SERIOUS SKIN INFECTIONS IN NEW ZEALAND CHILDREN

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STATEMENT OF CONTRIBUTION

This thesis is my own work. With the guidance and assistance of Dr Michael Baker I designed the studies, collected and entered the raw data, undertook necessary analyses, interpreted the results and wrote up the findings. However, there are a few distinct areas where the expertise of others was necessarily engaged. Anna Davies undertook the indirect standardisation analysis presented in Chapter 4, James Stanley assisted with statistical advice in Chapter 6, and Jane Zhang conducted the initial Excel-based data analyses of the epidemiology of serious skin infections in children in New Zealand (NZ) and the Tairawhiti Region.

ABSTRACT

Skin infections are a common and widespread ailment among children. While these infections have generally been considered benign, the number requiring overnight hospitalisation for treatment, termed 'serious skin infections', has risen markedly in recent years with the incidence in NZ children thought to be significantly higher than that in children of comparatively developed countries. This study aimed to define serious skin infections and describe their epidemiology in the NZ setting.

Increased awareness of serious skin infections has resulted in a number of national and regional reports being released over the past decade. However, the accuracy of these existing skin infection data has been limited by the lack of a consistent and valid case definition. By assessing the screening performance of various case definitions when applied in the setting of 4 years of paediatric admissions to a provincial NZ hospital, a new definition for serious skin infection was produced which improved sensitivity from 61% to 99% with negligible loss in specificity.

This new case definition was then applied to national hospitalisation data to identify all 0-14 year old children admitted overnight to a NZ hospital with a serious skin infection between January 1990 and December 2007. During this 18-year period the incidence of infection almost doubled from 294.1/100 000 in 1990 to 562.3/100 000 in 2007. Seasonality showed consistent peaks in late Summer and early Autumn. The highest rates were observed in boys, children under 5 years old, Māori (NZ Indigenous peoples) and Pacific children, those living in deprived neighbourhoods, in urban areas and in Northern districts of the country. Trends over time showed the distribution of disease changed with evidence of worsening ethnic and socioeconomic disparities in infection rates. The highest regional incidence was found in the Tairawhiti (Gisborne) Region, where during the same 18-year period admissions rose even more rapidly from 414.5/100 000 in 1990 to 993.3/100 000 in 2007. A closer comparison of hospitalisation data between Tairawhiti and NZ found ethnic disparities in serious skin infection rates were greater in the Tairawhiti Region than nationally. In addition, the overall disease incidence was significantly higher than that expected even after controlling for differences in the population

distribution of age, ethnicity and deprivation. This finding suggests the involvement of other unknown aetiological factors.

To better understand factors contributing to the need for inpatient treatment, a chart review was conducted of all 163 children admitted to Gisborne Hospital with a serious skin infection between January 2006 and December 2007. Compared to studies in other NZ settings, types, sites and causal organisms of infections were similar. However, there were longer delays to seek medical attention with only 77% of children seeing a GP after a median of 2 days of symptoms, resulting in 60% requiring immediate hospitalisation. In hospital, 70% of cases received intravenous antibiotics and 31% required surgical treatment for their infection. One third of children had suffered a previous skin infection with 12% requiring hospitalisation.

Finally, to investigate the hypothesis that trends in serious skin infections reflect corresponding patterns of infection in the community, and to estimate the often hidden burden of skin infection in primary care, a sample of Tairawhiti general practitioners recorded all cases of skin infection in children diagnosed over a 10-week period in 2008. There were 110 incident cases of infection during the study period; through age and ethnicity standardisation this was found to be equivalent to an annual incidence rate of 106.7 (95%CI 85.2-127.2) cases per 1000 children. For every one hospitalisation there were 14 cases seen in primary care. Comparing analogous primary care and hospital demographic data showed that three quarters of skin infections in both primary care and hospital settings occurred in Māori children. There was no gender predominance in either setting, however hospitalised cases of serious skin infection were more likely to occur in the preschool age group with children aged 5-9 years predominating at the primary care level.

Serious skin infections are a significant and increasing source of morbidity in NZ children. They now contribute to over 4,500 hospitalisations annually and, based on extrapolations from Tairawhiti data, an estimated 60,000 general practice presentations each year. In addition, they contribute to health disparities with evidence of worsening ethnicity and deprivation-related inequalities over time. Efforts need to be both directed towards effective and sustainable prevention of

these infections and towards ongoing research to better understand the aetiology of disease and opportunities for reducing their incidence.

PREFACE AND ACKNOWLEDGEMENTS

My work on serious skin infections began in 2008 when I was employed as a house surgeon at Gisborne Hospital. Skin infections in all age groups had long been noted as a common cause of admission to that Hospital, with anecdotal reports of increasing incidence rates over the years. A brief audit conducted by two house surgeons in 2006 had estimated that the local rate of hospitalisation for children with a skin infection could be double the national rate with an even greater incidence in Māori children; using this information, funding was secured from the Ministry of Health's Inequalities Budget to explore the problem in greater depth. I was approached and offered the opportunity to undertake nine months of funded research examining serious skin infections in the children of the Gisborne (Tairawhiti) Region.

This thesis has stemmed from that research, extending the regional focus to an examination of serious skin infections in children throughout NZ. While some of the raw data were gathered during my time in Gisborne, the work presented in this thesis was conducted during my Master of Medical Sciences degree.

There have been a large number of people who have assisted me with this research. They have given their time and expertise in a variety of ways and to a range of extents. I would like to thank and acknowledge them for this.

I would firstly and particularly like to thank my supervisor, Dr Michael Baker, who has been a great source of support, tireless enthusiasm, patience and good humour. His prompt reviewing and regular feedback on my work was greatly appreciated. Also from the Wellington School of Medicine, I would like to thank Jane Zhang for her impressive and efficient assistance with data analyses, and James Stanley, Kamalesh Venugopal and Gordon Purdie for their advice on all matters statistical.

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In Gisborne, my thanks go in many directions. Firstly to Dr Geoffrey Cramp, Public Health Physician, who provided encouragement, advice and local supervision during the early part of my Masters and willing involvement for the latter part. Thanks also go to Dr Hein Stander, Consultant Paediatrician, who initiated the early part of this work and with Dr Cramp and Dr Baker formed the multidisciplinary reference group mentioned in Chapter 2. My appreciation to Robert Hunter, Tom Scott and Dr Mary Stonehouse, who invited me to become involved in the project and provided ongoing support. Thank you to my tireless local data gurus, Iain Diamond and Geoff Joyce, and to the indefatigable ladies in medical records and coding. A special acknowledgement to the local general practitioners who volunteered to code their skin infection consultations despite already demanding workloads; Drs Moira Cunningham, Sally Diver, Francois Jacobs, Tom James, Johan Peters, Pauline Smale, Murray Smith, Dave Somerton, and Simon Spenceley, many thanks also to Phil Dunn and Dave Maplesden from Turanganui PHO who facilitated the primary care work and provided baseline data. And finally, my thanks and appreciation to the many other contributing staff of Gisborne Hospital and the wider health community of the Tairawhiti Region. Kia ora.

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CHAPTER ONE

INTRODUCTION

1.1. BACKGROUND

Skin and subcutaneous tissue infections are a heterogeneous group of acute and superficial bacterial infections, most commonly caused by normal skin commensals, *Staphylococcus aureus* and *Streptococcus pyogenes.*[1,2]

In most circumstances these infections are minor and either resolve spontaneously or are adequately managed in primary care. However, in some cases serious skin infections develop; these are skin and subcutaneous tissue infections which have failed early treatment for a variety of reasons and require hospitalisation for more aggressive medical and/or surgical treatment.

The profile of serious skin infections in children is rising worldwide, with increasing paediatric incidence rates reported in several international settings.[3-5]

In New Zealand (NZ), serious skin infections are a considerable source of medical and social morbidity in children.[6-8] National incidence rates have experienced a rapid increase over the last two decades,[9] making these infections one of the most common reasons for hospitalisation during childhood.[10] In addition, the NZ incidence appears high relative to that of comparably developed countries; in 2003 hospitalised cellulitis rates were just under double that reported in Australia and the USA.[11]

It is possible that microbiological factors may explain at least some of the increase in incidence. Methicillin-resistant *Staphylococcus aureus* (MRSA) isolations have steadily increased in NZ since 1990.[12-14] However, as recent increases have been limited to hospital rather than community isolates[14] it is unlikely that MRSA could completely explain the dramatic rise in serious skin infections.

Hospitalisations for these infections are a source of significant healthcare resource demands,[11,15] and are considered ambulatory sensitive, that is 'avoidable or preventable by primary health care'.[16] When this work began the MOH had identified the reduction of ambulatory sensitive hospital (ASH) admissions as a Health Target.[16] Skin infections were identified as the second and third highest causes of ASH admissions in Pacific and Māori populations respectively.[17]

Within NZ, serious skin infections contribute significantly to ethnic and deprivation-related health inequalities with the highest rates in children of Māori and Pacific Island descent, and children from lower socioeconomic backgrounds.[9-11,18-22] The reduction of health inequalities is one of the principles outlined by the Ministry of Health (MOH) in the New Zealand Health Strategy and He Korowai Oranga, the Māori Health Strategy.[23,24] These disparities, in combination with other epidemiological trends described below, are likely to at least partly explain observed inter-regional differences in incidence rates in NZ.[9,11,20] This hypothesis has not been tested, so is explored further in this thesis.

Despite the convincing evidence that serious skin infections in children are both a significant and increasing health issue in NZ, there is a paucity of published research in this field and further investigation is warranted.

1.2. GOAL

The overall goal of the research presented in this thesis is to provide high quality evidence to improve our understanding of serious skin infections in NZ children and to inform development of effective prevention strategies to reduce this disease burden.

The individual aims of each component of the research are presented in relevant chapters.

1.3. DEFINITIONS

These are general definitions for a range of terms used frequently and with specific meaning throughout this thesis.

Skin infections are a heterogeneous group of acute and superficial bacterial infections of the skin and subcutaneous layers. These include cellulitis, subcutaneous abscesses, furuncles, carbuncles, impetigo (also termed school sores or hakihaki), acute lymphadenitis, erysipelas, superficially infected eczema and scabies, pyoderma or any other bacterial infection of the skin and subcutaneous tissue.

Serious skin infections are any skin infections which fail outpatient management, for a variety of reasons including the absence of primary care, and require hospital admission for further medical or surgical treatment. Therefore, throughout this thesis, the term 'serious skin infections' is synonymous with 'hospitalised skin infections'.

Children in this thesis are considered to be any infant, child or adolescent between birth and fourteen years of age.

Tairawhiti is the customary Māori name used to describe the coastal region between the Mahia Peninsula and East Cape. It means 'the tides that are shone upon'. The term is used interchangeably with Gisborne throughout this thesis.

1.4. EPIDEMIOLOGY AND RISK FACTORS

Published medical literature on serious skin infections in NZ children is distinctly lacking, as is a reliable and standardised epidemiological case definition for serious skin infection. Current knowledge on the epidemiology of these infections has largely relied on unpublished regional and national reports and is presented here. Of the studies discussed, the only paper published in a peer reviewed journal is a small retrospective observational analysis of South Auckland cellulitis and subcutaneous abscess cases.[19]

The use of various case definitions has resulted in inconsistencies in the measured incidence of disease. However, all studies examining longitudinal trends have described an increasing incidence over time,[10,11,18] with one report documenting an increase from 2.06/1000 in 1996/7 to 2.69/1000 in 2002/3.[11]

Serious skin infection rates are higher in preschool-aged children than those in older age groups, and in boys compared to girls.[9-11,19] Admission rates have been consistently reported to peak in the Summer months.[10,11,20]

Examined by ethnicity, the highest rates of serious skin infection are found in Māori and Pacific children.[9-11,18-20] A 2007 review of the health of young people in NZ found the national incidence rate of serious skin infection in all children for the period 2002-2006 was 3.2/1000, with markedly higher rates in Māori and Pacific children (8.46/1000 and 5.24/1000 respectively) and the lowest in Asian/Indian children (1.66/1000).[9]

Incidence rates are also reported to be consistently higher in children from areas of greater socioeconomic deprivation.[9,11,20] The same 2007 review found hospitalisation rates were related to level of deprivation in a linear pattern, with a rate of 1.38/1000 for children from least deprived areas, and 6.00/1000 for children from most deprived areas.[9] Such analyses have not separated the effects of ethnicity and deprivation.

There are currently no published NZ studies specifically examining the risk factors for developing a serious skin infection in childhood.

Studies in the international literature differ from NZ reports in that they have largely examined individual subtypes of skin infection, usually in the outpatient setting. However the highest incidence rates are also reported in children under five years old, in groups of lower socioeconomic status, and in the summer months.[3,4,25-29] Interestingly, no gender predominance is found in most of these studies.[3,27,30] Factors that increase the risk of developing a skin infection have been identified as overcrowding, close skin to skin contact, undernourishment, low socioeconomic status, poor hygiene, shared bathing, sharing of soap, minor skin trauma, eczema, chickenpox, insect bites, scabies, recent seawater contact, and warm humid climates.[25-39]

1.5. Pathogenesis and Clinical Features

A skin infection is the outcome of a pathological process involving several stages. Normal skin is colonised by a range of bacteria, and in usual circumstances forms a protective barrier to prevent these potentially harmful bacteria invading the body. Any damage to this barrier, such as that caused by a graze or an insect bite, can result in the bacteria breaching the skin and initiating a local immunological process that may eventually culminate in infection.[2] Whether or not an infection occurs depends on a triad of interacting factors; host, environment and causal agent. The subsequent development of a serious skin infection is influenced by these variables and in addition by healthcare system factors.

The gross appearance of a skin infection varies with its subtype. Common local features include erythema, pain and tenderness, swelling, heat, induration and pustular discharge. Systemic signs and symptoms such as fever, lethargy, sepsis, leucocytosis, regional lymphadenopathy and raised inflammatory markers may also occur.[2]

The most common causative organisms are the normal skin commensals *Staphylococcus aureus* and *Streptococcus pyogenes*.[1] Standard treatment generally

requires topical, oral or parenteral antibiotics active against these organisms. It may also include drainage of any pustular collection, debridement of non-viable tissue, or treatment of any other underlying cause.

Failure to effectively treat these infections in a timely manner may lead to a range of serious local and systemic complications such as ulceration, abscess, extension to deeper tissues, bacteraemia, sepsis and even possibly acute rheumatic fever and post-streptococcal glomerulonephritis.[2,7,8,40,41] NZ has relatively high and increasing rates of necrotising fasciitis, a serious subcutaneous infection with a case fatality of 20%.[42] This infection is rare in children, with the incidence rising steadily with increasing age.

1.6. STUDY SETTING

This thesis examines serious skin infections in children in both the NZ and Gisborne settings.

Gisborne (Tairawhiti) is an isolated and sparsely populated region of 45 000 people on the East Coast of NZ's North Island. The district includes Gisborne City and the smaller rural communities of Tologa Bay, Tokomaru Bay, Ruatoria and Te Karaka. Tairawhiti District Health is the crown entity that provides regional inpatient and outpatient health services through Gisborne Hospital, a 120-bed secondary referral centre. Turanganui Primary Healthcare Organisation and Ngati Porou Hauora are responsible for primary care and the smaller rural hospitals and medical clinics in the area. The Tairawhiti Region is known for its surf beaches and warm climate, but is also unique for its large Māori population (comprising 47.3% of the total population, the highest proportion for any NZ region) and its large number of young people (26.2% of people are aged less than 15 years old, compared with the national average of 21.5%).[43] In addition, it is also one of the most deprived regions in NZ, with the highest proportion of NZDep[1] 10 residents in the country.[44] In Tairawhiti, skin infections in children present a major challenge in both primary and hospital

[1] The New Zealand Deprivation Index (NZDep) is a measure of socioeconomic deprivation based on nine variables extracted from census data.[52] NZDep 1 indicates least deprivation and 10 indicates highest deprivation.

level care; an internal hospital audit completed in 2006 indicated paediatric serious skin infection rates could be as high as double the national average.[45]

1.7. THESIS STRUCTURE

The structure of this thesis diverges from the traditional format and is instead comprised of a series of five independent academic papers, each presented as a chapter. This approach was deliberately chosen to facilitate rapid dissemination of the findings, through research papers, to support the goal of this thesis. One of these papers has been published (Chapter 2)[46] and another accepted for publication (Chapter 3). The other three have been submitted to journals. While every paper is a self-contained piece of work with its own introduction, aims, methods, results and discussion sections, the findings of each build on the knowledge gained by the previous.

Following this introductory chapter, Chapter 2 presents the development and analysis of an epidemiological case definition for serious skin infection in children. Chapters 3 and 4 then utilise this definition in describing the epidemiology of serious skin infection in children in NZ and the Tairawhiti Region respectively, with Chapter 4 also providing a comparison between the two. Chapter 5 presents the findings of a retrospective review of the case notes of children admitted to Gisborne Hospital with a serious skin infection during 2006 and 2007. Chapter 6 examines skin infections in children in primary care, comparing the basic epidemiology of infections in this setting with that of the hospital setting, and calculating an estimate of the total primary care burden of disease in the Tairawhiti Region. Finally Chapter 7 makes concluding comments and recommendations for further work.

CHAPTER TWO

A PROPOSED EPIDEMIOLOGICAL CASE DEFINITION FOR SERIOUS SKIN INFECTION IN CHILDREN

2.1. ABSTRACT

2.1.1. AIM

Researching the rising incidence of serious skin infections in children is limited by the lack of a consistent and valid case definition. This study aimed to develop and evaluate a good quality case definition, for use in future research and surveillance of these infections.

2.1.2. METHODS

The validity of the existing case definition, and that of eleven proposed alternative definitions, was tested by assessing their screening performance when applied to a population of paediatric skin infection cases identified by a chart review of 4-years of admissions to a New Zealand hospital.

2.1.3. RESULTS

Previous studies have largely used definitions based on the International Classification of Diseases skin infection sub-chapter. This definition is highly specific (100%) but poorly sensitive (61%); it fails to capture skin infections of atypical anatomical sites, those secondary to primary skin disease and trauma, and those recorded as additional diagnoses. Including these groups produced a new case definition with 98.9% sensitivity and 98.8% specificity.

2.1.4. CONCLUSION

Previous analyses of serious skin infection in children have underestimated the true burden of disease. Using this proposed broader case definition should allow future researchers to produce more valid and comparable estimates of the true burden of these important and increasing infections.

2.2. INTRODUCTION

Serious skin infections are a heterogeneous group of acute bacterial skin and subcutaneous tissue infections which require hospitalisation for often invasive treatment. While rising incidence rates have been noted in several international settings,[3-5] New Zealand (NZ) has experienced increases out of proportion to those of comparable countries; in 2003 hospitalised cellulitis rates were just under double that reported in Australia and the USA.[11]

Besides being a considerable source of medical and social morbidity in NZ's children,[6-8] serious skin infections contribute to ethnic and deprivation-related health inequalities[9-11,18-22,45] and have significant healthcare resource demands.[11,15] Hospitalisation for these conditions is considered 'ambulatory sensitive', that is preventable or avoidable through primary health care.[16]

The usefulness of recent epidemiological analyses has been limited by the lack of a consistent and valid case definition. This definition is necessary to provide a sound base for describing disease epidemiology, determining accurate incidence rates, comparing populations, and ongoing surveillance over time.[47,48] Such information is essential to guide development of health services and prevention programmes and to assess their impact.

The International Classification of Diseases (ICD) is a coding system published by the World Health Organisation which assigns diagnoses into categories of similar diseases, and is designed to support the international collection of comparable health information.[49] Identifying a set of ICD diagnostic codes as part of a case definition enables researchers to reliably describe and compare the epidemiology of disease over time and between populations.

This research aimed to develop and evaluate a valid, reliable and easy to use epidemiologic case definition for serious skin infection in children, based on a carefully selected set of ICD diagnostic codes.

2.3. METHODS

2.3.1. SUMMARY OF EXISTING CASE DEFINITIONS FOR SERIOUS SKIN INFECTION

Existing epidemiological literature on serious skin infections in children was reviewed. Studies from 1980 to February 2008 were sourced via electronic medical databases, hand searching relevant references and the grey literature. Reports not utilising an ICD code-based case definition or only examining one subtype of skin infection were excluded. The case definitions used in remaining studies were recorded and specific variables tabulated. Analyses using ICD-9 codes were forward and backward mapped to enable consistent comparison to those using ICD-10 codes. The ICD codes used by the NZ Ministry of Health (MOH) in 2007/2008 to define ambulatory sensitive hospitalisations (ASH) for cellulitis were tabulated for comparison.

2.3.2. IDENTIFICATION OF ALL ICD-10 CODES POTENTIALLY CODING FOR SERIOUS SKIN INFECTION

Existing case definitions were used as a foundation to construct a list of all ICD-10 codes (third edition) potentially coding for a diagnosis of serious skin infection. The list was extended and refined through discussions with clinicians and coders, and extensive consultation of the ICD Disease Tabular. The resulting 21 ICD code sets were analysed and grouped into four categories:

A – Serious skin infections described within the ICD-10 sub-chapter 'Infections of the skin and subcutaneous tissue' (excluding L05.1 pilonidal cyst without abscess). Apart from several areas of inconsistency, most previous case definitions include the majority of codes in this category.

B – Serious skin infections of atypical anatomical sites excluded from the ICD-10 skin infection sub-chapter. The rationale for this exclusion seems largely arbitrary, but likely stems from potential differences in the anatomical origin of infection; either the site is in an area where different epithelial types lie in contiguity, or where deeper structures may be implicated. The arbitrariness of this exclusion is evidenced

by the overlap between the Category A code 'Cellulitis of the face' and several codes within Category B describing cellulitis of parts of the face.

C – Serious skin infections secondary to a primary disease of the skin. Although aetiological factors may be distinct, they share common pathophysiological pathways with conditions in Category A. Moreover, while these codes may be non-specific for skin infection (a single code may describe both a simple skin disease and superficial infection of that disease), they account for a significant portion of the serious skin infection disease burden.

D – Serious skin infections secondary to skin trauma. The rationale for excluding these codes from the L01-08 range seems also related to aetiology, however consideration of the pathophysiology of these conditions reveals the distinction is again largely arbitrary. As in Category B there is considerable overlap between conditions in Category A, with subjective coding practices resulting. For example, many cases recorded in Category A are likely to have been precipitated by unrecognised or minor skin trauma.

2.3.3. DEVELOPING A CLINICAL DESCRIPTION

A written clinical description for a case of childhood serious skin infection was developed by the author and a multidisciplinary reference group (see Acknowledgements) based on existing descriptions in the literature, the clinical experience of the group, knowledge of infectious disease epidemiology and understanding of the attributes expected of an effective case-definition. This description (figure 1) was then used as the 'gold standard' definition against which the validity of each ICD-based case definition was evaluated.

