, transmission risks and the role of skin-borne carriage in GAS transmission.

Intervention and prevention

The key limitations listed above relate to intervention and prevention research in the following ways.

- Primordial prevention which addresses specific underlying conditions which exacerbate skin infections and skin conditions (such as access to potable water, hot water or laundry facilities)
- are largely absent in national programmes addressing other socially determined health needs
- There is little understanding of the role that social stigma, normalisation of skin infections and negative stereotyping plays in the accessibility of health care services, particularly with regard to the impact these may have on whānau abilities to manage persistent and ongoing skin infections.
- Few primary prevention interventions address lack of access to skin specialists.
- There is little research into the effectiveness of providing and adhering to appropriate treatment regimens for the range of wounds and skin conditions and the impact this has on GAS prevalence.
- There is little understanding of the impact on public messaging and campaigns to raise awareness of the connection between GAS skin infections and iGAS.
- Of the limited studies looking at the evidence of effective community-based programmes, those which documented an impact on reducing health disparities (eg, hospital admission or GP appointment rates) do not detail what specific health conditions were most prevalent as the underlying cause of the existing disparities.

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Supplementary Material 1: Search strategy and JBI quality assessment tool

Forty studies were identified in the initial search and assessed using JBI quality appraisal checklist for studies reporting prevalence data and the inclusion criteria based on the CoCoPop mnemonic (**Co**ndition, **Co**ntext and **Pop**ulation) to undertake a systematic review of incidence and prevalence of iGAS, ARF, RHD, PGSN caused by skin conditions.

- **Co**ndition = iGAS or ARF or RHD or PGSN ***&/or*** GAS infected eczema or impetigo or cellulitis or scabies
- **Co**ntext = Environmental/setting and time period
- **Pop**ulation = Any specified population (country, regional or otherwise with a stated denominator)

Inclusion criteria:

- Data collection within 2013-2024
- Peer reviewed journal or recognised authorities routine reporting
- Observational study designs include prospective and retrospective cohort studies, case-control studies, cross-sectional studies.
- Statistical analysis of prevalence and incidence included
- iGAS, ARF, RHD, PGSN
- Laboratory tested GAS or strep pyogenes reported as discrete group
- Infected clinically diagnosed eczema, impetigo, cellulitis or scabies
- Clearly defined population denominator
- Demographic aggregation by ethnicity and age as minimum
- Population context/environment clearly reported to understand setting

Exclusion criteria:

- Opinion, commentary or theoretical
- Grey literature
- Non-English
- Full text not available

Quality Assessment

The JBI Critical Appraisal Instrument for Studies Reporting Prevalence Data was used to assess each of the forty studies and peer reviewed by a second team member to confirm inclusion (Munn et al., 2015).

JBI Critical Appraisal Checklist

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?				
Were study participants sampled in an appropriate way?				
Was the sample size adequate?				
Were the study subjects and the setting described in detail?				
Was the data analysis conducted with sufficient coverage of the identified sample?				
Were valid methods used for the identification of the condition?				
Was the condition measured in a standard, reliable way for all participants?				
Was there appropriate statistical analysis?				
Was the response rate adequate, and if not, was the low response rate managed appropriately?				

Search Strategy

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations, Daily and Versions <1946 to January 26, 2024>, adapted for Scopus and Embase

Search Strategy:

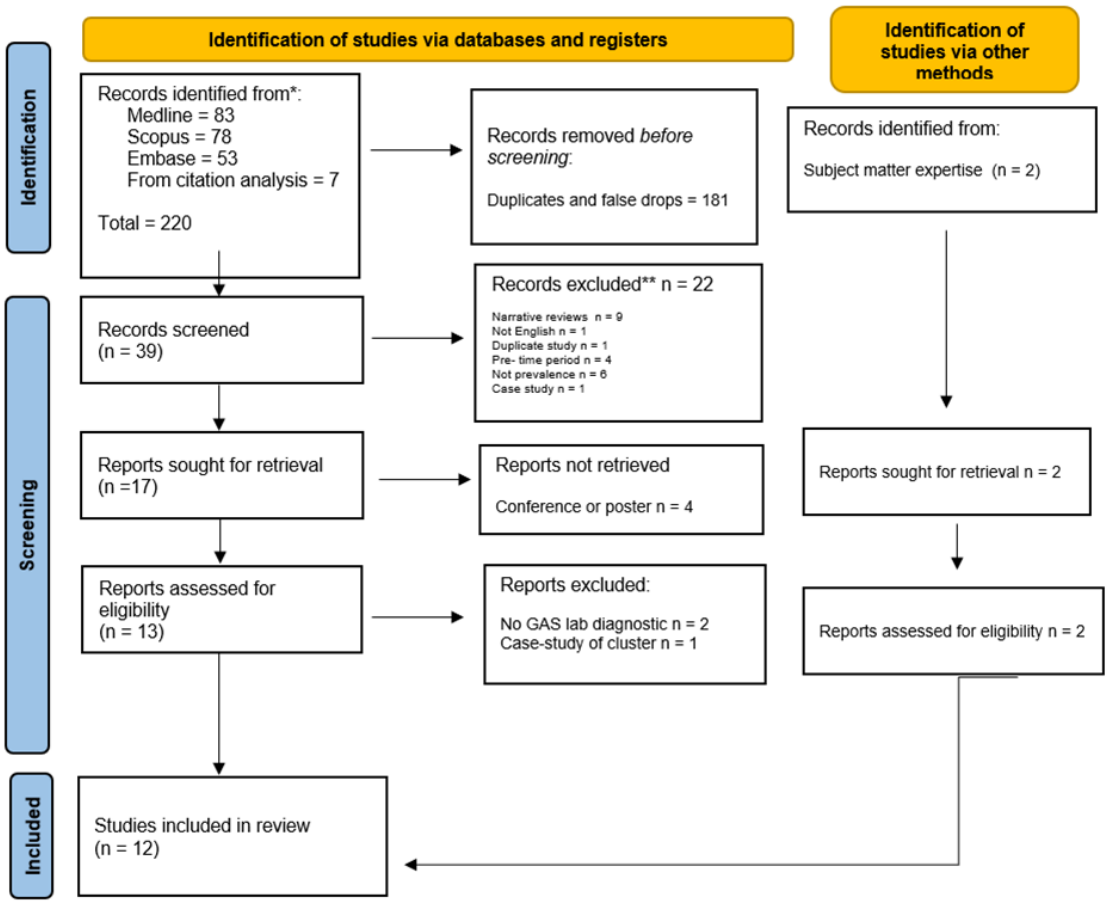
1 impetigo.mp. or Impetigo/
2 exp Eczema/ or eczema.mp.
3 Scabies/ or scabies.mp.
4 atopic dermatitis.mp. or Dermatitis, Atopic/
5 exp Pyoderma/ or pyoderma.mp.
6 (skin* adj3 (infect* or sore*)).mp.
7 Cellulitis/ or cellulitis.mp.
8 1 or 2 or 3 or 4 or 5 or 6 or 7
9 invasive group A streptococcal.mp.
10 iGAS.mp.
11 post-streptococcal glomerulonephritis.mp.
12 PSGN.mp.
13 "acute rheumatic fever".mp. or Rheumatic Fever/
14 rheumatic heart disease.mp. or Rheumatic Heart Disease/
15 9 or 10 or 11 or 12 or 13 or 14
16 8 and 15
17 Case-Control Studies/ or case control.mp.
18 Cohort Studies/ or cohort stud*.mp.
19 Retrospective Studies/ or retrospective.mp.
20 Prospective Studies/ or prospective.mp.
21 (population adj3 stud*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare

disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
22 systematic review*.mp.
23 meta-analysis.mp. or Meta-Analysis/
24 Randomized Controlled Trials as Topic/ or RCT*.mp.
25 Epidemiology/ or epidemiology.mp.
26 ((surveillance adj3 stud*) or (population adj3 surveillance)).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
27 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26
28 16 and 27
29 limit 28 to (english language and yr="2013 -Current")

Medline = 83
Scopus = 78
Embase = 53
Total = 214
From citation analysis = 7
Total after duplicates and false drops removed

Summary of study selection and quality assessment

Figure 4: PRISMA screening process iGAS and prevalence of skin infections



Search Results and inclusion/exclusion summary

#	Study Title	Inclusion Status	Reason
1	Abugrain, K., et al. (2023). "Review of Acute Post-Streptococcal Glomerulonephritis at the Red Cross War Memorial Children's Hospital, Cape Town, South Africa." Pediatric Nephrology 38(7): 2395-2396 DOI: 10.1007/s00467-022-05865-y	Excluded	Abstract Only
2	Abugrain, K., et al. (2024). "A 6-year review of acute post-streptococcal glomerulonephritis at a public children's hospital in Cape Town, South Africa." Pediatric nephrology (Berlin, Germany) DOI: **https://dx.doi.org/10.1007/s00467-023-06247-8**	Excluded	Non-lab diagnosed GAS
3	Amic-Desvaud, Q., et al. (2022). "RHEUMATIC FEVER and CUTANEOUS STREPTOCOCCAL INFECTION: A CASE-CONTROL STUDY in the LOYALTY ISLANDS, NEW CALEDONIA." Annals of the Rheumatic Diseases 81: 922 DOI: 10.1136/annrheumdis-2022-eular.4436	Excluded	Abstract/Poster Only
4	Armitage, E. P., et al. (2019). "High burden and seasonal variation of paediatric scabies and pyoderma prevalence in The Gambia: A cross-sectional study." PLoS neglected tropical diseases 13(10): e0007801 DOI: **https://dx.doi.org/10.1371/journal.pntd.0007801**	Included	
5	Arumugam, P., et al. (2024). "A Surveillance Study of the Serotypes of Streptococci in the Throat and Skin Lesions in Acute Rheumatic Fever and Rheumatic Heart Disease Patients and their Families." APIK Journal of Internal Medicine 12(1)	Included	
6	Barth, D., et al. (2019). "The missing piece study: A surveillance study for Strep A pharyngitis and Impetigo in the Kimberley, Australia." Cardiovascular Journal of Africa 30(5 SUPPL): S5	Excluded	Not about prevalence
7	Beaton, A., et al. (2014). "Usefulness of anti-streptococcal antibody profiling for confirmation of latent rheumatic heart disease in asymptomatic ugandan schoolchildren diagnosed by echocardiography." Global Heart 9(1): e278 DOI: 10.1016/j.gheart.2014.03.2226	Excluded	Not about prevalence
8	Beaudoin, A. L., et al. (2014). "Assessing the burden of pediatric acute rheumatic fever and rheumatic heart disease-American Samoa, 2011-2012." American Journal of Tropical Medicine and Hygiene 91(5): 574	Excluded	Abstract Only
9	Bocking, N., et al. (2017). "High Incidence of Invasive Group A Streptococcal Infections in Remote Indigenous Communities in Northwestern Ontario, Canada." Open forum infectious diseases 4(1): ofw243 DOI: **https://dx.doi.org/10.1093/ofid/ofw243**	Included	
10	Cannon, J., et al. (2016). "The economic case for a group a streptococcal vaccine in Australia and New Zealand." Global Heart 11(2): e172 DOI: 10.1016/j.gheart.2016.03.603	Excluded	Narrative
11	Chang, A. Y., et al. (2019). "Prevalence, Clinical Features and Antibiotic Susceptibility of Group A Streptococcal Skin Infections in School Children in Urban Western and Northern Uganda." The Pediatric infectious disease journal 38(12): 1183-1188 DOI: **https://dx.doi.org/10.1097/INF.0000000000002467**	Included	

#	Study Title	Inclusion Status	Reason
12	Chong, C., et al. (2021). "Clinical characteristics and outcome of hospitalised children with acute post-streptococcal glomerulonephritis at the Royal Darwin Hospital in northern territory of Australia." Nephrology 26(SUPPL 2): 44 DOI: 10.1111/nep.13931	Excluded	Duplicate
13	Chong, H.-Y. C., et al. (2023). "Clinical characteristics of hospitalised children with acute post-streptococcal glomerulonephritis in the Top End of Australia." Journal of paediatrics and child health 59(5): 735-742 DOI: **https://dx.doi.org/10.1111/jpc.16386**	Included	
14	Davidson, L., et al. (2020). "Skin infections in Australian Aboriginal children: a narrative review." Medical Journal of Australia 212(5): 231-237 DOI: 10.5694/mja2.50361	Excluded	Narrative
15	Dooley, L. M., et al. (2021). "Rheumatic heart disease: A review of the current status of global research activity." Autoimmunity reviews 20(2): 102740 DOI: **https://dx.doi.org/10.1016/j.autrev.2020.102740**	Excluded	Narrative
16	Dowler, J. and A. Wilson (2020). "Acute post-streptococcal glomerulonephritis in Central Australia." The Australian journal of rural health 28(1): 74-80 DOI: **https://dx.doi.org/10.1111/ajr.12568**	Included	
17	Francis, J. R., et al. (2019). "A cluster of acute rheumatic fever cases among Aboriginal Australians in a remote community with high baseline incidence." Australian and New Zealand journal of public health 43(3): 288-293 DOI: 10.1111/1753-6405.12893	Excluded	Cluster report – not iGAS
18	Gear, R. J., et al. (2015). "Changes in the clinical and epidemiological features of group A streptococcal bacteraemia in Australia's Northern Territory." Tropical medicine & international health : TM & IH 20(1): 40-47 DOI: **https://dx.doi.org/10.1111/tmi.12405**	Excluded	Outside time range
19	Gramp, P. and D. Gramp (2021). "Scabies in remote Aboriginal and Torres Strait Islander populations in Australia: A narrative review." PLoS neglected tropical diseases 15(9): e0009751 DOIn: **https://dx.doi.org/10.1371/journal.pntd.0009751**	Excluded	Narrative
20	Hempenstall, A., et al. (2021). "Echocardiographic Screening Detects a Significant Burden of Rheumatic Heart Disease in Australian Torres Strait Islander Children and Missed Opportunities for its Prevention." The American journal of tropical medicine and hygiene 104(4): 1211-1214 DOI: **https://dx.doi.org/10.4269/ajtmh.20-0846**	Included	
21	Lacey, J. A., et al. (2023). "Evaluating the role of asymptomatic throat carriage of Streptococcus pyogenes in impetigo transmission in remote Aboriginal communities in Northern Territory, Australia: a retrospective genomic analysis." The Lancet. Microbe 4(7): e524-e533 DOI: **https://dx.doi.org/10.1016/S2666-5247(23)00068-X**	Excluded	Outside time range
22	Leung, T. N. H., et al. (2018). "Group a streptococcus disease in hong kong children: An overview." Hong Kong Medical Journal 24(6): 593-601 DOI: 10.12809/hkmj187275	Excluded	Narrative

