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RESEARCH ARTICLE

The Global Epidemiology of Impetigo: A Systematic Review of the Population Prevalence of Impetigo and Pyoderma

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Abstract

Objective

We conducted a comprehensive, systematic review of the global childhood population prevalence of impetigo and the broader condition pyoderma.

Methods

PubMed was systematically searched for impetigo or pyoderma studies published between January 1 1970 and September 30 2014. Two independent reviewers extracted data from each relevant article on the prevalence of impetigo.

Findings

Sixty-six articles relating to 89 studies met our inclusion criteria. Based on population surveillance, 82 studies included data on 145,028 children assessed for pyoderma or impetigo. Median childhood prevalence was 12·3% (IQR 4·2–19·4%). Fifty-eight (65%) studies were from low or low-middle income countries, where median childhood prevalences were 8·4% (IQR 4·2–16·1%) and 14·5% (IQR 8·3–20·9%), respectively. However, the highest burden was seen in underprivileged children from marginalised communities of high-income countries; median prevalence 19·4%, (IQR 3·9–43·3%).

Conclusion

Based on data from studies published since 2000 from low and low-middle income countries, we estimate the global population of children suffering from impetigo at any one time to be in excess of 162 million, predominantly in tropical, resource-poor contexts. Impetigo is

an under-recognised disease and in conjunction with scabies, comprises a major childhood dermatological condition with potential lifelong consequences if untreated.

Introduction

Impetigo is a common dermatosis of childhood. Recent estimates of the global burden of impetigo are 111 million children from developing countries [1] to 140 million [2, 3] people affected at any one time. However, these estimates were based on a limited literature review of impetigo in the context of larger studies, have not been recently updated and acknowledge that impetigo estimates are imprecise due to the paucity of published literature from the highest prevalence contexts.[1–3] Additionally, most available data arise from hospital records, which may under-represent the true population prevalence of skin disease due to selection bias [4–9] and minimal health-care seeking for skin diseases in resource-poor contexts. [10–12] In this new study we have systematically collated data and updated estimates of the global population prevalence of childhood impetigo.

Staphylococcus aureus and *Streptococcus pyogenes* cause superficial skin infections. [13] Pyoderma is used to describe all superficial bacterial skin infections associated with the production of pus and is inclusive of impetigo (also known as skin sores or school sores), ecthyma and furunculosis. [14] Here we include reports on all pyodermas, but with a particular emphasis on impetigo. In resource-poor communities impetigo maintains a high burden of disease and affects well-being.[15] In addition, the infectious (staphylococcal and streptococcal cellulitis, bacteraemia, and deep tissue infections) and post-infectious (glomerulonephritis, rheumatic fever) sequelae cause high and persistent morbidity [1, 16–18] and variable mortality. [19, 20] The relative cost to families of missed school days and procuring treatments that may or may not work is also high. [10, 21]

The aim of this systematic review is to evaluate the prevalence of impetigo from studies in the general population (community or school surveys) and to explore variations in the epidemiology.

Methods

Search Strategy

This systematic review is reported according to PRISMA guidelines. [22] References were identified through PubMed for papers published in English between January 1970 and September 2014, which reported population based studies of skin disorders, with specific reference to impetigo or pyoderma prevalence. The search terms used were ["impetigo" OR "pyoderma"] AND ["Africa" OR "Asia" OR "Latin America" OR "Pacific" OR "Oceania" OR "North America" OR "Europe" OR "Russia" OR "China" OR "India" OR "Developing Country" OR "tropical" OR "Indigenous"]. Duplicates were removed before titles were reviewed for relevance (epidemiology, prevalence, impetigo, and pyoderma). If the title contained insufficient detail, abstracts or entire articles were reviewed for pre-determined inclusion criteria. The bibliographies of retrieved papers were hand-searched for additional references. An extensive search of the grey literature did not add any additional relevant studies after the abstracts or entire article was reviewed.

Selection Criteria

Population-based, prevalence studies, with extractable data on children with pyoderma or impetigo were included if a physical examination by a clinician was performed. Wherever a

term was used that inferred a bacterial skin infection (pyoderma, impetigo or sores) and numerator and denominator or proportion-affected data were available, these have been reported. Outpatient dermatology clinic and hospital-based studies from developing countries were excluded. Due to the overlap between impetigo and scabies, data on scabies was also extracted where available.

Reviewer Assessment

Papers meeting the inclusion criteria were sourced in full-text and data extracted by two reviewers independently. All papers were assessed by AB and a subset by each of the co-authors, after determining that they were not an author or involved in the primary data collection of any of the studies. Extracted data included date, country, climate, rural/urban environment, study site (e.g. school, household), study design, sampling method, population, age range, gender, qualifications of person conducting the screening, case definition, definition of bacterial skin infection, number of participants, number with impetigo, childhood and adult prevalence, location of lesions, microbiology and presence of scabies.

Definitions

Where the study date was not reported, the year of publication was used. The sampling method was defined as exhaustive if ≥85% of available population were surveyed and non-exhaustive if it was below 85%. Other options for sampling method included convenience (non-random selection of the available population), targeted (orphanages or institutions) and random selection of participants. The definition for a bacterial skin infection was recorded and later categorised as pyoderma (if the text used this term or indicated impetigo, folliculitis, ecthyma, furunculosis, and cellulitis), impetigo (only impetigo or skin sores were studied) and secondarily infected scabies (the primary focus of the study was scabies with a secondary focus on bacterial skin infection). We have concentrated on reporting impetigo prevalence in children. Where available, adult data were incorporated. If children and adults were included in the study, but separate rates were not provided, then the community wide prevalence of impetigo was reported. It was not possible to ascertain from the studies how representative the study sample was of the broader population.

Countries were categorised into regions according to the United Nations (UN) Population Division (www.esa.un.org/wpp/excel-Data/country-Classification.pdf, last accessed 10 November 2014). Childhood was defined as ages 0 to 15 years. To assess the total population at risk of impetigo based on the median prevalence estimate, population data from the UN Department of Economic and Social Affairs Population Division for 2012 were used, (www.esa.un.org/unpd/wpp/unpp/panel_indicators.htm, last accessed 7 December 2014). Each country was also categorised according to the World Development Index as at July 2005 (www.data.worldbank.org) as high (>$US 10,725 gross national income (GNI) per capita), upper middle ($US 3,466–$10,725 GNI per capita), lower middle ($US 876–$3,465 GNI per capita) or low (≤$US 875 GNI per capita) income. The Koppen Climate Classification System is the most widely used classification of climates and recognizes five major climate systems, tropical, arid, temperate, cold and polar. [23] Where climate data was not reported, the Koppen classification was used to code the climate by country and region.[23]

Statistical Analysis

The data are synthesized into a narrative summary. Statistical analysis was performed using Stata13 (Statacorp, Texas, USA). Where prevalence estimates have been combined to understand regional and global burden of impetigo, the median prevalence has been used. In order

to estimate regional and global burden of impetigo, the median prevalence has been applied to the 2011 Australian census and 2012 United Nations population estimate for less developed countries. The metaregression command in Stata was used to calculate the pooled prevalence (random-effects model), using the inverse of the sample size to account for variability in study size. To assess for any variation in reporting of prevalence based on the use of either pyoderma or impetigo, we assessed the use of each term, and calculated a statistical difference between the median prevalence using a chi squared statistic.