Figure 1. Clinical description of serious skin infection in children

A child aged 0-14 years, discharged from [a specified medical facility] between [a specified time period] with clinical evidence of active infection of the skin and/or subcutaneous tissue as indicated by local signs such as erythema, tenderness, swelling, heat, induration, pustular discharge, with or without systemic signs and symptoms such as fever, lethargy, sepsis, leucocytosis and raised inflammatory markers.

AND

The infection is the initial primary reason for the patient's admission to hospital for inpatient treatment

OR

The infection is one of the diagnoses making a significant contribution to the reason for hospital admission for inpatient treatment

EXCLUDING

- Any hospital-acquired skin or subcutaneous tissue infection, where the infection occurs during the admission or within 30 days of discharge
- Any condition where the primary infection is in tissues deeper to the subcutaneous tissue leading to overlying secondary skin changes
- Any condition where overwhelming cell damage is the principal injury and will inevitably lead to infection of the skin and subcutaneous layers

2.3.4. POPULATION, LOCATION AND DATA COLLECTION PERIOD

Gisborne Hospital is a 120-bed secondary referral centre serving a population of 45 000 people on the East Coast of New Zealand's North Island. Skin infections present a major challenge in both primary and hospital level care in Gisborne; an internal hospital audit completed in 2006 indicated the incidence of serious skin infection in children could be almost double the NZ national average.[45]

A complete set of hospital discharge data was obtained from the New Zealand Health Information Service (NZHIS) on March 1 2008. All paediatric cases (0-14 year olds) coded with any of the ICD-10 codes in Categories A-D as either a principal or additional diagnosis were extracted. Filters applied excluded day cases, readmissions within 30 days for the same diagnosis, transfers and overseas visitors. Discharges already coded by an ICD code in Category A (either as principal or additional) were excluded from Categories B, C and D.

The charts of each case were reviewed to determine whether the written clinical description of a serious skin infection was met (true positive) or not (false positive). A consensus decision between the author and a paediatrician (see

Acknowledgements) was used in ambiguous cases with a unanimous decision required.

Two separate ascertainment sources were employed to ensure all serious skin infection cases were likely to be identified. The NZHIS data set was searched firstly using ICD-10 codes for investigative or surgical procedures commonly performed during an admission for serious skin infection (see Appendix A) and subsequently using a range of free-text terms used to describe a serious skin infection (see Appendix B). The results were filtered and matched against the main data set. The charts of any additional admissions were reviewed for concurrence with the clinical description.

Regional Ethics Committee approval was sought and granted for this chart review.

2.3.5. DATA ANALYSIS

The results of the chart review were tabulated. The validity of the baseline and eleven alternative case definitions were assessed by calculating the sensitivity, specificity, negative predictive value (NPV) and positive predictive value (PPV) of each. The total filtered number of 0-14 year old patients admitted to Gisborne Hospital over the specified 4-year period was used as the total study population.

Validity was used as the primary measure of a good quality definition,[50] where validity was considered an optimal balance between sensitivity, specificity, PPV and NPV. A secondary quality measure was clarity and ease of use, as this is likely to promote consistent application and hence reliability of resulting data.

2.4. RESULTS

2.4.1. SUMMARY OF EXISTING CASE DEFINITIONS FOR SERIOUS SKIN INFECTION

Seven NZ studies on the epidemiology of serious skin infections in children were found.[9-11,18-20,45] Two were excluded from further analysis; the first examined subcutaneous abscesses only,[18] and the second contained incomplete case definition information despite contacting the authors.[20] No international studies were found that were suitable for analysis. Rather than examining the clinical syndrome of 'Serious Skin Infection', these international studies focused instead on subtypes of skin infection or particular causative organisms. Table 1 summarises the ICD-10 codes and other variables used in the remaining five case definitions with the MOH definition of cellulitis for comparison.

All codes within the ICD sub-chapter for skin infections (Category A) were included by the majority of previous case definitions. However, as detailed in table 1, there was variability in the exclusion of some codes within this sub-chapter, and the inclusion of other codes from outside the sub-chapter.

Four of the definitions included principal diagnoses only, one included principal and additional, and the sixth study did not specify. All studies included 1-14 year old children while two also included 0-1 year olds. Childhood ASH admissions were analysed for the 0-4 year age group only. All analyses occurred within the last 15 years.

Table 1. Summary of the ICD-10 codes and other variables used in previous case definitions of serious skin infection in children

ICD-10† code	J Allen and D McQuade[45]	Craig E et al.[9]	Finger F et al.[19]	Hunt D[11]	Lawes C[10]	MOH (ASH)
L01 – Impetigo	Yes	Yes	No	Yes	Yes	Yes
L02 – Cutaneous abscess, furuncle & carbuncle	Yes	Yes	Yes	Yes	Yes	Yes
L03 – Cellulitis	Yes	All codes within this ICD set excluding periorbital cellulitis	Only the codes: L030 – Cellulitis of finger and toe L0310 – Cellulitis of upper limb L0311 – Cellulitis of lower limb L032 – Cellulitis of face	All codes within this ICD set excluding periorbital cellulitis	Yes	Yes
L04 – Acute lymphadenitis	Yes	Yes	No	Yes	Yes	Yes
L05 – Pilonidal cyst	Yes, not specified if L05.1 excluded	Yes, not specified if L05.1 excluded	No	Yes, not specified if L05.1 excluded	Yes, not specified if L05.1 excluded	No
L08 – Other local infections of skin and subcutaneous tissue	Yes	Yes	Only L08.8 – Other specified local infections of skin and subcutaneous tissue	All codes within this ICD set excluding erythrasma (L08.1)	Yes	Yes
Other included ICD codes/descriptions	M00 - Septic arthritis (all sites) M86 – Osteomyelitis (all sites) Infected eczema (ICD codes used not specified)	L00 – staphylococcal scalded skin syndrome	No	L980 – Pyogenic granuloma	A46 – Erysipelas L980 – Pyogenic granuloma I89.1 – Lymphangitis	L980 – Pyogenic granuloma H010 – Blepharitis H050 – Acute inflammation of the orbit J340 – Abscess, carbuncle and furuncle of nose K122 – Cellulitis and abscess of mouth
Diagnosis level included‡	All level	Principal diagnoses only.	Not specified	Principal diagnosis only	Principal diagnosis only	Principal diagnoses only.
Age of cases	1-14 years old	0-14 year olds (15-24 year olds included but separate analysis)	1-14 year olds	1-14 year olds	0-14 year olds	All ages but specific paediatric group 0-4 year olds
Year and geographic location	2003-2006 Gisborne Region	2001-2006, Whole NZ population	2000 South Auckland (Middlemore Hospital)	1996/7-2002/3, Wellington Region	1994-1998 Auckland Region (two Hospitals)	Ongoing Whole NZ population, divided by DHB

Yes – indicates all ICD codes within set were included (no exceptions)

No – no ICD codes within set were included (no exceptions)

ASH – ambulatory sensitive hospitalisation

DHB – District Health Board

ICD – International Classification of Diseases

MOH – Ministry of Health

† ICD-10 is the tenth version of the ICD system, currently in use in NZ

‡ ICD codes are classified as either the principal code or an additional code for each admission (all level=principal and additional)

Table 2. The screening performance of serious skin infection ICD-10 codes for identifying 0-14 year olds admitted to Gisborne Hospital 2004-2007 with a clinically diagnosed serious skin infection

CATEGORY A ICD codes (skin infection sub-chapter of ICD-10)	Level of diagnosis	Frequency code use†	True positives	False positives	PPV
L01.0, L01.1 – Impetigo	Principal	9	9	0	1.00
	All level	25	18	7	0.72
L02.0-L02.9 – Cutaneous abscess, furuncle and carbuncle	Principal	101	101	0	1.00
	All level	114	112	2	0.98
L03.01-L03.9 – Cellulitis	Principal	102	102	0	1.00
	All level	126	122	4	0.97
L0.40-L04.9 – Acute lymphadenitis	Principal	7	7	0	1.00
	All level	8	8	0	1.00
L05.0 – Pilonidal cyst with abscess	Principal	0	0	0	-
	All level	0	0	0	-
L08.0 - Pyoderma	Principal	0	0	0	-
	All level	2	2	0	1.00
L08.1,L08.8,L08.9 – Other infections of skin and subcutaneous tissue	Principal	11	11	0	1.00
	All level	23	21	2	0.91
Total	**Principal**	**230**	**230**	**0**	**1.00**
	All level	**298**	**283**	**15**	**0.95**
CATEGORY B ICD codes (serious skin infections of atypical anatomical sites)					
A46 – Erysipelas	Principal	0	0	0	-
	All level	0	0	0	-
H00.0 – Hordeolum/cellulitis/abscess eyelid	Principal	2	2	0	1.00
	All level	2	2	0	1.00
H60.0-H60.3, H62.0, H62.4 – Abscess/cellulitis external ear and infective otitis externa	Principal	4	4	0	1.00
	All level	5	5	0	1.00
J34.0 – Abscess/cellulitis nose	Principal	0	0	0	-
	All level	0	0	0	-
K61.0 – Anal abscess/cellulitis (excludes rectal, ischiorectal or intersphincteric regions)	Principal	0	0	0	-
	All level	0	0	0	-
H05.0 – Acute inflammation/cellulitis/abscess of orbit	Principal	0	0	0	-
	All level	0	0	0	-
N48.2,N492,N49.9 – Other inflammatory disorders of penis, scrotum and unspec male genital organ (excludes deeper tissues)	Principal	3	3	0	1.00
	All level	3	3	0	1.00
N76.4 – Abscess/cellulitis of vulva	Principal	0	0	0	-
	All level	0	0	0	-
Total	**Principal**	**9**	**9**	**0**	**1.00**
	All level	**10**	**10**	**0**	**1.00**
CATEGORY C ICD codes (serious skin infections secondary to primary skin disease)					
B01.8 – Varicella with other complications	Principal	4	3	1	0.75
	All level	5	4	1	0.80
B86 – Scabies	Principal	2	1	1	0.50
	All level	13	3	10	0.23
L30.8,L30.9,L30.3 0 – Dermatitis unspecified and other specified (eczema) and infective eczema‡	Principal	25	19	6	0.76
	All level	74	30	44	0.41
Total	**Principal**	**31**	**23**	**8**	**0.74**
	All level	**92**	**37**	**55**	**0.40**
CATEGORY D ICD codes (serious skin infections secondary to external trauma)					
S10.13,S10.83,S10.93,S20.13,S20.33,S20.43,S20.83,S30.83, S30.93,S40.83,S50.83,S60.83,S70.83,S80.83, S90.83,T00.9, T09.03,T11.08,T13.03,T14.03,T14.03, T63.3,T63.4 – Insect/ spider bites	Principal	4	2	2	0.50
	All level	4	2	2	0.50
T79.3 – Post-traumatic wound infection not elsewhere classified	Principal	1	1	0	1.00
	All level	5	4	1	0.80
T89.01,T89.02 – Open wound infection with foreign body +-infection) and open wound with infection	Principal	0	0	0	-
	All level	26	22	4	0.85
Total	**Principal**	**5**	**3**	**2**	**0.60**
	All level	**35**	**28**	**7**	**0.80**

†Number of times ICD code used excluding admissions already detected by code in Category A (L01-L08 excl. L05.9)

‡The medical definition of infective eczema (a primarily inflammatory condition) is not in keeping with the clinical description of a serious skin infection, however due to similarities in terminology, this code is incorrectly used for eczema with a superficial bacterial infection. This confusion and the subsequent coding error is more widespread than Gisborne Hospital; Hunt[11] includes it in a tally of serious skin infections missed by his case definition.

2.4.2. ASSESSING SCREENING PERFORMANCE OF ALTERNATIVE CASE DEFINITIONS

There were 6657 paediatric admissions to Gisborne Hospital between 2004 and 2007. Of these, 435(6.5%) were coded with at least one of the Category A-D ICD codes as a principal or additional diagnosis. Table 2 summarises the results of the chart review.

The alternative sources of ascertainment yielded four additional cases each under a different ICD code; on review these would have been more accurately coded by one of the codes in categories A-D. These cases were regarded as false negatives.

The validity of the baseline case definition and that of eleven alternative definitions is shown in table 3. The baseline definition (skin infection sub-chapter of ICD-10) had the greatest PPV and specificity, along with Definition 2. However, this was at the expense of a lower NPV and a sensitivity of 61%, resulting in a loss of many true positive cases. Through inclusion of additional diagnosis levels and the ICD codes in categories B-D, the validity of the case definition could be significantly improved, with particular gains in sensitivity. Definition 12 was chosen as the most valid, clear and reliable option; it had the greatest sensitivity and NPV, and lost little specificity. The reduction in PPV was considered an acceptable trade-off for the improvement in these other measures of validity, and the clarity and ease of use of definition 12 supported its reliability over time.

Therefore a new standard epidemiologic case definition for serious skin infection in children is proposed in figure 2.

Table 3. Screening performance (sensitivity, specificity, PPV and NPV) of previous and alternative case definitions for identifying 0-14 year olds admitted to Gisborne Hospital 2004-2007 with clinically diagnosed serious skin infections

No.	Definition description	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
1	Category A codes, principal diagnosis only (previous ICD sub-chapter case definition)	61.0	100.0	100.0	97.7
2	Category A & B codes, principal diagnosis only	64.4	100.0	100.0	98.0
3	Category A & C codes, principal diagnosis only	67.1	99.9	96.8	98.1
4	Category A & D codes, principal diagnosis only	61.6	99.9	99.1	97.8
5	Category A & B & C codes, principal diagnosis only	70.7	99.9	97.0	98.3
6	Category A & B & C & D codes, principal diagnosis only	71.5	99.8	96.3	98.4
7	Category A codes, all level diagnosis	78.2	99.8	95.0	98.8
8	Category A & B codes, all level diagnosis	80.9	99.8	95.1	98.9
9	Category A & C codes, all level diagnosis	88.4	98.9	82.1	99.3
10	Category A & D codes, all level diagnosis	85.9	99.7	93.4	99.2
11	Category A & B & C codes, all level diagnosis	92.2	98.8	82.7	99.6
12	Category A & B & C & D codes, all level diagnosis	98.9	98.8	82.3	99.9

ICD – International Classification of Diseases
NPV – Negative predictive value
PPV – Positive predictive value

Figure 2. Proposed epidemiologic case definition for serious skin infection in children

A child aged 0-14 years, admitted to hospital with a principal or additional diagnosis of serious skin infection, with a diagnosis code either within the ICD skin infection sub-chapter, or within the categories of skin infection of an atypical site or skin infection following primary skin disease or external trauma (see categories A, B, C and D for full listing of codes).

ICD – International Classification of Diseases

2.5. DISCUSSION

Recent research into the epidemiology of childhood serious skin infections in NZ has been hampered by the lack of a consistent and valid case definition. While the ICD skin infection sub-chapter definition is highly specific, it is poorly sensitive, failing to detect 39% of clinically defined serious skin infection cases. After testing this previous definition and a variety of alternatives, a new case definition is proposed that improves sensitivity from 61% to 98.9% while only reducing specificity from 100% to 98.8%. This appears to be the first study to critically analyse the screening performance of various epidemiological case definitions of serious skin infection in children using a clinically defined population of cases.

The boundaries of the previously used ICD sub-chapter definition were found to be narrow and somewhat flawed. The exclusion of cases where skin infection was an additional diagnosis or based on anatomical or presumed aetiological grounds seems to be largely arbitrary. Instead the shared pathophysiological pathways of these infections seem to justify their inclusion. This hypothesis was supported by the increased sensitivity of the case definition when these additional forms of skin infection were included.

The practice of including principal diagnoses only is common in epidemiological analyses of hospitalised populations. A principal diagnosis is defined as "the diagnosis established after study to be chiefly responsible for causing the patient's episode of care in hospital" while additional diagnoses are theoretically reserved for "a condition or complaint either co-existing with the principal diagnosis or arising during the episode of care or attendance at a healthcare facility".[51] However, this analysis has shown that the process of deciding which diagnosis to specify as principal is flawed. The chart review found many incidences of serious skin infections coded as additional diagnoses arising from admissions with multiple significant diagnoses, application of specific coding rules, and individual coding errors. The inclusion of all level diagnoses does introduce new challenges however. For example, there is the potential for disease incidence rates to be influenced by coding practices in settings where extra funding is accessed through diligent coding

of additional diagnoses. It is important to be explicit about the disease codes used in all analyses of hospitalisation data. Ideally such analyses should present incidence rates based on both principal diagnoses and all level diagnoses in parallel for comparison.

Previous case definitions differed on the inclusion of children in the 0-1 year old age group, with most studies excluding this group due to concerns regarding capturing pathology related to pregnancy or birth in infants aged under 6 weeks. During the chart review it was found that the majority of cases in the 0-1 year old age group were typical Category A infections, sharing pathophysiological pathways with those infections seen in the 1-14 year old age group. The small number of skin infections that did represent pathologies related to pregnancy and birth were usually assigned the codes P38 (omphalitis), P39.4 (neonatal skin infection) and T81.4 (infection following a procedure not otherwise specified), all of which were excluded from the new proposed case definition. As such, and in order to not miss the significant number of clinically relevant cases in the 0-1 year old age group, the entire 0-14 year old age range were included in the definition.

Determining the quality of a case definition shares some similarities with assessing the performance of a surveillance system.[48] In designing a 'fit for purpose' case definition, two attributes were considered; validity (comprising sensitivity, specificity, PPV and NPV), and reliability (comprising clarity and ease of use). The proposed new case definition has a significantly strengthened sensitivity and a slightly improved NPV without an unduly compromised specificity. The improvement in sensitivity was made at the expense of a moderate loss in PPV: this concession was justified as firstly there was no other definition which provided an improved PPV without a loss of more than 10% in sensitivity, and secondly, utilised as an epidemiological tool, the risk of adverse effects from false positives is low. The chosen definition is also clear and easy to use which should enhance its reliability over time.

The implications of these findings are considerable. With almost 40% of cases of serious skin infection being overlooked in previous epidemiological analyses, the burden of this important and increasing condition has been seriously

underestimated. In addition, the lack of consistency between previous case definitions limits the validity of past comparisons between populations.

This study has several important limitations. The work was based on the paediatric inpatient population of a single small hospital. While this setting enabled the otherwise impractical methodology, it does raise the question of generalisability. By contrast there is an argument that the proposed broader case definition will increase consistency across hospitals, particularly because it is based on the widely used internationally standardised ICD coding system. However, similar evaluations of this case definition should ideally be carried out in other settings.

A broader question is whether these findings can be generalised to the adult population. There is no evidence that the case definition would be less valid in adults; however there are some differences in the aetiology and pathophysiology of serious skin infections particularly of atypical anatomical sites. This question requires further investigation.

Despite reviewing four years of admissions, several skin infection ICD codes had no recorded use. This situation is a likely consequence of the small study population, the relative rarity of some conditions, and the fact that cases counted in categories B-D excluded admissions already detected by codes in Category A. It is reasonable to retain these codes in the definition based on them having similar pathophysiology to more common conditions. These assumptions should be tested in a larger study.

There were several potential sources of error in assessing the validity of the case definition. The reliance on retrospective clinical judgment to identify cases introduces a source of potential selection bias which was minimised by the provision of a written clinical description of the diagnosis, and by reaching a consensus decision on complex cases. Although two alternative sources of case ascertainment were used to identify false negatives, this process would still have been incomplete resulting in some selection bias. Without reviewing the charts of all children admitted to Gisborne Hospital during the four-year study period, the precise sensitivity of each case definition cannot be calculated. However, as this approach was not feasible, a more practical but admittedly imperfect method of identifying

false negatives was accepted, although this could have resulted in an overestimation of the sensitivity of the case definition.

Ideally this case definition should be validated in other patient populations, particularly if its use is extended to adult age groups and international settings. Where this definition is applied, it is recommended that results be presented in a disaggregated format (by the four categories and two diagnosis levels). This presentation may help to highlight different coding practices across hospitals. This breakdown may also contribute towards an understanding of the aetiological processes involved in the development of serious skin infections on a regional basis, and aid in identifying the role of particular interventions.

Ultimately the utility of a case-definition is in supporting interventions to prevent and control the disease burden being measured. Given the apparently high rates of skin infection in NZ, it is hoped that this initial work on developing a standardised case definition will help to stimulate further research and interventions to reduce this serious public health problem.

CHAPTER THREE

INCREASING HOSPITALISATIONS FOR SERIOUS SKIN INFECTIONS IN NEW ZEALAND CHILDREN, 1990-2007

3.1. ABSTRACT

3.1.1. AIM

Serious skin infections are increasing worldwide but the incidence in New Zealand children is significantly higher than comparative countries. This study aimed to use a newly developed case definition to describe the epidemiology of serious skin infections in New Zealand children and investigate if changes in the distribution of disease over time could be contributing to increasing infection rates.

3.1.2. METHODS

Retrospective hospitalisation data were reviewed for all 0-14 year old children admitted overnight to a New Zealand public hospital with a diagnosis of a serious skin infection during the period 1990-2007. Variables including the season and year of admission, age, gender, ethnicity, level of deprivation, rurality, and geographic region of admission were compared over two time periods, 1990-1999 and 2000-2007.

3.1.3. RESULTS

There were 64 568 cases of serious skin infection in New Zealand children between 1990 and 2007. The age-adjusted incidence almost doubled from 294.1/100 000 in 1990 to 562.3/100 000 in 2007, and consistently peaked in Summer and Autumn. The highest rates were observed in boys, children under 5 years old, Māori and

Pacific children, those living in deprived neighbourhoods, in urban areas and in Northern districts of the country. Between the two time periods, the distribution of infections changed with disproportionate increases in infection rates in Māori and Pacific children and children from areas of highest deprivation.

3.1.4. CONCLUSION

Serious skin infections are a significant problem for New Zealand children. Worsening ethnic and socioeconomic health inequalities may be contributing to increasing infection rates. Further research is warranted to identify opportunities for effective infection prevention.

3.2. INTRODUCTION

Skin and subcutaneous tissue infections are a heterogeneous group of superficial bacterial infections, most frequently caused by normal skin commensals; *Staphylococcus aureus* and *Streptococcus pyogenes*.[1] These infections are common and are usually adequately treated within the community, however, in a number of cases serious skin infections develop which require hospitalisation for often invasive treatments. An increase in the incidence of serious skin infections has been recognised worldwide.[3-5] In New Zealand (NZ) this incidence has been particularly high with the rate of cellulitis double that of Australia and the United States of America.[11] The reasons for this high and increasing disease burden are not understood.