#	Study Title	Inclusion Status	Reason
23	Limm-Chan, B., et al. (2020). "Incidence of Acute Post-Streptococcal Glomerulonephritis in Hawai'i and Factors Affecting Length of Hospitalization." Hawai'i journal of health & social welfare 79(5): 149-152	Included	
24	Maalej, B., et al. (2018). "Post-streptococcal glomerulonephritis in the south of Tunisia: A 12-year retrospective review [French]." Nephrologie et Therapeutique 14(7): 518-522 DOI: 10.1016/j.nephro.2018.04.001	Excluded	Not in English
25	Manguilimotan, I. (2016). "The Observed Patterns in the Presentation and Latency Period of Acute Glomerulonephritis in Children in a Single Center." Pediatric Nephrology 31(10): 1825 DOI: 10.1007/s00467-016-3467-5	Excluded	Abstract Only
26	May, P. J., et al. (2019). "Treatment, prevention and public health management of impetigo, scabies, crusted scabies and fungal skin infections in endemic populations: a systematic review." Tropical Medicine and International Health 24(3): 280-293 DOI: 10.1111/tmi.13198	Excluded	Not about prevalence
27	Nasr, S. H., et al. (2013). "Bacterial infection-related glomerulonephritis in adults." Kidney international 83(5): 792-803 DOI: **https://dx.doi.org/10.1038/ki.2012.407**	Excluded	Not about prevalence
28	Olafsdottir, L. B., et al. (2014). "Invasive infections due to Streptococcus pyogenes: seasonal variation of severity and clinical characteristics, Iceland, 1975 to 2012." Euro surveillance : bulletin Europeen sur les maladies transmissibles = European communicable disease bulletin 19(17): 5-14	Excluded	Outside time range
29	Parajulee, P., et al. (2024). "State transitions across the Strep A disease spectrum: scoping review and evidence gaps." BMC infectious diseases 24(1): 108 DOI: **https://dx.doi.org/10.1186/s12879-023-08888-4**	Excluded	Narrative
30	Pearce, S., et al. (2020). "The incidence of sore throat and group A streptococcal pharyngitis in children at high risk of developing acute rheumatic fever: A systematic review and meta-analysis." PloS one 15(11): e0242107 DOI: **https://dx.doi.org/10.1371/journal.pone.0242107**	Excluded	Not about prevalence
31	Romani, L., et al. (2015). "Systematic review of the global prevalence of scabies and impetigo." Australasian Journal of Dermatology 56: 19 DOI: 10.1111/ajd.12337	Excluded	Not about prevalence
32	Satoskar, A. A., et al. (2020). "Epidemiology, pathogenesis, treatment and outcomes of infection-associated glomerulonephritis." Nature reviews. Nephrology 16(1): 32-50 DOI: **https://dx.doi.org/10.1038/s41581-019-0178-8**	Excluded	Narrative
33	Scheel, A., et al. (2022). "Standardization of Epidemiological Surveillance of Acute Rheumatic Fever." Open forum infectious diseases 9(Suppl 1): S41-S49 DOI: **https://dx.doi.org/10.1093/ofid/ofac252**	Excluded	Narrative
34	Sharmin, M., et al. (2020). "Clinical Profile and Immediate Outcome of Children Admitted With Acute Glomerulonephritis in Pediatrics Department of A Tertiary Level Hospital." Mymensingh medical journal : MMJ 29(1): 5-15	Included initially, then excluded	No lab confirmation

#	Study Title	Inclusion Status	Reason
35	Shortell, J. D., et al. (2019). "Overlooking Recurrent Acute Rheumatic Fever in Adulthood." Hawaii Journal of Health and Social Welfare 78(9): 293-296	Excluded	Case study
36	Thean, L. J., et al. (2021). "Prospective surveillance for invasive Staphylococcus aureus and group A Streptococcus infections in a setting with high community burden of scabies and impetigo." International journal of infectious diseases : IJID : official publication of the International Society for Infectious Diseases 108: 333-339 DOI: **https://dx.doi.org/10.1016/j.ijid.2021.05.041**	Included	
37	Thomas, L., et al. (2020). "Complicated skin and soft tissue infections in remote indigenous communities." Internal medicine journal 50(6): 752-754 DOI: **https://dx.doi.org/10.1111/imj.14858**	Excluded	Narrative
38	Valenciano, S. J., et al. (2021). "Invasive Group A Streptococcal Infections Among People Who Inject Drugs and People Experiencing Homelessness in the United States, 2010-2017." Clinical infectious diseases : an official publication of the Infectious Diseases Society of America 73(11): e3718-e3726 DOI: **https://dx.doi.org/10.1093/cid/ciaa787**	Included	
39	Whitehall, J., et al. (2013). "Burden of paediatric pyoderma and scabies in North West Queensland." Journal of paediatrics and child health 49(2): 141-143 DOI: **https://dx.doi.org/10.1111/jpc.12095**	Excluded	Outside time range

1n	Nwosu A, Schut A, Wood CA, Urquhart C, Bachman C, Thompson K, et al. (2022) Invasive group A streptococcal (iGAS) surveillance in Island Health, British Columbia, 2022. CCDRCANADA. 2023;49(7/8):342.	Included	Found from other research
2n	Taiaroa, G., Matalavea, B., Tafuna'i, M., Lacey, J. A., Price, D. J., Isaia, L., . . . Gorrie, C. L. (2021). Scabies and impetigo in Samoa: a school-based clinical and molecular epidemiological study. *The Lancet Regional Health–Western Pacific, 6*. Retrieved from **https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8315614/pdf/main.pdf**	Included	Found from other research

Supplementary Material 2: Summary of Evidence table

Study title & Country	Purpose & Methodology	Population characteristics	Skin results GAS infected eczema, impetigo, cellulitis or scabies	Prevalence/Incidence/outcomes	Associations between exposure and outcomes	JBI Quality indicators & limitations
Invasive Group A Streptococcal disease (iGAS)						
Bocking, N., Matsumoto, C.-L., Loewen, K., Teatero, S., Marchand-Austin, A., Gordon, J., . . . McGeer, A. (2017). High Incidence of Invasive Group A Streptococcal Infections in Remote Indigenous Communities in Northwestern Ontario, Canada. *Open Forum Infectious Diseases, 4*(1), ofw243. doi: **https://dx.doi.org/10.1093/ofid/ofw243** Canada	**Purpose:** Epidemiological analysis of burden of iGAS disease among remote First Nations communities in Northwestern Ontario, Canada Retrospective case review 2009 -2014 **Data collection:** All GAS-positive cultures processed by the primary care hospital that met the definition for iGAS disease from 2009 -2014. Possible iGAS cases (sterile site, operating room, or admitted to hospital). WGS surveillance	n = 65 iGAS cases n = 6674 GAS cases 26 remote Northern Canada on-reserve First Nations communities All ages Mean age = 40 years	Cellulitis present in 36/65 cases (55.4%). Underlying skin conditions 25/65 cases (38.5%) Annual rate of skin swabs positive for GAS = 61 per 1000 Annual rate of throat swabs positive for GAS = 46.6 per 1000 GAS-positive skin swabs were more prevalent during the summer months GAS-positive throat swabs did not demonstrate a seasonal trend. The most common *emm* types identified in the present investigation belong to the so-called skin (eg, *emm*83, *emm*101)	The annualized incidence of iGAS was 56.2 per 100 000 (95% CI, 35.4–76.9). 6674 cases positive for GAS 65/6674 diagnosed with iGAS Crude incidence rate = 56.2 per 100 000 [compared to the 2013 Canadian and Ontario rates for iGAS of 4.72 and 4.6 per 100 000 population] Incidence = 10 times higher in study comparable to indigenous populations in Australia and New Zealand 11/65 (17%) < 1 year Distribution of age-specific incidence	The majority of iGAS cases occurred during the months of October to March; however, no Statistically significant seasonal trend Two most common comorbidities = diabetes mellitus(38.5%) skin conditions (38.5%) Prominent other potential risk factor = alcohol dependence (25%) [consistent with iGAS epidemiology for both indigenous and non-indigenous populations in Northern Australia] There was significant overlap in underlying conditions: 10/25 patients with underlying diabetes had skin conditions, 3/25 had alcohol dependence	No clear definitions of skin conditions or confirmation of diagnostic criteria used for skin related analysis Missing data from one region (Winnipeg) Small population size and reported case numbers, Risk factors were self-reported from patient charts Community population statistics from the Indian Registry System relies on individuals to register for "Indian status" and may thus underrepresent the true population of communities, resulting in an overestimation of iGAS rates.

Study title & Country	Purpose & Methodology	Population characteristics	Skin results GAS infected eczema, impetigo, cellulitis or scabies	Prevalence/Incidence/outcomes	Associations between exposure and outcomes	JBI Quality indicators & limitations
	basic demographics, specimen details, clinical severity, comorbidities, risk factors, and antibiotic sensitivity profiles. History of skin condition included chronic dermatitis/wound causing breaks in skin integrity. **Data analysis:** Basic descriptive statistical analysis Crude incidence (removing duplicate isolates occurring within a 14-day period) and temporal trends of positive throat and wound swabs were assessed. The *emm* types of isolates from confirmed iGAS cases were determined through traditional Sanger sequencing using previously described primers and conditions		and generalist (eg, *emm*68, *emm*82, *emm*87, *emm*114) *emm* types with only a few strains belonging to *emm* types with tropism for throat (eg, *emm*1)	peaked in the 0–19 and 40–59 age groups. No detectable association between trends of iGAS incidence and either positive wound swab or positive throat swab rates.	2/25 had both skin conditions and alcohol dependence. 7/16 persons with alcohol dependence also had skin conditions, 12.3% of cases in this study were identified as having a history of injecting drug use, consistent with iGAS epidemiology reported in non-indigenous populations 5/7 persons reporting intravenous drug use were also dependent on alcohol. The variation in *emm* type distribution has important vaccine implications. The diversity of strains and rapid serotype replacement observed in Northwestern Ontario may mean that the vaccine will offer reduced protection in a population that	

Study title & Country	Purpose & Methodology	Population characteristics	Skin results GAS infected eczema, impetigo, cellulitis or scabies	Prevalence/Incidence/outcomes	Associations between exposure and outcomes	JBI Quality indicators & limitations
					experiences a disproportionate burden of severe disease	
Valenciano, S. J., Onukwube, J., Spiller, M. W., Thomas, A., Como-Sabetti, K., Schaffner, W., . . . Van Beneden, C. A. (2021). Invasive Group A Streptococcal Infections Among People Who Inject Drugs and People Experiencing Homelessness in the United States, 2010-2017. *Clinical infectious diseases : an official publication of the Infectious Diseases Society of America, 73*(11), e3718-e3726. doi: **https://dx.doi.org/10.1093/cid/ciaa787** USA	**Purpose:** To characterise people with iGAS infection and documentation of Injecting Drug Use (IDU), homelessness, or both Centralised lab based surveillance system 2010-2017 **Data collection:** *Definition of iGAS case:* an infection where GAS is isolated from a normally sterile site (eg, blood) or from a wound culture in a patient with necrotizing fasciitis or streptococcal toxic shock syndrome (STSS) GAS isolates collected prior to 2015 were *emm* subtyped. Isolates collected in 2015–2017 were characterized through whole genome sequencing and an associated bioinformatics pipeline	12,368 iGAS infections from 10 US States n = 12 368 iGAS cases Four sub-groups: n = 683 people who inject drugs (PWID) n = 531 people experiencing homelessness (PEH) [including mission, medical respite, or church community centre at the time of positive culture]. n = 365 PWID & PEH n = 10,807 neither PWID or PEH >13 years PEH = male (77%) 47.3% PWID aged 18–34 years; 51.8% PEH aged 50–64 years	48-55.5% PWID & PEH had cellulitis 46.3% PWID had acute skin breakdown 46.6% PWID & PEH 19.2% of neither PWID or PEH (acute: breakdown from recent surgery, varicella, penetrating or blunt trauma, surgical wounds, or burns) 10.7% PWID had chronic skin condition 7.3% PEH 8.8% PWID and PEH 11.3% neither PWID or PEH (chronic: psoriasis, eczema or other chronic skin ulcers, including decubitus ulcers)	Prevalence of PEH and PWID in iGAS cases increased significantly in during 2010–2017 in 2017 iGAS prevalence was: 8.7% = PWID 5.8% = PEH 6.1% = PWID & PEH In this time: PWID iGAS cases average annual increase of 17.5% (*P* < .001) PEH iGAS cases had an average annual increase of 20.0% (*P* < .001). PEH & PWID iGAS cases had an average increase of 35.3% (*P* < .001). 94.7%–96.6% iGAS cases were hospitalized 10.6% case fatality ratio neither PWID or PEH 5.7% case fatality PWID 5.3% case fatality PEH 5 0.8% case fatality PWID &	It is unclear what proportion of the overall increase in GAS incidence Alcohol abuse (42.6%) and chronic liver disease (16.0%) were more frequent among PEH only than the other 3 groups. HIV infection was 5 times more likely to be a comorbidity among PWID and PEH (8.6%) compared to those with neither risk factor (1.7%). Current smoking and other drug use were more common PWID, PEH, or both (44.8%–73.4%) than those with neither risk factor (15.6%). **Co-morbidities of iGAS cases:** Several chronic underlying conditions (eg, diabetes, obesity, coronary artery disease, chronic renal disease,	No lab testing for skin infections Surveillance case information is obtained from medical record review; IDU and homelessness might not be accurately documented, likely resulting in underestimation of the proportion of iGAS patients with these risk factors. 2016 change in ABCs' definition of homelessness may have contributed to the increase in prevalence of homelessness among patients with iGAS infection in that year We do not have concurrent estimates of the denominator of PWID and of PEH that exactly match the ABCs catchment populations, limiting our ability to

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	at the CDC's *Streptococcus* laboratory, *Medical records:* demographic characteristics, clinical syndromes, comorbidities **Data analysis:** Calculation of annual change in prevalence of risk factors using log binomial regression models. Est. national iGAS infections rates in cohorts studied	Most iGAS patients were non-Hispanic white, reflecting the underlying population. Approximately 34.2 million people reside in the 10 States in study		(*P*-value for each risk group compared to those with neither risk factor: <.001). **Emm/WGS:** The 17 most common *emm* types accounted for 80.2%–83.6% of cases across all 4 groups. The *emm* types that are substantially more common among iGAS PWID or PEH were all part of the E *emm* cluster (E2–E6) pattern, suggesting that these strains may have a predilection for skin infections GAS strains in PEH or PWID differed substantially from those among patients without such risk factors, suggesting expansion of selected GAS strains within these vulnerable populations	solid malignancies) were most common among iGAS patients with neither risk factor. PWID 10 times more likely to be diagnosed with endocarditis PEH 2 times more likely to be diagnosed with osteomyelitis Neither PWID PEH more likely to have septic shock, meningitis or pneumonia The increase in prevalence of IDU among iGAS patients could be due to increases in predisposing factors (eg, unsafe injection practices, poor hygiene, skin breakdown). Increases in prevalence of known risk factors (eg, skin breakdown, coinfection with HIV or hepatitis C) among PWID or PEH might have increased their	precisely estimate iGAS infection rates among these populations. Case rates not calculated for ethnicity No ethnicity breakdown provided for population denominator/PWID, PEH

Study title & Country	Purpose & Methodology	Population characteristics	Skin results GAS infected eczema, impetigo, cellulitis or scabies	Prevalence/Incidence/outcomes	Associations between exposure and outcomes	JBI Quality indicators & limitations
					susceptibility to iGAS infection, leading to an increased incidence of iGAS over time. For example, PWID might have increased skin breakdown from changes in injection practices. Alternatively, the increase might be partially related to the expansion of a limited number of relatively uncommon *emm* types among these iGAS patients, Similar to the general population, iGAS patients with documented IDU or homelessness may have developed long-lasting immunity to *emm* types most common in the United States (eg, *emm* 1, 3, 12) during childhood when their immune systems were healthy; relatively uncommon strains may now be spreading among these patients	