Results

Of the 1007 titles identified, 952 were from database searching and 55 from additional sources (Fig 1). Two hundred and thirteen duplicate records were removed and 628 papers excluded, due to insufficient data on impetigo or because the studies were conducted in dermatology clinics or hospitals. Full text review of the 128 remaining records resulted in 38 further exclusions, leaving 90 papers. A further 24 were excluded due to insufficient data reported on impetigo prevalence. The final dataset includes 66 papers [4, 6–9, 15, 24–82] reporting on 89 studies (Fig 1, Table 1, S1 Table) conducted over a 45-year period.

The studies were predominantly from Africa (30/89, 34%), Asia (20/89, 22%) and Oceania (19/89, 21%) and represented populations from 31 countries (Table 1). Studies with data available by decade were: 1970s (28, 32%), 1980s (15, 17%), 1990s (20, 23%), 2000s (23, 26%) and since 2010 (3, 3%).

Data on impetigo prevalence were available for 174,508 individuals of whom 145,028 were children. The study size varied, ranging from 31 to 19,775 participants per study. The median study size was 636 participants (inter-quartile range [IQR] 305–1817), median prevalence 11·2% (IQR 4·2–19·4%) and pooled prevalence 15·5% (95% CI 12·1–19·0%) (Table 2). Extractable prevalence data were available on children in 82 (92%) of the studies. The median impetigo prevalence in children was 12·3%, (IQR 4·2–19·3%) and pooled prevalence 16·6% (95% CI 12·7–20·5%). The median number of children in each study was 534 (IQR 258–1,729).

Reported impetigo prevalence ranged from 0·2% to 90%. The highest median prevalence of childhood impetigo was reported from Oceania, where from 19 studies, the median prevalence was 40·2% (IQR 17·2–48·1%). Excluding studies from Australia and New Zealand, of the eight remaining studies from Oceania, the median prevalence remained high at 29·7% (IQR 14·7–42·0%). The median impetigo prevalence in Africa was 7% (IQR 4·1–12·3%), Asia 7·3% (IQR 3·0–16·1%), resource poor populations in North America 13·3% (IQR 2·1–19·4%) and Latin America and the Caribbean 15·5% (IQR 12·2–20·8%). There was no data available for Europe or China.

We estimated the burden of impetigo in low and low-middle income countries using estimates for the global population below 15 years of age resident in less developed countries in the years 2000–2009 to be at least 1.6 billion children. Utilising the median impetigo population prevalence of 9·9%, (IQR 4·1–16·6%) from the studies conducted in developing economies (WDI2005 index of lower-middle or low) since 2000, the estimated population with impetigo at any one time is more than 162 million children. Excluding China where no studies were available, reduces the estimate to 137 million children with impetigo, in low and low-middle income countries. Table 3 outlines the regional estimates of children with impetigo at any one time using the available data.

There were 10 population prevalence studies available for Australia. All reported data from children living in remote Indigenous communities of northern Australia, with no studies available for non-Indigenous children. The median prevalence reported from these studies was 44·5% (IQR 34·0–49·2%). Four studies were conducted since 2000, with a median prevalence

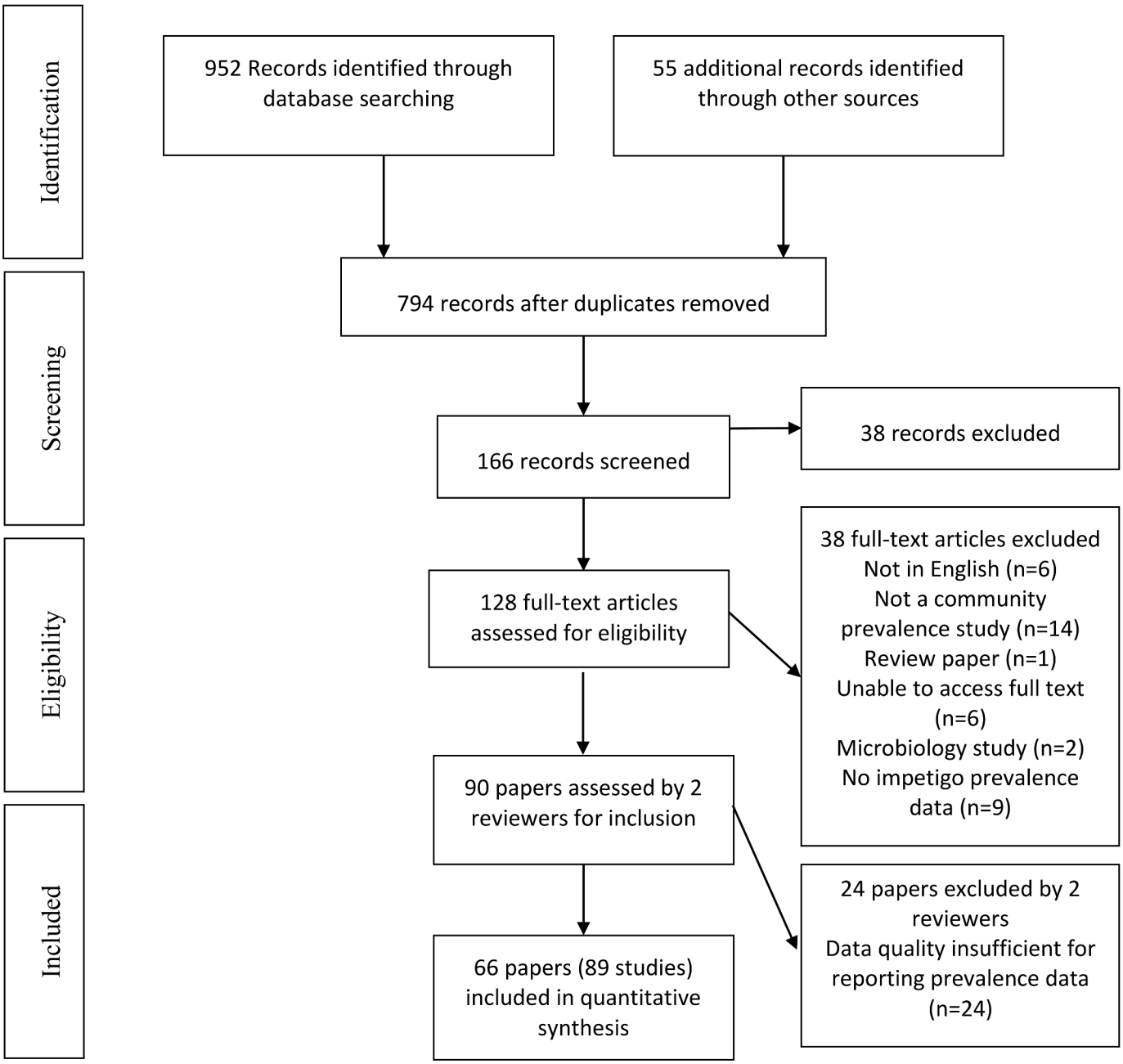


Fig 1. Flowchart of systematic review according to the PRISMA statement.