In 2007, a comprehensive report on the health and wellbeing of NZ children and young people was published by Craig et al.[9] It found the incidence of serious skin infections in children had doubled during the last two decades, with the highest rates occurring in preschool-aged children, Māori and Pacific children, boys and children living in areas of greatest deprivation. There have been a number of regional reports with similar observations,[10,11,20-22] however the only study in this field to have been published in the peer-reviewed medical literature is a one-year retrospective audit of paediatric skin infection admissions to a South Auckland hospital.[19] None of these studies have investigated whether changing epidemiology over time could be contributing to the increasing incidence of infection.

Furthermore, work described in Chapter 2 has shown the case definition for serious skin infection currently in use is deficient in several areas, with a sensitivity of just 61% when tested against a set of clinically defined serious skin infections.[46] As this case definition was used in the work by Craig et al., current national incidence rates are likely to underestimate the true burden of infection, and epidemiological trends are potentially different to those described.

This study aimed to use a newly developed and validated case definition of serious skin infection to describe the incidence of these conditions in NZ children during the period 1990-2007. It also aimed to investigate if there have been changes in the

distribution of disease over time that could help explain the increasing infection rates.

3.3. METHODS

3.3.1. CASE SELECTION AND DATA EXTRACTION

This study was based on hospital discharge data obtained from the NZ Ministry of Health. It selected children aged 0-14 years, admitted overnight to a NZ public hospital between 1 January 1990 and 31 December 2007, with a principal or additional discharge diagnosis from a defined list of serious skin infection International Classification of Disease (ICD) codes (see Appendix C).

This case definition, described in Chapter 2, found its validity was markedly improved by including categories of infection previously overlooked.[46] With the addition of skin infections of atypical anatomical sites, those secondary to either primary skin disease or trauma, and those recorded as additional diagnoses (see Appendix C), the sensitivity of the case definition increased from 61.0% to 98.9%, with little loss in specificity.

Each discharge record included a unique patient identifier (encrypted National Health Index number) enabling transfers and readmissions within 30 days with the same principal diagnosis code to be removed. To ensure a better match with the census population overseas visitors were removed. Day cases were excluded due to inconsistencies in data recording over time.

Cases were assigned rurality and deprivation levels based on their home domicile census area units (CAUs). Rurality assignment used a Statistics NZ classification which defines seven grades of rurality on the basis of population size and employment status. Ethnicity was based on prioritised ethnicity, a method which ensures that each patient is only counted once in the ethnic-specific hospital discharge data for each event. Assigning levels of socioeconomic deprivation used the New Zealand Deprivation Index (NZDep) which is based on nine variables extracted from census data.[52] NZDep 1 indicates least deprivation and 10 indicates highest deprivation. In 2.21% of cases domicile codes could not be linked to CAUs due to retired codes and addresses outside of classification. To reduce the impact of these

'missing CAUs', retired domicile codes were linked to new codes using files from the Ministry of Health and Statistics NZ.[53,54]

3.3.2. DATA ANALYSIS

The data were analysed using Microsoft Excel®. Denominators in rate calculations were derived from usually resident population counts from the 1991, 1996, 2001, and 2006 censuses. Counts from each census were used to approximate the population in the preceding and subsequent two years. Age adjustment used the World Health Organisation (WHO) standard population. Trends over time and between populations were explored by the calculation of rate ratios (RRs) with 95% confidence intervals (95% CIs) calculated using the log-transformation method.[55] Changes in the distribution of disease over time were measured by the difference in RRs for each variable between 1990-1999 and 2000-2007, with statistical significance indicated by a two-tailed p-value <0.01.

The first part of the analysis describes the incidence of serious skin infections for the entire period 1990-2007. To compare trends over time, the more detailed descriptive analyses have split the data into two periods, corresponding to the changeover from ICD version 9 (ICD-9) to ICD version 10 (ICD-10) in mid-1999.

3.4. RESULTS

3.4.1. SELECTION OF CASES, INCIDENCE AND IMPACT

A total of 82 408 hospitalisations met the case definition. From this, 213 private hospital admissions, 955 overseas visitors, 3109 transfers, 12 353 day cases, and 1210 readmissions were excluded.

Of the remaining 64 568 cases, 12 were reported to have been discharged dead from hospital (case fatality 0.04%) from 1990-1999 and 17 (0.05%) from 2000-2007. Hospitalisation data recorded a total of 213 141 hospital days over the study period. The median stay was 2 days and mean was 3.3 days in both 1990 to 1999 and 2000 to 2007.

Based on a 2003 estimate of hospitalisation costs per case of NZ$2180,[11] the direct cost of these infections for DHBs in 2007 alone was almost NZ$15 million (based on an inflation-adjusted cost per case of NZ$2434.21).

Table 4 shows the incidence of serious skin infections over 1990-1999 and 2000-2007. As recommended by the work in Chapter 2 developing the case definition,[46] and to provide an indication of the level of certainty of these estimates, these data are disaggregated by category and level of diagnosis (see Appendix C for detail). This analysis shows that the distribution of disease between principal and additional diagnosis categories changed little over this period (64.8% principal diagnosis in 1990-1999 and 62.8% in 2000-2007).

3.4.2. INCIDENCE BY YEAR AND SEASON, 1990-2007

Over the 18-year period analysed, the age-adjusted annual incidence rate of serious skin infection in NZ children almost doubled, from 294.1/100 000 (2335 cases) in 1990 to 562.3/100 000 (4748 cases) in 2007 (see figure 3). In the earliest two years of the study there was a largely stable incidence around 300/100 000, then from 1992-2002 infection rates steadily rose to over 500/100 000. Since 2002 the incidence has been relatively steady again. These trends were a direct reflection of changes in the incidence of serious skin infections of typical sites, with the rates of

infections of atypical sites and those secondary to primary skin disease and trauma fairly stable over time.

Table 5 shows the crude incidence of serious skin infections by season of admission. Infections were significantly more frequent during Summer and Autumn compared to Winter (Summer - RR 1.08 in 1990-1999 and 1.15 in 2000-2007, Autumn – RR 1.11 in 1990-1999 and 1.14 in 2000-2007). There was no change in this seasonal trend over time (p>0.01 for all seasons).

Table 4. The incidence of serious skin infections in 0-14 year children in NZ 1990-1999 and 2000-2007, disaggregated by category and level of diagnosis

		1990-1999		2000-2007	
Category	**Level of diagnosis**	***f***	**Rate† (per 100 000)**	***f***	**Rate† (per 100 000)**
Serious skin infections of typical sites (previously used case definition based on skin infection sub-chapter of ICD-10)	Principal	13541	166.3	18177	264.9
	All level	17074	209.7	24086	351.0
Serious skin infections of atypical anatomical sites	Principal	3170	38.9	1866	27.2
	All level	5233	64.3	2270	33.1
Serious skin infections secondary to primary skin disease	Principal	1406	17.3	1909	27.8
	All level	5364	65.9	6170	89.9
Serious skin infections secondary to external trauma	Principal	635	7.8	420	6.1
	All level	1270	15.6	3101	45.2
Crude total serious skin infections	**Principal**	**18752**	**230.3**	**22372**	**326.0**
	All level	**28941**	**355.4**	**35627**	**519.2**
Age-adjusted total serious skin infections	**All level**		**354.3**		**531.7**

f Frequency is number of cases in 1990-1999 and 2000-2007

†Average annual incidence per 100 000 based on usually resident population (from NZ Census)

Figure 3. Age-adjusted incidence of serious skin infections in 0-14 year old children in NZ by ICD-10 code category, 1990-2007

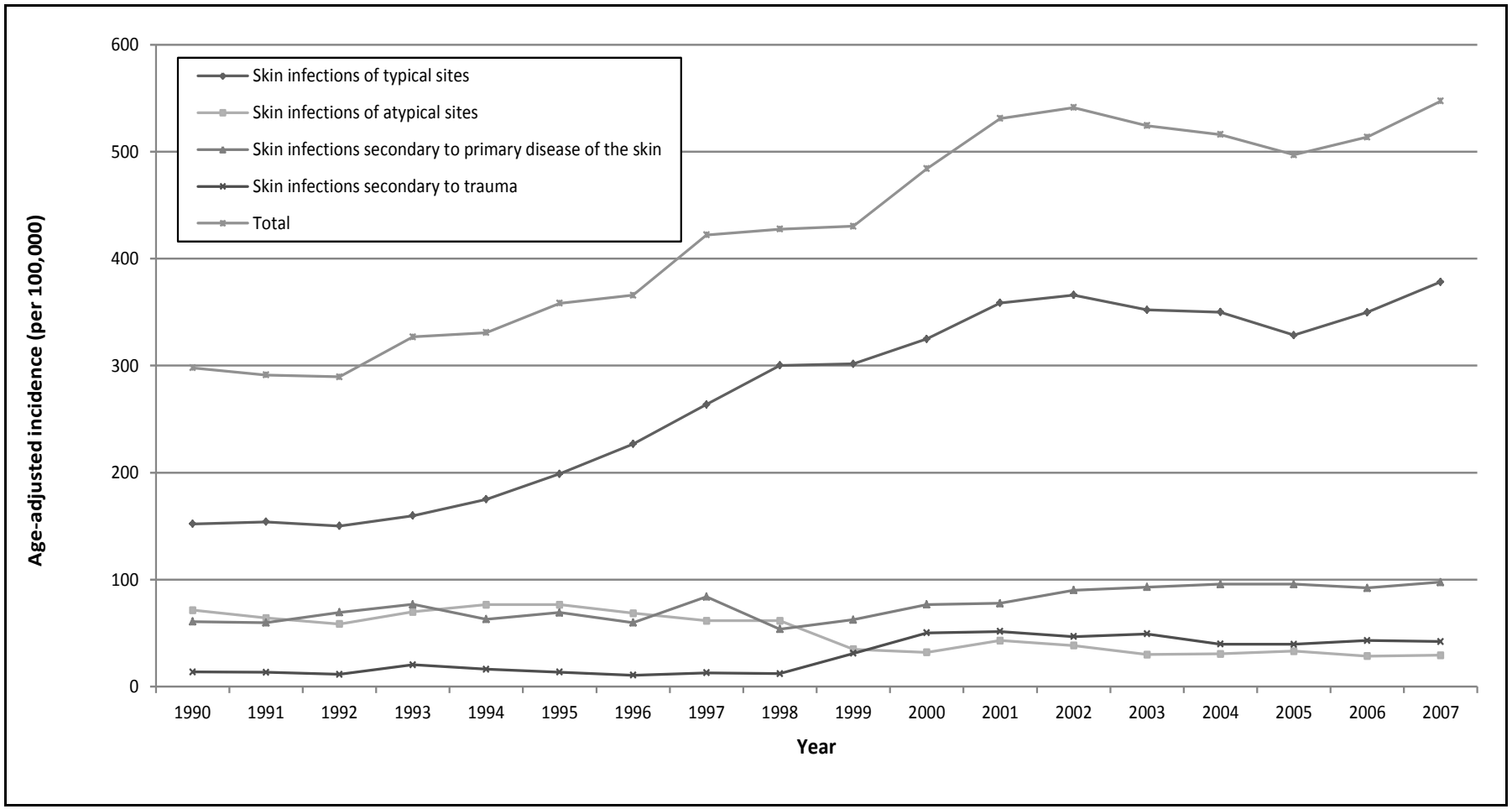


Table 5. Serious skin infection incidence and rate ratios by season, gender, age, ethnicity, rurality and deprivation, in 0-14 year old children in New Zealand, 1990-1999 and 2000-2007

	1990-1999			2000-2007			
Variable	***f***	**Rate†**	**RR (95% CI)**	***f***	**Rate †**	**RR (95% CI)**	**Difference in RRs between time periods¶ *p***
Season‡							
Summer	7508	368.8	1.08(1.05-1.11)	9594	559.3	1.15(1.12-1.18)	0.13
Autumn	7722	379.3	1.11(1.08-1.14)	9454	551.2	1.14(1.11-1.17)	0.51
Winter	6963	342.0	1.00#	8327	485.4	1.00#	
Spring	6748	331.5	0.97(0.94-1.00)	8252	481.1	0.99(0.97-1.02)	0.63
Gender							
Male	16909	405.2	1.34(1.31-1.37)	20440	581.5	1.28(1.25-1.31)	0.21
Female	12031	303.3	1.00#	15187	453.8	1.00#	
Unknown	1						
Age							
0-4 yr	16454	592.5	2.20(2.15-2.25)	19922	912.4	2.45(2.40-2.50)	0.03
5-9 yr	7348	268.9	1.00#	8525	372.1	1.00#	
10-14 yr	5139	195.1	0.73(0.71-0.75)	7180	300.8	0.81(0.79-0.83)	0.02
Ethnicity							
Māori	10002	546.3	2.28(2.22-2.34)	13734	866.2	2.90(2.84-2.96)	<0.001
Pacific	5251	885.7	3.70(3.59-3.81)	7849	1351.9	4.52(4.41-4.63)	<0.001
Other	13688	239.3	1.00#	14044	299.1	1.00#	
***NZDep*§**							
1-2	2376	179.3	1.00#	2937	226.2	1.00#	
3-4	3361	236.7	1.32(1.27-1.37)	3829	298.3	1.32(1.28-1.37)	1.00
5-6	4494	295.5	1.65(1.60-1.70)	4968	390.3	1.73(1.68-1.78)	0.34
7-8	6300	374.4	2.09(2.03-2.15)	7745	569.1	2.52(2.46-2.58)	<0.001
9-10	12136	637.8	3.56(3.48-3.65)	15966	972.0	4.30(4.21-4.39)	<0.001
Missing∞	274			182			
Rurality							
Urban	25757	390.0	1.00#	32177	555.3	1.00#	
Rural	2925	235.3	0.60(0.58-0.62)	3267	306.4	0.55(0.53-0.57)	0.16
Missing∞	259			183			
Total	**28941**			**35627**			

f Frequency is number of cases in 1990-1999 and 2000-2007

† Average annual crude incidence per 100 000 based on usually resident population (from NZ Census)

‡ Where Autumn is considered March, April, May; Winter is June, July, August; Spring is September, October, November; and Summer as December, January and February.

§ The New Zealand Deprivation Index (NZDep) is a measure of socioeconomic deprivation based on nine variables extracted from census data.[13] NZDep 1 indicates least deprivation and 10 indicates highest deprivation.

Arbitrary reference category

∞ Missing refers to cases with domicile codes that could not be linked to CAUs

¶ The p-value indicating if there has been a change in the rate ratios (RR) of each variable between the two time periods. A p<0.01 indicates a statistically significant difference in the RR of the variable between 1990-1999 and 2000-2007

3.4.3. INCIDENCE BY GENDER, AGE, ETHNICITY, DEPRIVATION LEVEL, AND RURALITY, 1990-2007

Table 5 details serious skin infections in NZ children by a range of patient characteristics, across two time periods 1990-1999 and 2000-2007.

Boys had a significantly greater risk of infection than girls, with a crude incidence rate of 405.2/100 000 compared to 303.3/100 000 (RR 1.34) in 1990-1999 and 581.5/100 000 compared to 453.8/100 000 (RR 1.28) in 2000-2007. There was no significant difference in the RRs between the two time periods (p 0.21).

The incidence of skin infection decreased with increasing age. Children aged 0-4 years had more than double the risk of infection than those aged 5-9 years (RR 2.20 in 1990-1999 and 2.45 in 2000-2007) and the 10-14 year old age group had the lowest rates of infection overall. Between the two time periods there were increases in the proportion of cases in both the youngest and oldest age groups relative to the reference 5-9 year old group; this difference in RRs approached but did not reach statistical significance (p 0.03 and 0.02).

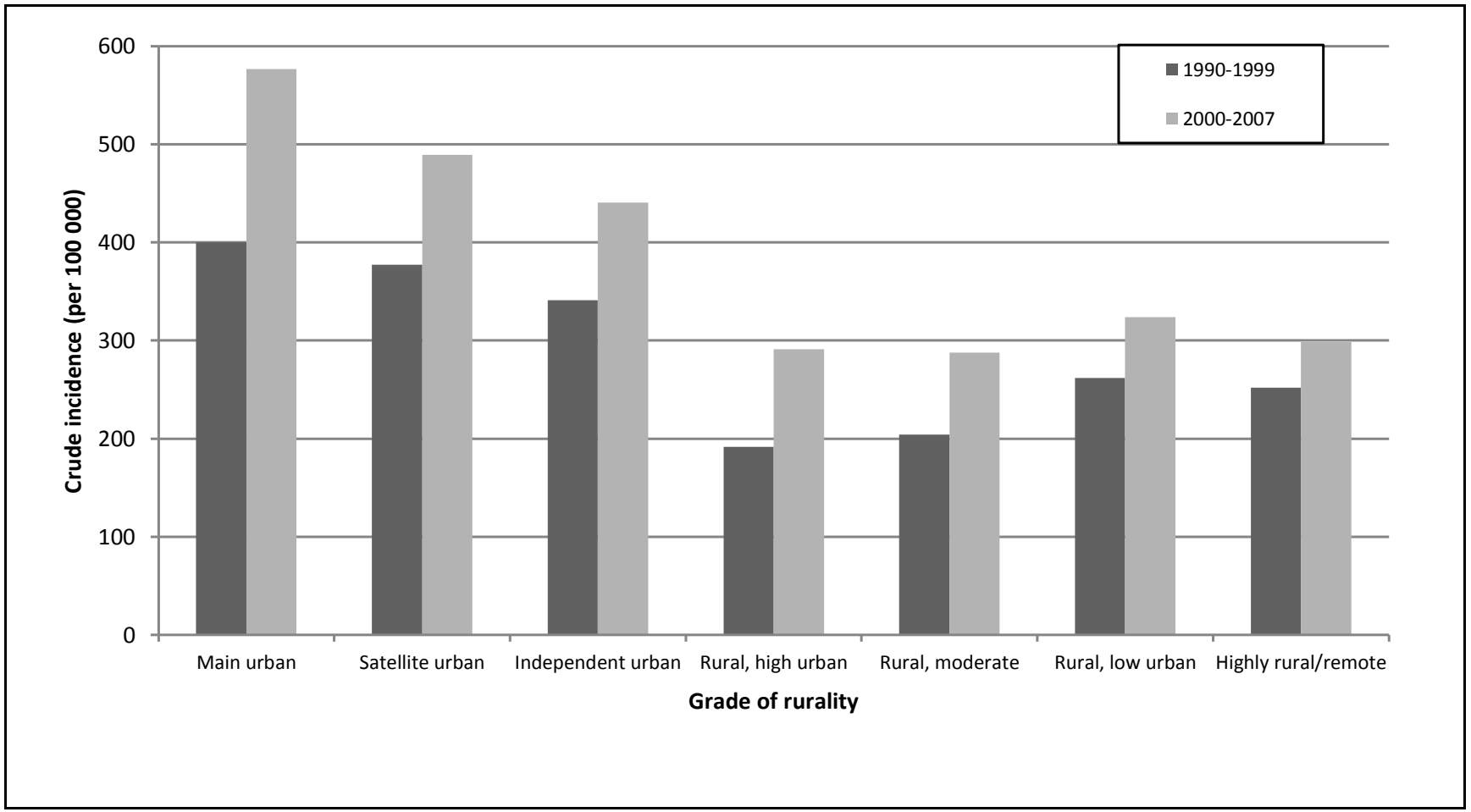
The rate of serious skin infection was significantly higher in Māori and Pacific children than those in other ethnic groups. In 1990-1999 the crude incidence rate was 2.28 times higher in Māori children, and 3.70 times higher in Pacific children, compared to those of other ethnicities. By 2000-2007 that difference had increased to 2.90 times higher in Māori children and 4.52 times higher in Pacific children. The difference in RRs over time was statistically significant ($p<0.001$).

The crude incidence of serious skin infection was lowest in areas of least deprivation and increased markedly with rising deprivation levels. During the period 1990-1999, the rate of infection in children from NZDep9-10 areas was 3.56 times greater than for children from NZDep1-2 areas (179.3/100 000 and 637.8/100 000 respectively). By 2000-2007 this difference had increased significantly to 4.30 times higher ($p<0.001$).

Serious skin infection rates were more than one and a half times higher in children from urban areas compared with children from rural areas (see figure 4). Of the

three urban classifications, the crude incidence of infection steadily decreased as areas became increasingly rural. The gradient of this trend appeared steeper in 2000-2007 compared with 1990-1999, but there was no statistically significant difference found (p 0.16). The incidence of infection in the four rural areas was similar, with no change over time.