Study title & Country	Purpose & Methodology	Population characteristics	Skin results GAS infected eczema, impetigo, cellulitis or scabies	Prevalence/Incidence/outcomes	Associations between exposure and outcomes	JBI Quality indicators & limitations
					with generally poor immune status and no immunity from prior exposure.	
Nwosu A, Schut A, Wood CA, Urquhart C, Bachman C, Thompson K, et al. (2022) Invasive group A streptococcal (iGAS) surveillance in Island Health, British Columbia, 2022. CCDRCANADA. 2023;49(7/8):342. Canada	**Purpose:** Public Health annual iGAS surveillance report Year end 2022 **Data collection:** Passive surveillance system through central lab testing Case definition includes lab confirmation of GAS isolated from a normally sterile site, or DNA from GAS from a normally sterile site. iGAS is a reportable disease – all cases reported. Subtyping (emm typing) of all isolates is conducted by the Canadian National Microbiology Laboratory Standardised surveillance form of demographics, clinical	N = 101 cases Island Health region 0-96 years Median age = 53 years Female/n/a = 36% Male = 64% Island Health region has a population of about 860,000 people, which includes residents of Vancouver Island, the Islands in the Salish Sea and the Johnstone Straight, and the mainland communities north of Powell River and south of Rivers Inlet	Skin infection, 47% (n=47/101) having a wound, 46% (n=46/101) severe cases (n=27), most common reported risk factors were: having a wound, 52% (n=14) using substances, 52% (n=14) having a skin infection, 44% (n=12)	iGAS incidence = 11.4 per 100,000 the highest rate reported in the last six years and above the preliminary annual provincial rate 8.5 cases per 100,000 27/101 (27%) of cases clinically classified as: severe (streptococcal toxic shock syndrome (STSS), soft-tissue necrosis (including necrotizing fasciitis, myositis, or gangrene), meningitis, GAS pneumonia, or death directly attributable to GAS infection 85% of cases were hospitalized, 21% were admitted to ICU 6% died There was no dominant emm type reported among severe cases.	The highest risk of infection was observed in men 40 years of age and older further analysis on iGAS in 40+ years males required as is a confounding factor, since other risk factors, such as substance use, are known to be higher in this population	When breaking down case numbers by subgroups, cell sizes became too small to report for age and regions No ethnicity reported Risk factors is predominantly collected through chart reviews No specialist skin assessment/diagnosis No lab testing of skin infections of GAS

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	progression of illness, and risk factors Skin infection, varicella and wound **Data analysis:** Trends in case counts, incidence rates, geographic distribution, demographics, severity, and risk factors were summarized for 2022 and compared with historical data from 2017–2021. Population denominators were used to calculate rates.			For both severe and non-severe cases, the most common emm types were the same The three most common reported emm types were emm92 (n=14), emm49 (n=13), and emm83 (n=12). Prior to 2021, these emm types were uncommon in the Island Health region and British Columbia, representing on average 0.4%–4% and 1% of subtyped cases reported from 2016 to 2020, respectively To date in the available literature, emm types 49, 83, and 92 have not been associated with more life-threatening illness		
Thean, L. J., Jenney, A., Engelman, D., Romani, L., Wand, H., Mani, J., . . . Steer, A. C. (2021). Prospective surveillance for invasive Staphylococcus	**Purpose:** To increase understanding of the incidence of iSA and iGAS in settings with a high skin and soft tissue Infections burden.	N = 70 iGAS or iSA cases All ages Northern Division of Fiji, 1 hospital region	53.3% of iGAS cases clinical infection was observed in skin and soft tissue	Incidence rates of: iGAS = 12.3 per 100,000 person years iSA = 45.2 per 100,000 person years	The incidence of disease was six times higher in the iTaukei population compared with people of other ethnicities in Fiji.	Surveillance limited to the referral hospital providing a minimum estimate of the burden of iSA and iGAS in this population.

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aureus and group A Streptococcus infections in a setting with high community burden of scabies and impetigo. *International journal of infectious diseases : IJID : official publication of the International Society for Infectious Diseases, 108*, 333-339. doi: **https://dx.doi.org/10.1016/j.ijid.2021.05.041** Fiji	Prospective surveillance 2018 - 2019 **Data collection:** laboratory records and ward registers Patient demographics, clinical site of infection, comorbidities (type 2 diabetes mellitus, immunosuppression, heart disease, renal disease, liver disease, malignancy and chickenpox), culture results, management and outcomes. The presence of non - invasive SSTIs, such as cellulitis and abscesses, as diagnosed by the treating clinician was recorded. **Data analysis:** Part of a larger trial ('Big SHIFT', Trial ID: ACTRN12618000461291), which aims to measure the impact of ivermectin-based mass drug administration on	**Ethnicity:** iTaukei (Indigenous) Other minorities Fijians of Indian Descent Northern Division of Fiji Population =131,914	75% of iSA cases clinical infection was observice in skin and soft tissue. Almost all iGAS isolates belonged to *emm* types and *emm* clusters that are associated with skin infections	15/70 admissions with iGAS = 12.3 per 100,000 person years 55/70 admissions with iSA = 45.2 per 100,000 person years 1/70 had both iSA and iGAS 14.5% case fatality rate 33.3% in iGAS 10.9% in iSA One of the deaths was the patient with both iSA and iGAS. Higher CFR in cases over 55 and with diabetes Most patients had bacteraemia: 48 cases of iSA (92.3%) and eight cases of iGAS (53.3%). The all-age incidence rates of 6.6 per 1000,000 = GAS bacteraemia 39.4 per 100,000 = *S. aureus* Highest incidence in:	A major contributing factor to the high rates of iSA and iGAS in these settings is likely to be the high community burden of SSTIs. The prevalence of scabies and impetigo are very high in Fiji, especially in the Northern Division, with reported rates of 28.5% and 23.7%, respectively. The highest incidence was found in the youngest and oldest age groups, particularly among those aged <5 and ≥65 years. Children comprised 90% of ICU admissions. The CFR was highest in older patients Diabetes was noted in 26.9% of iSA cases 46.7% of iGAS cases	Data on length of stay, treatment received and outcomes may have been incomplete for patients transferred back to their referring hospitals. Collection of samples from patients was determined by clinician assessment. Samples collected after the administration of antibiotics which may reduce the detection of bacteria using standard culture methods No report if MDA for scabies programme prior to the study Limited demographic analysis No specialist clinical assessment or testing for diagnosing skin condition

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	downstream complications of scabies, including iSA and iGAS. Defined iGAS as lab confirmed isolation of S aureus or GAS from a usually sterile site. Incidence calculated using 2017 Northern Division of Fiji statistics			iGAS ≥65 years = 67.9 per 100,000 55-64 years = 29.3 per 100,000 0-4 years = 14.9 per 100,000 Incidence rates were higher in the iTaukei population = 59/70 (89.4%) cases, six times higher in the iTaukei population compared with people of other ethnicities in Fiji. The incidence of iGAS among patients with diabetes was 33 per 100,000 person-years compared with 8 per 100,000 person-years in patients without diabetes Forty-one patients (78.9%) with iSA Nine patients (60%) with iGAS required surgery in the operating theatre, some on repeated occasions.		

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				The median length of stay in hospital was 15 days for both iSA & iGAS Children comprised 90% of ICU admissions.		
GAS Skin infections						
Armitage, E. P., Senghore, E., Darboe, S., Barry, M., Camara, J., Bah, S., . . . de Silva, T. I. (2019). High burden and seasonal variation of paediatric scabies and pyoderma prevalence in The Gambia: A cross-sectional study. *PLOS Neglected Tropical Diseases, 13*(10), e0007801. doi: **https://dx.doi.org/10.1371/journal.pntd.0007801** Gambia	**Purpose:** Determining prevalence of scabies, pyoderma, cellulitis/abscess and fungal infections in Sukuta, a peri-urban settlement in western Gambia, in children <5 years Cross sectional population based study May – Sept 2018 (including dry and rainy season) **Data collection:** *Wound swabs:* to determine the presence of *S. aureus* and/or GAS by microbiological culture *Case records:* number of presentations per month for skin complaints (including impetigo,	n = 1441 37 geographical clusters of approximately 100 households < 5 years mean age = 28.9 mths sleeping in a compound within the geographical area of the cluster female/N/A = 52.1% male = 47.9%	Before (after) rainy season prevalence: scabies = 15.3% (16.3% not significant) pyoderma = 8.9% (23.1% significant) fungal infection = 14.4% (6.6% significant) The odds of scabies and fungal infections were significantly lower in females than males (aOR 0.70, 95% CI 0.61–0.82 and aOR 0.44, 95% CI 0.32–0.61 respectively) Pyoderma increased with age (aOR 3.13 of pyoderma in 3–4 years compared to <1 year, 95% CI 2.00–4.88), was higher in Serehule children compared to Mandinka children (aOR 1.99, 95% CI 1.16–3.41) and	Pyoderma swabs were taken from 250/1441 participants. 17.4% prevalence 80.8% positive for S. aureus, 50.8% positive for GAS 41.6% for S aureus & GAS A history of previous skin infections increased the odds of all three infections The proportion of GAS and *S. aureus* causing pyoderma were similar regardless of scabies infection Swabs taken from the lower limbs were significantly more likely to be positive for GAS	Scabies may play a less significant role in pyoderma rates in West Gambia Data were not collected on insect bites, but increased insect activity during the rainy season may play a more significant role than scabies in this setting.	Sampled from one peri-urban population, not generalisable, particularly to rural settings, excludes older school-age children and households sampling only able to resample one cluster to compare prevalence directly, prevalence varied by cluster so limited evdience

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	cutaneous abscess, furuncle or carbuncle, and cellulitis) between 2011 and 2018 were interrogated to ascertain if seasonal variation was observed. *Information on socio-demographic factors and possible risk factors:* breastfeeding status, birthweight (if known), household water source and distance, frequency of full body washing and ironing of clothes, whether clean clothes were worn every day, the presence in the compound of a handwashing area, an open fire for cooking, previous history of skin infections, burns, malnutrition or nutritional supplementation. **Data analysis:** A one-stage, random cluster sampling method was used, sampling clusters in a randomly generated order		increased with household size (aOR 1.03, 95% CI 1.01–1.06) lower odds of scabies in those whose clothes are always ironed (aOR 0.26, 95% CI 0.07–0.98), higher odds of fungal infections in those not wearing freshly washed clothes every day (aOR 13.5, 95% CI 3.22–26.60). Current breastfeeding was protective against fungal infections, but increased the odds of scabies (aOR 1.67, 95% CI 1.12–2.49). Pyoderma was significantly associated with scabies infestation (OR 2.74 95%CI1.61-4.67) The population attributable risk of scabies as a cause of pyoderma was 18.5% (95% CI 4.1–30.8) before the start of the rainy	than swabs from other sites The start of the rains did not significantly affect the proportion of *S. aureus* or GAS detected		

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	Adjusted binomial exact confidence intervals were calculated for prevalence estimates Associations between socio-demographic and other risk factors and skin infections were investigated using multivariable logistic regression models To determine the sensitivity and specificity of the algorithm used, a subset of participants were selected opportunistically and re-examined by a general physician with experience of diagnosing paediatric dermatological conditions in The Gambia, blinded to the nurse's diagnosis.		season compared to 13.6% (95% CI -0.7–25.8) afterwards.			
Chang, A. Y., Scheel, A., Dewyer, A., Hovis, I. W., Sarnacki, R., Aliku, T., . . . Beaton, A. Z. (2019). Prevalence, Clinical Features and Antibiotic Susceptibility of Group A Streptococcal Skin	**Purpose:** To determine the prevalence of skin infections and the clinical features and antibiotic susceptibility of GAS skin infection. Cross sectional study	n = 3265 participants 343 Northern Uganda A 352 Northern Uganda B 2570 Western Uganda 3 schools enrolled in the National RHD Registry	60/3265 (1.8%)1 bacterial infection 1050/3265 (32%) 1 fungal infection 30/3265 (0.9%) 1 viral infection 7/3265 (0.2%) ectoparasitic infestation	Overall prevalence of GAS skin infection by PCR = 0.8% This is lower than clinical estimates of prevalence at 1.8% for bacterial skin infection (as determined	Our low prevalence of GAS skin infection may be a reflection of an urban population's better access to water, sanitation, and hygiene.	PCR analysis for Staphylococcus aureus was outside the scope of this study a recent round of ivermectin prophylaxis could have treated

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Infections in School Children in Urban Western and Northern Uganda. *The Pediatric Infectious Disease Journal, 38*(12), 1183-1188. doi: **https://dx.doi.org/10.1097/INF.0000000000002467** Uganda	March 2017 **Data collection:** Skin swab from lesions with bacterial infection GAS identified by PCR. Antibiotic susceptibility testing was performed on PCR-confirmed GAS bacterial isolates. Skin examination occurred in two-phases: Phase 1: Full body skin screening examination by a local healthcare professional (nurse, clinical officer, or pediatrician) who had received training on identification of abnormal skin findings, including clinical signs of skin infection (bacterial, fungal, viral) and ectoparasitic infestation. Examination of the groin/buttocks and female breasts was deferred Phase 2: Positive phase one participants were	female = 1677/3265 (51%) male/NA = 1588/3265 (49%) 4-20 years larger proportion of teenage participants at both Northern Ugandan primary schools.	934/3265 (28%) scalp ringworm (tinea capitis) 1344/3265 = skin abnormality (including clinical signs of skin infection (bacterial, fungal, viral) and ectoparasitic infestation) 87/1344 assessed as bacterial infection 79/87 infections completed PCR 25/79 (32%) PCRs GAS positive For the 79 PCR specimens: tinea capitis = 39% impetigo = 22% folliculitis/furunculosis, non-scalp 20% scalp folliculitis = 18% scabies = 1% Of the 17/79 impetigo cases, 13 (76%) were located on the lower extremity (leg or foot) No impetigo cases were associated with scabies	by clinical diagnosis) which fell within the prevalence range of 1.3% to 12.7% reported from schoolchildren in rural, mixed rural/urban, and urban areas of East Africa Of the 31 specimens submitted for GAS PCR: GAS PCR-positive skin specimens were more likely to be associated with a clinical diagnosis of impetigo ($p<0.05$). 4 of 31 (13%) cases of tinea capitis with pustules/crust and 1 of 14 (7%) cases of scalp folliculitis were GAS PCR positive. This finding could represent asymptomatic scalp carriage of GAS or true GAS skin infection. **Anti-microbial resistance:** Of the 25 specimens with GAS identified by PCR, 21 had cultures that	Impetigo is more common in rural areas and GAS skin infection is influenced by hygiene factors. Another consideration is the potential impact of the Onchocerciasis Control Program, which utilizes mass drug administration of ivermectin twice yearly to households in endemic areas. In other world regions, impetigo is driven by scabies and when scabies is treated, both scabies and impetigo rates decline. If a similar relationship exists in Northern Uganda where onchocerciasis is endemic, a recent round of ivermectin prophylaxis could have treated scabies and impetigo before our study was conducted. The observation that about one-third of GAS skin specimens were	scabies and impetigo before our study was conducted. Measurements of point prevalence do not account for seasonal weather patterns. The lack of uniform definitions for bacterial skin infections and GAS skin infection was a major challenge for this study.