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of 43·0% (IQR 40·2–45·7%). We estimated the total number of remote Indigenous children with impetigo at any one time by applying the median prevalence of 44·5% to the remote living Indigenous population from the states of Western Australia, Queensland and Northern Territory aged less than 15 years in the 2011 Australian census (35,272). We estimate 15,696 Indigenous children are suffering from impetigo at any one time. This is the first time that prevalence estimates have been used to generate a total number at risk amongst Australian Indigenous children. This will be important for local health care planning.

Table 1. Number of studies of impetigo prevalence by decade, country and region.

Decade	Number of studies	Countries	Regions
1970–1979	28	Colombia, Ghana, Tanzania, New Zealand, Brazil, India, USA, Gambia, Panama	Latin America & Caribbean, Africa, Asia, Oceania, North America
1980–1989	15	Pakistan, Solomon Islands, Nigeria, Ethiopia, Vanuatu, India, Fiji, Canada	Asia, Oceania, Africa, North America
1990–1999	20	Australia, Honduras, Mali, Malaysia, Ethiopia, Tanzania, Ecuador, Samoa, Taiwan, Kenya, Solomon Islands	Oceania, Latin America & Caribbean, Africa, Asia
2000–2009	23	Nepal, Australia, India, Fiji, Tanzania, Nigeria, Timor Leste, Turkey, Mali, Ghana, Gabon, Rwanda, Egypt	Asia, Oceania, Africa
2010–2014	3*	Ethiopia, Cameroon, Tanzania	Africa

* Two studies were published in 2010 and did not provide a year of data collection in the manuscript.

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Only 13 (15%) studies reported prevalence of impetigo according to age group. Of these, the median prevalence in 0–4 year olds was 19% (IQR 15–31%), 5–9 year olds 19% (IQR 12–43%) and 10–14 year olds 10% (IQR 7–28%). Most studies, 58/89 (65%) (Table 4), were from low or low-middle income countries. The remainder were from middle-income or resource-poor populations within high-income countries. Table 5 summarises the median prevalence estimates according to income level of the country, with the highest estimates coming from underprivileged populations within high-income countries.

Fifty-seven (64%) studies also reported data on scabies prevalence. The median prevalence of scabies was 3·3% (IQR 0·7–12·9%). Twenty-seven (87%) countries had available data on scabies prevalence. Scabies prevalence varied by region with the highest median prevalence found in Oceania (n = 14) at 16% (IQR 4·9–25%). The median scabies prevalence in Africa (n = 28) was 2% (IQR 0·7–7%) and in Asia (n = 11) was 3·4% (IQR 0·9–11·9%). The median prevalence of scabies in studies from Latin America and the Caribbean (n = 3) was 3% (IQR 0.6–10%). Scabies prevalence also varied by decade. In the 1970s (n = 12), the median was 3·2% (IQR 1·4–13%), 1980s (n = 8) 1·1% (IQR 0·4–1·8%), 1990s (n = 14) 9·2% (IQR 4·9–17%), 2000s (n = 20) 1·9% (IQR 0·6–15·1%) and since 2010 (n = 3) 1·4% (IQR 0·3–1·8%). The prevalence of pyoderma and scabies were closely correlated (p = 0·01).

Thirty-four (38%) studies reported culture based microbiology results, predominantly on streptococcal infection (n = 31). Only 11/89 (12%) studies reported on the relative contributions of *S. pyogenes* and *S. aureus* from microbiological culture of skin lesions. *S. pyogenes* was identified in a median of 74% (IQR 57–95%) of cultures and *S. aureus* in a median of 64% (IQR 53–80%) of cultures. These culture results should be treated with caution as the microbiology methods were heterogenous or not reported.

Table 2. Summary statistics of available studies by age grouping.

	Total available population (N = 89 studies)	Childhood population (N = 82 studies)	Adult population (N = 11 studies)
Median (IQR) prevalence of impetigo	11·2% (4·2–19·4%)	12·3% (4·2–19·4%)	4·9% (3·1–9·6%)
Pooled prevalence (95% CI)	15·5% (12·1–19·0%)	16·6% (12·7–20·5%)	9·7% (2·2–7·2%)
Median (IQR) number of participants per study	636 (305–1,817)	534 (258–1,729)	638 (264–1,645)
Population with impetigo	23,759	19,811	2,427
Total population studied	174,508	145,028	18,246

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Table 3. Estimates of children with impetigo by regions of the world with available data*.

Region	Population in 2012 under 15 years	Median impetigo prevalence in children	Estimated number of children with impetigo
Africa	424,072,000	7% (IQR 4·1–12·3%)	29,685,040
Asia	1,060,076,000	7·3% (IQR 3·0–16·1%)	77,385,548
Oceania*	3,653,000	29·7% (IQR 14.7–42·0%)	1,084,941
Latin American & Caribbean	167,654,000	15·5% (IQR 12·2–20·8%)	25,986,370
TOTAL	**1,655,455,000**	**N/A**	**134,141,899**

*Studies from Australia, New Zealand and North America excluded as all these studies were conducted in small, impoverished populations within these countries that may not reflect the overall burden of impetigo for the childhood population.

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Data were reported on body distribution of impetigo in 23 studies, with the lower limbs being the most common site in 21 studies (91%). In 11 studies, the proportion of body regions affected was given. After re-classification as lower limbs, upper limbs and other [scalp, face, neck, torso], the medians for body region distributions (these were not mutually exclusive) were 58% (IQR 44–86%), 18% (IQR 14–54%) and 38% (IQR 5–43%) respectively.

Studies were classified broadly as rural (n = 61), urban (n = 15) or both (n = 13). A higher prevalence of impetigo was reported from rural locations compared to urban settings (Table 6). Most studies were from tropical environments, 67/89 (75%) with the remainder from cold 9/89 (10%), temperate 9/89 (10%) and arid 4/89 (5%) climates. Median impetigo prevalence in childhood was 12·2% (IQR 4·8–20·8%), 17·5% (IQR 8·2–42·8%), 15·8% (IQR 2·2–30·2%) and 3·9% (IQR 1·0–13·3%) for tropical, arid, temperate and cold climates respectively.

There was variability in the population sampling techniques employed. The most common technique described was exhaustive sampling. Of the exhaustive population surveillance studies (n = 57/89, 64%), the median number of participants was 636 (IQR 305–2528) and median prevalence 10·8% (IQR 4·3–19·4%). The median prevalence was 4% (IQR 2·0–16·6%) in the seven studies where random sampling was employed.

Table 4. Classification of studies by region and World Bank Development Indicator in 2005.