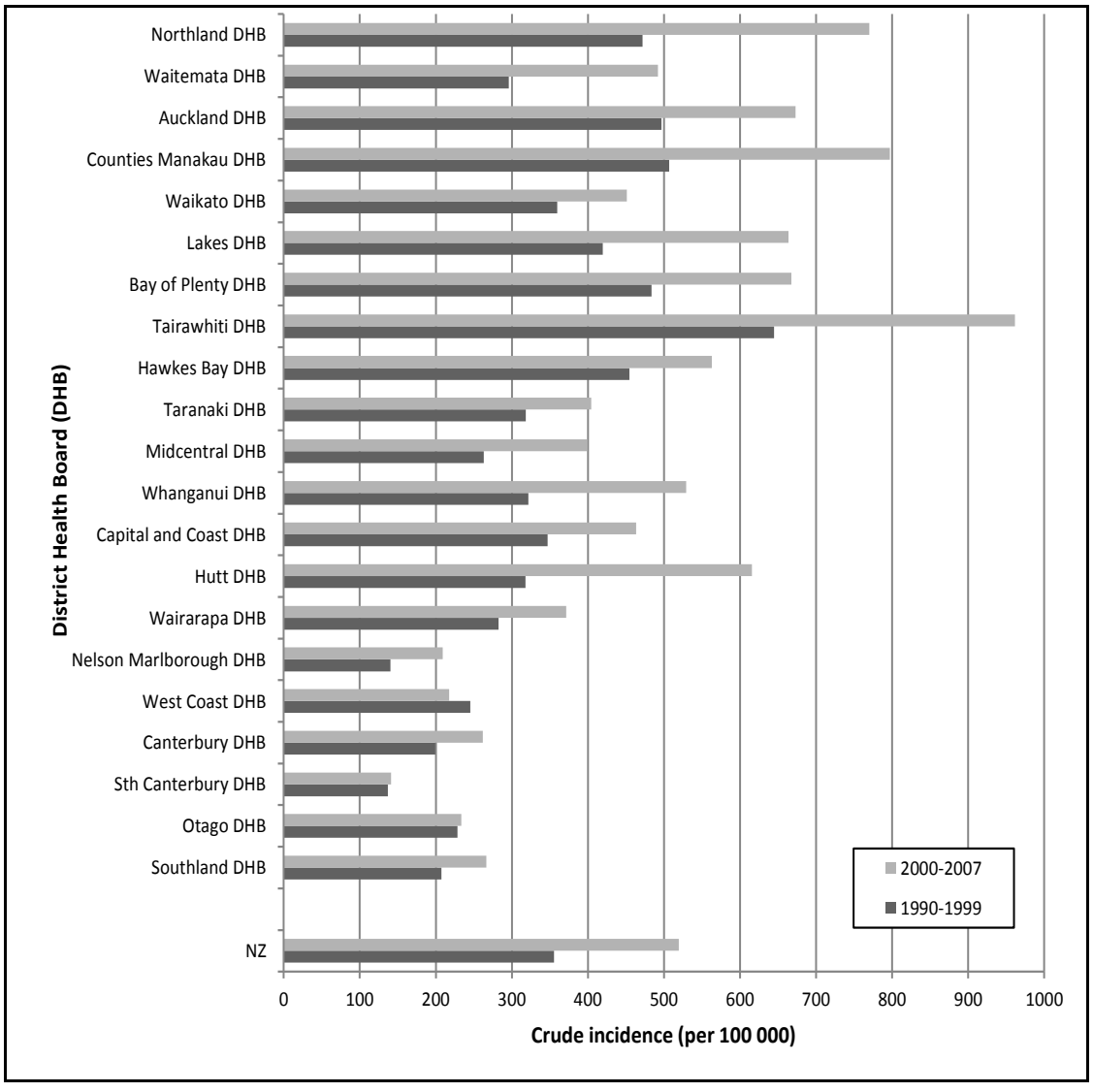
Figure 4. Incidence of serious skin infections in 0-14 year old children in NZ by rurality, 1990-2007



3.4.4. INCIDENCE BY DHB

Figure 5 shows the crude incidence of serious skin infections across all 21 geographically-assigned NZ DHBs. There was a rough North-South gradient with higher rates generally observed in North Island DHBs (Northland-Wairarapa) compared to South Island DHBs (Nelson Malborough-Southland). The incidence of infection increased over time in all DHBs except West Coast, where a small decrease was observed. Tairawhiti DHB had the highest incidence rate during both time periods studied, approaching double the national rate with an incidence of 644.9/100 000 in1990-1999 rising to 961.4/100 000 in 2000-2007.

Figure 5. Incidence of serious skin infection in 0-14 year old children in NZ by DHB, 1990-2007



3.5. DISCUSSION

Serious skin infections are an important and increasing challenge to the health of NZ children, and are making a growing contribution to ethnic and socioeconomic health inequalities.

Chapter 2 has shown the case definition for serious skin infections used in previous publications has been deficient in a number of areas and, by including several categories of skin infections previously overlooked, the sensitivity of this definition could be increased from 61.0% to 98.9% with minimal loss of specificity.[46] This is the first study to apply this new published case definition to the NZ paediatric population. Findings showed that between 1990 and 2007 the age-adjusted incidence of serious skin infections almost doubled, from 294.1/100 000 to 562.3/100 000. By 2007, these infections were contributing 4748 hospitalisations per year. Besides the considerable medical and social impact, this incidence equates to a sizeable public expenditure on health services, even without accounting for other direct and indirect economic costs.

Furthermore, this is the only study known to investigate whether there have been changes in the distribution of serious skin infections over time which could account for the increasing incidence of disease. Between 1990 and 2007 the highest infection rates were observed in boys, children under 5 years old, Māori and Pacific children, those living in deprived neighbourhoods, in urban areas and in Northern districts of the country. While these high-risk groups have remained the same between 1990-1999 and 2000-2007, ethnic and deprivation-related disparities have significantly increased. This change in the distribution of serious skin infections over time is contributing to the increasing incidence of disease; however it cannot explain the whole increase as rates have risen across all population groups.

The incidence of infections showed consistent seasonality. High disease rates in Summer and Autumn have been observed in other settings and are thought to result from warmer air temperatures leading to more frequent insect bites, deficiencies in hygienic precautions, and increased skin exposure resulting in greater skin to skin contact and minor trauma.[3,4,11,26,28-31,56]

High rates of infection in preschool-aged children and boys have important implications for directing community prevention efforts. In both groups this increased risk could be attributable to more frequent injuries, poorer general hygiene, or longer delays in seeking medical attention. It is not known whether these trends reflect similar patterns in the community, or in the case of younger children, of lower hospital admission thresholds. Previous NZ reports have observed similar trends,[9-11,19] but interestingly studies in the international literature report no gender predominance.[3,25,27,30,56,57] As these studies mainly comprise primary care and population surveys, it is possible that simple skin infections are experienced equally by both genders but boys are more likely to suffer progression to a serious skin infection.

Māori and Pacific children had higher rates of serious skin infection than children of other ethnicities. This finding is consistent with the wider observation that Māori and Pacific Peoples generally experience high rates of infectious diseases.[58] The reasons for this pattern are complex and multifactorial; they include household crowding and a range of socioeconomic factors.[59,60] It is not known whether the high incidence of serious skin infections directly reflects higher community rates of disease, but it is known that Māori and Pacific families experience greater barriers to accessing primary healthcare including cost, cultural differences and longer travel distances.[61-63] In addition, hospitalisation data has been found to often undercount Māori[64,65] which would result in an underestimation of ethnic inequalities. The significant increase in ethnic disparities between the two time periods is of particular concern. While some of this increase could be due to changes in how census (denominator) data have been collected, leading to a numerator-denominator bias, this factor is unlikely to completely account for the difference.

Socioeconomic deprivation was an important risk factor for serious skin infection with a steady increase in incidence with increasing neighbourhood deprivation. While this association is well established and thought to be mediated by hygiene, nutrition, household crowding, and the ability to afford timely medical treatment,[9,11,25,26] the evidence of increasing inequality has not been previously recognised. As there has been little change to the allocation and recording of deprivation status, these findings suggest truly worsening deprivation disparities.

The association between skin infection incidence and rurality has not been reported previously in NZ. The high incidence of infection in children from urban areas could be due to socioeconomic deprivation, household crowding and a higher frequency of skin contact with other children in more densely populated cities. It is possible that lower infection rates in rural areas could reflect more frequent treatment in the community due to reduced access to hospitals. However, as the management of serious skin infections in children frequently involves hospital-based treatments such as intravenous antibiotics and surgical debridement, it is unlikely that many true serious skin infections would be managed in an outpatient setting.

Within NZ, Tairawhiti DHB had the highest incidence of childhood serious skin infections. This finding could be a result of the large Māori population and high deprivation of the region, but requires greater investigation (see Chapter 4). The observed North-South gradient may in part reflect the distribution of population groups who experience higher disease rates, but could also relate to climatic differences, with Northern districts of NZ experiencing relatively warmer weather compared to those in the South.

Hospitalisation data have strengths and weaknesses as a basis for surveillance of serious skin infections. The main limitation of these data is that, by definition, they only represent the 'tip of the iceberg' and cannot measure the incidence of mild to moderate skin infections in the community. This limitation is common to other areas of infectious disease epidemiology, such as acute gastroenteritis.[66] Examining hospitalisation data only cannot give us insight into whether the increasing incidence of serious skin infections observed is due to an increasing incidence in the community, worsening severity of infections requiring more aggressive management, changes in referral practices over time, or conversely of improvements in the accessibility of primary (and therefore tertiary) healthcare.

The advantages of this data source is that it is accessible and is likely to be relatively sensitive for serious skin infections as few paediatric cases would be treated outside of the public hospital setting due to the invasive treatments required. On this basis, and as by definition serious skin infections are those skin infections which require hospitalisation, the term 'incidence' was used to describe hospitalisation rates.

It is possible that the sensitivity of such surveillance has changed over time, for example, changes to the recording of day patients as admissions. Attempts have been made to minimise such effects by the use of a fairly high threshold for inclusion. A further consideration is modifications to the disease coding system; despite using standardised mapping tables, translating diagnoses between ICD-9 and ICD-10 was problematic in some areas with the incidence of several diagnoses markedly varying over time (see Appendix C). However, as there was a steady increase in the total infection incidence over the years when the ICD revision occurred, the variation is more likely to reflect inter-code and inter-category drift, and further justifies the use of a more inclusive case definition than that used previously. Finally, while age-adjusted rates were calculated for the overall incidence of infections, age stratified rates could not be obtained for all variables so in some cases crude rates are presented. However, at a national population level there is little difference with the WHO standard population which indicates that age-standardisation for individual variables is unlikely to make a significant difference.

This study demonstrates an urgent need for action to prevent serious skin infections in NZ children. It highlights population groups with disparate rates of disease to which these efforts should be particularly focussed. Future work could include extending this simple univariate analysis to a multivariate model to identify the independent effects of each risk factor. A retrospective case note review or a case-control study would better elucidate the aetiological processes contributing to the development of serious skin infections. The epidemiology of skin infections in primary care and the community is largely unknown; future study in this area could improve our understanding of whether the increases and inequalities seen in serious skin infection rates directly reflect community trends of disease, or alternatively reflect changes in primary care treatment or referral practices. In combination with such ongoing work, the findings of this present study indicate some priority areas for directing interventions to reduce the morbidity of serious skin infections in NZ children and to narrow health inequalities.

CHAPTER FOUR

THE EPIDEMIOLOGY OF SERIOUS SKIN INFECTIONS IN NEW ZEALAND CHILDREN; COMPARING THE TAIRAWHITI REGION WITH NATIONAL TRENDS

4.1. ABSTRACT

4.1.1. AIM

Serious skin infections are an increasing problem for New Zealand children with the highest national incidence in the Gisborne (Tairawhiti) Region. This study aimed to describe the epidemiology of serious skin infections in children in this Region, and make comparisons with equivalent national data to identify factors that might be contributing to elevated infection rates.

4.1.2. METHODS

Hospitalisation data were reviewed for 0-14 year old children in the Tairawhiti Region discharged from hospital with a serious skin infection between 1990 and 2007. A range of demographic variables were compared to equivalent data for New Zealand cases over the same period. The ratio of observed to expected discharges was calculated after indirectly standardising the Tairawhiti population age, ethnicity and deprivation composition to that of the total New Zealand population.

4.1.3. RESULTS

In Tairawhiti the age-adjusted incidence of serious skin infections more than doubled from 414.5/100 000 in 1990 to 993.3/100 000 in 2007, while the New Zealand incidence increased from 294.1/100 000 to 562.3/100 000. Preschool-aged children, Māori children, and those living in deprived neighbourhoods had the highest infection rates in all regions. However, the disparity between Māori and non-

Māori children was significantly greater in Tairawhiti than nationally. The standardised ratio of observed to expected discharges in Tairawhiti compared with New Zealand was 1.42(1.32-1.52) in 1990-1999 and 1.28(1.19-1.36) in 2000-2007.

4.1.4. CONCLUSIONS

Serious skin infections are an increasing problem for all New Zealand children, but incidence rates in the Tairawhiti Region are greater and rising more rapidly than average national trends, with significantly larger ethnic disparities. The population composition of this Region only partly accounts for the difference, suggesting the involvement of other unknown aetiological factors; these warrant further research.

4.2. INTRODUCTION

Skin and subcutaneous tissue infections are a heterogeneous group of superficial bacterial infections, most commonly caused by the normal skin commensals, *Staphylococcus aureus* and *Streptococcus pyogenes*.[1] While these infections are usually effectively treated within the primary care setting, several international studies have recognised an increase in the number of cases requiring hospitalisation, termed serious skin infections.[3-5] In New Zealand (NZ) this increase has been particularly marked with incidence rates almost doubling during the last two decades (see Chapter 3), making these infections one of the most common reasons for hospitalisation during childhood.[10]

Within NZ significant inter-regional variation in the incidence of serious skin infections has been noted; these differences are hypothesised to be multi-factorial and in part reflect the distribution of population groups who are known to experience higher disease rates, notably Māori (Indigenous NZ peoples) and Pacific children, children from lower socioeconomic backgrounds, and children less than five years old (see section 3.4 and [9-11,19,20]).

The Tairawhiti (Gisborne) Region and District Health Board (DHB) is a geographically isolated area of 45 000 people on the East Coast of NZ's North Island. The Region is unique for its warm climate, large Māori population (47.3% of the total population and 58.0% of the 0-14 year old population[43]), youthfulness (26.2% of people are aged less than 15 years old[43]), and high level of deprivation (the Region has the largest proportion of highly-deprived residents in the country[44]). In Tairawhiti, skin infections present a major challenge in both primary and secondary level care; between 1990 and 2007 Tairawhiti District Health had the highest incidence of childhood serious skin infections out of all NZ DHBs (see section 3.4.4).

The aims of this study were to describe the incidence and epidemiology of serious skin infections in children in the Tairawhiti Region over the period 1990-2007, to compare these local patterns to equivalent national data, and to determine whether the infection incidence observed in the Tairawhiti Region is greater than that which is expected given the 'high-risk' population composition.

4.3. METHODS

4.3.1. CASE SELECTION AND DATA EXTRACTION

Hospital discharge data were obtained from the NZ Ministry of Health for all children aged 0-14 years, admitted at least overnight to a NZ public hospital between 1 January 1990 and 31 December 2007, with a principal or additional discharge diagnosis from a defined list of serious skin infection International Classification of Disease (ICD) codes (see Appendix D). Cases after July 1999 were identified using ICD-10 diagnostic codes, and cases prior to this date by ICD-9 codes which were forward and backward mapped to ICD-10.

This ICD-based case definition was developed in recent work (see Chapter 2) which found the validity of the previous definition was markedly improved by including categories of skin infection previously overlooked in epidemiological analyses. With the addition of skin infections of atypical anatomical sites, those secondary to either primary skin disease or trauma, and those recorded as additional diagnoses (see Appendix D), the sensitivity of the case definition increased from 61.0% to 98.9% with little loss in specificity.[46]

Each discharge record included a unique patient identifier (encrypted National Health Index number) enabling transfers and readmissions within 30 days with the same principal diagnosis code to be removed. To ensure a better match with the census population overseas visitors were excluded. Day cases were excluded from the case definition due to inconsistencies in the recording of this data between regions and over time.

Patient variables including age, prioritised ethnicity, gender and home domicile code and admission variables such as the season, year, DHB, duration and outcome of admission were recorded and collated. Due to the small numbers of Pacific and other non-Māori ethnic groups in the Tairawhiti Region, prioritised ethnicity used only two categories, Māori and non-Māori, with non-Māori including NZ European, Pacific, Asian and all other non-Māori ethnic groups. Assigning levels of socioeconomic deprivation used the New Zealand Deprivation Index (NZDep) and

was based on the home domicile census area units (CAUs) of cases. The NZDep is based on nine variables extracted from census data;[52] NZDep 1 indicates least deprivation and 10 indicates highest deprivation. In 2.21% of cases domicile codes could not be linked to CAUs due to retired codes and addresses outside of classification. To reduce the impact of these 'missing CAUs', retired domicile codes were linked to new codes using files from the Ministry of Health and Statistics NZ.[53,54]

4.3.2. DATA ANALYSIS

The data were analysed using Microsoft Excel® and SAS®. Denominators in rate calculations were derived from usually resident population counts from the 1991, 1996, 2001, and 2006 censuses. Counts from each census were used to approximate the population in the preceding and subsequent two years. Age adjustment used the World Health Organisation (WHO) standard population. Trends between populations were explored by the calculation of rate ratios (RRs) with 95% confidence intervals (95% CIs) calculated using the log-transformation method.[55] Significant differences in RRs were indicated by a two-tailed p-value <0.05.

4.3.3. INDIRECT STANDARDISATION

The final part of this analysis used indirect standardisation to adjust for variables in the Tairawhiti population that could affect disease rates, and hence establish whether the observed incidence (or crude incidence) of serious skin infections in the Region was in line with the incidence expected after taking into account the high-risk age, ethnicity and deprivation composition of the population.

Typically, direct standardisation is used to validly compare two or more groups that differ in health determinants, however this method requires a large population to ensure age, deprivation and ethnicity-specific rates remain stable. Due to the small numbers in some subgroups in the Tairawhiti population, direct standardisation could not be used.

Age/ethnicity/deprivation-specific rates were calculated using interpolated usually resident population counts by CAU from the 1991, 1996, 2001, and 2006 censuses.

Indirect standardisation was used to standardise each variable, both individually and in combination, across two time periods (1990-1999 and 2000-2007) with NZ in total (including Tairawhiti) used as the standard population. Expected discharge numbers for each age/ethnicity/deprivation group were calculated by multiplying the national rates for that stratum by the usually resident population for that stratum in the Tairawhiti Region. Five cases with unknown deprivation scores were excluded from this analysis.

The ratio of observed to expected (O:E) cases was then calculated. An O:E of '1' denoted the observed number of discharges was the same as the expected number, an O:E less than '1' indicated the observed number was less than the expected number and conversely an O:E greater than '1' indicated the observed number was greater than the expected number. Statistical significance was determined by calculating 95% confidence intervals for these ratios.

4.4. RESULTS

4.4.1. SELECTION OF CASES, INCIDENCE AND IMPACT

In the Tairawhiti Region a total of 1976 hospitalisations met the case definition for serious skin infection. From this, 10 (0.5%) overseas visitors, 50 (2.5%) transfers, 166 (8.4%) day cases, and 39 (2.0%) readmissions were excluded. This left 1711 (86.6%) cases of childhood serious skin infection for further analysis. Of these cases, 1 patient was reported to have been discharged dead from hospital (case fatality of 0.06%). Hospitalisation data recorded a total of 6459 hospital days over the study period. The median and mean lengths of stay were 2 and 3.8 days respectively.

During the same period, there were 64 568 cases of serious skin infection in children in NZ (after exclusions) with a case fatality of 0.04% and a total of 213 141 hospital days. The median and mean lengths of stay were 2 and 3.3 days respectively.

Table 6 shows the incidence of childhood serious skin infections in both the Tairawhiti Region and NZ during 1990-1999 (ICD-9) and 2000-2007 (ICD-10). As recommended by the work in Chapter 2 developing the case definition, these data are disaggregated by category and level of diagnosis.[46] A more detailed version of this table is provided in Appendix D.

Table 6. The incidence of serious skin infections in 0-14 year children in Tairawhiti and NZ disaggregated by category and level of diagnosis, between 1990-1999 (ICD-9) and 2000-2007 (ICD-10)

		Tairawhiti Region				New Zealand			
		1990-1999		2000-2007		1990-1999		2000-2007	
Category	**Level of diagnosis**	**Freq†**	**Rate‡**	**Freq†**	**Rate‡**	**Freq†**	**Rate‡**	**Freq†**	**Rate‡**
Serious skin infections of typical sites (previously used case definition)	Principal	352	284.5	431	453.8	13541	166.3	18177	264.9
	All level	456	368.5	580	610.7	17074	209.7	24086	351.0
Serious skin infections of atypical anatomical sites	Principal	72	58.2	37	39.0	3170	38.9	1866	27.2
	All level	100	80.8	45	47.4	5233	64.3	2270	33.1
Serious skin infections secondary to primary skin disease	Principal	81	65.5	82	86.3	1406	17.3	1909	27.8
	All level	194	156.8	212	223.2	5364	65.9	6170	89.9
Serious skin infections secondary to external trauma	Principal	25	20.2	15	15.8	635	7.8	420	6.1
	All level	48	38.8	76	80.0	1270	15.6	3101	45.2
Crude total serious skin infections	**Principal**	**530**	**428.3**	**565**	**594.9**	**18752**	**230.3**	**22372**	**326.0**
	All level	**798**	**644.9**	**913**	**961.4**	**28941**	**355.4**	**35627**	**519.2**
Age-adjusted total serious skin infections	**All level**		**641.1**		**988.4**		**354.3**		**531.7**

ICD – international classification of disease

†Frequency of cases during time period

‡Average annual incidence per 100 000 (based on usually resident population counts from NZ Census)

4.4.2. INCIDENCE BY YEAR AND SEASON, 1990-2007

Figures 6 and 7 illustrate the incidence of serious skin infections in the Tairawhiti Region and in the whole of NZ over the 18 years studied. Between 1990 and 2007 the age-adjusted incidence of infection more than doubled in the Tairawhiti Region from 414.5/100 000 in 1990 to 993.3/100 000 in 2007 (a 140% increase). Over the same period the national incidence of infection also increased markedly, but not as steeply, from 294.1/100 000 in 1990 to 562.3/100 000 in 2007 (a 91% increase). In both settings this rise was largely caused by increases in the incidence of serious skin infections of typical sites, along with a small contribution from infections secondary to primary skin trauma. Infections secondary to primary skin disease increased less, and those of atypical sites declined over this period.

Table 7 shows the seasonal variation in the incidence of serious skin infections. In NZ, the crude incidence of infections was significantly higher during Summer and Autumn compared to Winter (RR 1.12 for both). This trend was less distinct in Tairawhiti, with no significant difference in the seasonal incidence of infections. There was however, no statistically significant difference in this trend between Tairawhiti and NZ.