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	evaluated by a board-certified dermatologist (A.Y.C), who rendered a clinical diagnosis. Clinical signs of bacterial infection were defined as pus, pustule, crust, or erythema. A distinction was made in clinical diagnosis between folliculitis of the scalp versus non-scalp as asymptomatic scalp carriage of GAS has been reported		or eczema (scabies and eczema had low prevalence.) Ringworm (tinea capitis) was the most common infectious skin condition,	grew GAS. For these 21 GAS+ culture specimens, AST was performed. Six of 21 (29%) specimens demonstrated resistance to tetracycline (inhibition zone 15–18mm)	resistant to tetracycline is consistent with other studies demonstrating tetracycline-resistance in the majority of GAS isolates from referral healthcare settings in sub-Saharan Africa	
Taiaroa, G., Matalavea, B., Tafuna'i, M., Lacey, J. A., Price, D. J., Isaia, L., . . . Gorrie, C. L. (2021). Scabies and impetigo in Samoa: a school-based clinical and molecular epidemiological study. *The Lancet Regional Health–Western Pacific, 6*. Retrieved from **https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8315614/pdf/main.pdf** Samoa	**Purpose:** To assess the prevalence of impetigo and scabies in schoolchildren residing in rural Samoa, integrated with descriptive epidemiological and microbial genomic data Observational cross sectional survey 7 – 20 Feb 2018. **Data collection:** Assessments of skin infection, followed by swabs on active impetigo sores.	n = 833 rural areas of Upolu Island, Samoa. 4 – 15 years median = 9 years males = 428 (51.4%) females = 397 (46.7%) 8 (1.0%) = not specified Median household size 8 (range 1 – 30 occupants). 70.8% of children reported sharing a bedroom	Impetigo prevalence was 57.1%. Scabies prevalence was 14.4%. Active impetigo lesions 31.6% Active and inactive impetigo 6% Active impetigo significantly higher in males(37.9%) than females (24.9%) Active impetigo significantly higher in 4-	88% of children enrolled in school district were assessed. 65/833 S. pyogenes isolates (7.8%), 16/65 oropharyngeal isolates (1.9%) 50/65 skin isolates (6.0%). 288/833 S. aureus isolates (34.6%) 147/288 oropharyngeal isolates 202/288 skin isolates. 22 co-infection at skin sites between S. pyogenes and S. aureus.	scabies prevalence was far lower than that of active impetigo the prevalence of scabies in this study (14.4%,), was higher than that described in a previous study of Samoan schoolchildren conducted in 1999, where the prevalence was estimated at 4.9. This discrepancy may be partly explained by the widespread use of ivermectin to eradicate filariasis in Samoa at the time of the first study	a subset of the participant data were self-reported including age and household size, by children as young as four years. observation of scabies was made clinically, without the support of confirmatory microscopy or molecular tests the survey included children attending school on the southern coast of Upolu, Samoa, and therefore may not be representative of the

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	Assessment for scabies. Throat swab. Isolates sequenced if possible demographic data were collected from the children by senior medical students from the National University of Samoa who were trained in the survey methods with a questionnaire, age, gender, number of occupants in the participants household and their sleeping arrangements	81.8% reported sharing bedmats	7 years (42.3%) compared to 12-15 years (20.7%) prevalence of active impetigo varied between schools – the highest prevalence being 45.8% compared to 25.4% prevalence of scabies did not differ significantly between males and females, or between different age groups, although prevalence varied greatly between schools Statistically significant association between scabies and active impetigo was observed (aOR 2.1, 95% CI [1.4–3.1])	52 S. pyogenes isolates had whole-genome sequence data generated A total of 22 S. pyogenes emm types were observed, belonging to seven emm clusters The most commonly observed emm types were emm101 (7/52; 13.5%), emm100 (5/52; 9.6%) and emm225 (5/52; 9.6%) the most commonly observed cluster types were D4 (20/52; 38.5%), E3 (10/52; 19.2%) and E6 (7/52; 13.5%). Samoa population = 195,000	it has been suggested that seasonal variation in scabies prevalence may be linked to lower temperatures and higher relative humidity secondary bacterial infection of scabies was relatively uncommon in this and an earlier study of Samoan schoolchildren [50], suggesting that other factors may be driving impetigo in this setting. Household size and sharing of bedding have also been reported as drivers of skin infections in other settings, and likely contribute to these infections in Samoa [64]. However, these factors were not included as variables in our model as, following discussions with members of the local community, the majority of children were thought to share a communal sleeping space and communal bedding with other	broader Samoan community The microbiological culture in the study likely represents a limited view of the microbial diversity present at the given body sites in the study population, with local isolation, transport and storage practices likely affecting these results

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					household members, which may not have been recognised as 'sharing a bedroom'. There appears to be an acceptance of these conditions as 'normal' in Samoa, with 224 children self-reporting no impetigo despite having one or more impetigo lesions on observation.	
Acute Post-Streptococcal Glomerulonephritis (APSGN) and Post-Streptococcal Glomerulonephritis (PSGN)						
Chong, H.-Y. C., Hung, T.-Y., Hohls, A., Francis, J. R., & Chaturvedi, S. (2023). Clinical characteristics of hospitalised children with acute post-streptococcal glomerulonephritis in the Top End of Australia. *Journal of Paediatrics and Child Health, 59*(5), 735-742. doi: **https://dx.doi.org/10.1111/jpc.16386** Australia	**Purpose:** To describe clinical characteristics and outcomes of hospitalised children with APSGN in the Northern Territory. Single centre, retrospective cohort study 2012- 2017 **Data collection:** case notes and electronic hospital records. Age at diagnosis, gender,	n = 96 <18 years median age was 7.1 years (IQR 6.7–11.4) male = 51.0% female/N/A = 49% Aboriginal or Torres Strait Islanders = 90.6% Rural/remote = 82.3% APSGN admissions to tertiary hospital 41 remote communities	65.6% with preceding skin infection (sores).	85 definite APSGN 11 probable APSGN 84/96 PCR swabs 20/84 (23.8%) GAS-positive skin 3/84 (3.6%) GAS-positive throat 93.8 % had immunological markers of recent GAS infection indicated by low C3 complement levels and elevated streptococcal serology (88.5%). 33.4% severe presentations	Despite the high acuity of presentations in our study, most children improved with supportive medical care However, while our study reflected a rigorous approach to the acute management of APSGN, it exposed a shortcoming in the systems of follow-up post-discharge from the hospital	No definition of what was considered a skin infection Likely that case ascertainment was biased towards severe presentations researchers did not have access to all community health records; children who may have met the inclusion criteria may have been discharged to primary health-care follow-up were missed

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	Aboriginal and Torres Strait Islander status and residence Clinical data, including symptoms and signs during admission, co-morbidities, laboratory parameters and inpatient management,			Twelve (12.5%) children were continued on anti-hypertensive treatment on discharge. The median length of stay was 7 days (IQR 5–12). All patients were discharged home, except for one child who was referred to another hospital. Two children were readmitted to hospital within a month for a prolonged course of APSGN. None of the children required kidney replacement therapy including dialysis.		Little analysis of demographic and no reporting of household make-up 42.7% were lost to follow-up; and even amongst those who attended their follow-up review, key clinical makers of kidney disease – such as blood pressure, SCr, urinalysis, complement levels – were incompletely recorded in up to 76.4% of encounters.
Dowler, J., & Wilson, A. (2020). Acute post-streptococcal glomerulonephritis in Central Australia. *The Australian journal of rural health, 28*(1), 74-80. doi: **https://dx.doi.org/10.1111/ajr.12568**	**Purpose:** To determine the incidence, clinical presentation and progress of acute post-streptococcal glomerulonephritis in Central Australia. Retrospective observational analysis	n = 69 < 14 years 62.3% <6 years Male = 35/69 (51%) Female/n/a = 34 (49%) 100% Aboriginal	57/69 (83%) recent streptococcal infection 54/69 (78%) acute or symptoms of pyoderma or pharyngitis 45/69 (65.2%) skin infection source 5/69 (7.2%) throat as source	69/174 admissions confirmed or probable APSGN Incidence = 228.7/100 000 in Central Australian <14 years children 63/69 lab confirmed cases 6/69 probable cases	Cases of co-morbid infections at during admission included scabies/head lice (24), urinary tract infection (15), pneumonia (12), streptococcal pneumonia bacteraemia (5),	No clinical definition of what was considered a skin infection or who made the diagnosis Study did not examine subclinical cases of APSGN in contacts of confirmed or probable cases.

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Australia	2010 - 2014 **Data collection:** ICD-10 coded nephritis syndrome or persistent haematuria Aboriginal or Torres Strait Islander status, age, gender, residence, month and year diagnosed. Clinical information at presentation included history of APSGN, clinical evidence of streptococcal infection, clinical signs of fluid overload, macroscopic haematuria, medical documentation of hypertension, admission weight-discharge weight and evidence of co-morbid disease. follow-up repeat C3 and C4 serology after discharge	Central Australia – Alice Springs Admissions for APSGN data at Alice Springs Hospital	4/69 (5.8%) pneumonia as source 24/69 scabies/head lice on admission		Streptococcal mitis bacteraemia (1) and cardiomyopathy (1). ongoing poverty endemic in Central Australia. It is well recognised that skin health is associated with environmental and housing factors. Approximately 28% of homes do not have functioning facilities to bathe children and 37% do not have facilities to appropriately wash clothes	The true burden of disease and economic cost of APSGN cannot just be assessed by looking at hospital admission data. Small patient numbers, retrospective data collection and variable or incomplete documentation of key clinical information such as the presence of macroscopic haematuria, oedema and co-morbidities 27/69 patients did not have repeat complement levels taken.

Limm-Chan, B., Musgrave, J., Lau, R., Ahn, H. J., Nguyen, L., & Kurahara, D. (2020). Incidence of Acute Post-Streptococcal Glomerulonephritis in Hawai'i and Factors Affecting Length of Hospitalization. *Hawai'i journal of health & social welfare, 79*(5), 149-152. Retrieved from **https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7226310/** Hawai'i	**Purpose:** To estimate the incidence of APSGN among children in Hawai'i, to identify populations at increased risk for APSGN, and to recognize risk factors correlated with the length of hospitalization by subtype of APSGN Retrospective case review 2008 - 2014 APSGN was defined by the following criteria: acute onset of glomerulonephritis with hematuria and/or proteinuria, depression of serum C3 levels, and evidence of streptococcal infection. **Data collection:** Medical records Descriptive characteristics (ie, age, sex, race), clinical features (ie, history of streptococcal infection, blood pressure at hospital admission, blood urea nitrogen, creatinine, streptococcal titers), as well as length of hospitalization.	n = 106 2- 21 years Mean age = 8.3 years Hospital admissions for APSGN at one hospital on island of O'hau 80 from O'hau 11 from Hawai'i, 7 from Maui, 6 from Kaua'i, 2 from Moloka'i males = 64% females = 36% Pacific Islanders = 62% Asian = 22% White = 1% African American = 1% Other = 11%	93/106 patients (88%) clinicians identified a likely source of infection from history, examination, or diagnostic tests, Skin infection likely = 41% Pharyngitis likely = 47% Serum antistreptolysin O (ASO) titer was elevated in 83% of cases [ASO titers measure antibodies against streptolysin O, a hemolytic toxic substance produced by *Streptococcus pyogenes*]	4 per 100,000 cases APSGN in people aged 21 years or younger The length of hospitalization ranged from 2 to 21 days, (mean 4.7) length of hospitalization between people who had pyodema and/or pharyngitis was not statistically significant difference [106 as the numerator, and 372,955 as the denominator (the estimated population of people 21 years and younger in Hawai'i each year during the time period 2008-2014), and then further divided by the duration of 7 years]	62% admissions were Pacific Islanders, (including Native Hawaiians, Polynesians, and Micronesians), [cf ~10% general population Pacific Islanders]	No clinical diagnosis or testing of skin Calculated incidence is likely an underestimate of the true incidence because study did not capture outpatient data only from one hospital in Hawai'i. small sample uncontrolled study design calculated the annual incidence of APSGN for the entire state of Hawai'i (rather than the island of O'ahu) despite collecting cases from only 1 O'ahu hospital.

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	Demographic and clinical information were summarized using means and standard deviations (SD) for continuous variables and frequencies and percentages for categorical variables.					
Acute Rheumatic Fever (ARF) and Rheumatic Heart Disease (RHD)						
Arumugam, P., Yadav, A., & Rawat, Y. (2024). A Surveillance Study of the Serotypes of Streptococci in the Throat and Skin Lesions in Acute Rheumatic Fever and Rheumatic Heart Disease Patients and their Families. *APIK Journal of Internal Medicine, 12*(1). Retrieved from **https://journals.lww.com/joim/fulltext/2024/12010/a_surveillance_study_of_the_serotypes_of.7.aspx** (India)	**Purpose:** To determine the colonization of the throat and skin among patients of rheumatic heart disease (RHD) or acute rheumatic fever (ARF) from Lohia Hospital, New Delhi, and to elucidate the different Lancefield serotypes of streptococci (Group A, Group C, and Group G) among them. Prospective observational surveillance study 2016 –2018 **Data collection:** Self-report interview of presence of sore throat	n = 30 RHD = 19 (63%) ARF = 11 (37%) *Cases:* 8-18 years Mean age = 10.73 years male = 18/30 (60%) female = 12/30 (40%) n = 131 family members	In our study, the incidence of pyoderma was negligible (single case) as opposed to studies done in the past in various parts of India on the epidemiology of GAS infections and in other countries such as Australia and New Zealand on the incidence of GAS pyoderma. 913/915 throat swabs 2/915 skin swabs 7/ 30 (23%) families had GAS positive cultures including throat and skin samples. 19/131 family members had positive cultures	Overall prevalence of GAS throat carriage was 3.2% Prevalence for winter-spring = 5.8% spring-summer = 2%. Of the GAS-positive (including case and family) 72.2% (13 out of 18) were children <15 years, The age difference was statistically significant (P = 0.025) between culture-positive and culture-negative cases, suggesting that the carriage rate of GAS is more in children. GAS colonization in significantly higher	100% of the families met the overcrowding criteria. Sanitation facilities were satisfactory in 87% of the families climatic conditions of South India (temperate) and North India (tropical) are grossly different, and it is quite possible that skin infections subsequent to serotypes of streptococci are climate-specific.	Small sample size and very small skin related data Self-report of pyoderma stated as assessment criteria only, no clinical criteria described