Region	High income	Upper Middle income	Low Middle Income	Low Income
Oceania	Australia (10) New Zealand (1)		Fiji* (4) Vanuatu (1) Samoa (1)	Solomon Islands* (2)
Africa		Gabon (1)	Egypt* (2)	Ghana* (3) Rwanda (1) Cameroon* (1) Ethiopia (3) Nigeria* (2) Tanzania (9) Kenya (3) Mali (3) The Gambia (2)
Asia	Taiwan (1)	Malaysia* (2) Turkey* (1)		India* (12) Nepal (2) Pakistan* (1) Timor-Leste* (1)
Caribbean & Latin America		Panama* (2)	Honduras* (1) Brazil (2)* Colombia* (1) Ecuador*(1)	
North America	Canada (6) USA (7)			
TOTAL	**25**	**6**	**13**	**45**

*Category has shifted rather than remaining stable within period from 1987–2013.

Source: data.worldbank.org/data-catalog/world-development-indicators, accessed 12.11.2014.

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Table 5. Median prevalence of impetigo in childhood and overall, categorised by the World Development Index.

WDI and number of studies	Median childhood prevalence (IQR) N = 82	Median overall prevalence (IQR) N = 89
High income (N = 25)	19·4% (IQR 3·9–43·3%)	19·4% (IQR 3·9–43·3%)
Middle income (N = 4 [childhood] OR N = 6 [overall])	9·9% (1·8–18·6%)	9·9% (IQR 2·0–15·1%)
Low-Middle (N = 12)	14·5% (IQR 8·3–20·9%)	12·8% (7·8–18·3%)
Low (N = 41 [childhood] OR N = 46 [overall])	8·4% (IQR 4·2–16·1%)	7·9% (4·3–16·1%)

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Twenty-seven (30%) studies reported on impetigo as the primary definition under investigation. Of these, 25 have data on the childhood prevalence of impetigo, median 13·3% (IQR 2·3–22·6%). Pyoderma was reported in 62 (70%) studies with a median prevalence of 11·8% (IQR 5·1–19·0%). There was no statistical difference in the median prevalence reported based on these definitions, p = 0·85. Both definitions were used throughout all decades of the study. There was some variability in the use of definition by region: studies from Africa, Asia and Latin America predominantly reported on pyoderma, whereas studies from Oceania used either definition and North American studies were more likely to report on impetigo (Table 7).

Discussion

This systematic review provides comprehensive data and confirms an ongoing, high burden of impetigo in childhood, estimating more than 162 million children in low and low-middle income countries are affected at any one time. Our study revises upwards the previous point-prevalence estimate of 111 million children with impetigo.[1] The reported burden has remained high throughout the study period, with a median prevalence of 12·3% (IQR 4·2–19·3%). Our estimate derived from 89 studies over 45 years is higher than previously published estimates, which were between 5 and 10%. [12] Impetigo is more than a benign, nuisance condition and these numbers demonstrate the public health priority of impetigo. Each study is valuable in describing the impetigo burden for a local or regional population, but collectively they tell a far more compelling story of an under-appreciated disease.

The data cover large regions of the globe and include studies from countries that were not available in previous disease burden estimates. By highlighting the global burden, which has previously been estimated at >2% of the global population at any one time, [3] an agenda for screening, treatment and further work can crystallise. This will inform primary prevention of kidney and heart disease and gram-positive bacterial sepsis in resource poor contexts. Likewise, highlighting the population-based burden in resource-poor settings may prioritise the conduct of treatment studies in contexts with the highest burden of impetigo. The Cochrane review on

Table 6. Variability in median impetigo prevalence by urban and rural study locations.

	Median impetigo prevalence overall	Median impetigo prevalence in children
Rural	N = 61 studies	N = 55 studies
	13·3% (6·7–20·9%)	16·1% (5·9–22·6%)
Urban	N = 15 studies	N = 14 studies
	4·8% (2·0–10·0%)	4·5% (2·0–7·3%)
Both	N = 13 studies	N = 13 studies
	5·8% (2·4–13·3%)	5·8% (2·4–13·3%)

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Table 7. Regional variation in the use of pyoderma or impetigo to describe bacterial skin infections.

Region	Pyoderma reported (%)	Impetigo reported (%)
Africa (N = 30)	27 (90%)	3 (10%)
Asia (N = 18)	15 (79%)	4 (21%)
Oceania (N = 19)	10 (53%)	9 (47%)
North America (N = 13)	3/13 (23%)	10/13 (77%)
Latin America & Caribbean (N = 7)	7/7 (100%)	0

doi:10.1371/journal.pone.0136789.t007

the optimal treatment of impetigo[83] includes studies predominantly from high income countries and references only one study (out of 68) conducted in a similar setting to those reported in our systematic review.

Collectively, the data describe limited progress in impetigo control. Over a 45-year interval, the burden of impetigo has remained relatively unchanged. Adding bacterial skin infections to the list of neglected tropical diseases is one strategy that might accelerate progress. We also describe a high impetigo burden in impoverished populations within wealthy countries, in keeping with version 2.0 of the neglected tropical diseases agenda where 'blue marble health' identifies the contribution of poverty in all countries as a key underlying factor of neglected tropical diseases. [84]

Our study confirms that the greatest burden of impetigo is in children, with steady decreases in prevalence with increasing age. [12, 32] We also confirm childhood impetigo predominantly affects the lower limbs in these studies, and is caused by both *S. pyogenes* and *S. aureus*. Despite our study reflecting predominantly impoverished settings, increases in impetigo have also been reported in children in developed countries attending general practices for care [85] and it causes a large volume of health care consultations in all regions of the world. [86–88]

The definitions and clustering of conditions used was variable. Using the two dominant terms of impetigo and pyoderma, there was no statistical difference in the median prevalence, suggesting that our inclusion of both terms as a descriptor of bacterial skin infections in populations is robust. Other forms of pyoderma were much less common which may explain the similarities in population prevalence of impetigo and pyoderma.

We recommend that guidelines for skin surveillance be used for future studies. [89] Our study found the clinical skills of those performing cutaneous disease surveillance varied greatly, ranging from dermatologists to community health workers trained in identification of skin conditions. This limitation may have resulted in under-reporting of impetigo. In addition, many of the studies were focussed on a specific dermatosis, conducted in the context of nutrition or child health surveys or to demonstrate the substantial burden of skin disease and significant unmet need. [80]

It is possible that studies have been conducted in the regions of highest disease burden leading to an over-estimate of the global burden. [12] We think this is unlikely, given the size, consistency and duration of the estimated burden of impetigo that we have described. However, population-based prevalence studies from Europe, East and South-East Asia and more recent work from North America, are under-represented. The inclusion of geographic locations as search terms was used to explore possible publication bias. We were not able to identify additional studies using this approach. Despite these gaps, our findings are consistent with the 2010 global burden of disease estimates for impetigo. [2, 3] Our study may also be limited by the exclusion of unpublished data and by restricting the analysis to English language publications. The grey literature was searched without adding to the studies synthesised.

