Mitj, O; Marks, M; Konan, DJ; Ayelo, G; Gonzalez-Beiras, C; Boua, B; Houinei, W; Kobara, Y; Tabah, EN; Nsiire, A; Obvala, D; Taleo, F; Djupuri, R; Zaixing, Z; Utzinger, J; Vestergaard, LS; Bassat, Q; Asiedu, K (2015) Global epidemiology of yaws: a systematic review. The Lancet Global health, 3 (6). e324-31. ISSN 2214-109X DOI: https://doi.org/10.1016/S2214-109X(15)00011-X

Downloaded from: http://researchonline.lshtm.ac.uk/2173682/

DOI: 10.1016/S2214-109X(15)00011-X

Usage Guidelines

Please refer to usage guidelines at http://researchonline.lshtm.ac.uk/policies.html or alternatively contact researchonline@lshtm.ac.uk.

Available under license: http://creativecommons.org/licenses/by/2.5/
Global epidemiology of yaws: a systematic review


Summary

Background To achieve yaws eradication, the use of the new WHO strategy of initial mass treatment with azithromycin and surveillance twice a year needs to be extended everywhere the disease occurs. However, the geographic scope of the disease is unknown. We aimed to synthesise published and unpublished work to update the reported number of people with yaws at national and subnational levels and to estimate at-risk populations.

Methods We searched PubMed and WHO databases to identify published data for prevalence of active and latent yaws from Jan 1, 1990, to Dec 31, 2014. We also searched for ongoing or recently completed unpublished studies from the WHO yaws surveillance network. We estimated yaws prevalence (and 95% CIs). We collected yaws incidence data from official national surveillance programmes at the first administrative level from Jan 1, 2010, to Dec 31, 2013, and we used total population data at the second administrative level to estimate the size of at-risk populations.

Findings We identified 103 records, of which 23 published articles describing 27 studies and four unpublished studies met the inclusion criteria. Prevalence of active disease ranged from 0·31% to 14·54% in yaws-endemic areas, and prevalence of latent yaws ranged from 2·45% to 31·05%. During 2010–13, 256 343 yaws cases were reported to WHO from 13 endemic countries, all of which are low-income and middle-income countries. 215 308 (84%) of 256 343 cases reported to WHO were from three countries—Papua New Guinea, Solomon Islands, and Ghana. We estimated that, in 2012, over 89 million people were living in yaws-endemic districts.

Interpretation Papua New Guinea, Solomon Islands, and Ghana should be the focus of initial efforts at implementing the WHO yaws eradication strategy. Community-based mapping and active surveillance must accompany the implementation of yaws eradication activities.

Funding None.

Copyright © 2015 Mitjà et al; licensee Elsevier. This is an Open Access article published under the CC BY 3.0 IGO license, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. In any use of this article, there should be no suggestion that WHO endorses any specific organisation, products or services. The use of the WHO logo is not permitted. This notice should be preserved along with the article’s original URL.

Introduction Yaws is a neglected tropical disease caused by Treponema pallidum subspecies pertenue. This bacterium causes a chronic relapsing non-venerable treponematosis, characterised by highly contagious primary and secondary cutaneous lesions and non-contagious tertiary destructive lesions of the bones. The infection can become latent at any time, with only serological evidence of infection, and relapses can occur for up to 5–10 years. The ratio of clinically apparent to latent cases has been estimated to be as high as 1:6.

In 2012, WHO launched a new initiative to eradicate yaws by 2020. Undertaking surveys and mapping the disease at a community level and immediately treating the entire endemic community with single-dose azithromycin is recommended. The efficacy of this approach has been shown in a study of mass treatment in Papua New Guinea. A key principle inherent in an eradication campaign is the need to intervene everywhere the disease occurs. However, the present geographic extent of yaws is incompletely known, because yaws is not a notifiable disease in many affected countries. To guide the WHO eradication programme, a better knowledge of yaws epidemiology is needed.

Data that can be used to identify the burden of yaws in a community include the prevalence of active infectious yaws (ie, ulcers or papilloma), which shows the intensity of yaws transmission, and the prevalence of latent yaws (ie, seropositivity in healthy individuals), which shows the extent of latent or hidden infection in the community. Clinical surveys for active yaws lesions can be done without any sophisticated laboratory test through interviews and physical examinations, whereas serological tests measuring yaws antibody (treponemal and non-treponemal) are needed for surveys of latent disease. Another important source of information is national routine surveillance data, which allow estimation of the incidence of yaws at country and regional levels; countries report the number of cases at the first administrative level. In this study, we undertook a systematic review of published and unpublished work to improve our understanding of the extent of yaws in the affected populations.
understanding of yaws epidemiology stratified by country, and to provide an update on the number of people with active yaws to estimate at-risk populations in endemic countries.