Study title & Country	Purpose & Methodology	Population characteristics	Skin results GAS infected eczema, impetigo, cellulitis or scabies	Prevalence/Incidence/outcomes	Associations between exposure and outcomes	JBI Quality indicators & limitations
	or skin lesions such as impetigo or pyoderma. throat and any pyoderma lesions were swabbed irrespective of symptomatology Blood samples were taken to determine the antistreptolysin-O (ASO) and anti-DNAse titers of the patients. **Data analysis:** prevalence of streptococci, streptococcal and association of age and antibody titers with RHD/ARF.		18/19 throat, 1/19 skin Positivity only for Group A Strep No positivity for Group C or G	proportion among the family members of cases of ARF in comparison to RHD		
Hempenstall, A., Howell, E., Kang, K., Chau, K. W. T., Browne, A., Kris, E., . . . Hanson, J. (2021). Echocardiographic Screening Detects a Significant Burden of Rheumatic Heart Disease in Australian Torres Strait Islander Children and Missed Opportunities for its Prevention. *The American journal of tropical medicine and hygiene,*	**Purpose:** To identify the clinical, demographic, and socioeconomic characteristics of Torres Strait Islander children, newly diagnosed with RHD, that might be used to inform strategies to reduce local RHD incidence. Retrospective case control study	n = 862 5-18 years median age = 10 years female = 49% male/n/a = 51% From 12/17 of the Torres Strait Islands 97% identified as Torres Strait Islanders	25/862 new cases RHD identified, 16/25 GAS positivity on skin swab [6/25 controls] 18/25 history of skin infections [16/25 in the control group] 17/25 previous swab GAS positivity [9/25 in control]	Prevalence = 34 cases per 1,000 population among those aged between 5 and 20 years in the region. 2.9% of the screened Torres Strait Islander children had RHD, a rate that is comparable with the prevalence seen in Aboriginal Australian, Maori, and Timor-Leste children	skin sores were more common than presentations with sore throat more likely to have GAS cultured from a skin swab than a throat swab. The median (IQR) number of people living in the households of children with RHD was six (4–7) compared with	No clinical definition of skin infections or how diagnosed Little examination of all the socioeconomic, environmental, and behavioural factors that influence GAS incidence except for crowding and rates of unemployment The small sample size increases the risk of type

Study title & Country	Purpose & Methodology	Population characteristics	Skin results GAS infected eczema, impetigo, cellulitis or scabies	Prevalence/Incidence/outcomes	Associations between exposure and outcomes	JBI Quality indicators & limitations
104(4), 1211-1214. doi: **https://dx.doi.org/10.4269/ajtmh.20-0846** Australia	July 2018 **Data collection:** Community based echocardiogram screening programme demographics, socioeconomic indices, previous clinic presentations from medical records **Case control:** All children diagnosed with RHD were matched by age (±2 years), geographic location, and gender (where possible) with children who had a normal screening		11/25 history of sore throat 100% Torres Strait Island ethnicity All 25 were asymptomatic	[25/862 new cases of RHD when added to the 21 existing local RHD cases 862/2,327 individuals aged 5–19 years living on the 17 inhabited Torres Strait Islands]	seven (5–8) in the controls (P = 0.24). There was no employed adult in the household of the 7/23 (30%) children with RHD, compared with 10/22 (45%) controls in whom these data were available (P = 0.37).	2 statistical errors, and its retrospective design increases the likelihood of incomplete or inaccurate data.

Supplementary Material 3: JBI Critical Appraisal Ratings

Bocking, N., Matsumoto, C.-L., Loewen, K., Teatero, S., Marchand-Austin, A., Gordon, J., . . . McGeer, A. (2017). High Incidence of Invasive Group A Streptococcal Infections in Remote Indigenous Communities in Northwestern Ontario, Canada. *Open Forum Infectious Diseases, 4*(1), ofw243. doi: **https://dx.doi.org/10.1093/ofid/ofw243**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of iGAS?	√√			
Were skin conditions measured in a standard, reliable way for all participants?		√√ Cellulitis and skin conditions not described in detail or how diagnosis obtained		
Was there appropriate statistical analysis?		√√ Little explanation of the likelihood of over-estimation due to using the Indian Registry System as population denominator Also missing data from a region		
Was the response rate adequate, and if not, was the low response rate managed appropriately?	√√			

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Valenciano, S. J., Onukwube, J., Spiller, M. W., Thomas, A., Como-Sabetti, K., Schaffner, W., . . . Van Beneden, C. A. (2021). Invasive Group A Streptococcal Infections Among People Who Inject Drugs and People Experiencing Homelessness in the United States, 2010-2017. *Clinical infectious diseases : an official publication of the Infectious Diseases Society of America, 73*(11), e3718-e3726. doi: **https://dx.doi.org/10.1093/cid/ciaa787**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of iGAS?	√√			
Was acute and chronic skin conditions measured in a standard, reliable way for all participants?	√√			
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?	√√			

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Nwosu, A., Schut, A., Wood, C. A., Urquhart, C., Bachman, C., Thompson, K., . . . Restemeyer, T. (2023). Invasive group A streptococcal (iGAS) surveillance in Island Health, British Columbia, 2022. *CCDRCANADA, 49*(7/8), 342. Retrieved from **https://www.canada.ca/en/public-health/services/reports-publications/canada-communicable-disease-report-ccdr/monthly-issue/2023-49/issue-7-8-july-august-2023/invasive-group-igas-surveillance-island-health-british-columbia-2022.html**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?		√√ No ethnicity, socio-economic or other demographic features of Island region described or part of analysis of cases		
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of iGAS?	√√			
Were skin infections, varicella or wounds measured in a standard, reliable way for all participants?	√√	√ No specialist skin assessment/diagnosis No lab testing of skin infections of GAS		
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?	√√			

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Armitage, E. P., Senghore, E., Darboe, S., Barry, M., Camara, J., Bah, S., . . . de Silva, T. I. (2019). High burden and seasonal variation of paediatric scabies and pyoderma prevalence in The Gambia: A cross-sectional study. *PLOS Neglected Tropical Diseases, 13*(10), e0007801. doi: **https://dx.doi.org/10.1371/journal.pntd.0007801**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of GAS?	√√			
Was scabies and pyoderma measured in a standard, reliable way for all participants?	√√			
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?		√√ excludes older school-age children and households sampling not generalisable to populations over 5 only able to resample one cluster to compare prevalence directly, prevalence varied by cluster so limited evidence		

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Chang, A. Y., Scheel, A., Dewyer, A., Hovis, I. W., Sarnacki, R., Aliku, T., . . . Beaton, A. Z. (2019). Prevalence, Clinical Features and Antibiotic Susceptibility of Group A Streptococcal Skin Infections in School Children in Urban Western and Northern Uganda. *The Pediatric Infectious Disease Journal, 38*(12), 1183-1188. doi: **https://dx.doi.org/10.1097/INF.0000000000002467**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of GAS?	√√			
Was the bacterial, fungal or viral skin infections measured in a standard, reliable way for all participants?	√	√ lack of uniform definitions for bacterial/GAS skin infection noted as a study limitation		
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?	√√			

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Thean, L. J., Jenney, A., Engelman, D., Romani, L., Wand, H., Mani, J., . . . Steer, A. C. (2021). Prospective surveillance for invasive Staphylococcus aureus and group A Streptococcus infections in a setting with high community burden of scabies and impetigo. *International journal of infectious diseases : IJID : official publication of the International Society for Infectious Diseases, 108*, 333-339. doi: **https://dx.doi.org/10.1016/j.ijid.2021.05.041**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√			
Were valid methods used for the identification of iGAS & GAS?	√√			
Was cellulitis, abscesses and other skin infections measured in a standard, reliable way for all participants?		√√ No specialist clinical assessment or testing for diagnosing skin condition		
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?	√√			

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Taiaroa, G., Matalavea, B., Tafuna'i, M., Lacey, J. A., Price, D. J., Isaia, L., . . . Gorrie, C. L. (2021). Scabies and impetigo in Samoa: a school-based clinical and molecular epidemiological study. *The Lancet Regional Health–Western Pacific, 6*. Retrieved from **https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8315614/pdf/main.pdf**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of GAS?	√√			
Was the scabies and impetigo measured in a standard, reliable way for all participants?		√√ observation of scabies was made clinically, without the support of confirmatory microscopy or molecular tests		
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?	√√			

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Chong, H.-Y. C., Hung, T.-Y., Hohls, A., Francis, J. R., & Chaturvedi, S. (2023). Clinical characteristics of hospitalised children with acute post-streptococcal glomerulonephritis in the Top End of Australia. *Journal of Paediatrics and Child Health, 59*(5), 735-742. doi: **https://dx.doi.org/10.1111/jpc.16386**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√	√ Little analysis of demographics, no reporting of household make up		
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of PGSN?	√√			
Were skin infections measured in a standard, reliable way for all participants?		√√ No definition of what was considered a skin infection		
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?		√√ 42.7% were lost to follow-up; and even amongst those who attended their follow-up review, key clinical makers of kidney disease were incompletely recorded in up to 76.4% of encounters.		

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Dowler, J., & Wilson, A. (2020). Acute post-streptococcal glomerulonephritis in Central Australia. *The Australian journal of rural health, 28*(1), 74-80. doi: **https://dx.doi.org/10.1111/ajr.12568**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of PGSN?	√√			
Was the skin infection measured in a standard, reliable way for all participants?		√√ No clinical definition of what was considered a skin infection or who made the diagnosis		
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?		√√ 27/69 patients did not have repeat complement levels taken.		

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Limm-Chan, B., Musgrave, J., Lau, R., Ahn, H. J., Nguyen, L., & Kurahara, D. (2020). Incidence of Acute Post-Streptococcal Glomerulonephritis in Hawai'i and Factors Affecting Length of Hospitalization. *Hawai'i journal of health & social welfare, 79*(5), 149-152. Retrieved from **https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7226310/**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√	√- only one island hospital sampled		
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of PGSN?	√√			
Was the skin infection measured in a standard, reliable way for all participants?		√√ No clinical diagnosis or testing of skin		
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?	√√			

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Arumugam, P., Yadav, A., & Rawat, Y. (2024). A Surveillance Study of the Serotypes of Streptococci in the Throat and Skin Lesions in Acute Rheumatic Fever and Rheumatic Heart Disease Patients and their Families. *APIK Journal of Internal Medicine, 12*(1). Retrieved from **https://journals.lww.com/joim/fulltext/2024/12010/a_surveillance_study_of_the_serotypes_of.7.aspx**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?		√√ Small sample size and very small skin related data 2/915 were skin swabs and only 1 was GAS		
Were valid methods used for the identification of ARF or RHD?	√√			
Was the skin infection/pyoderma measured in a standard, reliable way for all participants?		√√ Self-report of pyoderma stated as assessment criteria only, no clinical criteria described		
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?	√√			

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Hempenstall, A., Howell, E., Kang, K., Chau, K. W. T., Browne, A., Kris, E., . . . Hanson, J. (2021). Echocardiographic Screening Detects a Significant Burden of Rheumatic Heart Disease in Australian Torres Strait Islander Children and Missed Opportunities for its Prevention. *The American journal of tropical medicine and hygiene, 104*(4), 1211-1214. doi: **https://dx.doi.org/10.4269/ajtmh.20-0846**

JBI Quality Appraisal Tool

	Yes	No	Unclear	N/A
Was the sample frame appropriate to address the target population?	√√			
Were study participants sampled in an appropriate way?	√√			
Was the sample size adequate?	√√			
Were the study subjects and the setting described in detail?	√√			
Was the data analysis conducted with sufficient coverage of the identified sample?	√√			
Were valid methods used for the identification of RHD?	√√			
Was the skin infection measured in a standard, reliable way for all participants?		√√ No clinical definition of what was considered a skin infection or who made the diagnosis		
Was there appropriate statistical analysis?	√√			
Was the response rate adequate, and if not, was the low response rate managed appropriately?	√√			

Overall appraisal: Include Include

Comments (Including reason for exclusion)

Supplementary Material 4: Search Strategy One

Search Strategy for Skin Infections Epidemiology in Aotearoa New Zealand

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations, Daily and Versions <1946 to December 06, 2023> , adapted for Embase and Scopus

Search Strategy:

1 epidemiol*.mp.
2 incidence.mp. or Incidence/
3 Prevalence/ or prevalence.mp.
4 "Global Burden of Disease"/ or burden.mp.
5 burden.mp.
6 1 or 2 or 3 or 4 or 5
7 impetigo.mp. or Impetigo/
8 exp Eczema/ or eczema.mp.
9 Scabies/ or scabies.mp.
10 atopic dermatitis.mp. or Dermatitis, Atopic/
11 exp Pyoderma/ or pyoderma.mp.
12 7 or 8 or 9 or 10 or 11
13 6 and 12
14 (zealand or maori or aotearoa).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
15 13 and 14
16 limit 15 to (english language and yr="2013 -Current")

Total Citations
Medline=46
Embase=45
Scopus=44
Total=135
Total after Duplicates Removed=15

Search Strategy - Treatment of GAS Skin Infections in New Zealand

1 impetigo.mp. or Impetigo/
2 exp Eczema/ or eczema.mp.
3 Scabies/ or scabies.mp.
4 atopic dermatitis.mp. or Dermatitis, Atopic/
5 exp Pyoderma/ or pyoderma.mp.
6 ((GAS or "group a strep*") adj7 skin adj7 infect*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
7 1 or 2 or 3 or 4 or 5 or 6
8 ("new zealand" or maori or aotearoa).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
9 7 and 8
10 treat*.mp.
11 Pharmaceutical Preparations/ or Drug Therapy/ or pharmacolog*.mp.
12 (prescription* or prescrib*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
13 exp Anti-Infective Agents, Local/ or exp Anti-Bacterial Agents/ or antiseptic*.mp.
14 Fusidic Acid/ or fusidic acid*.mp.
15 exp Medicine/ or medicin*.mp.
16 antibiotic*.mp.
17 Drug Prescriptions/ or drug*.mp.
18 therapeutic* or methotrexate
19 supplement*.mp.
20 exp Probiotics/ or probiotic*.mp.
21 (Corticosteroid* or steroid*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
22 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21
23 9 and 22
24 limit 23 to (english language and yr="2013 -Current")

Search Totals

Medline=67

Embase=55

Scopus=59
Total=181
Total After Duplicates and False Drops Removed=25

Search Strategy - Qualitative Studies on Skin Infection Programmes in NZ- 2013-2023

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations, Daily and Versions <1946 to December 06, 2023>, adapted for Embase, Scopus

Search Strategy:

1 impetigo.mp. or Impetigo/
2 exp Eczema/ or eczema.mp.
3 Scabies/ or scabies.mp.
4 atopic dermatitis.mp. or Dermatitis, Atopic/
5 exp Pyoderma/ or pyoderma.mp.
6 (skin* adj3 (infect* or sore*)).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
7 1 or 2 or 3 or 4 or 5 or 6
8 ("new zealand" or maori or aotearoa).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
9 7 and 8
10 exp qualitative research/
11 qualitative.ab,ti.
12 grounded theory.mp. or Grounded Theory/
13 action research.mp.
14 ethnograph*.mp.
15 Phenomenolog*.mp.
16 interview*.mp.
17 10 or 11 or 12 or 13 or 14 or 15 or 16
18 9 and 17
19 limit 18 to (english language and yr="2013 -Current")

Totals
Medline=9
Embase=6
Scopus=7
Total=22
Total After Duplicates Removed=4

Search Strategy for Research Projects and Protocols Skin Infections or GAS or iGAS

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations, Daily and Versions <1946 to December 06, 2023>, adapted for Scopus, Embase (supplemented with full text Google Scholar Search)

Search Strategy:

1 (Aboriginal* or Indigenous* or First Nation* or Native* or First Australian* or Torres Strait Islander* or Maori* or Pacific Islander* or Native Hawaiian* or American Indian* or First American* or Amerind* or Alaska Native* or Eskimo* or Inuit* or Sami*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
2 (pasifik* or samoa* or tonga* or fiji* or cook island* or Niue* or hawaiian* or polynesian* or micronesian* or melanesian* or Papua New Guinea or Solomon Islands or Kiribati or Tokelau*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
3 ("new zealand" or maori or aotearoa).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
4 exp australia/ or austral*.mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
5 1 or 2 or 3 or 4
6 impetigo.mp. or Impetigo/
7 exp Eczema/ or eczema.mp.
8 Scabies/ or scabies.mp.
9 atopic dermatitis.mp. or Dermatitis, Atopic/
10 exp Pyoderma/ or pyoderma.mp.
11 ((GAS or "group a strep*") adj7 skin adj7 infect*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
12 6 or 7 or 8 or 9 or 10 or 11
13 research design/