Figure 6. The age-adjusted incidence of serious skin infection in 0-14 year old children in the Tairawhiti Region by category and year, 1990-2007

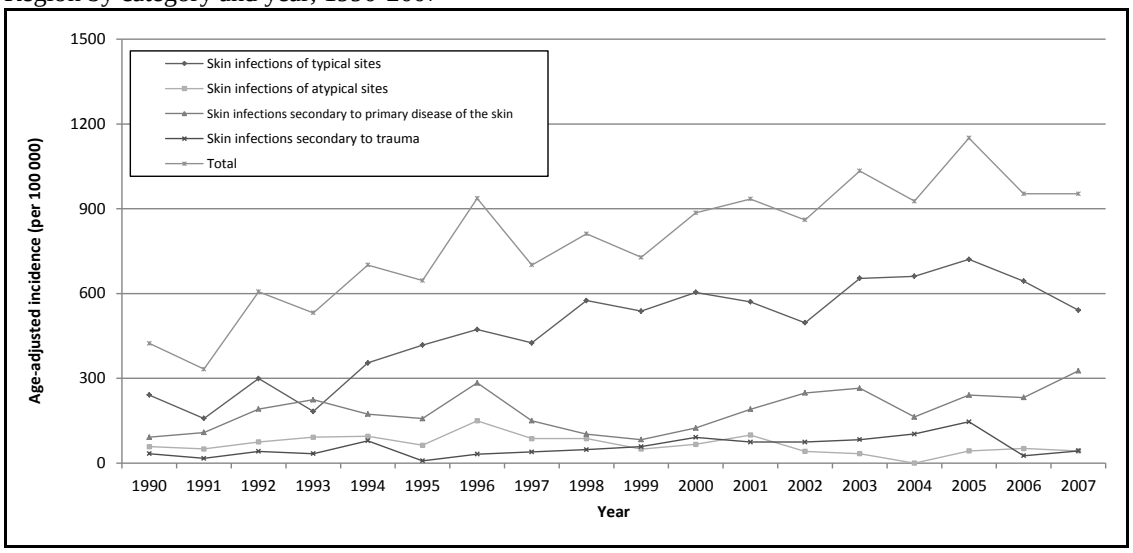


Figure 7. The incidence of serious skin infection in 0-14 year old children in NZ by category and year, 1990-2007

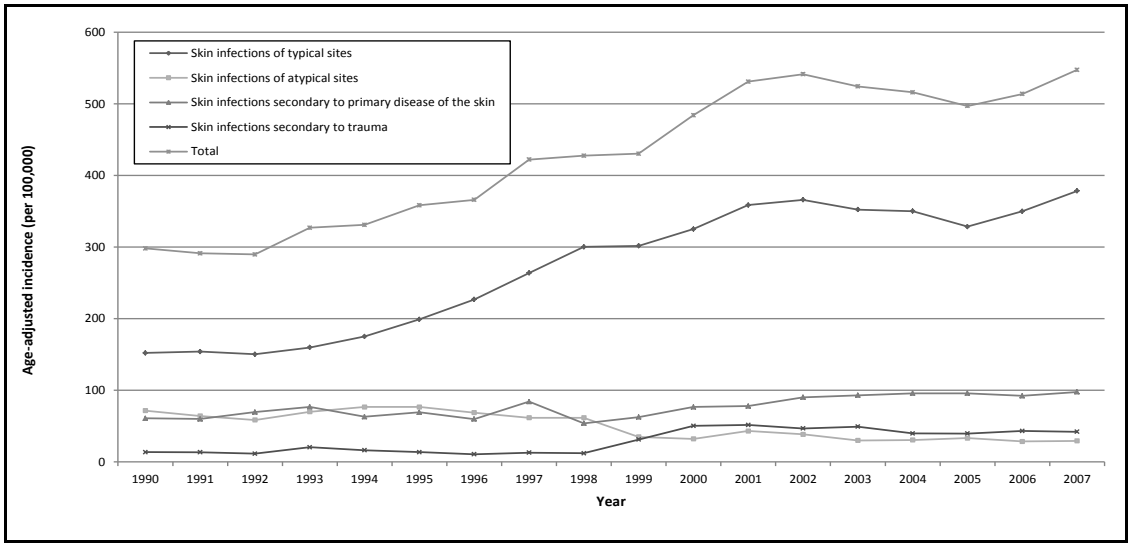


Table 7. Crude incidence of serious skin infections in 0-14 year old children by season, gender, age group, ethnicity and deprivation level for the Tairawhiti Region and NZ, 1990-2007

		Tairawhiti Region			New Zealand			
Variable	**Category**	**Freq**	**Rate**	**RR (95% CI)**	**Freq**	**Rate**	**RR (95% CI)**	**Difference in RRs# *p***
Season†	Autumn	450	823.0	1.01(0.95-1.08)	17176	457.9	1.12(1.11-1.14)	0.42
	Winter	445	813.9	1.00*	15290	407.6	1.00*	
	Spring	391	715.1	0.88(0.82-0.94)	15000	399.9	0.98(0.97-0.99)	0.42
	Summer	425	777.3	0.96(0.90-1.02)	17102	455.9	1.12(1.11-1.13)	0.24
Gender	Male	935	834.1	1.15(1.09-1.20)	37349	485.7	1.31(1.30-1.32)	0.25
	Female	776	727.8	1.00*	27218	372.1	1.00*	
	Unknown				1			
Age	0-4 yr	988	1364.0	2.99(2.81-3.17)	36376	733.3	2.99(2.96-3.02)	1.00
	5-9 yr	394	530.9	1.16(1.08-1.25)	15873	316.0	1.29(1.27-1.30)	0.43
	10-14 yr	329	456.6	1.00*	12319	245.4	1.00*	
Ethnicity	Māori	1312	1068.0	2.56(2.43-2.71)	23736	694.8	1.97(1.96-1.99)	0.048
	Non-Māori	399	416.4	1.00*	40832	352.4	1.00*	
NZDep‡	1-2	18	262.2	1.00*	5313	207.3	1.00*	
	3-4	72	364.9	1.39(1.08-1.79)	7190	270.6	1.31(1.28-1.33)	0.90
	5-6	72	227.3	0.87(0.67-1.11)	9462	336.3	1.62(1.60-1.65)	0.03
	7-8	130	428.5	1.63(1.29-2.08)	14045	451.5	2.18(2.14-2.21)	0.17
	9-10	1414	1200.9	4.58(3.66-5.74)	28102	788.2	3.80(3.75-3.86)	0.21
	Missing§	5						
Total		**1711**			**64568**			

Freq – frequency of cases for the entire period; Rate – average annual crude incidence per 100 000; RR – rate ratio

† Where Autumn is considered March, April, May; Winter is June, July, August; Spring is September, October, November; and Summer as December, January and February.

‡ The New Zealand Deprivation Index (NZDep) is a measure of socioeconomic deprivation based on nine variables extracted from census data.[52] NZDep 1 indicates least deprivation and 10 indicates highest deprivation.

§Missing refers to cases with domicile codes that could not be linked to CAUs

*Arbitrary reference category

Compares the RR of each variable between the Tairawhiti Region and NZ, with $p<0.05$ indicating a statistically significant difference between settings

4.4.3. INCIDENCE BY AGE, GENDER, ETHNICITY, AND DEPRIVATION LEVEL, 1990-2007

Table 7 details the crude incidence of serious skin infections in both the Tairawhiti Region and NZ by a range of patient characteristics.

Boys had a significantly greater risk of suffering a serious skin infection than girls in both settings, with an incidence of 834.1/100 000 in male children compared to 727.8/100 000 in female children in the Tairawhiti Region (RR 1.15) and 485.7/100 000 compared to 372.1/100 000 in NZ (RR 1.31). There was no difference in this trend between settings (p 0.247).

The incidence of skin infections decreased with increasing age. Preschool-aged children were at the greatest risk with just under three times the rate of infections compared with 10-14 year old children in both settings (RR 2.99 in Tairawhiti and NZ). While the Tairawhiti Region had a greater incidence of serious skin infections in all age groups compared with the NZ population, there was no significant difference in the age-distribution between settings.

In the Tairawhiti Region, the incidence of serious skin infections in Māori children was 1068.0/100 000, over double that in non-Māori children - 416.4/100 000 (RR 2.56). In NZ the incidence of infections was not only lower in both groups (Māori 694.8/100 000, non-Māori 352.4/100 000), but the disparity between them was significantly less (RR 1.97, p 0.048).

In both Tairawhiti and NZ the incidence of serious skin infections was lowest in areas of least deprivation and increased with rising deprivation levels. The ratio of deprivation appeared greater in the Tairawhiti Region, where the incidence of serious skin infection in the most deprived children was over four times higher than the incidence in least deprived children (RR 4.58 in Tairawhiti compared with RR 3.80 in NZ), however this difference did not reach statistical significance.

4.4.4. INDIRECT STANDARDISATION

The results of the indirect standardisation analysis are presented in table 8. From 1990 to 1999 there were 793 children living in the Tairawhiti Region discharged

from hospital with a diagnosis of a serious skin infection, double the crude expected number of 398.2 discharges (O:E 1.99, 95%CI 1.86-2.14). Between 2000 and 2007 there were 913 observed discharges, also double the crude expected number of 453.8 discharges (O:E 2.01, 95%CI 1.88-2.15).

Age-standardisation produced little change in the expected number of discharges in either 1990-1999 (O:E 1.98, 95%CI 1.85-2.13) or 2000-2007 (O:E 2.02, 95%CI 1.89-2.16). Adjusting for the ethnic composition of the Region produced more of an effect, reducing the number of observed discharges to 65% more than expected in 1990-1999 (O:E 1.65, 95%1.53-1.76) and 60% more in 2000-2007 (O:E 1.60, 95%CI 1.49-1.70). Deprivation-standardisation reduced the difference even further, although there were still 45% more observed than expected discharges in 1990-1999 (O:E 1.45, 95%CI 1.35-1.56) and 35% more in 2000-2007 (O:E 1.35, 95%CI 1.26-1.44).

After standardising the Tairawhiti population composition to that of the NZ population by age, ethnicity and deprivation in combination, the observed number of discharges was still 42% higher than the expected number of 559.9 cases in 1990-1999 (O:E 1.42, 95%CI 1.32-1.52) and nearly a third higher than the expected 715.8 cases in 2000-2007 (O:E 1.28, 95%CI 1.19-1.36).

Table 8. The ratio of observed to expected childhood serious skin infection discharges in the Tairawhiti Region after indirectly standardising age, deprivation and ethnicity to the NZ population, 1990-1999 and 2000-2007

Period	Variable(s) standardised	Expected number of discharges	Observed number of discharges	Ratio observed to expected discharges (O:E)	95% CI
1990-1999	None (crude)	398.2	793	1.99	1.86 - 2.14
	Age	399.8	793	1.98	1.85 - 2.13
	Ethnicity	481.7	793	1.65	1.53 - 1.76
	Deprivation	545.6	793	1.45	1.35 - 1.56
	Age, ethnicity	478.2	793	1.66	1.54 - 1.78
	Age, deprivation	540.7	793	1.47	1.37 - 1.57
	Ethnicity, deprivation	567.4	793	1.40	1.30 - 1.50
	Age, ethnicity, deprivation	559.9	793	1.42	1.32 - 1.52
2000-2007	None (crude)	453.8	913	2.01	1.88 - 2.15
	Age	451.4	913	2.02	1.89 - 2.16
	Ethnicity	571.8	913	1.60	1.49 - 1.70
	Deprivation	676.9	913	1.35	1.26 - 1.44
	Age, ethnicity	559.6	913	1.63	1.53 - 1.74
	Age, deprivation	665.0	913	1.37	1.29 - 1.46
	Ethnicity, deprivation	730.2	913	1.25	1.17 - 1.33
	Age, ethnicity, deprivation	715.8	913	1.28	1.19 - 1.36

4.5. DISCUSSION

This is the first study to describe the epidemiology of serious skin infections in children in the Tairawhiti Region, an area of NZ with the highest national incidence of these infections. Findings showed that while serious skin infections are a important and increasing problem for all NZ children, the incidence in Tairawhiti is not only considerably higher but is also rising more rapidly than national trends. Over the last 18 years, observed infection rates have been significantly greater than that expected despite taking into account the higher risk population composition of this Region. In addition, already large ethnic disparities in national infection rates are considerably wider in the Tairawhiti Region.

The disparity between infection rates in Māori and non-Māori children in Tairawhiti was significantly greater than that observed nationally. In a region that is already suffering the highest national incidence of infection, and is home to one of the largest Māori populations in NZ, this is of particular and significant concern. Māori generally experience higher rates of infectious diseases than non-Māori.[58] The reasons for this disparity are complex and multifactorial; they include household overcrowding, barriers to accessing primary healthcare and a range of socioeconomic factors.[58-61,63] Pacific Peoples form an important and unique proportion of the NZ population that are known to suffer particularly high rates of skin infection.[19] Due to the small number of Pacific Peoples in the Tairawhiti Region a separate analysis of this ethnic group (and likewise other ethnic groups) was not able to be undertaken. It is worth noting that by not analysing Pacific Peoples separately, the disparity between infection rates in Māori and non-Māori children is likely to be underestimated.

Socioeconomic deprivation was an important risk factor for infection, with children from highly deprived neighbourhoods in the Tairawhiti Region more than four times as likely to suffer a serious skin infection as their least deprived counterparts. Similar disparities were observed in the national population. This association has been described previously [9,11,25,26,28,57] and elsewhere in this thesis (see section 3.5) with mediating factors thought to include hygiene, nutrition, household crowding, and the ability to access timely medical care.

In both Tairawhiti and NZ populations, boys and preschool-aged children were found to be at a greater risk of infection than girls and children over the age of five. This finding could reflect an increased frequency of minor skin trauma in these groups or delays in seeking medical care. While it is unlikely that gender affects hospitalisation practices, it is possible that age trends are in part due to a lower threshold for hospital admission in younger children.

Interestingly, the usual seasonal trends in skin infection rates were not observed in the Tairawhiti Region. Previous analyses have found the greatest incidence during the late Summer and early Autumn months,[3,10,11,20,26,28,31,56] (and see section 3.4.2 of this thesis) thought to be due to warmer air temperatures leading to more frequent insect bites, deficiencies in hygienic precautions, and the wearing of loose clothing exposing skin to skin contact and minor trauma.[4,29,30] It is possible that the year-round warmer temperatures in the Tairawhiti Region results in less seasonal fluctuation.

In Chapter 3 it was suggested that Tairawhiti DHB's elevated incidence of childhood serious skin infections could be solely due to the 'high-risk' population structure. This hypothesis was investigated by using indirect standardisation to control for the age, ethnicity and deprivation composition of the Region. Adjusting for these population variables did reduce the difference between the number of skin infections observed and expected, with deprivation and ethnicity standardisation producing the largest reductions. However, even after taking all three factors into account, the observed rate of infections was still significantly greater than the expected rate, by 42% in 1990-1999 and 28% in 2000-2007. This persisting difference suggests that other unaccounted for or unknown factors are contributing to the high disease burden in the Tairawhiti Region. A proportion of the local population lacks reticulated water and relies on rainwater tanks; this often results in suboptimal hygiene practices with local rivers providing a commonly used source of water for bathing during dry Summer months. The effect of water supply and other local environmental factors warrants further investigation. Similarly it is important to investigate access to health services and the potential role that the local normalisation and acceptance of skin infections may play in delays in seeking medical care. It is also possible that the risk of skin infection has a non-linear

relationship with the size of the vulnerable population in a region. This outcome could be observed if there are high rates of carriage of the organisms causing skin infections in these same vulnerable population groups. Finally, it is possible that some of the difference between observed and expected infection incidence could be due to misclassification of risk categories, such as deprivation and ethnicity. The influence that this may have had on the results is unknown.

Indirect standardisation is limited in that it cannot be used to compare a population over time, hence the changes in the ratios between 1990-1999 and 2000-2007 could not be analysed. Likewise it cannot be used to compare different populations, such as other DHBs. Direct standardisation would enable these comparisons, but due to small numbers in some age-ethnic-deprivation groups, this analysis was not viable.

Hospitalisation data have strengths and weaknesses as a basis for the surveillance of serious skin infections. The main limitation of these data is that, by definition, they only represent the 'tip of the iceberg' and cannot on their own provide a measure of the total incidence of skin infection in the community. This is a limitation that is common to other areas of infectious disease epidemiology where the clinical condition is on a continuous disease spectrum and any case definition will be somewhat arbitrary.[66] The strengths of this data source are that it is accessible and likely to be relatively sensitive as, by definition, serious skin infections are those skin infections which require overnight hospitalisation for treatment. On this basis the term 'incidence' was used to describe hospitalisation rates. It is possible that the sensitivity of such surveillance has changed over time, such as the increased recording of day patients as admissions, however the use of a high threshold for inclusion (notably the requirement for a minimal one night admission) should minimise this effect. Modifications to the ICD coding system may have contributed to changes in surveillance over time; despite using standardised mapping tables the frequency of some diagnoses varied markedly between the two periods studied (see Appendix D). However, as there was a steady increase in the total infection incidence over the years when the ICD revision occurred, the variation is likely to reflect inter-code and inter-category drift and gives further justification to the use of a more inclusive case definition than that used previously. Finally, while age-adjusted rates were calculated for the overall incidence of infections, age stratified rates could not

be obtained for all variables so crude rates are presented. However, both national and regional populations do not significantly differ with the WHO standard population, which indicates that age-standardisation for individual variables is unlikely to make a significant difference.

This study highlights a need for action to prevent serious skin infections in the children of both the Tairawhiti Region and throughout NZ. Ongoing work is required to better understand the cause of these infections and the measures which will most effectively reduce their incidence. Further elucidation of the aetiological processes contributing to the development of serious skin infections in the Tairawhiti Region could take the form of a retrospective case note review, a prospective case series, or a case-control study, and would assist in determining areas to most effectively direct local interventions. The epidemiology of skin infections in primary care and the wider population is largely unknown; future study in this area could improve our understanding of whether inequalities in serious skin infection rates are a direct reflection of similar trends in the community. In combination with the findings of this study, ongoing work could aid in the reduction of serious skin infection morbidity and the narrowing of health inequalities for children in both the Tairawhiti Region and wider NZ.

CHAPTER FIVE

SERIOUS SKIN INFECTIONS IN CHILDREN; A REVIEW OF ADMISSIONS TO GISBORNE HOSPITAL 2006-2007

5.1. ABSTRACT

5.1.1. AIM

Serious skin infections are an important and increasing problem in New Zealand children. The highest national rates are in the Tairawhiti (Gisborne) Region, where evidence of significant ethnic disparities exists. This study aimed to describe the characteristics of serious skin infections in children hospitalised in the Tairawhiti Region.

5.1.2. METHODS

The hospital charts of all children aged 0-14 years admitted to Gisborne Hospital between 1 January 2006 and 31 December 2007 for a serious skin infection were retrospectively reviewed and data on a range of variables analysed.

5.1.3. RESULTS

There were 163 cases of serious skin infection during the study period with 83% occurring in Māori children. The most common types of infection were cellulitis (38%) and subcutaneous abscesses (36%), and the most frequent sites of infection were the head, face and neck (32%) and lower limbs (32%). A previous episode of skin infection was recorded in 34% of children, with prior hospitalisation in 12%. A skin injury preceded infection in 37% of cases, more than reported in the Auckland and Wellington Regions. Of the 77% of children who saw a GP 60% required

immediate hospital admission. Compared with figures from the Auckland Region, there were longer delays to medical care with a mean duration of symptoms of 2.45 days prior to visiting a GP. The most frequently isolated organisms were *Staphylococcus aureus* (48%) and *Streptococcus pyogenes* (20%) with similar proportions and resistance patterns to other New Zealand settings.

5.1.4. CONCLUSIONS

The characteristics of serious skin infections in the Tairawhiti Region are largely similar to those reported in other New Zealand regions. However, some differences exist in preceding skin injuries and delays in seeking medical care which may contribute to the high incidence of hospitalised infections in the Region. These differences, along with ethnic variations in pre-hospital care, require further investigation.

5.2. INTRODUCTION

Skin and subcutaneous tissue infections are a heterogeneous group of infections, predominantly caused by *Staphylococcus aureus (S aureus)* and *Streptococcus pyogenes (S pyogenes)*,[1] which are common childhood complaints in primary care where they are usually adequately treated. However in an increasing number of cases worldwide, failed or delayed outpatient therapy is leading to more severe disease, requiring costly hospitalisations for often invasive treatment.[3-5]

In New Zealand (NZ), the incidence of serious skin infections in children has almost doubled over the last two decades. This increasing disease burden results in important health, social and economic consequences (in 2007 the estimated direct hospitalisation costs alone of these infections was NZ$15 million). These infections also contribute to ethnic and deprivation-related health inequalities with evidence of worsening disparities over time (see Chapter 3).

In NZ, serious skin infection rates are known to be highest in Māori (NZ indigenous peoples) and Pacific Island children, children younger than 5 years old, boys, children living in deprived neighbourhoods and urban areas, and in Northern districts of the country (see Chapter 3). Risk factors for infection have been reported in a number of international studies as overcrowding, close skin to skin contact, undernourishment, low socioeconomic status, poor hygiene, shared bathing, sharing of soap, minor skin trauma, eczema, chickenpox, insect bites, scabies, recent seawater contact, and warm humid climates.[25-39] While there are a number of recent national and regional reports,[9-11,19,20] there are no studies published in the peer reviewed literature that examine these risk factors in the NZ setting.

Gisborne (Tairawhiti) is a region of NZ where skin infections present a major challenge to the health system. Chapters 3 and 4 showed the incidence of serious skin infections in children in this area is the highest out of all NZ regions, with the rate increasing more rapidly than average national trends, and evidence of significantly greater ethnic disparities. During the period 1990-2007 the incidence of these infections observed in the Tairawhiti Region was significantly greater than that expected, even after standardising for the high-risk age, ethnicity and

deprivation population composition. This study follows on from that work and aimed to further describe the characteristics of serious skin infections in children of the Tairawhiti Region to identify any features that might explain the high burden of disease.

5.3. METHODS

A retrospective review was undertaken of clinical notes from all children aged 0-14 years admitted overnight to Gisborne Hospital between 1 January 2006 and 31 December 2007 with a principal diagnosis of serious skin infection.

The Tairawhiti Region is a relatively isolated area of 45 000 people on the East Coast of NZ's North Island. The Region experiences a warm year-round climate and is unique for its large Māori population (47.3% of the total population[43]), youthfulness (26.2% of people are aged less than 15 years old[43]), and high level of deprivation (the Region has the largest proportion of highly-deprived residents in the country[44]). Gisborne Hospital is a 120-bed secondary referral centre which provides inpatient and outpatient health services for the Region.

Cases of serious skin infection were identified using a defined list of skin infection International Classification of Disease Tenth Revision (ICD-10) codes; this definition is described in Chapter 2 and the ICD-10 codes are listed in Appendix A.[46] Transfers, overseas visitors, day cases and readmissions within 30 days with the same diagnosis were excluded.

The clinical notes of all selected patients were reviewed. Information on patient demographics, prioritised ethnicity, social and environmental characteristics, past medical history, clinical findings, precipitating events, progress and outpatient management of the current infection, investigations, inpatient management and outcome were recorded on a standardised data collection form. Levels of socioeconomic deprivation were assigned based on the patient's home address using the New Zealand Deprivation Index (NZDep); a neighbourhood index based on nine variables extracted from census data where NZDep 1 indicates least deprivation and 10 indicates highest deprivation.[52] Information was primarily collected from the records of the relevant admission, but previous admission notes, general practitioner referral letters and computerised investigation results were reviewed if relevant.

Raw data were entered into Microsoft Excel® and analysed in EpiInfo™ (version 3.4.3, Centers for Disease Control and Prevention). Confidence intervals for proportions were calculated using the Wald method.

Regional Ethics Committee approval was sought and granted for this study.

5.4. RESULTS

There were 161 children with 163 discrete cases of serious skin infection admitted to Gisborne Hospital between 1 January 2006 and 31 December 2007. These 163 cases accounted for 2.8% of the 5876 serious skin infection paediatric admissions to all NZ hospitals during the study period. Appendix E provides a detailed breakdown of patient characteristics and Appendix F summarises inpatient investigations, management and outcome of cases.