Methods
Search strategy and selection criteria
We did a systematic review to identify all relevant studies that examined yaws prevalence and incidence. We searched PubMed and WHO databases for (“yaws” OR “treponematosis” AND “prevalence” OR “incidence”) OR (“yaws” AND [each individual previous and current yaws-endemic country]). We consulted the Department for the Control of Neglected Tropical Diseases at WHO regarding previous and present yaws-endemic countries. We limited the search to studies published between Jan 1, 1990, and Dec 31, 2014. This period covers studies published since the last systematic review of yaws epidemiology, which was published in 1992. No language restrictions were set for searches. We hand-searched the reference lists of all recovered documents for additional references. We also searched for ongoing or recently completed but unpublished studies from the WHO yaws surveillance network.

We included studies if they investigated active or latent yaws prevalence or incidence. Studies on active yaws had to meet the surveillance case definition provided by WHO: a person with a history of residence in an affected area who presents with signs of clinically active yaws, consisting of chronic skin ulcers, multiple papillomata, squamous macules, bone or joint lesions, or plantar hyperkeratosis. For latent yaws seroprevalence studies, we deemed serological test rapid plasma reagin titres of at least 1:2 as acceptable evidence of untreated latent infection. Use of the treponemal test (T pallidum haemagglutination assay, T pallidum particle agglutination assay, and the fluorescent treponemal antibody absorption) alone was not sufficient evidence of latent infection because people who have had yaws at any time will test positive for life, even after successful treatment.

Procedures
We calculated the number of people with active disease at the first administrative level (eg, province, region, and prefecture) between Jan 1, 2010, and Dec 31, 2013. First, whenever possible, we obtained the country estimates of yaws cases at the first administrative level from the latest national reporting figures provided to WHO. Second, for countries for which no recent data were available, we contacted yaws control programme managers to request official national routine surveillance data. To estimate the maximum population at risk of yaws, we made calculations at the second administrative level (eg, district, department, and regency). We contacted yaws control programme managers to request data on the proportion of second-administrative level regions that reported yaws cases in 2012. We summed the population living in endemic districts using the 2012 reported populations.

Statistical analysis
For all qualifying studies, we extracted data on study country, sample size, diagnostic test used, number of people with latent or active yaws, and age range. We undertook descriptive analyses of the extracted data. Prevalence estimates are presented for each study with 95% CIs on the basis of binomial distribution. We did not undertake quantitative meta-analyses because the studies we identified did not sample populations at
random and hence the estimates are not representative for a broader geographical area. All statistical analyses were done using Stata version 13.1.

Role of the funding source
There was no funding source for this study. The corresponding author had full access to all the data in the analysis.