14 research method*.mp.
15 data collection method*.mp.
16 protocol*.mp.
17 13 or 14 or 15 or 16
18 5 and 12 and 17
19 limit 18 to (english language and yr="2013 -Current")

Totals

Medline=33

Embase=58

Scopus=16

Total=107

Total after false drops removed=8

Supplementary Material 5: Search Strategy Two

Search strategy for population skin infection intervention stocktake

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations, Daily and Versions <1946 to January 31, 2024>, adapted for Embase, Scopus

Search Strategy:

1 impetigo.mp. or Impetigo/
2 exp Eczema/ or eczema.mp.
3 Scabies/ or scabies.mp.
4 atopic dermatitis.mp. or Dermatitis, Atopic/
5 exp Pyoderma/ or pyoderma.mp.
6 (skin* adj3 (infect* or sore*)).mp.
7 Cellulitis/ or cellulitis.mp.
8 1 or 2 or 3 or 4 or 5 or 6 or 7
9 (population* adj3 intervent*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
10 (community adj3 intervent*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
11 Mass Drug Administration/
12 (mass adj3 (administ* or screen*)).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
13 health promotion/
14 housing.mp. or exp Housing/
15 housing quality/
16 health education/
17 (stigma* adj3 reduc*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
18 (stigma* adj3 interven*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading

word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
19 (hygiene adj3 (promotion* or education* or intervent*)).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
20 (((environmental or social) adj3 determinant*) and interven*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
21 (primordial adj3 interven*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
22 Community Health Services/
23 (population adj3 initiative*).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
24 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23
25 8 and 24
26 limit 25 to yr="2013 -Current"

Medline = 411
Scopus = 359
Embase = 446
Total = 1216
Total After False Drops Removed = 96

Supplementary Material 6: Evidence of iGAS Interventions in International Settings

Primordial iGAS Interventions in International Settings

Study Topic & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
Primordial Interventions – Targeting Eczema, Scabies and GAS Skin Infections				
Environmental and Personal Hygiene				
Eczema/Atopic Dermatitis Tuller, M. and K. Arca-Contreras (2023). Implementation of the Hand Hygiene Eczema Education Program to Improve Patient Knowledge and Symptoms. Journal of doctoral nursing practice 16(1): 54-61 DOI: **https://dx.doi.org/10.1891/JDNP-2022-0003** USA	Before and after study on self-assessed, patient-oriented eczema N=21 completed the study Post-tests conducted immediately after intervention and again 1-2 months after	At risk population Newly diagnosed or established patients with eczema in private practice	*Intervention:* Educational intervention to increase patients' knowledge of appropriate hand hygiene *Outcomes:* Results demonstrated an improvement in patients' knowledge with regards to atopic dermatitis management and reduction in symptoms • Difference between average pre-test and initial post-test of knowledge was statistically significant ($p<0.05$) • Difference between average pre-test and follow-up post-test of knowledge was also statistically significant ($p<0.05$) • Participants had a 2.04 mean point decrease in symptom severity	This paper lacks specificities about the intervention itself, how/why it was implemented etc. Small study
Public Health Messaging and Stigma				
Skin Infections McRae, T., et al. (2023). Culturally supported health promotion to See, Treat, Prevent (SToP) skin infections in Aboriginal children living in the Kimberley	Qualitative study is embedded within broader clinical trial Based across 9 community settings in the region	Healthcare providers Intervention is tailored to Aboriginal Children in Western Australia	*Intervention:* Culturally supported and tailored public health program Holistic strengths-based approach that aligns with Aboriginal worldview of wellness to reduce prevalence of skin infections and downstream consequences	Revealed ongoing challenges with service practices and protocols associated with treating and preventing skin infections. Possible lack of inter-agency collaboration

Study Topic & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
region of Western Australia: a qualitative analysis. The Lancet Regional Health - Western Pacific 35 DOI: 10.1016/j.lanwpc.2023.100757 Kimberly, Western Australia, Australia	Project officers interviewed (yarning sessions) with community members and providers Included community providers to co-design and implement Recruitment involved purposive sampling and mixed approach. Recruited school and clinic staff involved in study based on knowledge and experiences and community recommendations		*Outcomes:* • There is a strong knowledge base with regards to the recognition, treatment and prevention of skin infections • Knowledge did not extend to the role skin infections play in causing ARF, RHD or APSGN • The biomedical model of treatment of skin infections remained important to staff living in communities • Community members have a reliance and belief in traditional remedies for skin infections	Concerns about environmental health and cultural factors including lore and sorry business Intervention is specific to healthcare provided to Aboriginal youth living in rural Australia, may not be generalisable to other settings
Skin Infections McRae, T., et al. (2023). HipHop2SToP a community-led health promotion initiative empowering Aboriginal youth in the Kimberley region of Western Australia: a process evaluation. Frontiers in public health 11: 1258517 DOI: **https://dx.doi.org/10.3389/fpubh.2023.1258517** Kimberly, Western Australia, Australia	Qualitative process evaluation Participants involved in planning and production of HipHop2SToP selected using purposive approach to share experiences	At risk population Aboriginal youth in Kimberly	*Intervention:* Community-led hip hop music video 'HipHop2SToP' produced involving young people in Dampier Peninsular communities to address healthy skin and healthy living practices *Outcomes:* Validates need for Aboriginal community led health promotion programs • Observed young people actively engaged in the project	Noted gaps in communication, clarification of stakeholder roles and expectations Intervention is specific to healthcare provided to Aboriginal youth living in rural Australia, may not be generalisable to other settings
Skin Infections Phillips, K. T., et al. (2021). "A randomized controlled trial of a brief behavioural intervention to reduce skin and soft tissue infections among people who inject drugs." Drug and alcohol dependence 221:	Randomised control trial N=525 people who inject drugs People who inject drugs were recruited from inpatient hospital units at a single urban medical centre	At risk population Injecting drug users	*Intervention:* SKIN is a two-session intervention which included psychoeducation, behavioural skin demonstrations and motivational interviewing	Skin and soft tissue infections are grouped together, not specifically addressed as a particular bacterium Single site trial, findings may not be generalisable

Study Topic & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
108646 DOI: **https://dx.doi.org/10.1016/j.drugalcdep.2021.108646** Boston, United States of America	Participants randomly assigned to an assessment only condition or intervention arm		*Outcomes:* • SKIN participants had 35% lower skin or soft tissue infections, when compared to control arm (p=0.179), a difference of nearly one infection a year • Mean rate of uncleaned skin injections about 66% lower (p<0.001) among SKIN participants compared to control arm • Almost 1/3 of participants reported no injection over follow up and mean rate of injection during follow-up was 39% lower (p-0.058) among those in SKIN vs control arm	Needle cleaning protocol may not be realistic for injecting drug users living on the streets SSTI's were self-reported

Primary iGAS Interventions in International Settings

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
Primary Interventions – Targeting Eczema, Scabies and GAS Skin Infections				
Diagnosis and Management of Skin Conditions/GAS Skin Infections				
Eczema/Atopic Dermatitis Joseph, A. K., et al. (2022). Evaluating the impact of a community health worker (Promotora de Salud) program on attitudes and beliefs regarding atopic dermatitis among Spanish-speaking Latin-American caregivers. Pediatric dermatology 39(2): 182-186 DOI: 10.1111/pde.14917 Texas, United States of America	Sub-study of ongoing randomised, investigator-blinded, placebo-controlled trial N=48 children with moderate/severe AD recruited from dermatology clinic at Children's Health, Dallas, Texas Randomised group to clinic education (n=26) or clinic education and promotora home visits (n=22) Mann-Whitney U tests compared questionnaire responses in standard education group to promotora group	Healthcare providers Intervention is tailored to Latin American caregivers of paediatric patients with atopic dermatitis	*Intervention:* Community health workers/ promotora on attitudes and beliefs regarding atopic dermatitis management *Outcomes:* Found that culturally competent and language concordant education interventions may improve confidence in AD management skills and medication adherence among Latin-American caregivers of children with AD • Caregivers in intervention (promotora group) were more likely they knew how to apply wet wraps and use bleach baths at 1 month (wet wraps p=0.027, bleach baths p=0.005) and 3 months (wet wraps p=0.005, bleach baths <0.001) • Demonstrated greater self-efficacy compared with standard education group	Tailored to specific cultural group, may not be generalisable to other settings Detail about specific intervention is lacking, including training of community health workers
Eczema/Atopic Dermatitis Ryu, H. and Y. Lee (2015). The Effects of a School-Based Atopy Care Program for School-Aged Children. Western journal of nursing research 37(8): 1014-1032 DOI: **https://dx.doi.org/10.1177/0193945914539737** Seoul, South Korea	Study compared groups using a pre- and post- test design N=32 in the test group and N=66 in the control group in 4 elementary schools	At risk populations For children with atopic dermatitis and their parents	*Intervention:* School-based atopy care program for eczema, administered by health teachers who are also school nurses *Outcomes:* • Parents in test group has significantly increased knowledge of AD (p+0.04) and a greater sense of parental efficacy (p=0.02) when compared to control group	Specific to eczema Doesn't detail actions and efficacy that improved Different setting, whereby, schools have health teachers who are also school nurses

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
Eczema/Atopic Dermatitis Yoo, J.-B., et al. (2018). Effects of a Hybrid Education Programme for Korean Mothers of Children with Atopic Dermatitis. Acta dermato-venereologica 98(3): 329-334 DOI: **https://dx.doi.org/10.2340/00015555-2862** South Korea	Prior and after intervention study N=20 mothers of patients with eczema treated in South Korean hospital	At risk populations For mothers of patients with atopic dermatitis	*Intervention:* A hybrid AD education programme, consisting of one face-to-face session and 8 weekly online modules *Outcomes:* • After intervention, mothers mean+/- standard deviation anxiety reduced (from 50.3 +/- 14.2 to 31.7 +/- 6.3 points, p<0.001) • Caregiving efficacy and caregiving behaviour improved significantly (from 18.3 +/- 3.5 to 29.4 +/- 3.2 points, p < 0.001 and from 47.7 +/- 7.7 to 78.8 +/- 4.9 points, p < 0.001)	Intervention specific to mothers Lack of detail about nature of efficacy and behaviour Only applicable to those who have been hospitalised with eczema (relatively rare)
Eczema/Atopic Dermatitis Luna, P. C., et al. (2022). ECHO project in atopic dermatitis in Argentina: An innovative strategy to reach underserved areas with up to date knowledge, first year of experience. Anais brasileiros de dermatologia 97(4): 443-447 DOI: **https://dx.doi.org/10.1016/j.abd.2021.09.006** Argentina	1 year follow-up Survey carried out among participants to evaluate impact of program on care of patients with atopic dermatitis 12 scheduled interviews Before meeting clinical cases presented and moderated by experts. After meetings, professionals answered survey to evaluate educational results of project on medical skills and impact on daily practice	Healthcare providers Intervention tailored for youth with eczema Healthcare providers included; dermatologists (and in training) and other related specialists from Society of Pediatric Dermatology for Latin America and ECHO Psoriasis program participants	*Intervention:* ECHO – Extension for community healthcare outcomes is an innovative guided practice model whose main purpose is to support health providers in the management of patients with chronic, prevalent, and complex diseases worldwide ECHO takes place through knowledge-sharing teleconferences between physicians and specialist mentors *Outcomes:* Project revealed a significant improvement in the management of patients with atopic dermatitis • Program contributed to the interpretation and use of severity scores, use of phototherapy and management and prescription of classic and innovative topical and systemic treatments	Unknown connection to centralised eczema management guidelines
Eczema/Atopic Dermatitis Pickett, K., et al. (2016).	Systematic review 7 RCTs met inclusion crititeria	At risk population Tailored for children with chronic inflammatory	*Intervention:* Group-based education for children with eczema and their parents	Systematic review on existing RCT's, does not going into depth on particular interventions

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
Education to improve quality of life of people with chronic inflammatory skin conditions: a systematic review of the evidence. The British journal of dermatology 174(6): 1228-1241 DOI: **https://dx.doi.org/10.1111/bjd.14435** United Kingdom		skin conditions and their parents	*Outcomes:* • Found that group-based education for children in eczema and their parents resulted in greater improvement in health-related quality of life and the children's disease severity than no education at 12 months • Common features of effective interventions were long delivery (over 6 weeks to 3 months) and delivery by a multidisciplinary team	
Scabies Ibekwe, P. U., et al. (2020). Scabies Education in secondary schools: A multi-center study. Annals of African medicine 19(4): 263-268 DOI: **https://dx.doi.org/10.4103/aam.aam_67_19** Nigeria	Pre- and post-intervention evaluation N=1768 junior secondary students evaluated at first visit, same group re-evaluated 6 months later (N=1525) Questionnaires with standard questions on scabies administered to students across 4 states in Nigeria Information obtained included subjects' demographics, scabies symptomatology, risks and preventive behaviours Students with active scabies were diagnosed and treated	At risk population Tailored for junior aged secondary school students in Nigeria (aged approx. 11-12 years)	*Intervention:* School-based education on scabies aetiology, risk factors, clinical features, treatment and prevention *Outcomes:* The introduction of frequent health talks on scabies in school curriculum can increase awareness and knowledge of scabies transmission and prevention in secondary schools • Mean test scores for pre-test and post-test first visit were 2.82 +/- 1.38 and 6.30 +/- 1.09, respectively, statistically significant (p=0.004) • Six months later, mean test scores for pre-test and post-test were 4.63 +/- 0.54 and 5.87 +/- 0.25, respectively, statistically significant (p=0.003) • Prevalence of scabies at first visit was 3.5% and 4.34% at second visit • May have reduced apprehension and stigma with regards to scabies treatment and diagnosis • Reduction of inappropriate treatment behaviours	Recognised potential for bias due to stigma related to scabies and self-reporting of symptoms Students quite young and may have needed assistance to fill out questionnaire Also specific to scabies, did not include evaluation about escalation to other diseases