Conclusions

Impetigo prevalence throughout was highest in Oceania, in both resource-poor countries and underprivileged populations within high-income countries. This synthesis of studies is important for regional and national targeting of healthy skin interventions, as the burden of disease is large. At a global level, this study revises our estimate upwards of the number of children affected with impetigo at any one time from 111 million [1] to 162 million. This finding alone should drive a comprehensive public health and research agenda for the detection, treatment and prevention of impetigo in resource-poor contexts, and ongoing evaluation of comprehensive programs to train primary care workers in the treatment of skin infections. As antibiotics are the backbone of current treatment for impetigo, this disease burden may contribute to burgeoning antibiotic resistance in the absence of evidence-based treatment algorithms. [90] This combination of high prevalence and moderate morbidity makes impetigo a high population health priority.

Supporting Information

S1 Table. Overall and childhood pyoderma and scabies prevalence from 89 studies.
*Resource-poor populations within high-income OECD countries, ^reflects year of publication when year study was commenced is unknown.
(DOC)

Author Contributions

Conceived and designed the experiments: ACB AM RJH ACS SYCT JRC. Performed the experiments: ACB AM RJH ACS SYCT RMA JRC. Analyzed the data: ACB. Wrote the paper: ACB AM RJH ACS SYCT RMA JRC.

References

1. Carapetis JR, Steer AC, Mulholland EK, Weber M. The global burden of group A streptococcal diseases. Lancet Infect Dis. 2005; 5(11):685–94. Epub 2005/10/29. S1473-3099(05)70267-X [pii] doi: 10.1016/S1473-3099(05)70267-X PMID: 16253886.
2. Vos T, Flaxman AD, Naghavi M, Lozano R, Michaud C, Ezzati M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012; 380(9859):2163–96. Epub 2012/12/19. S0140-6736(12)61729-2 [pii] doi: 10.1016/S0140-6736(12)61729-2 PMID: 23245607.
3. Hay RJ, Johns NE, Williams HC, Bolliger IW, Dellavalle RP, Margolis DJ, et al. The global burden of skin disease in 2010: an analysis of the prevalence and impact of skin conditions. J Invest Dermatol. 2014; 134(6):1527–34. Epub 2013/10/30. doi: 10.1038/jid.2013.446 PMID: 24166134.
4. Hogewoning A, Amoah A, Bavinck JN, Boakye D, Yazdanbakhsh M, Adegnika A, et al. Skin diseases among schoolchildren in Ghana, Gabon, and Rwanda. Int J Dermatol. 2013; 52(5):589–600. Epub 2013/04/06. doi: 10.1111/j.1365-4632.2012.05822.x PMID: 23557028.
5. Saw SM, Koh D, Adjani MR, Wong ML, Hong CY, Lee J, et al. A population-based prevalence survey of skin diseases in adolescents and adults in rural Sumatra, Indonesia, 1999. Trans R Soc Trop Med Hyg. 2001; 95(4):384–8. Epub 2001/10/03. PMID: 11579879.
6. Lawrence DN, Facklam RR, Sottnek FO, Hancock GA, Neel JV, Salzano FM. Epidemiologic studies among Amerindian populations of Amazonia. I. Pyoderma: prevalence and associated pathogens. Am J Trop Med Hyg. 1979; 28(3):548–58. Epub 1979/05/01. PMID: 110164.
7. Bechelli LM, Haddad N, Pimenta WP, Pagnano PM, Melchior E Jr., Fregnan RC, et al. Epidemiological survey of skin diseases in schoolchildren living in the Purus Valley (Acre State, Amazonia, Brazil). Dermatologica. 1981; 163(1):78–93. Epub 1981/01/01. PMID: 7274519.
8. Gibbs S. Skin disease and socioeconomic conditions in rural Africa: Tanzania. Int J Dermatol. 1996; 35 (9):633–9. Epub 1996/09/01. PMID: 8876289.
9. Bissek AC, Tabah EN, Kouotou E, Sini V, Yepnjio FN, Nditanchou R, et al. The spectrum of skin diseases in a rural setting in Cameroon (sub-Saharan Africa). BMC Dermatol. 2012; 12:7. Epub 2012/06/

23. 1471-5945-12-7 [pii] doi: 10.1186/1471-5945-12-7 PMID: 22720728; PubMed Central PMCID: PMC3445843.

10. Hay RJ, Estrada Castanon R, Alarcon Hernandez H, Chavez Lopez G, Lopez Fuentes LF, Paredes Solis S, et al. Wastage of family income on skin disease in Mexico. BMJ. 1994; 309(6958):848. Epub 1994/10/01. PMID: 7950615; PubMed Central PMCID: PMC2541080 community and are often poorly managed. The impact of ineffective treatment of skin disease on family life in rural Mexico was investigated. In the community of Cayaco, a house to house questionnaire survey was conducted to study the distribution of skin disease and the use and cost of treatments. The diagnosis of skin lesions was validated by physical examination and in a separate random survey in 120 primary school children. Regression analysis was carried out. 380 households with 1528 people (713 males, 815 women) were surveyed, of whom 207 reported skin disease. 131 attended the outpatient clinic (41 males, 90 females). The commonest skin disease among them was pyoderma (27 patients), followed by scabies (26), pityriasis alba (23), acne (8), dermatophytosis (8), viral warts (8), and pediculosis capitis (8). 66 had other skin conditions ranging from urticaria (2) to scrofuloderma (1). 58 patients had more than one condition, a total of 189 dermatoses. Six conditions accounted for 102 of the dermatoses. 15 patients with scabies and 21 with pyoderma had received ineffective treatment over the previous six months at a mean cost of 66 new pesos and 136 new pesos, respectively. Many of the affected children had missed school: eight days for scabies (12 patients) and 15 days for pyoderma (10 patients). 68 of the 120 primary school children in the random survey had at least one treatable skin condition. In half of the households people had symptoms, and 57% of the children had at least one treatable skin disease. The mean total cost of ineffective treatment for the two commonest conditions over six months was a major financial burden on families where the mean daily wage was 15.2 new pesos. Both diseases are readily curable by eliminating scabies. In the area a new system of community dermatology is implemented with close collaboration between specialists and primary health care workers.

11. Behl PNMKCBS. Ecological study of skin diseases in Delhi area. Indian Journal of Dermatology, Venereology and Leprology. 1979; 50:213–4.

12. Mahe AH, R.J. Epidemiology and Management of common skin diseases in children in developing countries. Geneva: World Health Organisation 2005 2005. Report No.

13. Brook I, Frazier EH, Yeager JK. Microbiology of nonbullous impetigo. Pediatr Dermatol. 1997; 14 (3):192–5. Epub 1997/05/01. PMID: 9192410.

14. Mahe A, Faye O, N'Diaye HT, Ly F, Konare H, Keita S, et al. Definition of an algorithm for the management of common skin diseases at primary health care level in sub-Saharan Africa. Trans R Soc Trop Med Hyg. 2005; 99(1):39–47. Epub 2004/11/20. S0035-9203(04)00182-8 [pii] doi: 10.1016/j.trstmh.2004.03.008 PMID: 15550260.