5.4.1. DEMOGRAPHICS AND ENVIRONMENTAL CHARACTERISTICS

The mean age of patients was 4.64 years with over half of children in the preschool age group. Males accounted for 54% of cases. Eighty-three percent (n=135) of children were Māori, 14% (n=23) were NZ European/Pakeha, 2% (n=4) Pacific, and the remaining 1% (n=1) other ethnicities. Almost half the cases came from households with residents who smoke, solely outside in 36% of cases and both inside and outside in 13% of cases. The mean number of usual household residents was 5.44 people (range 2-11). Forty-one percent of children measured greater or equal to the 90th weight percentile, with mean weight in the 67th percentile.

5.4.2. PAST MEDICAL HISTORY

Fifty-six children (34%) had a recorded history of at least one previous skin infection, with a further 47 (29%) having no documentation of this in their notes. In 20 of the 56 children (12% of total) the previous skin infection was serious, requiring hospitalisation. Ten patients (6%) had a potentially significant pre-existing or concurrent medical condition recorded; these included prematurity (4), impaired glucose tolerance (1), behavioural disorders (1), iron deficiency anaemia (2), Downs' Syndrome (1), and juvenile arthritis requiring systemic immunosuppressants (1).

5.4.3. CLINICAL PRESENTATION

The two most common subtypes of infection were cellulitis and subcutaneous abscesses accounting for 38% and 36% of cases respectively. A superficial bacterial

infection of a pre-existing skin condition such as eczema, scabies or chickenpox was present in 14% of cases, impetigo in 5%, acute lymphadenitis in 4%, and other specified types of skin infection in the remaining 3% of cases. The head, face and neck and the lower limbs were the most frequently involved sites (32% of cases each), followed by the trunk, groin and buttocks (18%), and upper limbs (11%). Multiple site involvement occurred in 7% of children.

5.4.4. PREDISPOSING CONDITIONS AND PRE-HOSPITAL MANAGEMENT

Just over one third (37%) of children had a recorded history of trauma to the skin in the two weeks prior to the development of the infection. These injuries ranged in type and severity; table 9 details the individual causes of injury and compares the frequency of these to that documented in previous reports on the Wellington and Auckland Regions.[10,11] The Tairawhiti Region had the highest percentage of cases with a preceding injury identified. There was some variation in the distribution of individual causes of injury between the regions; Tairawhiti had the greatest proportion of insect bite/sting related trauma, sports injuries and cuts by a sharp object.

Table 9. Identified causes of injury in children with a trauma-related serious skin infection in the Tairawhiti, Wellington and Auckland Regions

Cause	**Tairawhiti (%) 2006-2007 (n=163)**	**Wellington (%) 1996-2003**[11] **(n=1199)**	**Auckland (%) 1994-1998**[10] **(n=2055)**
Insect bite/sting	37.7	20.8	30.0
Accidental fall	9.8	15.1	15.0
Cut by sharp object	24.6	11.3	22.0
Animal related injury	3.3	8.8	1.0
Struck by person or object	4.9	8.2	12.0
Motor vehicle/cycle or pedestrian accident	0.0	6.9	6.0
Sports injury	4.9	3.8	2.0
Complication of surgical procedure	1.6	2.5	2.0
Vaccination related or iatrogenic	0.0	2.5	2.0
Other or unspecified	13.1	20.1	8.0
Total % of cases with preceding injury/trauma identified	**37.0**	**13.3**	**29.0**

Forty-two percent of children had a recorded history of a chronic or sub-acute skin pathology preceding the development of infection. These conditions included eczema (16%), school sores (10%), scabies (6%), varicella (4%) and other conditions (6%).

Over three-quarters (77%) of children consulted their general practitioner prior to eventual hospital admission with the median duration of skin infection symptoms prior to this consultation found to be 2 days (mean 2.45 days, range <24 hours to >7 days). Forty percent of children who visited their GP had a course of outpatient antibiotics trialed prior to hospitalisation, the remaining 60% were referred for admission immediately. The median duration of skin infection symptoms prior to hospital admission was 2 days (mean 3.96 days) and ranged from less than 24 hours to longer than a week.

Table 10 details the different variables leading up to infection in both Māori and non-Māori children. While the number of non-Māori children was too small to enable the calculation of statistically valid comparisons, the absolute percentages of each variable are not widely divergent. The largest absolute differences are seen in the number of children with a previous serious skin infection; 13% of Māori children and 7% of non-Māori children, and the proportion of cases where antibiotics were started by the GP; 42% of Māori cases and 60% of non-Māori cases. Little absolute ethnic difference is found in the history of a previous skin infection or skin pathology, the frequency of consulting a GP and the duration of symptoms prior to seeking medical attention.

Table 10. Predisposing conditions and pre-hospital management of serious skin infections in 0-14 year old Māori and non-Māori children in the Tairawhiti Region, 2006-2007

Variable	Total(%)	Māori (n=135)		Non-Māori (n=28)	
		f	% (95% CI)	*f*	% (95%CI)
Previous skin infection					
- Yes	56 (34)	47	35(27.3-43.2)	9	32(17.8-50.8)
- No	60 (37)	49	36(28.7-44.7)	11	39(23.5-57.6)
- Not recorded	47 (29)	39	29	8	29
Previous serious skin infection					
- Yes	20 (12)	18	13(8.5-20.2)	2	7(0.9-23.7)
- No	139 (85)	113	84(76.5-89.1)	26	93(76.3-99.1)
- Not recorded	4 (3)	4	3		0
Skin injury/trauma					
- Yes	61 (37)	53	39(31.4-47.7)	8	29(15.1-47.2)
- No	94 (58)	75	56(47.1-63.7)	19	68(49.2-82.2)
- Not recorded	8 (5)	7	5	1	4
Skin pathology†					
- Yes	68 (42)	58	43(34.9-51.4)	10	36(20.6-54.3)
- No	91 (56)	73	54(45.7-62.2)	18	64(45.8-79.3)
- Not recorded	4 (2)	4	3	0	0
Duration prior to admission					
- <24 hours	24 (15)	20	15(9.7-21.9)	4	14(5.1-32.1)
- 1 day	23 (14)	19	14(9.1-21.0)	4	14(5.1-32.1)
- 2 days	28 (17)	26	19(13.4-26.8)	2	7(0.9-23.7)
- 3 days	25 (15)	20	15(9.7-21.9)	5	18(7.4-36.1))
- 4 days	12 (7)	11	8(4.5-14.1)	1	4(<0.01-19.2)
- 5 days	5 (3)	5	4(1.4-8.6)	0	0
- 6 days	4 (3)	4	3(0.9-7.6)	0	0
- ≥7 days	25 (15)	17	12(7.9-19.3)	8	29(15.1-47.2)
- Not recorded	17 (11)	13	10	4	14(5.1-32.1)
Mean/median (days)	*3.96/2*		*3.81/2*		*4.71/3*
Consulted general practitioner					
- Yes	126 (77)	106	79(70.8-84.7)	20	71(52.8-84.9)
- No	37 (23)	29	21(15.4-29.2)	8	29(15.1-47.2)
Duration prior to consulting GP					
- <24 hours	23 (14)	20	15(9.7-21.9)	3	11(2.9-28.0)
- 1 day	25 (15)	22	16(11.0-23.5)	3	11(2.9-28.0)
- 2 days	23 (14)	19	14(9.1-21.0)	4	14(5.1-32.1)
- 3 days	17 (10)	14	10(6.2-16.8)	3	11(2.9-28.0)
- 4 days	9 (6)	8	6(2.9-11.4)	1	3(<0.01-19.2)
- 5 days	3 (2)	2	2(<0.1-5.6)	1	3(<0.01-19.2)
- 6 days	2 (1)	2	2(<0.1-5.6)	0	0
- ≥7 days	8 (5)	8	6(2.9-11.4)	0	0
- Not recorded	16 (10)	11	8(4.5-14.1)	5	18(7.4-36.1)
Not applicable	37 (23)	29	21	8	29(15.1-47.2)
Mean/median (days)	*2.45/2*		*2.51/2*		*2.03/2*
Antibiotics started by GP					
- Yes	50 (40)	45	42(33.5-52.0)	12	60(38.6-78.2)
- No	76 (60)	61	58(48.0-66.5)	8	40(21.8-61.4)
Not applicable	37	29		8	
TOTAL	**163 (100)**	**135**	**100**	**28**	**100**

f Frequency of variable †Skin pathologies include eczema, dermatitis, chicken pox, scabies, school sores, or any other chronic or sub-acute skin condition that could predispose to infection

5.4.5. INVESTIGATIONS

Ninety-nine children (61%) had blood drawn for laboratory analysis; of these two-thirds (66/99) had a white cell count above the reference range (4.0-13.4 x 10^9/L), 36% (36/99) had a c-reactive protein greater than 5mg/L, and 29% (29/99) had an elevated platelet count (above the reference range 150-400 x 10^9/L). Eighty-one children (50%) had blood cultures taken with significant growth in 2 patients; both were methicillin-sensitive *S aureus* (MSSA). Just over half of patients (52%) had a microbiological swab taken with growth in 88% of cases; the most common organisms isolated were *S aureus* (40/84), *S pyogenes* in (17/84) cases and a combination of both (9/84). There were no cases of methicillin-resistant *S aureus* (MRSA) isolated during the study period. Ultrasonography of subcutaneous tissues was used in 3% of all cases (5/163) and computer tomography assisted diagnosis in one case.

5.4.6. TREATMENT

Ninety-six percent of patients received antibiotics during their admission, with just over two thirds (70%) of these being administered intravenously (IV), 29% orally and 1% intramuscularly. Flucloxacillin was the most common IV antibiotic prescribed, being given to 56% of patients overall and 84% of those receiving IV antibiotics. Augmentin was prescribed in 11% of cases and was most frequently used for infections involving the face, head and neck and those related to an animal or human bite. Macrolide antibiotics and cephalosporins were prescribed in the remaining 2% and 3% of IV cases respectively. The median length of IV antibiotic administration was 2 days (mean 2.45 days, range 0.5-10 days). Surgical management, such as incision and drainage or debridement, was required in 31% of all cases. A large proportion of these surgical procedures were performed under general anaesthetic.

5.4.7. LENGTH OF STAY, COMPLICATIONS AND OUTCOME

The median length of stay was 3 days (mean 3.9). While this ranged from 1-14 days, just under two thirds (65%) of cases were admitted for three days or less. Most

admissions were medically uneventful, but 6 children (4%) experienced a potentially serious complication; these included new abscess formation (3), osteomyelitis (1), febrile convulsion (1), and sepsis/septic shock (2). Four children required transfer to a specialist paediatric referral centre; in all cases this was due to young age and the requirement for a surgical procedure. There were no deaths during the study period.

5.5. DISCUSSION

Serious skin infections are a diverse group of conditions, with cellulitis and subcutaneous abscesses the most common subtypes in this series. These infections occurred in mainly healthy children from a range of backgrounds, but in keeping with the findings of previous reports,[9-11,19,20] Māori children, boys and children in the preschool age group were overrepresented (see section 3.4).

Ethnic disparities in disease rates in NZ children are not unique to skin infection; similar patterns are noted in many infectious diseases[58,60] and are thought due to household crowding, barriers to accessing healthcare and a range of socioeconomic factors.[59-61,63,67]

Compared to data from unpublished studies in Wellington and Auckland,[10,11] a greater proportion of serious skin infections were preceded by an identified skin injury in this series. This difference could be related to the warmer climate of the Tairawhiti Region. Increased environmental air temperature has been linked to higher frequencies of insect bites and subsequent rises in impetigo incidence.[30] In addition, increased skin exposure due to individual, socioeconomic and climatic factors may increase the rate of both insect bites and other minor skin injuries. While differences in the size, time period and methodology of this study and that used in the Wellington and Auckland studies must be taken into account, the high burden of disease in Tairawhiti could in part be explained by the hypothesis that more frequent minor skin injuries in local children in general lead to a higher incidence of skin infection overall.

Reliable comparative data for the proportion of serious skin infections preceded by sub-acute or chronic skin pathology in other settings could not be found, but with the identification of such a condition in 42% of cases in this series, pre-existing skin conditions seem to be an important risk factor for infection. Eczema was particularly recognised as a frequent precipitant to infection and NZ has one of the highest reported rates of childhood eczema in the world;[68,69] multiple macroscopic and microscopic breaches in the skin surface, itching leading to further skin damage and

the introduction of sub-ungal microorganisms, and increased bacterial colonisation of chronically damaged skin can all predispose to infection.[70,71]

The lower limbs and the head, face and neck were the most commonly affected sites in this study. Other authors have reported a predominance of lower limb infections and have reasoned this is likely to be a result of frequent minor trauma to the legs;[10,18,28,29] this hypothesis is of particular relevance given the climate of the Tairawhiti Region as described above. The equally high incidence of infections of the head, face and neck has not been observed in other settings, and may be due to regional differences in the mechanisms of skin barrier disruption, with higher rates of infection secondary to insect bites in Tairawhiti.

The number of children suffering a recurrence of skin infection is concerning, especially those 12% who had previously been hospitalised at least once for a serious skin infection. It suggests that opportunities to reduce modifiable risks, such as delays to medical care, are being missed at the time of initial infection and that secondary prevention efforts by health providers need further improvement and resourcing. Comparative data from other settings were not available.

The 77% of children who saw their GP prior to hospital admission is considerably less than the 93% reported in a currently unpublished Starship Hospital cellulitis case series,[22] and may reflect difficulties in accessing primary care for functional, geographic, socioeconomic and cultural reasons. The mean duration of symptoms prior to consulting a GP was also significantly longer in this series compared to the Starship study[22] (2.45 days compared to 1.5 days respectively). This delay is likely due to the typical barriers described above, but may also be contributed to by the normalisation of skin infections in the Tairawhiti Region; a widely discussed local hypothesis, likely due to the persistently high incidence of disease. Whatever the cause of late presentation to primary care, the impact is evidenced by the difference in the proportion of children referred immediately for hospital admission; 60% in this series compared to 40% in the Starship study.

The ethnic distribution of predisposing conditions and pre-hospital management is interesting, with small absolute differences observed in a number of areas. However

this study does not have enough power to detect statistically significant differences between the two groups due to the small number of non-Māori children in the series and resulting wide confidence intervals. A similar study with a larger non-Māori sample size is needed to provide sufficient statistical power to investigate these differences.

The diagnosis of skin infection was primarily based on clinical signs and symptoms, with infrequent need for any investigations beyond basic haematology, biochemisty and microbiological testing. It is unclear whether even these tests were necessary for diagnostic purposes in the majority of cases; the Starship Hospital Cellulitis Clinical Guideline states investigations are not indicated in most children with cellulitis/subcutaneous abscess as they are of little diagnostic value.[72]

The types and proportions of causative organisms isolated were in keeping with those reported in previous NZ reviews,[19] suggesting no difference in local microbiological patterns that might explain higher rates of disease. In addition, during 2006 the incidence of antibiotic resistance was lower in Gisborne Hospital *S aureus* isolates than comparative isolates nationally.[14,73]

Treatment was primarily antibiotic-based with the majority administered intravenously; the 30% of children who did not receive IV treatment yet still required hospitalisation were either those where a surgical procedure was the primary treatment or where intensive topical skin cares were required in addition to oral antibiotic therapy, such as in cases of superficially infected eczema. The 4% who did not receive antibiotics were short admissions for drainage of a small abscess with oral antibiotics commenced on discharge.

Besides the small non-Māori sample size discussed above, this study had several other limitations. The study relied on retrospectively reviewing information recorded in standard hospital notes; in some cases these data were unavailable or unclear, resulting in high rates of 'not recorded' for some variables and the inability to investigate others. Comparisons between the Tairawhiti Region and other NZ settings largely relied on data in unpublished regional reports; differences in

infection characteristics could be due to variations in study methodologies in addition to true differences.

This study has described factors contributing to the development of serious skin infections in the children of the Tairawhiti Region. It has highlighted areas where variation in infection characteristics may account for some of the inter-regional differences in observed incidence rates. A case-control study should be considered to further explore these risk factors and quantify their importance with a specific examination on differences between Māori and non-Māori children. Robust information on these risk factors is critical to the design of evidence based interventions to reduce the high rate of serious skin infections and the large and widening ethnic disparities for children of the Tairawhiti Region.

CHAPTER SIX

SKIN INFECTIONS IN CHILDREN IN A NEW ZEALAND PRIMARY CARE SETTING; EXPLORING BENEATH THE TIP OF THE ICEBERG

6.1. ABSTRACT

6.1.1. AIM

It has been hypothesised that the incidence of children with skin infections presenting to primary care is very high compared with that seen in hospitals, and that the demographic characteristics of patients are similar in both settings. However there are no published New Zealand studies examining skin infections in the primary care setting. This study aimed to describe the epidemiology of childhood skin infections presenting to primary care in a region of New Zealand with a particularly high burden of infection and compare this to hospitalised cases during the same period.

6.1.2. METHODS

A sample of general practitioners in the Tairawhiti (Gisborne) Region recorded all cases of skin infection in 0-14 year old children diagnosed over a 10-week period. Observed case rates were directly standardised by age and ethnicity to the Tairawhiti population to give estimated rates for the whole Region. Demographic data from primary care cases were compared to similar data from hospitalised cases during the same period.

6.1.3. RESULTS

There were 110 incident cases of skin infection seen by the nine participating general practitioners during the study period, equivalent to an annual incidence rate of 106.7 (95% CI 85.2-127.2) cases per 1000 children in the region. For every one hospitalisation there were an estimated 14 primary care cases. Three quarters of skin infections in both primary care and hospital settings occurred in Māori children. There was no gender predominance in either setting, however hospitalised cases of serious skin infection were more likely to occur in the preschool age group whereas children aged 5-9 years predominated at the primary care level.

6.1.4. CONCLUSION

Skin infections are a common childhood complaint in primary care in the Tairawhiti Region, with hospital-based surveillance using coded discharge data only capturing a small proportion of the overall community disease burden. Previously observed ethnic disparities in hospitalisation rates for serious skin infections reflect similar disparities in skin infection rates in primary care. The establishment of a sentinel surveillance system in the New Zealand primary care setting would facilitate further research and monitoring of this and other important conditions.

6.2. INTRODUCTION

Skin infections are a common complaint in primary care and are usually adequately treated within that setting. While often considered benign, these infections are becoming an increasingly significant source of childhood morbidity in both international settings[3-5] and in New Zealand (NZ).[6,7,9]

In NZ, the rate of skin infections requiring hospitalisation, termed serious skin infections, has almost doubled over the last two decades (see Chapter 3) with a 2004 report finding the national rates of cellulitis in children was twice that of Australia and the United States of America.[11] Recent analyses have found that serious skin infections contribute heavily to health inequalities with the greatest hospitalisation rates observed in Māori (NZ indigenous peoples) and Pacific children (see section 3.4.3).[9-11,19,20]. These trends are hypothesised to reflect corresponding patterns of disease in the community,[11] however there are no published studies examining skin infections in the NZ primary care setting, where many patients initially present and the major burden of illness is managed. This deficit is likely due the lack of routine primary care level surveillance for most health conditions in NZ.

Hospital admissions for serious skin infections must be recognised as only representing the 'tip of the iceberg' in relation to the wider community burden of disease.[11] This study aimed to estimate the incidence of skin infection cases in primary care in children in the Tairawhiti (Gisborne) Region, describe the basic epidemiology of these infections, and compare these characteristics with serious skin infections hospitalised in the Region during the same period.

6.3. METHODS

A prospective observational analysis of skin infection cases in children seen by a cohort of general practitioners in the Tairawhiti Region was conducted.

6.3.1. STUDY LOCATION

The Tairawhiti Region is a relatively isolated area of 45 000 people on the East Coast of NZ's North Island. The Region is unique for its large Māori population (47.3% of the total population[43]), young age distribution (26.2% of people are aged less than 15 years[43]), and high levels of deprivation (the Gisborne Region has the highest proportion of the most deprived residents in the country[44]). In Tairawhiti, childhood skin infections present a major challenge in both primary and hospital level care; findings described in Chapter 3 showed the Region has the highest rate of hospitalisation for childhood serious skin infections in NZ.

6.3.2. GENERAL PRACTITIONER RECRUITMENT AND DATA COLLECTION

The facility to code patient diagnoses exists within the computerised practice management systems used in almost all NZ general practices. However, most consultations are not routinely assigned a diagnostic code. The raw data for this study were collected by prospective consultation coding by a group of Tairawhiti general practitioners (GPs). All GPs within the Region were approached and their voluntary participation in this study sought. Out of the usual local GP population of approximately 25 full and part-time practitioners, nine GPs from three different practices agreed to participate. During the study period, 4627 of the 18 456 (25.1%) 0-14 year old usually resident population of the Tairawhiti Region were registered in the practice populations of these GPs.

Over the ten-week period, 19 May 2008 to 28 July 2008, GPs coded all incident cases of skin infection in children using the READ code system. Repeat visits for the same episode of infection were not coded. A minimum level code of 'M0.00' (Skin/subcutaneous tissue infections) was recorded in the computerised clinical records of appropriate patients using MedTech32®, the electronic patient

management system used in all participating practices. Email reminders were sent to GPs every 3-4 weeks during the data collection phase. At the end of this period, the Query Builder® function of MedTech32® was used to design and run a standardised data query. An arbitrary and anonymous unique identifier was assigned to each case and raw data variables including READ code and free-text diagnosis description, date of birth, gender and ethnicity (Māori vs. non-Māori) were extracted and collated centrally.

6.3.3. CASE DEFINITION

Cases of skin infection were diagnosed clinically based on the experience of participating GPs, however a written case definition was provided to standardise inclusion criteria (see figure 8).

Figure 8. Definition of primary care skin infection cases

A child aged 0-14 years, seen by a participating general practitioner during the study period, with clinical evidence of a new episode of active infection of the skin and/or subcutaneous tissues.

INCLUDING

- Cellulitis/erysipelas
- Impetigo
- Subcutaneous abscess/furuncle/carbuncle
- Acute lymphadenitis
- Any pyoderma including bacterial super-infection of eczema/scabies/chickenpox/inset bite
- Any other infection of the skin or subcutaneous tissue as indicated by local signs such as erythema, tenderness, swelling, heat, induration, pustular discharge, with or without systemic signs and symptoms such as fever, lethargy, sepsis, leucocytosis and raised inflammatory markers

6.3.4. HOSPITAL CASES

Anonymised hospitalisation data provided by the New Zealand Ministry of Health were used to identify all cases of serious skin infection in children aged 0-14 years admitted to Gisborne Hospital over the same ten-week period specified above. The case definition of hospitalised serious skin infections utilised in this study was that described in Chapter 2.[46] Cases were assigned an arbitrary and anonymous unique identifier and the same basic demographic variables as those collated for GP cases were extracted.