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
Scabies Yotsu, R. R., et al. (2023). An mHealth App (eSkinHealth) for Detecting and Managing Skin Diseases in Resource-Limited Settings: Mixed Methods Pilot Study. JMIR Dermatology 6 DOI: 10.2196/46295 sub-Saharan Africa	Mixed methods pilot study 2 arm trial with local health care providers and patients with skin disease implemented over 3-month period Providers assigned to intervention arm or control arm (usual care) Evaluated with system usability scale and in-depth interviews	Health care providers Intervention aimed to target populations/communities in resource limited settings	*Intervention:* Developed mobile health app, eSkinHealth, a field-adapted platform to serve as a portable electronic patient chart and for tele dermatology *Outcomes:* All participants interviewed were satisfied with the app and community healthcare providers felt empowered being equipped with the tool • 79 cases of skin NTDS were reported in the intervention arm as compare to 17 cases in control arm (p=0.002) • 66% of cases in control arm were not given any particular diagnosis • In intervention arm, 72.9% of cases were diagnosed by eSkinHealth platform, and remaining by on-site dermatologists	Not solely specific to particular NTD, scabies is included Internet connection required for certain functions, poor connectivity hindered results and assessment Pilot trial in one health district, might not be generalisable to other health districts or settings
Scabies Yotsu, R. R., Ding, Z., Hamm, J., & Blanton, R. E. (2023). Deep learning for AI-based diagnosis of skin-related neglected tropical diseases: A pilot study. *PLOS Neglected Tropical Diseases*, *17*(8), e0011230. Sub-Saharan Africa	Pilot study Used 1,709 images from 506 patients, from a variety of ongoing studies (including the one above)	At risk population Patients with scabies and other skin NTDs	*Intervention:* Used two convolutional neural networks, ResNet-50 and VGG-16 models to examine ability to and feasibility in diagnosis of targeted NTD skin *Outcomes:* • The two models were able to correctly predict over 70% of the diagnoses • The ResNet-50 model performed better than the VGG-16 model	Also groups NTDs together A major source of bias in AI applications stems from the availability and variety of images used in training Need to reinforce requirement for more images from a wider diversity of cases Images were heterogenous, taken in different conditions
Scabies Gezmu, T., et al. (2020). Does training of health extension workers reduce scabies load in district health facilities in rural Ethiopia?	Comparative cross-sectional study All individuals presenting with scabies before and after introduction of training in 2 districts were included	Healthcare providers	*Intervention:* Training health extension workers, including in the identification and reporting of scabies Health extension workers spend half a day in community going house-to-house to screen for scabies and offer treatment	Unable to report on the number of scabies managed by health extension workers at a community level

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
Journal of infection in developing countries 14(6.1): 36S-41S DOI: 10.3855/jidc.11730 Ethiopia	Compared between control and intervention district		*Outcomes:* Introduction of trained health extension workers at community level associated with reductions in health facility load for scabies and secondary skin infections • Scabies cases declined in intervention district (4.8 fold reduction from 7.6 to 1.6 per 1,000 population) • Scabies cases increased in control district (1.8 fold increase from 1.3 to 2.4 per 1000 population) • In intervention district proportion with secondary skin infections reduced from 1227 to 156 ($p<0.001$). No such significant difference in control district	These workers might not be equipped with appropriate reporting forms There may have been differences in health-seeking behaviour or awareness of scabies in different districts which may have influenced number of cases presenting to healthcare Specific to scabies, also in a setting in which it might be difficult to generalise to other settings May not be feasible to do such a large scale survey
Scabies Marks, M., et al. (2020). Prevalence of Scabies and Impetigo 3 Years After Mass Drug Administration With Ivermectin and Azithromycin. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America 70(8): 1591-1595 DOI: **https://dx.doi.org/10.1093/cid/ciz444** Solomon Islands	Comparative study Compared prevalence of scabies and impetigo at 36 months to the prevalence at baseline	Population-based	*Intervention:* Mass drug administration (MDA) in 10 villages in Solomon Island Intervention was single round of ivermectin and azithromycin mass drug co-administration *Outcomes:* Sustained impact of single round MDA on prevalence of scabies and impetigo 3 years after intervention • At 36 months, prevalence of scabies was 4.7% compared to baseline 18.7% ($p<0.001$) • Prevalence of impetigo was 9.6%, significantly lower than baseline 24.7% ($p<0.001$)	At province level there is considerable heterogeneity in scabies prevalence

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
Scabies Rinaldi, G. and K. Porter (2021). Mass drug administration for endemic scabies: a systematic review. Tropical diseases, travel medicine and vaccines 7(1): 21 DOI: **https://dx.doi.org/10.1186/s40794-021-00143-5** Global	Systematic review Included 12 articles	Population-based	*Intervention:* Mass drug administration (MDA) *Outcomes:* MDA is effective in treating scabies in endemic community • Drivers for success include; Low levels of migration, MDA uptake of >85%, use of oral Ivermectin therapy, treatment of children and pregnant women and repeated treatment for participants diagnosed with scabies at baseline • Average absolute reduction in scabies prevalence was 22% and relative reduction average was 73.4%	Further evidence needed surrounding MDA use in urban areas with increased levels of migration MDA should not substitution tackling socioeconomic factors which contribute to endemic disease, such as sanitation and hygiene Systematic review, not specific to a particular intervention
Scabies Enbiale, W., Baynie, T. B., Ayalew, A., Gebrehiwot, T., Getanew, T., Ayal, A., ... & Zachriah, R. (2020). "Stopping the itch": mass drug administration for scabies outbreak control covered for over nine million people in Ethiopia. *The Journal of Infection in Developing Countries*, *14*(06.1), 28S-35S. Ethiopia	Cross-sectional descriptive study using routine monitoring data from the MDA campaign	Population-based Where scabies was endemic	*Intervention:* Campaign process included; planning and organisation, community mobilisation and advocacy, awareness-raising among health workers, engagement of local leaders, field implementation, logistics and monitoring and evaluation Drug treatment based on age group, pregnancy/lactation status Scabies treatment type included permethrin lotion, sulphur and oral ivermectin *Outcomes:* A total of 9.7% scabies cases were detected, with 11% contacts	Doesn't have follow-up of impact Doesn't include bacterial complications
Scabies and Skin Infections Romani, L., et al. (2020). Sustained reduction of scabies and impetigo two years after mass drug	Comparative study Skin health Intervention Fiji Trial (SHIFT) randomly assigned 3 island communities to 1 of 3 interventions	Population-based	*Intervention:* SHIFT is a community intervention trial of mass drug administration (MDA) for scabies 1 intervention was standard care involving administration of permethrin to people with	Lacks specific information about how intervention was carried out

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
administration. Journal of the Dermatology Nurses' Association 12(2) Fiji	Measured change in prevalence of scabies and impetigo from baseline to 24 months		scabies and their contacts, 2nd was MDA or permethrin and 3rd was MDA of an ivermectin-based regimen *Outcomes:* A single round of MDA, particularly in the ivermectin-based group was effective for the control of scabies and impetigo out to 24 months • Scabies prevalence declined from 36.6% to 15.2% in standard care group, from 41.7% to 13.5% in permethrin group and from 32.1% to 1.8% in the ivermectin group • Prevalence of impetigo declined in all groups with greater reduction in ivermectin group, dropping from 24.6% to 2.6%	
Scabies and Skin Infections Thean, L. J., et al. (2022). Prevention of bacterial complications of scabies using mass drug administration: A population-based, before-after trial in Fiji, 2018–2020. The Lancet Regional Health - Western Pacific 22 DOI: 10.1016/j.lanwpc.2022.100433 Fiji	Before and after trial Northern Division of Fiji (pop 131,914)	Population-based	*Intervention:* Ivermectin-based mass drug administration, which involved 2 doses of oral ivermectin or topical permethrin, delivered alongside diethylcarbamazine and albendazole for lymphatic filariasis *Outcomes:* • Incidence of hospitalisations with skin and soft tissue infections was 17% lower after intervention, compared to baseline (388 vs 467 per 100,000 person-years, p=0.002) • No difference in incidence of childhood invasive infections and post-streptococcal sequalae • Incidence of primary healthcare presentations with scabies and skin infections was 21% lowers (89.2 vs 108 per 1000 person-years) • Community prevalence of scabies declined from 14.2% to 7.7% • Cluster-adjusted prevalence of impetigo declined from 15.3% to 6.1%	Location is not as remote compared to previous locations of MDA trials Hospitalisations due to ARF and PSGN were infrequent in this area, and low baseline incidence limited ability to detect significant change Measured impact after single round of treatment, WHO informal consultation framework recommends 3-5 rounds Recommend further research to better understand factors associated with reduction in scabies and sstis following MDA, including; coverage, impact of seasonal migration, accessibility of healthcare services and water.

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
				Sanitation and hygiene conditions Grouped skin and soft tissue infections together sometimes
Skin Infections Gahlawat, G., et al. (2021). Emerging Treatment Strategies for Impetigo in Endemic and Nonendemic Settings: A Systematic Review. Clinical therapeutics 43(6): 986-1006 DOI: **https://dx.doi.org/10.1016/j.clinthera.2021.04.013** Global	Systematic review Included 10 studies that involved 6651 participants	Population-based In endemic and non-endemic settings	*Intervention:* Drug administrated treatment strategies for impetigo *Outcomes:* • In nonendemic settings, ozenoxacin 1% cream has strongest evidence base • In endemic settings, oral co-trimoxazole and BPG injection equally effective in treatment of severe impetigo • Mass drug administration as promising public health strategy	Systematic review, doesn't detail specific interventions Varied risk of bias within different studies
Skin Infections Nepal, S., et al. (2018). Systematic literature review to identify methods for treating and preventing bacterial skin infections in Indigenous children. The Australasian journal of dermatology 59(3): 194-200 DOI: **https://dx.doi.org/10.1111/ajd.12680** Australia, NZ, USA and Canada	Systematic literature review 10 articles included	At risk population Indigenous children	*Interventions:* Strategies for treatment and prevention of bacterial skin infections included the management of active infections and lesions, improving environmental and personal hygiene, the installation of swimming pools and screening treatment *Outcomes:* • As prior • Until underlying SES conditions are addressed skin infections will continue to be a burden to communities	Doesn't assess impact that particular interventions had Generalises indigenous populations
Skin Infections Wyber, R., et al. (2021).	Formative evaluation	At risk population Aboriginal community members	*Intervention:* Novel-outreached based approach to improve primary and primordial prevention of Strep A skin sores, sore throats and ARF	May have been language barriers

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
Formative evaluation of a community-based approach to reduce the incidence of Strep A infections and acute rheumatic fever. Australian and New Zealand journal of public health 45(5): 449-454 DOI: **https://dx.doi.org/10.1111/1753-6405.13127** Australia	Evaluation of intervention using fortnightly household serveys about health, housing and clinical records (N=27) primary participants Participants provided 37.8 years retrospective baseline data and 18.5 years prospective data		Prevention programme delivered by trained aboriginal community workers Provision included support to households affected by ARF, including environmental health support and education Included options for secondary prophylaxis *Outcomes:* • No Strep A infections reported by primary participants were recorded in clinical records, and vice versa • Indication of more familiarity with words related to ARF, Strep and a clearer sense of skin sores and sore throats as cause of disease • Acceptance of intervention broadly demonstrated by retention of participants, staff and sites	Health staff in tertiary education may not document skin sores; it is unclear whether this normalisation also occurs in primary care Inconsistencies between community and clinical reporting of skin sores/strep A infections
Skin Infections Hendrickx, D., et al. (2016). A systematic review of the evidence that swimming pools improve health and wellbeing in remote Aboriginal communities in Australia. Australian and New Zealand journal of public health 40(1): 30-36 DOI: **https://dx.doi.org/10.1111/1753-6405.12433** Australia	Systematic review Included 12 studies	At risk population Remote Aboriginal communities	*Intervention:* Access to swimming pools as a means to improve health and wellbeing *Outcomes:* Prospective studies that collected data on skin infections found access to swimming pools to be associated with a drop of skin sore prevalence and severity	As it is a systematic review, study heterogeneity limits ability to assess bias Doesn't quantify association or impact of swimming pool Not specific to a particular skin infection

Study Title & Country	Methodology	Target Population	Intervention and Outcomes	Limitations
Eczema, Scabies and Skin Infections Jacob, J., et al. (2021). The development of a community-based public health response to an outbreak of post-streptococcal glomerulonephritis in a First Nations community. Canada communicable disease report = Releve des maladies transmissibles au Canada 47(7-8): 339-346 DOI: **https://dx.doi.org/10.14745/ccdr.v47i78a07** Canada	Literature review Made intervention to break chain of transmission of PSGN strain of strep in community 7 paediatric cases of PSGN presented to nursing station	Population-based Public health response	*Intervention:* Intervention involved screening of all children in the community for skin sores and treatment with antibiotic if noted Also developed case, contact and outbreak definitions *Outcomes:* • Community wide screening for skin sores completed for 95% of communities children (of the 9 PSGN cases), including 17 household contacts • Some contacts were skin sores treated with intramuscular penicillin or oral cephalexin • Can serve as a model for management of future PSGN outbreaks	Geography presents challenges for medical care in remote communities Lack of prior screening precludes any conclusions on the effectiveness of the intervention in curbing the outbreak

Secondary iGAS Interventions in International Settings

Country	History	Primordial Intervention	Primary Intervention	Secondary Intervention
The United Kingdom and Ireland: UK Health Security Agency. (2023). *UK guidelines for the management of contacts of invasive group A streptococcus (iGAS) infection in community settings*. Retrieved from **https://assets.publishing.service.gov.uk/media/64071ec5d3bf7f25fa417a91/Management-of-contacts-of-invasive-group-a-streptococcus.pdf** Health Protection Surveillance Centre. (2023). *Group A Streptococcal Disease Guidance*. Retrieved from **https://www.hpsc.ie/a-z/other/groupastreptococcaldiseasegas/guidance/**	Invasive group A streptococcus (iGAS) infection was introduced as a statutorily notifiable disease in England and Wales in 2010 to enable public health actions to prevent and control the spread of infection. In Scotland both necrotising fasciitis and iGAS have been notifiable since 2008. iGAS is statutorily notifiable in Ireland, as of 2003. However, in Northern Ireland iGAS is not currently notifiable; suspected or confirmed iGAS is reported by microbiologists and clinicians on a voluntary basis.	Stigma, marginalisation and criminalisation of injecting drug use are a challenge to effective engagement with people who inject drugs. It is important to identify whether cases has been linked to sheltered accommodation, a drug service or specific injecting network, military base or prison setting Targeted communications and educational resources can be supplied via needle exchanges, drug and alcohol services and services for the underhoused in order to raise awareness	Breaching the skin barrier provides a portal of entry for the organism, therefore children and staff should be reminded that all scrapes or wounds, especially bites, should be thoroughly cleaned and covered Cleaning of the environment, including toys and equipment, with hypochlorite at 1,000 ppm of available chlorine should as a minimum be carried out daily during the outbreak and a very thorough terminal clean should be undertaken when the outbreak is declared over. During the terminal clean, carpets and rugs should be cleaned with a washer-extractor. Curtains, soft furnishing covers and all linen should be removed, and washed at the hottest compatible temperature Background ventilation (through good design and opening doors or windows where appropriate) removes airborne contaminants such as co-circulating viruses known to increase the risk of iGAS infection. If there is co-circulating GAS, chickenpox or influenza, additional communication to the locality, including, health professionals, to ensure prompt identification and treatment of cases is necessary	*High risk close contacts:* • Older persons (≥75 years) • Pregnant women ≥37 weeks gestation • Women within 28 days of giving birth • Neonates (up to 28 days old) • Individuals who develop chickenpox with active lesions within the time period of 7 days prior to diagnosis in the iGAS case or within 48 hours after commencing antibiotics by the iGAS case, if exposure ongoing *Diagnosis:* All iGAS isolates should be sent to the designated laboratories Clinical, demographic and risk factor details should be provided on the referral form At present WGS is not routinely used during outbreak investigations in the UK but it has been used during a number of outbreaks in care homes, hospital and maternity settings, outbreaks among people who inject drugs or experience homelessness and outbreaks associated with community health services delivered at home. *Recommended Treatment:*