15. Murgia V, Bilcha KD, Shibeshi D. Community dermatology in Debre Markos: an attempt to define children's dermatological needs in a rural area of Ethiopia. Int J Dermatol. 2010; 49(6):666–71. Epub 2010/07/14. IJD4284 [pii] doi: 10.1111/j.1365-4632.2009.04284.x PMID: 20618472.

16. Hoy WE, White AV, Dowling A, Sharma SK, Bloomfield H, Tipiloura BT, et al. Post-streptococcal glomerulonephritis is a strong risk factor for chronic kidney disease in later life. Kidney Int. 2012; 81 (10):1026–32. Epub 2012/02/03. ki2011478 [pii] doi: 10.1038/ki.2011.478 PMID: 22297679.

17. Marshall CS, Cheng AC, Markey PG, Towers RJ, Richardson LJ, Fagan PK, et al. Acute post-streptococcal glomerulonephritis in the Northern Territory of Australia: a review of 16 years data and comparison with the literature. Am J Trop Med Hyg. 2011; 85(4):703–10. Epub 2011/10/07. 85/4/703 [pii] doi: 10.4269/ajtmh.2011.11-0185 PMID: 21976576; PubMed Central PMCID: PMC3183781.

18. Skull SA, Krause V, Coombs G, Pearman JW, Roberts LA. Investigation of a cluster of Staphylococcus aureus invasive infection in the top end of the Northern Territory. Aust N Z J Med. 1999; 29(1):66–72. Epub 1999/04/14. PMID: 10200815.

19. Jackson SJ, Steer AC, Campbell H. Systematic Review: Estimation of global burden of non-suppurative sequelae of upper respiratory tract infection: rheumatic fever and post-streptococcal glomerulonephritis. Trop Med Int Health. 2011; 16(1):2–11. doi: 10.1111/j.1365-3156.2010.02670.x PMID: 21371205.

20. Tibazarwa KB, Volmink JA, Mayosi BM. Incidence of acute rheumatic fever in the world: a systematic review of population-based studies. Heart. 2008; 94(12):1534–40. doi: 10.1136/hrt.2007.141309 PMID: 18669552.

21. Yamamah GA, Emam HM, Abdelhamid MF, Elsaie ML, Shehata H, Farid T, et al. Epidemiologic study of dermatologic disorders among children in South Sinai, Egypt. Int J Dermatol. 2012; 51(10):1180–5. Epub 2012/07/28. doi: 10.1111/j.1365-4632.2012.05475.x PMID: 22834561.

22. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009; 6(7):e1000097. Epub 2009/07/22. doi: 10.1371/journal.pmed.1000097 PMID: 19621072; PubMed Central PMCID: PMC2707599.

23. Peel MC, Finlayson BL, T.A. M. Updated world map of the Koppen-Geiger climate classification. Hydrology and Earth System Sciences Discussion. 2007; 11(5):1633–44.
24. Chuttani CS, Pal SC. An epidemiological study of streptococcal skin infection. Indian J Med Res. 1971; 59(11):1822–6. PMID: 5143172.
25. Dajani AS, Ferrieri P, Wannamaker L. Endemic superficial pyoderma in children. Arch Dermatol. 1973; 108(4):517–22. Epub 1973/10/01. PMID: 4200825.
26. Nelson KE, Bisno AL, Waytz P, Brunt J, Moses VK, Haque R. The epidemiology and natural history of streptococcal pyoderma: an endemic disease of the rural southern United States. Am J Epidemiol. 1976; 103(3):270–83. Epub 1976/03/01. PMID: 769539.
27. Taplin D, Lansdell L, Allen AM, Rodriguez R, Cortes A. Prevalence of streptococcal pyoderma in relation to climate and hygiene. Lancet. 1973; 1(7802):501–3. Epub 1973/03/10. PMID: 4119945.
28. Allen AM, Taplin D. Skin infections in eastern Panama. Survey of two representative communities. Am J Trop Med Hyg. 1974; 23(5):950–6. Epub 1974/09/01. PMID: 4451236.
29. Koshi G, Benjamin V. Surveillance of streptococcal infections in children in a south Indian community—a pilot survey. Indian J Med Res. 1977; 66(3):379–88. Epub 1977/09/01. PMID: 598909.
30. Masawe AE, Nsanzumuhire H, Mhalu F. Bacterial skin infections in preschool and school children in coastal Tanzania. Arch Dermatol. 1975; 111(10):1312–6. Epub 1975/10/01. PMID: 811175.
31. Lines DR. An Auckland high school health survey. Aust N Z J Med. 1977; 7(2):143–7. Epub 1977/04/01. PMID: 268170.
32. Belcher DW, Afoakwa SN, Osei-Tutu E, Wurapa FK, Osei L. Endemic pyoderma in Ghana: a survey in rural villages. Trans R Soc Trop Med Hyg. 1977; 71(3):204–9. Epub 1977/01/01. PMID: 888167.
33. Masawe AE, Nsanzumuhire H. Scabies and other skin diseases in pre-school children in Ujamaa villages in Tanzania. Trop Geogr Med. 1975; 27(3):288–94. Epub 1975/09/01. PMID: 810929.
34. Bhavsar BS, Mehta RN. Pyoderma—an epidemiological study through school survey in Surat District (South Gujarat). Indian J Public Health. 1985; 29(4):233–7. Epub 1985/10/01. PMID: 3841874.
35. Brahmadathan KN, Koshi G. Epidemiology of streptococcal pyoderma in an orphanage community of a tropical country. J Trop Med Hyg. 1988; 91(6):306–14. Epub 1988/12/01. PMID: 3060623.
36. Porter MJ. Seasonal change and its effect on the prevalence of infectious skin disease in a Gambian village. Trans R Soc Trop Med Hyg. 1980; 74(2):162–8. Epub 1980/01/01. PMID: 7385295.
37. Margolis HS, Lum MK, Bender TR, Elliott SL, Fitzgerald MA, Harpster AP. Acute glomerulonephritis and streptococcal skin lesions in Eskimo children. Am J Dis Child. 1980; 134(7):681–5. Epub 1980/07/01. PMID: 7395831.
38. Patel RB, Udani RH, Khanna SA. Pediatric dermatoses and eradication in slums. Indian J Pediatr. 1982; 49(396):135–9. PMID: 7106919.
39. Sharma RS, Mishra RS, Pal D, Gupta JP, Dutta M, Datta KK. An epidemiological study of scabies in a rural community in India. Ann Trop Med Parasitol. 1984; 78(2):157–64. Epub 1984/04/01. PMID: 6742927.
40. Porter MJ, Mack RW, Chaudhary MA. Pediatric skin disease in Pakistan. A study of three Punjab villages. Int J Dermatol. 1984; 23(9):613–6. Epub 1984/11/01. PMID: 6519873.
41. Bhalla KK. Pattern of skin diseases in a semi-urban community in Delhi area. Indian Journal of Dermatology, Venereology and Leprology. 1984; 50:213–4.
42. Jinadu MK. Pediculosis humanus capitis among primary school children in Ile-Ife, Nigeria. J R Soc Health. 1985; 105(1):25–7. Epub 1985/02/01. PMID: 3919182.
43. Stenderup A SE, Mataika J. Dermatomycosis and other skin diseases in a Fijian village. Fiji Medical Journal. 1983:18–9.
44. Nicolle LE, Postl B, Urias B, Law B, Ling N. Group A streptococcal pharyngeal carriage, pharyngitis, and impetigo in two northern Canadian native communities. Clin Invest Med. 1990; 13(3):99–106. Epub 1990/06/01. PMID: 2194720.
45. Eason RJ, Tasman-Jones T. Resurgent yaws and other skin diseases in the Western Province of the Solomon Islands. P N G Med J. 1985; 28(4):247–50. Epub 1985/12/01. PMID: 2940770.
46. Sharma NK, Garg BK, Goel M. Pattern of Skin Diseases in Urban School Children. Indian Journal of Dermatology, Venereology and Leprology. 1986; 52(6):330–1.
47. Bhatia V. Extent and pattern of paediatric dermatoses in rural areas of central India. Indian J Dermatol Venereol Leprol. 1997; 63(1):22–5. Epub 1997/01/01. ijdvl_1997_63_1_22_4495 [pii]. PMID: 20944252.
48. Harris M, Nako D, Hopkins T, Powell DM, Kenny C, Carroll C, et al. Skin infections in Tanna, Vanuatu in 1989. P N G Med J. 1992; 35(2):137–43. Epub 1992/06/01. PMID: 1509813.