6.3.5. DATA ANALYSIS

Age and ethnicity-specific skin infection rates from participating GP registers were directly standardised to the Regional population to give an estimate of the total number and rate of skin infection cases seen in children in primary care in the Tairawhiti Region. Confidence intervals (CIs) were constructed using the methods of Clayton and Hills.[74]

Denominators in rate calculations were based on usually resident population counts from the 2006 census.

Annual infection rates were calculated from extrapolations of observed data. In these calculations seasonal adjustment was not considered necessary as previous work has shown there is very little seasonality in infection rates in the Tairawhiti Region compared to NZ (see section 4.4.2).

The ethnicity and gender distribution of children in general practice and in the hospital setting were compared using the Fisher's exact test. Age distributions were compared using the Mann Whitney U test. A two-tailed p-value of less than 0.05 was considered statistically significant.

Regional Ethics Committee approval was obtained for this study.

6.4. RESULTS

6.4.1. INCIDENCE AND CHARACTERISTICS OF PRIMARY CARE SKIN INFECTION CASES

Over the 10-week data collection period, 110 incident cases of skin infection in 107 children were recorded by the nine participating GPs. Table 11 summarises the observed number and rate of cases in each age and ethnicity group.

Based on age and ethnicity standardisation of observed rates, there were an estimated 378.6 (95% CI 312.4-458.9) cases of skin infection seen in primary care, equivalent to a rate of 20.5 cases (95% CI 16.9 to 24.9) per 1000 0-14 year old children in the Tairawhiti Region during the 10-week study period (see table 11).

Extrapolating these data longitudinally, without taking seasonal adjustment into account, there were an estimated 1968.7 (95%CI 1624.5-2386.3) cases of skin infection in children in the Tairawhiti Region primary care setting during 2008. This frequency is equivalent to an annual incidence rate of 106.7 (95% CI 85.2-127.2) per 1000 children in the Region, or 10.7%.

In Māori children, there was a trend towards reducing case incidence with increasing age. This trend was less apparent in non-Māori children. Annual infection rates range from 29.0 per 1000 for non-Māori children aged 10-14 years, up to 245.5 per 1000 for Māori children aged 0-4 years.

6.4.2. COMPARING SKIN INFECTION CASES SEEN IN PRIMARY CARE AND HOSPITAL SETTINGS

During the same 10-week data collection period, 27 cases of serious skin infection in 27 children were admitted to Gisborne Hospital. Based on the estimated 378.6 primary care skin infection cases in the Region over this period, there were 14 primary care cases for every one hospitalised serious skin infection.

Table 12 and figure 9 summarise and compare the basic demographic characteristics of primary care and hospital cases seen over the same period in 2008. Most primary care cases were coded only to the minimum code level of

'M0.00', so information on subtypes of skin infection and free-text diagnosis description was not available.

There was a significant difference in the age distribution of skin infection cases between the two settings (p 0.0041). Preschool-aged children accounted for two thirds (67%) of hospitalised cases of serious skin infection but only 38% of infections in primary care. While just 15% of hospitalised cases were in children aged 5-9 years, this group made up the largest proportion of cases in primary care (41%). The 10-14 year old age group accounted for the smallest proportion of cases overall.

Slightly more boys were admitted to hospital with a serious skin infection than girls, 56% and 44% respectively, but this difference did not reach statistical significance. There was no gender predominance in primary care cases with equal numbers of male and female children suffering skin infections. The difference between settings was not significant (p 0.67).

Just over three-quarters (77%) of skin infection cases in the primary care setting were in Māori children. Hospitalised cases of serious skin infection exhibited a similar ethnic distribution, with 78% occurring in Māori children (p 1.00).

Table 11. Skin infection incidence observed in the study population, and estimated for the Tairawhiti Region, 0-14 year old children, May-July 2008

Ethnicity/ age group	Observed case rate per 1000† (no. of cases/no. at risk)	Tairawhiti Region population‡	Estimated no. of primary care cases in Tairawhiti Region§	Estimated annual rate of primary care cases in Tairawhiti Region#
Māori				
- 0-4 years	47.2 (34/720)	2163	102.1	245.5
- 5-9 years	42.6 (33/774)	2241	95.4	221.4
- 10-14 years	24.0 (18/751)	2403	57.6	124.6
Non-Māori				
- 0-4 years	11.9 (8/671)	3651	43.5	62.0
- 5-9 years	14.8 (12/813)	3852	56.9	76.8
- 10-14 years	5.6 (5/898)	4146	23.1	29.0
Total	**20.5 (95% CI 16.9-24.9)**	**18 456**	**378.6 (95% CI 312.4-458.9)**	**106.7 (95% CI 85.2-127.2)**

95% CI – 95% confidence interval; No. - number

† Ethnicity and age specific rates of skin infection observed in participating primary care practices during 10-week study period

‡ Based on usually resident population data in 2006 census

§ Estimated number of primary care cases of skin infection in children in the Tairawhiti Region during the 10-week study period, based on multiplying the age and ethnicity specific rates observed in participating GP practices by the Tairawhiti Region population for that age/ethnicity group.

Estimated annual rate per 1000 of primary care cases of skin infection in the Tairawhiti Region, based on annualising the 10-week rate (without seasonal adjustment)

Table 12. Comparing demographic characteristics of children with skin infections seen in primary care and hospital settings in the Tairawhiti Region, May-July 2008

	Primary care cases		Hospital cases		Difference	
Variable	**No.**	**P_P (95% CI)**	**No.**	**P_H (95% CI)**	**$P_P - P_H$**	**p**
Age (yrs)						
0-4	42	0.38(0.30-0.48)	18	0.67(0.48-0.81)	- 0.29	
5-9	45	0.41(0.32-0.50)	4	0.15(0.05-0.33)	+0.26	0.0041
10-14	23	0.21(0.14-0.29)	5	0.18(0.08-0.37)	+0.03	
Gender						
Male	55	0.50(0.41-0.59)	15	0.56(0.37-0.72)	- 0.06	0.67
Female	55	0.50(0.41-0.59)	12	0.44(0.28-0.63)	+0.06	
Ethnicity						
Māori	85	0.77(0.69-0.84)	21	0.78(0.59-0.90)	- 0.01	1.00
Non-Māori	25	0.23(0.16-0.31)	6	0.22(0.10-0.41)	+0.01	

No. Number of cases

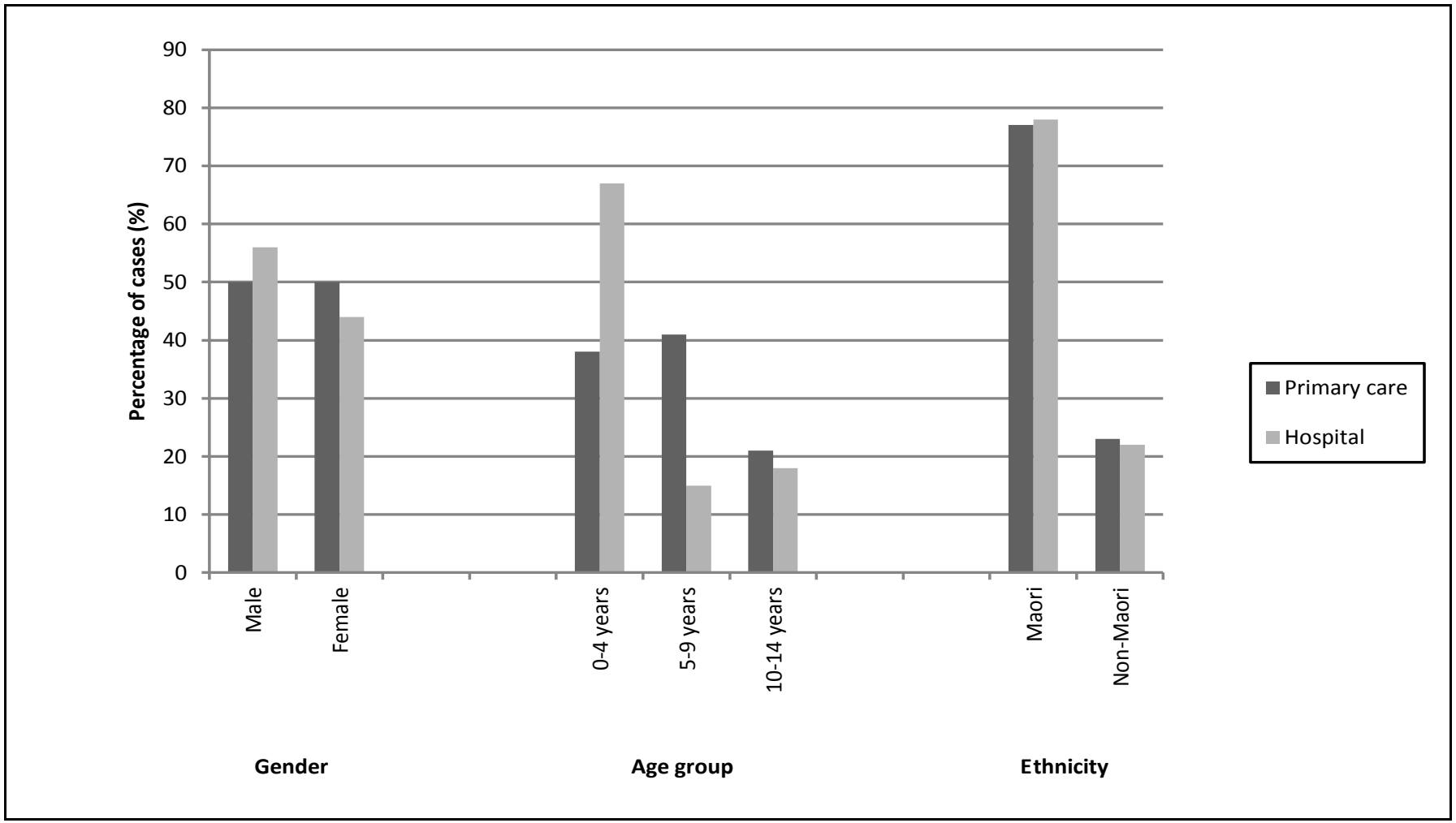
P_P Proportion of primary care cases

P_H Proportion of hospital cases

$P_P - P_H$ Difference between the primary care and hospital proportions

p Two tailed p-value (>0.05 considered statistically significant)

Figure 9. Gender, age and ethnicity of children with skin infections seen in primary care and hospital settings in the Tairawhiti Region, May-July 2008



6.5. DISCUSSION

Skin infections are a common childhood illness in NZ. In the Tairawhiti Region one in every nine children (10.7%) consulted their GP for a skin infection during 2008. Population groups with the highest rates of infection were Māori children and those in both the 0-4 and 5-9 year old age groups, with no difference between male and female children. The epidemiology of skin infections in primary care reflected that of hospitalised serious skin infections, except for the age distribution of cases where there was a relatively higher proportion of 5-9 year olds presenting to primary care, whereas preschool-aged children were the most common age group in hospital.

This study provides the first NZ estimate of the rate of skin infection in children at the regional primary care level. Findings indicate that during a ten-week period in 2008, there were 378.6 cases (95% CI 312.4-458.9) of skin infection seen in primary care in the Tairawhiti Region, equivalent to an annual incidence rate of 106.7 cases per 1000 children. There were an estimated 14 primary care cases for every one hospitalised serious skin infection. The total number of individual GP consultations would have been far greater as many of these children would have consulted their doctor more than once for the same episode of infection.

Over three-quarters of skin infections in primary care occurred in Māori children with an almost identical proportion accounting for hospitalised cases. This similarity in ethnic trends between the two settings is important; it indicates that the high incidence of serious skin infection in Māori children found in Chapter 3 is a reflection of a similarly high burden of disease at the primary care level, rather than ethnic disparities in hospital admission thresholds. Māori experience higher rates of infectious diseases in general.[58] The reasons for this are complex and multifactorial; they include household crowding, barriers to accessing primary healthcare such as cost and longer travel distances, and a range of socioeconomic factors.[59-63]

There was no gender predominance in either setting, but there was a significant difference in age distribution with hospitalised cases of serious skin infection more likely to occur in the preschool age group than primary care cases which were more evenly spread across the 0-4 and 5-9 year age groups. Previous analyses have found

hospitalisation rates for serious skin infection are highest in preschool-aged children [9-11,25,27,30,56,57] (and see Chapter 3). This distribution has been taken to directly reflect community trends in infection incidence. This study's findings challenge this assumption and indicate that age-trends in skin infection hospitalisation rates may also reflect lower admission thresholds in young children or more severe disease requiring admission in a greater proportion of cases.

This study is the first to describe the basic epidemiology of skin infections in children in a primary care setting and made comparisons to equivalent data from hospitalised serious skin infection cases over the same period. It is also only study known of that has attempted to quantify the total primary care burden of childhood skin infections within a region in NZ. However several limitations must be considered in conjunction with its results.

This analysis was based on a small number of primary care cases. Regional infection rates were extrapolated from these observed data, and hence are subject to considerable sampling error, reflected in wide confidence intervals. However, in comparison to previous work estimating the primary care burden of skin infections, which have solely comprised of workforce surveys,[11,75] this is an important step forward. The results are an indication of the magnitude of the problem beyond frequently measured hospitalisation data, and start to illuminate the area beneath the 'tip of the iceberg'.

The generalisability of the findings to populations outside the Tairawhiti Region needs to be considered. While the results of this analysis may be used with caution to approximate the primary care burden of disease in other regions, widespread application should not occur without validation in another population.

As involvement in this study was voluntary, it was not feasible to have a randomly selected sample of local GPs participating. Convenience sampling was therefore used. Potential clustering of practices meant analysis of certain census area unit-based demographic variables was not possible, namely deprivation status. In addition, the analyses of the local primary care burden of disease assume that the group of participating GPs are a representative sample of all GPs in the Gisborne

Region and exhibited an average hospital admission threshold similar to the population mean. While this would be best guaranteed by randomisation, selection bias was minimized by including over one-quarter of the usually resident 0-14 year old population of Region in the sample group, and by ensuring participating GPs were recruited from a broad range of practice sizes, types and locations. It is not known if the age, ethnicity and deprivation distribution of the GP sample was similar to that of the Region.

There was a large difference between the expected number of GP cases (based on GP-reported estimates of the number of paediatric skin infection cases they saw on a daily and weekly basis) and the actual number of recorded cases. It is likely that poor coding compliance accounts for much of this discrepancy; despite good intentions, a minimal level code for simplicity, and regular email reminders, several participating GPs estimated their coding compliance was approximately 50%. This bias will result in an underestimation of the primary care burden of disease. However, it is also possible that some of the discrepancy was because anecdotal case numbers were initially overestimated.

This study was not able to ascertain whether children admitted to hospital with a serious skin infection were referred immediately by their GP or after a failed trial of outpatient treatment. In addition, because this was not a longitudinal study, it could not determine if the marked rise in hospitalisation rates over the last two decades described in Chapter 3 was due to comparative increases in primary care case rates over this same period.

Further research is warranted to explore childhood skin infections beneath the tip of the iceberg of serious hospitalised cases. While infections seen by primary care providers do not comprise the whole community burden of disease (infections may be self resolving or self treated), they do account for a significant proportion. Further work is needed to investigate whether the high admission rates in NZ, compared to other developed countries,[11] solely reflect greater community rates of disease, or whether a larger proportion of skin infections result in hospital admission due either to increased severity of infection, or differences in referral practices. Further research using routinely collected primary care consultation data

would facilitate this endeavour, and eliminate many of the limitations described in this study. However, this would require that primary care diagnostic data was routinely coded, collected and available for use in a similar way to hospital diagnostic data.

Surveillance of health events in primary care (including general practice and emergency departments) is arguably one of the largest gaps in NZ's infectious disease surveillance system.[76] Many countries have well established general practice sentinel systems that NZ could emulate[77-81] and NZ has successfully piloted syndromic surveillance in the past for conditions including skin and subcutaneous tissue infection.[82] If NZ established sentinel surveillance of important primary care conditions then skin infections would be one event that could be monitored in this way.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1. SUMMARY OF KEY FINDINGS

Serious skin infections are an important and under-recognised challenge to the health of NZ children. Their incidence is significantly increasing over time, and they are making a growing contribution to ethnic and socioeconomic health inequalities.

Due to the low sensitivity of previously used case definitions, existing analyses of serious skin infections have markedly underestimated the true burden of disease. Based on a broader and more valid case definition developed as part of this thesis, the age-adjusted incidence of serious skin infections in NZ children was found to have almost doubled over the 18-year period 1990-2007. They now contribute to over 4,500 hospitalisations annually and, based on extrapolations from Tairawhiti data, an estimated 60,000 presentations to general practice each year.

These infections were most commonly suffered by boys and pre-school aged children, those of Māori and Pacific ethnicity, and children living in socioeconomically deprived neighbourhoods. Their marked contribution to ethnic and socioeconomic health inequalities appears to be worsening over time.

Within NZ, the greatest incidence of infections was in the Tairawhiti Region, an area with a young population distribution, large Māori populace, and the greatest proportion of socioeconomically deprived residents in the country. In this Region the incidence of infection was not only more than twice the national rate, it was also found to have increased more rapidly than average national trends, with significantly greater ethnic disparities. The high-risk population composition of Tairawhiti only partly accounted for the higher incidence rate, suggesting the involvement of other unknown aetiological factors.

A more thorough review of serious skin infection cases in the Tairawhiti Region found that infection types, sites and microbiological isolates were similar to those reported in other NZ regions, but there were differences in the types of preceding skin injuries and longer delays to seek medical care. These differences could in part contribute to the high incidence of infection in the Region. One third of children had suffered a previous skin infection with a significant proportion of these requiring hospitalisation. Little difference was found in the distribution of infection characteristics between Māori and non-Māori children, however the sample size was too small to draw statistically significant conclusions regarding this.

The majority of cases of skin infection in children are successfully treated in primary care, however due to the lack of routine coding and collection of this data, the wider community burden of disease often goes unreported and under-recognised. Tairawhiti GPs saw an estimated 1969 cases of skin infection during 2008, equivalent to an annual incidence rate of 106.7 (95% CI 85.2-127.2) cases per 1000 children, or one in every nine children in the Region. Comparison between the demographics of cases in primary care and hospital found statistically significant differences in age distribution but no differences in gender distribution. Māori children accounted for a similar proportion of skin infections in primary care and hospital settings, suggesting the disparities in ethnicity-related risk long noted in hospitalisation data reflect similar disparities in community rates of disease, rather than more severe infection or differences in hospital referral practices.

7.2. RECOMMENDATIONS FOR ACTION

The growing problem of serious skin infections in NZ children must be addressed as a public health priority. The key findings of this thesis highlight the necessity for action, and provide an improved evidence base to guide and inform the development of strategies to affect change.

While it was not considered within the scope of this thesis to present a comprehensive list of interventions, some brief and preliminary recommendations are outlined below. There have been a number of comprehensive but regional-specific approaches described in previous reports.[11,20]

Interventions need to meet several well established criteria, notably effectiveness, affordability (cost effectiveness), practicality, and acceptability. Information on effective interventions would usually be drawn from the large body of published evidence collated through such systems as the Cochrane Collaboration. Unfortunately, the body of literature on prevention of skin infection is small, with no published systematic reviews and few published randomised controlled trials. Given the high burden of skin infections, even moderately effective interventions have the potential to be cost effective (affordable). However, it is difficult to make such assessments without evidence to quantify effectiveness or knowledge of the cost of interventions. It is self-evident that interventions need to be practical for them to be introduced and sustained. This criterion is strongly related to the capacity of the public health and health care infrastructure to deliver the interventions and potential opportunity costs of having to drop lower priority activities. Such questions are particularly important in more socioeconomically deprived areas like the Tairawhiti Region. Acceptability is another necessary condition for the success of programmes. For a disease that disproportionately affects Māori and Pacific children, any interventions will need to be culturally appropriate.

Given the lack of a substantial evidence base of effective interventions to reduce skin infection in children, the following suggested strategies are based on a logical assessment of approaches that the author considers are worth considering. Because

of the lack of knowledge about interventions, it is even more important that NZ invests effort in the research strategies highlighted in the next section.

7.2.1. COMMUNITY EDUCATION AND AWARENESS CAMPAIGNS

This thesis has found that despite high and increasing hospitalisation rates, the large majority of childhood skin infections are managed effectively in primary practice. As such, implementing basic public health measures such as community education programmes and awareness campaigns will serve to both reduce the incidence of serious skin infections requiring hospitalisation, while lessening the wider disease burden on the primary health care system and community.

These programmes would need to be delivered in various settings and encompass education on what skin infections are, how to prevent them through basic hygiene measures, and what to do and when to seek help if they occur. In addition the normalisation of skin infections needs to be challenged by improving awareness and understanding of the significance of the problem.

Such programmes have the additional advantage of raising awareness about the importance of skin infections among clinicians and public health workers.

7.2.2. DIRECTING STRATEGIES TOWARDS HIGH RISK POPULATION GROUPS

In addition to generalised education programmes, specific strategies need to be directed towards sectors of the population shown to be at particularly high risk. With the evidence of increases in ethnicity and deprivation-related disparities over time that this thesis has shown, targeted interventions are of particularly high priority.

Relevant education and prevention programmes developed by and tailored for Māori and Pacific Peoples, and delivered in appropriate settings (such as marae, churches and community centres) are required.

Unfortunately, without substantial, co-ordinated and sustained change to the socioeconomic and environmental disparities which affect these high risk

population groups, specific interventions are likely to have only a limited impact on reducing the specific burden of skin infection.

7.2.3. SCHOOL AND EARLY CHILDHOOD PROVIDER-BASED PROGRAMMES

Programmes based in school and early childhood centres are likely to provide an important and feasible opportunity for reducing the burden of skin infections by improving awareness and influencing children's risk behaviours.

The school syllabus, covering both skin infections and more general hygiene and health topics, could be taught either by visiting public health nurses (PHNs) or by teachers supported by local public health services. This collaborative approach could serve to improve cooperation between these organisations, thus aiding the early reporting of classroom infection outbreaks and the identification of high-risk children requiring PHN assistance in receiving treatment.

Besides school-based programmes, this thesis has identified that preschool children make up the greatest proportion of cases of serious skin infection, and as such, prevention and education efforts need to be particularly directed towards this age group through appropriately designed teaching programmes at early childhood education centres and kohunga reo.