Country	History	Primordial Intervention	Primary Intervention	Secondary Intervention
			Anti-virals can be used for treatment of uncomplicated and complicated influenza among specific at-risk groups (ideally within 48 hours of onset of symptoms). If chickenpox or influenza is co-circulating in a nursery or pre-school setting where an iGAS case has been notified, consider post-exposure prophylaxis with varicella vaccine and/or the flu vaccine. Before eradication of GAS can be achieved in residential aged care treatment of chronic skin conditions may also be required to aid clearance of GAS from colonised lesions All community iGAS cases, including those occurring in nursing or residential homes, should be investigated for links to home healthcare Educational materials aimed at wound care and the increased risk of GAS infection among specific groups is required. Investigation of prior infestations at case site, that is, of lice, bedbugs, scabies, as these infestations and any topical treatment may cause additional damage to the skin	Antibiotic prophylaxis for eligible close contacts of a single case to commence as soon as possible (within 24 hours, and preferably the same day) but not to commence beyond 10 days of iGAS diagnosis in the index case. In an outbreak of iGAS, or when there is evidence of ongoing GAS, chickenpox or influenza, transmission in a nursery, school, aged care provider, set up an outbreak response team
Canada: Public Health Agency of Canada. (2006). *Supplement: Guidelines for*	From January 2000, iGAS became a statutorily notifiable disease in every province and territory of Canada. Please note, clinical and case management	Public health communication pertaining to cases should be tailored to the context of sporadic finding or cluster. With an outbreak, timely information should be provided to the public	In long term care facilities, all residents should be screened for GAS and skin lesions identified, swabbed and treated.	*High Risk Close Contacts:* • Older persons (≥ 65) • Children (at pre-school, day-care) • Injecting drug users

Country	History	Primordial Intervention	Primary Intervention	Secondary Intervention
the Prevention and Control of Invasive Group A Streptococcal Disease. Retrieved from **https://www.canada.ca/content/dam/phac-aspc/migration/phac-aspc/publicat/ccdr-rmtc/06pdf/32s2_e.pdf**	guidelines have not been updated since 2006.	community, and liaison consistent with the broader healthcare community.	Consistent adherence to good hand hygiene practice recommended within long-term care facilities and hospital clusters. PPE recommended Undertake contact precautions, in hospital settings or long-term case facilities, including disinfection of iGAS case patient care equipment	• Contacts in long term care, child care centre or hospital settings *Diagnosis:* iGAS diagnosis confirmed through local laboratory testing As of 2006, the National Centre for Streptococcus were the only laboratory able to undertake WGS investigation Establish possible epidemiologic link with another confirmed case *Recommended Treatments:* Antibiotic chemoprophylaxis recommended only for contacts of the highest risk of acquisition of the organism and of subsequent severe disease. Prophylaxis to commence as soon as possible (within 24 hours) but not to commence beyond 7 days of iGAS diagnosis in the index case Organise outbreak response to potential clusters in long-term care facilities, childcare centres or hospitals
Australia: Australian Government Department of Health and Aged Care. (2024). *Invasive Group A Streptococcal (iGAS) Disease : CDNA National Guidelines for Public Health Units*. Retrieved from **https://www.health.gov.au/sites/default/files/2024-01/invasive-group-a-streptococcal-igas-**	Became notifiable under different jurisdictions at differing times; • Australian Capital Territory notifiable in Feb 2022 • New South Wales notifiable in Sep 2022 • Northern Territory notifiable in May 2011 • Queensland notifiable in Dec 2005	Primordial prevention aimed at reducing levels of circulating GAS through improved social determinants of health (including; housing, health hardware and education about basic hygiene practices) Institutional settings can reduce risk by following infection prevention and control practices and encouraging basic hygiene principles	Primary prevention focusing on early detection and treatment of GAS (skin and throat) infections, in line with clinical practice guidelines In institutional facility review cleaning, hygiene and infection control practices	*High Risk Close Contacts:* • Residents or attendees of institutional settings, including but not limited to; childcare centres, aged care or residential care facilities, prisons and jails, hospitals, schools, military barracks, hostels or shelters • Birthing person-neonate pairs during first 28 days after birth

Country	History	Primordial Intervention	Primary Intervention	Secondary Intervention
disease-cdna-national-guidelines-for-public-health-units_0.pdf	• South Australia notifiable in Oct 2021 • Tasmania notifiable in July 2022 • Victoria notifiable in Feb 2022 • Western Australia notifiable in 2021	Supply contacts with fact sheet about disease, adapted for cultural and literacy needs of recipients Stigma, marginalisation and criminalisation of injecting drug users and homelessness are a challenge to keep in mind when responding to case increase rates among these populations Recognise intersectional risk factors that place Aboriginal and Torres Strait Islander people at increased risk of iGAS and severity of outcomes. These include; crowded and inadequate housing, barriers to appropriate and timely healthcare and community burden of disease		• Aboriginal or Torres Strait Islander people • Elderly people (>75 years) • Children aged <5 years • People with chronic or immunocompromising disease or condition • Haemodialysis recipients • People who inject drugs • People experiencing homelessness • Other special risk groups unique to states or territories *Diagnosis:* Confirmed case requires laboratory definitive evidence only; through bacterial culture as gold standard, but NAAT assays also available for blood and sterile tissues/fluids *Recommended Treatments:* Limited evidence of antibiotic chemoprophylaxis for all close contacts, suggest only for birthing parent-neonate pairs only PHU's to adopt risk-assessment approach based on priority populations With clusters, confirm with molecular typing, prior to response. PHU to consider outbreak response and potential for chemoprophylaxis. This may include increased screening

Country	History	Primordial Intervention	Primary Intervention	Secondary Intervention
United States of America: Note: the only nationally reported Group A streptococcal disease is STSS Centre for Disease Control and Prevention. (2022). *Streptococcal Toxic Shock Syndrome (STSS) for Clinicians*. **https://www.cdc.gov/groupastrep/diseases-hcp/Streptococcal-Toxic-Shock-Syndrome.html**	STSS was made notifiable in 1995, case definition most recently updated in 2010	Encourage that the spread of GAS can be reduced by standard infection control practices, including good hand hygiene and respiratory etiquette	In long-term care facilities, strong infection prevention and control strategies are critical to stop GAS transmission, including; hand hygiene, wound care practices	*High Risk Close Contacts:* • Those aged >65 years • People with skin injury or breakdown (recent surgery or varicella) • People with chronic illnesses • Those in settings such as; school, healthcare settings *Diagnosis:* STSS case to be defined by laboratory criteria for diagnosis in order to match clinical manifestation (which can vary) with evidence of isolation of GAS CDC tracks iGAS through active bacterial core surveillance (although iGAS is not notifiable) CDC collects this data from local and state health laboratories *Recommended Treatments:* Specific to STSS; cases require hospitalisation and antibiotic therapy Antibiotic chemoprophylaxis recommended for those >65 years

Supplementary Material 7 - Current Research and Surveillance in the Pacific Region

Project	Population	Methodology & Purpose
Aotearoa New Zealand		
Thornley, S., Sundborn, G., Engelman, D., Roskvist, R., Pasay, C., Marshall, R., . . . Morris, A. J. (2023). Children's scabies survey indicates high prevalence and misdiagnosis in Auckland educational institutions. *Journal of Paediatrics and Child Health, 59*(12), 1296-1303. doi: **https://doi.org/10.1111/jpc.16512**	181 children from five early childcare centres and two schools 4/7 in low decile areas	Observational cross-sectional prevalence survey to assess the prevalence of scabies among children attending educational settings, including early childcare centres and schools.
Tu'akoi, S., Ofanoa, M., Ofanoa, S., Lutui, H., Heather, M., Jansen, R. M., . . . Goodyear-Smith, F. (2022). Co-designing an intervention to prevent rheumatic fever in Pacific People in South Auckland: a study protocol. International Journal for Equity in Health, 21(1), 101. doi:10.1186/s12939-022-01701-9	GAS infections, acute rheumatic fever cases and related hospitalisations over a five-year period in Aotearoa New Zealand + Four PHOs (Alliance Health Plus, National Hauora Coalition, ProCare and Tamaki Health) which serve the majority of Pacific and Māori populations in Auckland. All ages	Participatory mixed-methods study with three phases: 1) a quantitative analysis of the rheumatic fever burden within Auckland and across New Zealand over the last five years, including sub-analyses by ethnicity. 2) co-design workshops with Pacific community members, families affected by rheumatic fever, health professionals, and other stakeholders in order to develop a novel intervention to reduce rheumatic fever in South Auckland. 3) implementation and evaluation of the intervention.
Primhak, S., Gataua, A., Purvis, D., Thompson, J. M. D., Walker, C., Best, E., & Leversha, A. (2022). Treatment of Impetigo with Antiseptics—Replacing Antibiotics (TIARA) trial: a single blind randomised controlled trial in school health clinics within socioeconomically disadvantaged communities in New Zealand. *Trials, 23*(1), 108. doi:10.1186/s13063-022-06042-0	Urban based school clinics aged 5-13 years	A single blind randomised controlled trial to compare topical fusidic acid with topical hydrogen peroxide with simple wound care in the treatment of childhood impetigo
Bennett, J., Moreland, N. J., Oliver, J., Crane, J., Williamson, D. A., Sika-Paotonu, D., . . . Baker, M. G. (2019). Understanding group, A streptococcal pharyngitis and skin infections as causes of rheumatic fever: protocol for a prospective disease incidence study. *BMC Infectious Diseases, 19*(1), 633. doi:10.1186/s12879-019-4126-9	1000 children (5–14 years) from Auckland, New Zealand	Prospective disease incidence study, with an associated case-control study incidence of true GAS pharyngitis and serological responses to GAS skin infections. The effectiveness of antibiotics for these conditions will be explored as well as modifiable risk factors.

Project	Population	Methodology & Purpose
Lacey, J. A., Bennett, J., James, T. B., Hines, B. S., Chen, T., Lee, D., . . . Moreland, N. J. (2024). A worldwide population of Streptococcus pyogenes strains circulating among school-aged children in Auckland, New Zealand: a genomic epidemiology analysis. *The Lancet regional health. Western Pacific, 42*, 100964. doi: **https://dx.doi.org/10.1016/j.lanwpc.2023.100964**	469 isolates collected between March 2018 and October 2019 from the throats and skin of children (5–14 years) living in Auckland, New Zealand. Equal representation by ethnic group (Māori, Pacific Peoples and NZ European/Other)	Case control- study. Genomic analysis of GAS isolates from throat and skin swabs to provide a baseline of the distribution and diversity of GAS strains (emm-types) in circulating in Auckland
Rapua te mea ngaro ka tau. (2021-2025). Strep A vaccine development. Lead investigators: The University of Auckland A/Prof Nikki Moreland - Principal Investigator and Science Lead Dr Rachel Webb - Clinical Lead Dr Anneka Anderson - Community Lead Project Manager: Dr Julie Bennett - University of Otago / University of Auckland Contract Manager: Ministry of Health	All ages hospital admissions Te Whatu Ora Counties Manukau Te Toka Tumai Auckland hospital Children in Auckland region (sore throat)	Retrospective surveillance of 10 years of invasive Strep A disease at Auckland and Middlemore Hospitals Prospective Hospital-based surveillance of severe Strep A disease 2022-2024 Community Perceptions and community surveillance of Strep A (sore throat study) Qualitative study of vaccine acceptability in communities
Routine surveillance of iGAS infections in Aotearoa Undertaken by ESR, based on isolates sent to the ESR Invasive Pathogens Laboratory (IPL). Five yearly reporting cycle. Latest report covers 2017-2022.	Nationwide, all ages	Retrospective case surveillance and epidemiological analysis A contracted scientific service for Ministry of Health
Rheumatic Fever Care Coordination System (RFCCS) Centralised national Rheumatic Fever data collection platform rolling out nationwide over 2024. Includes: Registration of all RF patients Recording & updating diagnosis details Recording & updating a patient's care plan and care team	All ages National wide	The primary objective of the RFCCS is to implement a national system to improve the delivery of RF/RHD secondary prevention activities. It does this by enabling care coordination, transfer of patients between districts, shared care, and access to care irrespective of where the patient is with the aim of reducing the number of patients who are lost to follow-up.
Australia		
Barth, D. D., Mullane, M. J., Sampson, C., Chou, C., Pickering, J., Nicol, M. P., . . . Bowen, A. C. (2022). Missing Piece Study protocol: prospective surveillance to determine the epidemiology of group A streptococcal pharyngitis and impetigo in remote Western Australia. BMJ Open, 12(4), e057296. doi:10.1136/bmjopen-2021-057296	Remote living Australian children	prospective surveillance with two components: 1) screening of all children at school for GAS pharyngitis and impetigo up to three times a year 2) weekly active surveillance visits to detect new cases of pharyngitis and impetigo.

Project	Population	Methodology & Purpose
		3) Documentation of the epidemiology of GAS pharyngitis and impetigo through collection of clinical, serological, microbiological and bacterial genomic data
Mullane, M. J., Barnett, T. C., Cannon, J. W., Carapetis, J. R., Christophers, R., Coffin, J., . . . Bowen, A. C. (2019). SToP (See, Treat, Prevent) skin sores and scabies trial: study protocol for a cluster randomised, stepped-wedge trial for skin disease control in remote Western Australia. *BMJ Open, 9*(9), e030635. doi:10.1136/bmjopen-2019-030635	Four community clusters in the remote Kimberley region of Western Australia School based children aged 5-9 years	Cluster randomised, stepped-wedge trial with three components: 1) seeing skin infections (development of training resources implemented within a community dermatology model) 2) treating skin infections (employing the latest evidence for impetigo, and scabies treatment); 3) preventing skin infections (embedded, culturally informed health promotion and environmental health activities)
Lydeamore, M. J., Campbell, P. T., Price, D. J., Wu, Y., Marcato, A. J., Cuningham, W., . . . McCaw, J. M. (2020). Estimation of the force of infection and infectious period of skin sores in remote Australian communities using interval-censored data. *PLOS Computational Biology, 16*(10), e1007838. doi: 10.1371/journal.pcbi.1007838	Remote Australian communities All ages	Mathematical modelling using Susceptible-Infectious-Susceptible (SIS) modelling to estimate the force of infection, and the duration of infectiousness of skin sores in individuals.
Pacific Nations		
Taiaroa, G., Matalavea, B., Tafuna'i, M., Lacey, J. A., Price, D. J., Isaia, L., . . . Gorrie, C. L. (2021). Scabies and impetigo in Samoa: a school-based clinical and molecular epidemiological study. *The Lancet Regional Health–Western Pacific, 6*. Retrieved from **https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8315614/pdf/main.pdf**	Rural areas of Upolu Island, Samoa Children aged 4-15 years	Observational cross-sectional survey of scabies, impetigo and GAS or Staph Aureus prevalence in a Samoan school district
Thornley, S., & Sundborn, G. (pre-publication). The prevalence of scabies, skin infection and rheumatic heart disease in a cross-sectional study of Tongan primary school children	Children attending four primary schools in Tongatapu, Tonga	Cross-sectional survey for scabies, bacterial skin infections and RHD
Thornley, S., & Sundborn, G. (pre-publication). Scabies is strongly associated with rheumatic heart disease: a cross-sectional study of school children in 'Eua Tonga	Children aged 5-14 years attending primary schools on the island of 'Eua	Cross-sectional survey for scabies, impetigo and bacterial infection and RHD prevalence survey