49. Dagnew MB, Erwin G. Epidemiology of common transmissible skin diseases among primary school children in north-west Ethiopia. Trop Geogr Med. 1991; 43(1–2):152–5. Epub 1991/01/01. PMID: 1750105.

50. Nimmo GR, Tinniswood RD, Nuttall N, Baker GM, McDonald B. Group A streptococcal infection in an aboriginal community. Med J Aust. 1992; 157(8):521–2. Epub 1992/10/19. PMID: 1479971.

51. Henderson CA. Skin disease in rural Tanzania. Int J Dermatol. 1996; 35(9):640–2. Epub 1996/09/01. PMID: 8876290.

52. Kottenhahn RK, Heck JE. Prevalence of paediatric skin diseases in rural Honduras. Trop Doct. 1994; 24(2):87–8. Epub 1994/04/01. PMID: 8009634.

53. Figueroa JI, Fuller LC, Abraha A, Hay RJ. The prevalence of skin disease among school children in rural Ethiopia—a preliminary assessment of dermatologic needs. Pediatr Dermatol. 1996; 13(5):378–81. Epub 1996/09/01. PMID: 8893236.

54. Van Buynder PG, Gaggin JA, Martin D, Pugsley D, Mathews JD. Streptococcal infection and renal disease markers in Australian aboriginal children. Med J Aust. 1992; 156(8):537–40. Epub 1992/04/20. PMID: 1565046.

55. Streeton CL, Hanna JN, Messer RD, Merianos A. An epidemic of acute post-streptococcal glomerulonephritis among aboriginal children. J Paediatr Child Health. 1995; 31(3):245–8. Epub 1995/06/01. PMID: 7669388.

56. Mahe A, Prual A, Konate M, Bobin P. Skin diseases of children in Mali: a public health problem. Trans R Soc Trop Med Hyg. 1995; 89(5):467–70. Epub 1995/09/01. PMID: 8560510.

57. Schmeller W. Community health workers reduce skin diseases in East African children. Int J Dermatol. 1998; 37(5):370–7. Epub 1998/06/10. PMID: 9620485.

58. San Sebastian M, Santi S. The health status of rural school children in the Amazon basin of Ecuador. J Trop Pediatr. 1999; 45(6):379–82. Epub 2000/02/10. PMID: 10667014.

59. Carapetis JR, Johnston F, Nadjamerrek J, Kairupan J. Skin sores in Aboriginal children. J Paediatr Child Health. 1995; 31(6):563. Epub 1995/12/01. PMID: 8924314.

60. Carapetis JR, Connors C, Yarmirr D, Krause V, Currie BJ. Success of a scabies control program in an Australian aboriginal community. Pediatr Infect Dis J. 1997; 16(5):494–9. Epub 1997/05/01. PMID: 9154544.

61. Fry AM, Jha HC, Lietman TM, Chaudhary JS, Bhatta RC, Elliott J, et al. Adverse and beneficial secondary effects of mass treatment with azithromycin to eliminate blindness due to trachoma in Nepal. Clin Infect Dis. 2002; 35(4):395–402. Epub 2002/07/30. CID020038 [pii] doi: 10.1086/341414 PMID: 12145722.

62. Shelby-James TM, Leach AJ, Carapetis JR, Currie BJ, Mathews JD. Impact of single dose azithromycin on group A streptococci in the upper respiratory tract and skin of Aboriginal children. Pediatr Infect Dis J. 2002; 21(5):375–80. Epub 2002/08/02. PMID: 12150171.

63. Norazah A, Normaznah Y, Kamel AG, Rohani MY. Streptococcal impetigo among aboriginal children in Malaysia. Southeast Asian J Trop Med Public Health. 1995; 26(4):803–4. Epub 1995/12/01. PMID: 9139400.

64. Lawrence G, Leafasia J, Sheridan J, Hills S, Wate J, Wate C, et al. Control of scabies, skin sores and haematuria in children in the Solomon Islands: another role for ivermectin. Bull World Health Organ. 2005; 83(1):34–42. Epub 2005/02/01. S0042-96862005000100012 [pii] /S0042-96862005000100012. PMID: 15682247; PubMed Central PMCID: PMC2623469.

65. Wu YH, Su HY, Hsieh YJ. Survey of infectious skin diseases and skin infestations among primary school students of Taitung County, eastern Taiwan. J Formos Med Assoc. 2000; 99(2):128–34. Epub 2000/04/19. PMID: 10770027.

66. Norhayati binti Moktar M, Noor Hayati MI, Nor Fariza N, Rohani AK, Halimah AS, Sharom MY, et al. Health status of Orang Asli (aborigine) community in Pos Piah, Sungai Siput, Perak, Malaysia. Southeast Asian J Trop Med Public Health. 1998; 29(1):58–61. Epub 1998/09/18. PMID: 9740269.

67. Steer AC, Adams J, Carlin J, Nolan T, Shann F. Rheumatic heart disease in school children in Samoa. Arch Dis Child. 1999; 81(4):372. Epub 1999/11/30. PMID: 10577365; PubMed Central PMCID: PMC1718099.

68. Schmeller W, Dzikus A. Skin diseases in children in rural Kenya: long-term results of a dermatology project within the primary health care system. Br J Dermatol. 2001; 144(1):118–24. Epub 2001/02/13. bjd3962 [pii]. PMID: 11167692.

69. Wong LC, Amega B, Connors C, Barker R, Dulla ME, Ninnal A, et al. Outcome of an interventional program for scabies in an Indigenous community. Med J Aust. 2001; 175(7):367–70. Epub 2001/11/10. PMID: 11700814.