These teaching programmes would be most effective when complimented by the implementation of supportive policies and the provision of appropriate resources within the educational setting. Examples of this could include a requirement to have all open wounds and sores covered whilst at school, mandatory reporting of all scabies and impetigo outbreaks to PHNs, and improved bathroom facilities with guaranteed access to warm water, soap and adequate hand drying facilities as specified by the Ministry of Education's Health and Safety Code of Practice for Schools.[83] This final example is noted to be of particular significance in the Tairawhiti Region, with an audit conducted by local PHNs finding only 7 of 28 local schools and educational facilities complied with Ministry of Education hygiene facility requirements.[84]

Schools also provide the opportunity for novel interventions such as the trial of alcohol-based no rinse hand sanitisers, currently widely used in the health sector, as an alternative to traditional hand-washing. A study trialing the health outcomes of introducing this product to the classroom is currently underway throughout NZ with several Tairawhiti schools taking part.[85]

In addition to direct contact with children, schools and early childhood providers present excellent access point to the wider community, with lessons learnt during the day often shared with family members in the evening and an opportunity for further reinforcement through the distribution of relevant educational notices in newsletters.

7.2.4. CHANGES TO HOSPITAL-BASED MANAGEMENT

Despite the existence of a number of regional clinical pathways and treatment recommendations, a national best-practice guideline for skin infections does not exist in NZ. This subject was discussed by Hunt in 2004[11] when he made a call for the Paediatric Society and New Zealand Guidelines Group to collaborate to develop guidelines encompassing standardised antibiotic treatment, advice for risk factor modification and protocols for chronic or recurrent infections.

In addition to these recommendations, the role of outpatient treatment of infections needs to be explored. Many DHBs within NZ operate successful outpatient treatment programmes for uncomplicated cellulitis in adult populations, however, due to a range of issues including safety, logistics, supervision, differences in physiology and difficulties in IV access, the paediatric population are excluded. The international literature describes one programme providing outpatient treatment of cellulitis to children in Canada which had excellent outcomes with treatment failure rates of 8.1-8.9% depending on the antibiotic used.[86] Obviously this approach is limited to cellulitis only rather than the wider range of skin infection subtypes, and only serves to prevent hospitalisation, not reduce the incidence of serious skin infections in the population.

7.2.5. SECONDARY PREVENTION

While community and school-based programmes are important in the primary prevention of infections, the high rate of recurrence reported in this thesis highlights the need for improvements in secondary prevention; that is, prevention of future recurrence in patients with existing disease. If the modifiable determinants contributing to the original infection are not addressed, then the child will continue to have at least the same risk of infection. An episode of skin infection presents an opportunity for a short intervention that may reduce the likelihood of future infections with the cost and risk of complications that accompany them. Secondary prevention needs to occur both in primary care and hospital settings and could involve a simple education session on the causes and prevention of skin infections, or referral to a community-outreach service for a home visit when more complex risk factors are suspected.

7.2.6. IMPROVING COLLABORATION BETWEEN PRIMARY AND SECONDARY CARE

Given that the health burden of childhood skin infections is shared between community and hospital settings, with some patients moving several times between hospital and primary care, an effective means of improving collaboration between primary and secondary care services is required. Many DHBs already have measures in place, and approaches will often be region-dependent and not necessarily specific to skin infections. They could include shared electronic patient records, hospital-primary care liaison clinicians, joint continuing education sessions, and the establishment of a community-outreach service to follow high-risk patients from hospital discharge to the community, providing education and prevention support to their families, communities, GP and schools.

7.3. RECOMMENDATIONS FOR FUTURE RESEARCH

As discussed in each of the chapters of this thesis, there are important research questions covering all aspects of serious skin infections. More needs to be known about the aetiological factors involved in infection development, the wider epidemiology of infections in the community, the mechanisms for disparate incidence rates in particular population groups, and strategies for effective prevention and early intervention.

Importantly, ongoing use of the case definition developed in Chapter 2 of this thesis will allow researchers to produce more valid measurements of the burden of serious skin infections and improve collaboration in the field by enabling accurate comparisons between populations. Adopting this approach will help in measuring the effectiveness of specific interventions in a comparable way, and in monitoring the overall impact of programmes over time.

A series of retrospective chart reviews, standardised and conducted across different DHBs or different time periods, could aid in identifying aetiological and risk factors for infection, and elicit changes in these which may account for geographic or temporal variation in disease incidence.

There is an important need to identify risk factors for infection and quantify their importance. A large prospective case series could be a useful way to begin this process. However, a case-control study would be the method of choice. These study types have the advantage of allowing the researcher to design study questions and gather additional information as required, rather than having to rely on information recorded in hospital charts which may be limited. Disadvantages are the increased cost and resource requirements when compared to a retrospective study. Case control studies have the advantage over case series of allowing the quantification of risk factors for developing serious skin infection, leading on to the use of multivariate analysis to tease out the independent effects of ethnicity and deprivation.

Further on in the process, interventions hypothesised to prevent or reduce the burden of serious skin infections could be tested by a controlled trial. As these are expensive and resource-intensive, they require adequate forward planning often including a pilot study. Given its isolation and high disease rates, the Tairawhiti Region could lend itself well to such work.

Chapter 6 of this thesis demonstrates both the value and difficulty of primary care data collection in NZ. The establishment of a primary care sentinel surveillance system would both enable monitoring of skin infection rates and facilitate further research into skin infections in the community. NZ has previously trialled systematic ongoing surveillance of skin infections by general practitioners so has experience with such data gathering. Larger comparisons between infections in primary care and hospital settings could help further elucidate the factors involved in the development of serious infection.

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APPENDICES

APPENDIX A: LIST OF ICD-10 CODES USED FOR PROCEDURE CODE SEARCH

- 300230 - Excisional debridement of wound of soft tissue
- 300260 - Repair of wound of skin and subcutaneous tissue
- 300290 - Repair of wound of skin and subcutaneous tissue.
- 300320 - Repair of wound of skin and subcutaneous tissue
- 300350 - Repair of wound of skin and subcutaneous tissue
- 300610 - Removal of foreign body from skin and subcutaneous tissue
- 300640 - Removal of foreign body from skin and subcutaneous tissue
- 300750 - Biopsy of lymph node
- 302160 - Aspiration abscess of skin and subcutaneous tissue
- 302230 - Incision and drainage of abscess of skin and subcutaneous tissue
- 302240 - Percutaneous drainage of abscess of soft tissue
- 303640 - Incision and drainage of breast
- 306760 - Incision of pilonidal sinus or cyst
- 465160 – Debridement/removal of fingernail
- 900840 - Incision of eyelid
- 902810 - Incision of lymphatic structure
- 905800 - Debridement of open fracture site
- 906610 - Other incision of skin and subcutaneous tissue
- 906650 - Excisional debridement of skin and subcutaneous tissue
- 907250 - Aspiration of breast
- 922010 - Removal of foreign body without incision not elsewhere classified

APPENDIX B: LIST OF TERMS USED FOR FREE-TEXT SEARCH

(* indicates truncation)

- skin
- subcutaneous
- cutaneous
- superficial
- cellulitis
- abscess
- furuncle
- carbuncle
- impetigo
- pyoderma
- collection
- infect*
- inflamm*
- boil
- wound
- bite
- pus*
- suppurative
- erythema
- flare
- chickenpox
- varicella
- scabies
- eczema
- dermatitis
- insect
- spider
- animal
- staph
- strep

APPENDIX C: THE INCIDENCE OF SERIOUS SKIN INFECTIONS IN 0-14 YEAR OLD CHILDREN IN NEW ZEALAND, 1990-1999 AND 2000-2007, DISAGGREGATED BY ICD CODE, CODING CATEGORY AND LEVEL OF DIAGNOSIS

Serious skin infections of typical sites (skin infection sub-chapter of ICD-10)	**ICD-9†**	**ICD-10†**	**Level of diagnosis**	***f* 1990-1999**	**Rate 1990-1999‡**	***f* 2000-2007**	**Rate 2000-2007‡**
Impetigo	684	L01.0-L01.1	Principal	643	7.9	694	10.1
			All level	1486	18.2	1609	23.5
Cutaneous abscess, furuncle and carbuncle	6800-6809	L02.0-L02.9	Principal	767	9.4	7368	107.4
			All level	900	11.1	8120	118.3
Cellulitis	68100-68102, 68110, 68111, 6819-6829	L03.01-L03.9	Principal	10300	126.5	8411	122.6
			All level	11949	146.7	11002	160.3
Acute lymphadenitis	683	L0.40-L04.9	Principal	553	6.8	1026	15.0
			All level	632	7.8	1168	17.0
Pilonidal cyst with abscess	6850	L05.0	Principal	43	0.5	108	1.6
			All level	49	0.6	111	1.6
Pyoderma	6860	L08.0	Principal	35	0.4	45	0.7
			All level	94	1.2	452	6.6
Other infections of skin and subcutaneous tissue	390, 6868-6869, 9101-9179, 9191-9199	L08.1,L08.8,L08.9	Principal	1200	17.5	525	7.7
			All level	1964	24.1	1624	23.7
Total			**Principal**	**13541**	**166.3**	**18177**	**264.9**
			All level	**17074**	**209.7**	**24086**	**351.0**
Serious skin infections of atypical anatomical sites							
Erysipelas	035	A46	Principal	42	0.5	22	0.3
			All level	47	0.6	25	0.4
Hordeolum/cellulitis/abscess eyelid	37311-37313	H00.0	Principal	308	3.8	449	6.5
			All level	371	4.6	555	8.1
Abscess/cellulitis external ear and infective otitis externa	38010, 38011, 38013, 38014	H60.0-H60.3, H62.0, H62.4	Principal	599	7.4	378	5.5
			All level	974	12.0	533	7.8
Abscess/cellulitis nose	4781	J34.0	Principal	695	8.5	111	1.6
			All level	2080	25.5	133	1.9
Anal abscess/cellulitis (excludes rectal, ischiorectal or intersphincteric regions)	566	K61.0	Principal	666	8.2	496	7.2
			All level	701	8.6	536	7.8
Acute inflammation/cellulitis /abscess of orbit	37600-37601	H05.0	Principal	584	7.2	143	2.1
			All level	733	9.0	155	2.3
Other inflammatory disorders of penis, scrotum and unspecified male genital organ (excludes deeper tissues)	6072, 6084	N48.2,N49.2,N49.9	Principal	149	1.8	97	1.4
			All level	194	2.4	150	2.2
Abscess/cellulitis of	6164	N76.4	Principal	127	1.6	170	2.5

vulva			All level	133	1.6	183	2.7
Total			**Principal**	**3170**	**38.9**	**1866**	**27.2**
			All level	**5233**	**64.3**	**2270**	**33.1**
Serious skin infections secondary to primary skin disease							
Varicella with other complications	0527-0528	B01.8	Principal	240	2.9	271	3.9
			All level	293	3.6	316	4.6
Scabies	1330	B86	Principal	269	3.3	92	1.3
			All level	1273	15.6	504	7.3
Dermatitis unspecified and other specified (eczema) and infective eczema§	6908, 6929, 7028	L30.8,L30.9,L30.3 0	Principal	897	11.0	1546	22.5
			All level	3798	46.6	5350	78.0
Total			**Principal**	**1406**	**17.3**	**1909**	**27.8**
			All level	**5364**	**65.9**	**6170**	**89.9**
Serious skin infections secondary to external trauma							
Insect/spider bites	9104, 9114, 9124, 9134, 9144, 9154, 9164, 9174, 9192, 9194, 9198, 9248, 9895	S10.13,S10.83,S10.93,S20.13,S20.33,S20.43,S20.83,S30.83,30.93,S40.83,S50.83,S60.83,S70.83,S80.83,S90.83,T00.9,T09.03,T11.08,T13.03,T14.03,T14.03, T63.3,T63.4	Principal	469	5.8	288	4.2
			All level	646	7.9	454	6.6
Post-traumatic wound infection not elsewhere classified	9583	T79.3	Principal	158	1.9	108	1.6
			All level	442	5.4	457	6.7
Open wound infection with foreign body (+-infection) and open wound with infection	8799	T89.01,T89.02	Principal	8	0.1	24	0.3
			All level	182	2.2	2190	31.9
Total			**Principal**	**635**	**7.8**	**420**	**6.1**
			All level	**1270**	**15.6**	**3101**	**45.2**

ƒ Frequency is number of cases in 1990-1999 and 2000-2007

† Cases after 1999 were identified using ICD-10 diagnostic codes, while cases prior to this year were identified by IC-.9 codes which were forward and backward mapped from ICD-10

‡ Average annual incidence per 100 000 based on usually resident population (from NZ Census)

§The medical definition of infective eczema (a primarily inflammatory condition) is not in keeping with the clinical description of a serious skin infection, however due to similarities in terminology, this code is incorrectly used for eczema with a superficial bacterial infection.

APPENDIX D: THE INCIDENCE OF SERIOUS SKIN INFECTIONS IN 0-14 YEAR OLD CHILDREN IN TAIRAWHITI AND NZ, 1990-2007, DISAGGREGATED BY ICD CODE, CODING CATEGORY AND LEVEL OF DIAGNOSIS

				Tairawhiti		New Zealand	
CATEGORY A ICD codes (skin infection sub-chapter of ICD-10)	**ICD-10**	**ICD-9**	**Level of diagnosis**	**Rate 1990-1999†**	**Rate 2000-2007†**	**Rate 1990-1999†**	**Rate 2000-2007†**
Impetigo	L01.0-L01.1	684	Principal	17.8	17.9	7.9	10.1
			All level	57.4	57.9	18.2	23.5
Cutaneous abscess, furuncle and carbuncle	L02.0-L02.9	6800-6809	Principal	18.6	185.3	9.4	107.4
			All level	21.8	208.5	11.1	118.3
Cellulitis	L03.01-L03.9	68100-68102, 68110, 68111, 6819-6829	Principal	225.5	209.5	126.5	122.6
			All level	250.5	268.5	146.7	160.3
Acute lymphadenitis	L0.40-L04.9	683	Principal	5.7	20.0	6.8	15.0
			All level	5.7	24.2	7.8	17.0
Pilonidal cyst with abscess	L05.0	6850	Principal	0.8	3.2	0.5	1.6
			All level	0.8	3.2	0.6	1.6
Pyoderma	L08.0	6860	Principal	0.8	0.0	0.4	0.7
			All level	0.8	6.3	1.2	6.6
Other infections of skin and subcutaneous tissue	L08.1,L08.8, L08.9	390, 6868-6869, 9101-9179, 9191-9199	Principal	15.4	17.9	17.5	7.7
			All level	31.3	43.2	24.1	23.7
Total			**Principal**	**284.5**	**453.8**	**166.3**	**264.9**
			All level	**368.5**	**610.7**	**209.7**	**351.0**
CATEGORY B ICD codes (serious skin infections of atypical anatomical sites)							
Erysipelas	A46	035	Principal	0.0	1.1	0.5	0.3
			All level	0.8	1.1	0.6	0.4
Hordeolum/cellulitis/abscess eyelid	H00.0	37311-37313	Principal	13.7	10.5	3.8	6.5
			All level	16.2	10.5	4.6	8.1
Abscess/cellulitis external ear and infective otitis externa	H60.0-H60.3, H62.0, H62.4	38010, 38011, 38013, 38014	Principal	9.7	9.5	7.4	5.5
			All level	21.0	15.8	12.0	7.8
Abscess/cellulitis nose	J34.0	4781	Principal	5.7	2.1	8.5	1.6
			All level	11.3	2.1	25.5	1.9
Anal abscess/cellulitis (excludes rectal, ischiorectal or intersphincteric regions)	K61.0	566	Principal	17.8	8.4	8.2	7.2
			All level	17.8	8.4	8.6	7.8
Acute inflammation/cellulitis/abscess of orbit	H05.0	37600-37601	Principal	8.9	0.0	7.2	2.1
			All level	10.5	0.0	9.0	2.3
Other inflammatory disorders of penis, scrotum and unspecified male genital organ (excludes deeper tissues)	N48.2,N49.2, N49.9	6072, 6084	Principal	1.6	4.2	1.8	1.4
			All level	2.4	5.3	2.4	2.2
Abscess/cellulitis of vulva	N76.4	6164	Principal	0.8	3.2	1.6	2.5
			All level	0.8	4.2	1.6	2.7
Total			**Principal**	**58.2**	**39.0**	**38.9**	**27.2**
			All level	**80.8**	**47.4**	**64.3**	**33.1**
CATEGORY C ICD codes (serious skin infections secondary to primary skin disease)							
Varicella with other complications	B01.8	0527-0528	Principal	9.7	11.6	2.9	3.9
			All level	12.9	12.6	3.6	4.6
Scabies	B86	1330	Principal	12.9	3.2	3.3	1.3
			All level	28.3	16.8	15.6	7.3
Dermatitis unspecified and other specified (eczema) and	L30.8,L30.9, L30.3 0	6908, 6929, 7028	Principal	42.8	71.6	11.0	22.5
			All level	115.6	193.7	46.6	78.0

infective eczema‡							
Total			**Principal**	**65.5**	**86.3**	**17.3**	**27.8**
			All level	**156.8**	**223.2**	**65.9**	**89.9**
CATEGORY D ICD codes (serious skin infections secondary to external trauma)							
Insect/spider bites	S10.13,S10.83,S10.93,S20.13,S20.33,S20.43,S20.83,S30.83,30.93,S40.83,S50.83,S60.83,S70.83,S80.83,S90.83,T00.9,T09.03,T11.08,T13.03,T14.03,T14.03,T63.3,T63.4	9104, 9114, 9124, 9134, 9144, 9154, 9164, 9174, 9192, 9194, 9198, 9248, 9895	Principal	15.4	12.6	5.8	4.2
			All level	27.5	15.8	7.9	6.6
Post-traumatic wound infection not elsewhere classified	T79.3	9583	Principal	3.2	3.2	1.9	1.6
			All level	8.1	10.5	5.4	6.7
Open wound infection with foreign body (+-infection) and open wound with infection	T89.01,T89.02	8799	Principal	1.6	0.0	0.1	0.3
			All level	3.2	53.7	2.2	31.9
Total			**Principal**	**20.2**	**15.8**	**7.8**	**6.1**
			All level	**38.8**	**80.0**	**15.6**	**45.2**

†Average annual incidence use per 100 000 in 1990-1999 and 2000-2007 by discharge diagnosis code with Category A prioritisation (Categories B-D exclude admissions already included by a code in Category A, then by a code in Category B, then by a code in Category C)

‡The medical definition of infective eczema (a primarily inflammatory condition) is not in keeping with the clinical description of a serious skin infection, however due to similarities in terminology, this code is incorrectly used for eczema with a superficial bacterial infection.

APPENDIX E: THE DEMOGRAPHIC, SOCIAL AND ENVIRONMENTAL CHARACTERISTICS OF 0-14 YEAR OLD CHILDREN WITH A SERIOUS SKIN INFECTION IN THE TAIRAWHITI REGION, 2006-2007

Characteristic	Description	Number (%)	Mean
Age (years)	0-4	95 (58)	4.64
	5-9	39 (24)	years
	10-14	29 (18)	
Gender	Male	88 (54)	
	Female	75 (46)	
Ethnicity	NZ Māori	135 (83)	
	Pacific Island	4 (2)	
	NZ European/Pakeha	23 (14)	
	Other European	1 (1)	
Weight percentile	≤10th	13 (8)	67th
	25th	17 (11)	
	50th	33 (20)	
	75th	28 (17)	
	≥90th	66 (41)	
	Not applicable†	5 (3)	
Household smoking status	No smokers	27 (17)	
	Outside smokers only	59 (36)	
	Inside and outside smokers	22 (13)	
	Not recorded	55 (34)	
Number of people in household	2-3	12 (7)	5.44
	4-5	84 (52)	
	6-7	37 (23)	
	8-9	8 (5)	
	10-11	10 (6)	
	Not recorded	12 (7)	
Significant past medical history	Yes	10 (6)	
(excluding previous skin infections)	No	153 (94)	
TOTAL		**163 (100)**	

† Due to inconsistencies in gestation accuracy and the largely maternal determinant of birth weight, weight percentiles were not calculated in children younger than 1 month old.

APPENDIX F: INPATIENT INVESTIGATIONS, MANAGEMENT AND OUTCOME OF 0-14 YEAR OLD CHILDREN WITH A SERIOUS SKIN INFECTION IN THE TAIRAWHITI REGION, 2006-2007

Variable	Description	Number (%)	Mean
Length of stay (days)	1-3 days	105 (65)	3.87
	4-6 days	30 (18)	days
	7-9 days	12 (7)	
	10-12 days	9 (6)	
	≥13 days	7 (4)	
Blood drawn for analysis	No	64 (39)	
	Yes	99 (61)	
	- *Leucocytosis (>13.4 x 10^9/L)*	*66 (66)*	
	- *Elevated CRP (>5mg/L)*	*36 (36)*	
	- *Thrombocytosis (>400 x 10^9/L)*	*29 (29)*	
Blood cultures taken	No	82 (50)	
	Yes	81 (50)	
	- *No growth*	*76 (94)*	
	- *Contaminant growth only*†	*3 (4)*	
	- *Staphylococcus aureus*	*2 (2)*	
Microbiological swabs taken	No	79 (48)	
	Yes	84 (52)	
	- *No growth*	*10 (12)*	
	- *Staphylococcus aureus*	*40 (48)*	
	- *Streptococcus pyogenes*	*17 (20)*	
	- *Staphylococcus aureus and Streptococcus pyogenes*	*9 (11)*	
	- *Staphylococcus aureus and other*	*5 (6)*	
	- *Other*	*3 (3)*	
Ultrasonography	No	158 (97)	
	Yes	5 (3)	
Computer tomography scan	No	162 (99)	
	Yes	1 (1)	
Antibiotic prescribed	No	6 (4)	
	Yes	157 (96)	
Route and type of antibiotic	Oral	46 (29)	
	Intramuscular	1 (1)	
	Intravenous	110 (70)	
	- *Flucloxacillin*	*92 (84)*	
	- *Augmentin*	*12 (11)*	
	- *Macrolide*	*2 (2)*	
	- *Cephalosporin*	*4 (3)*	
Duration of IV antibiotics	≤24 hours	10 (6)	2.45
	1-2 days	59 (36)	days
	3-4 days	27 (17)	
	5-6 days	11 (7)	
	≥7 days	3 (2)	
	Not given	53 (32)	
Surgical management required‡	No	113 (69)	
	Yes	50 (31)	
Complications§	None	157 (96)	
	New abscess formation	3 (2)	
	Osteomyelitis	1 (1)	
	Febrile convulsion	1 (1)	
	Sepsis or septic shock	2 (1)	
	Transfer	4 (2)	
	Death	0 (0)	
TOTAL		**163 (100)**	

†Based on conclusion of microbiological report

‡Surgical management of a serious skin infection refers to surgical procedures under general anaesthetic and includes incision and drainage, and surgical debridement

§The absolute numbers and percentages of complications do not sum to the total due to more than one type of complication in one some patients.