70. Lehmann D, Tennant MT, Silva DT, McAullay D, Lannigan F, Coates H, et al. Benefits of swimming pools in two remote Aboriginal communities in Western Australia: intervention study. BMJ. 2003; 327 (7412):415–9. Epub 2003/08/23. doi: 10.1136/bmj.327.7412.415 327/7412/415 [pii]. PMID: 12933727; PubMed Central PMCID: PMC181254.

71. Kumar R, Vohra H, Chakraborty A, Sharma YP, Bandhopadhya S, Dhanda V, et al. Epidemiology of group A streptococcal pharyngitis & impetigo: a cross-sectional & follow up study in a rural community of northern India. Indian J Med Res. 2009; 130(6):765–71. Epub 2010/01/22. PMID: 20090140.

72. Fathy H, El-Mongy S, Baker NI, Abdel-Azim Z, El-Gilany A. Prevalence of skin diseases among students with disabilities in Mansoura, Egypt. East Mediterr Health J. 2004; 10(3):416–24. PMID: 16212219.

73. Dogra S, Kumar B. Epidemiology of skin diseases in school children: a study from northern India. Pediatr Dermatol. 2003; 20(6):470–3. Epub 2003/12/04. 20602 [pii]. PMID: 14651562.

74. Inanir I, Sahin MT, Gunduz K, Dinc G, Turel A, Ozturkcan S. Prevalence of skin conditions in primary school children in Turkey: differences based on socioeconomic factors. Pediatr Dermatol. 2002; 19 (4):307–11. PMID: 12220273.

75. Ferie J, Dinkela A, Mbata M, Idindili B, Schmid-Grendelmeier P, Hatz C. Skin disorders among school children in rural Tanzania and an assessment of therapeutic needs. Trop Doct. 2006; 36(4):219–21. Epub 2006/10/13. doi: 10.1258/004947506778604823 PMID: 17034696.

76. Thomas M, Woodfield G, Moses C, Amos G. Soil-transmitted helminth infection, skin infection, anaemia, and growth retardation in schoolchildren of Taveuni Island, Fiji. N Z Med J. 2005; 118(1216): U1492. Epub 2005/06/07. PMID: 15937527.

77. Andrews RM, Kearns T, Connors C, Parker C, Carville K, Currie BJ, et al. A regional initiative to reduce skin infections amongst aboriginal children living in remote communities of the Northern Territory, Australia. PLoS Negl Trop Dis. 2009; 3(11):e554. Epub 2009/11/26. doi: 10.1371/journal.pntd.0000554 PMID: 19936297; PubMed Central PMCID: PMC2775159.

78. Steer AC, Jenney AW, Kado J, Batzloff MR, La Vincente S, Waqatakirewa L, et al. High burden of impetigo and scabies in a tropical country. PLoS Negl Trop Dis. 2009; 3(6):e467. Epub 2009/06/24. doi: 10.1371/journal.pntd.0000467 PMID: 19547749; PubMed Central PMCID: PMC2694270.

79. dos Santos MM, Amaral S, Harmen SP, Joseph HM, Fernandes JL, Counahan ML. The prevalence of common skin infections in four districts in Timor-Leste: a cross sectional survey. BMC Infect Dis. 2010; 10:61. Epub 2010/03/12. 1471-2334-10-61 [pii] doi: 10.1186/1471-2334-10-61 PMID: 20219136; PubMed Central PMCID: PMC2841184.

80. Walker SL, Shah M, Hubbard VG, Pradhan HM, Ghimire M. Skin disease is common in rural Nepal: results of a point prevalence study. Br J Dermatol. 2008; 158(2):334–8. Epub 2007/08/23. BJD8107 [pii] doi: 10.1111/j.1365-2133.2007.08107.x PMID: 17711533.

81. Ogunbiyi AO, Omigbodun Y, Owoaje E. Prevalence of skin disorders in school children in southwest Nigeria. Int J Adolesc Med Health. 2009; 21(2):235–41. Epub 2009/08/26. PMID: 19702203.

82. Komba EV, Mgonda YM. The spectrum of dermatological disorders among primary school children in Dar es Salaam. BMC Public Health. 2010; 10:765. doi: 10.1186/1471-2458-10-765 PMID: 21162714; PubMed Central PMCID: PMC3009652.

83. Koning S, van der Sande R, Verhagen AP, van Suijlekom-Smit LW, Morris AD, Butler CC, et al. Interventions for impetigo. Cochrane Database Syst Rev. 2012; 1:CD003261. Epub 2012/01/20. doi: 10.1002/14651858.CD003261.pub3 PMID: 22258953.

84. Hotez PJ. NTDs V.2.0: "blue marble health"—neglected tropical disease control and elimination in a shifting health policy landscape. PLoS Negl Trop Dis. 2013; 7(11):e2570. Epub 2013/11/28. doi: 10.1371/journal.pntd.0002570 PMID: 24278496; PubMed Central PMCID: PMCPmc3836998.

85. Shallcross LJ, Petersen I, Rosenthal J, Johnson AM, Freemantle N, Hayward AC. Use of primary care data for detecting impetigo trends, United kingdom, 1995–2010. Emerg Infect Dis. 2013; 19(10):1646–8. Epub 2013/09/21. doi: 10.3201/eid1910.130433 PMID: 24047615.

86. Mohammedamin RS, van der Wouden JC, Koning S, van der Linden MW, Schellevis FG, van Suijlekom-Smit LW, et al. Increasing incidence of skin disorders in children? A comparison between 1987 and 2001. BMC Dermatol. 2006; 6:4. Epub 2006/03/23. 1471-5945-6-4 [pii] doi: 10.1186/1471-5945-6-4 PMID: 16551358; PubMed Central PMCID: PMC1435925.

87. Razmjou RG, Willemsen SP, Koning S, Oranje AP, Schellevis F, van der Wouden JC. Determinants of regional differences in the incidence of impetigo. Environ Res. 2009; 109(5):590–3. Epub 2009/04/17. S0013-9351(09)00048-6 [pii] doi: 10.1016/j.envres.2009.03.003 PMID: 19368906.

88. Koning S, Mohammedamin RS, van der Wouden JC, van Suijlekom-Smit LW, Schellevis FG, Thomas S. Impetigo: incidence and treatment in Dutch general practice in 1987 and 2001—results from two national surveys. Br J Dermatol. 2006; 154(2):239–43. Epub 2006/01/26. BJD6766 [pii] doi: 10.1111/j.1365-2133.2005.06766.x PMID: 16433791.

89. Kotloff K, Van Beneden C. Standardization of epidemiologic protocols of surveillance of acute diseases caused by Streptococcus pyogenes: Pharyngitis, Impetigo, and Invasive diseases2008.

90. Tong SY, Varrone L, Chatfield MD, Beaman M, Giffard PM. Progressive increase in community-associated methicillin-resistant Staphylococcus aureus in Indigenous populations in northern Australia from 1993 to 2012. Epidemiol Infect. 2015; 143(7):1519–23. doi: 10.1017/S0950268814002611 PMID: 25302939.