<table>
<thead>
<tr>
<th>Year of study</th>
<th>Country</th>
<th>Location</th>
<th>Schoolchildren or community survey</th>
<th>Case ascertainment</th>
<th>Cases (sample size)</th>
<th>Prevalence, % (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Cameroon</td>
<td>Lomié, Zoubalot, Messok</td>
<td>Community</td>
<td>Clinical</td>
<td>97 (1075)</td>
<td>9·02 (7·38–10·90)</td>
</tr>
<tr>
<td>1990</td>
<td>Central African Republic</td>
<td>Lobaye</td>
<td>School children</td>
<td>VDRL and TPHA</td>
<td>12 (213)</td>
<td>5·63 (2·94–9·63)</td>
</tr>
<tr>
<td>2012</td>
<td>Republic of Congo</td>
<td>Bétou, Eybió</td>
<td>Community</td>
<td>RDT</td>
<td>183 (6215)</td>
<td>2·94 (2·54–3·40)</td>
</tr>
<tr>
<td>2004</td>
<td>Côte d’Ivoire</td>
<td>Adopé</td>
<td>Community</td>
<td>RPR</td>
<td>11 (2182)</td>
<td>0·50 (0·25–0·90)</td>
</tr>
<tr>
<td>2005</td>
<td>Democratic Republic of the Congo</td>
<td>Wasolo</td>
<td>Community</td>
<td>RPR and TPHA</td>
<td>56 (1176)</td>
<td>4·76 (3·62–6·14)</td>
</tr>
<tr>
<td>2011</td>
<td>Ghana</td>
<td>Volta Region</td>
<td>School children</td>
<td>ND</td>
<td>3159 (125 364)</td>
<td>2·52 (2·43–2·61)</td>
</tr>
<tr>
<td>1998</td>
<td>Nigéria</td>
<td>Garbida</td>
<td>Community</td>
<td>Clinical</td>
<td>64 (1523)</td>
<td>4·20 (3·25–5·33)</td>
</tr>
<tr>
<td>2012</td>
<td>Benin</td>
<td>Toffo, Zé, Aïlada</td>
<td>School children</td>
<td>RPR</td>
<td>22 (900)</td>
<td>2·44 (1·54–3·68)</td>
</tr>
<tr>
<td>1990</td>
<td>Central African Republic</td>
<td>Lobaye</td>
<td>School children</td>
<td>VDRL and TPHA</td>
<td>42 (213)</td>
<td>19·72 (14·60–25·70)</td>
</tr>
<tr>
<td>1988</td>
<td>Papua New Guinea</td>
<td>Karkar Island</td>
<td>School children</td>
<td>VDRL, FTA-Abs, and TPHA</td>
<td>26 (632)</td>
<td>4·11 (2·70–5·97)</td>
</tr>
<tr>
<td>2001</td>
<td>Papua New Guinea</td>
<td>Port Moreby-NCD</td>
<td>School children</td>
<td>VDRL and TPHA</td>
<td>32 (277)</td>
<td>14·54 (10·22–19·81)</td>
</tr>
<tr>
<td>1989</td>
<td>Vanuatu</td>
<td>Tanna Island</td>
<td>Community</td>
<td>VDRL</td>
<td>464 (20 200)</td>
<td>2·30 (2·09–2·52)</td>
</tr>
<tr>
<td>2001</td>
<td>Vanuatu</td>
<td>Santo Island</td>
<td>Community</td>
<td>VDRL</td>
<td>57 (273)</td>
<td>20·88 (16·21–26·19)</td>
</tr>
<tr>
<td>2008</td>
<td>Vanuatu</td>
<td>Tanna Island</td>
<td>Community</td>
<td>VDRL and TPHA</td>
<td>95 (306)</td>
<td>31·05 (25·90–36·56)</td>
</tr>
<tr>
<td>2010</td>
<td>Wallis and Futuna</td>
<td>Wallis and Futuna</td>
<td>Community</td>
<td>RPR and TPHA</td>
<td>27 (264)</td>
<td>10·23 (6·85–14·53)</td>
</tr>
<tr>
<td>1988</td>
<td>Indonesia</td>
<td>Sumatra</td>
<td>School children</td>
<td>VDRL, TPHA, FTA-Abs, TmpA EIA, and WB</td>
<td>114 (37 000)</td>
<td>0·31 (0·25–0·37)</td>
</tr>
<tr>
<td>2007</td>
<td>Timor-Leste</td>
<td>Oecussi, Bobonaro, Cova Lima, Atauro Island</td>
<td>Community</td>
<td>Clinical</td>
<td>6 (1535)</td>
<td>0·39 (0·14–0·85)</td>
</tr>
<tr>
<td>2005</td>
<td>India</td>
<td>Ten states</td>
<td>School children</td>
<td>RPR and TPHA</td>
<td>0 (3831)</td>
<td>0·00 (0·00–0·00)</td>
</tr>
<tr>
<td>1993</td>
<td>Ecuador</td>
<td>Santiago basin</td>
<td>Community</td>
<td>VDRL and TPHA</td>
<td>16 (1118)</td>
<td>1·43 (0·82–2·21)</td>
</tr>
<tr>
<td>1998</td>
<td>Ecuador</td>
<td>Santiago basin</td>
<td>Community</td>
<td>VDRL and TPHA</td>
<td>0 (1926)</td>
<td>0·00 (0·00–0·19)</td>
</tr>
<tr>
<td>2000</td>
<td>Guyana</td>
<td>Bartica</td>
<td>School children</td>
<td>MHA-TP</td>
<td>52 (1020)</td>
<td>5·10 (3·83–6·63)</td>
</tr>
<tr>
<td>1993</td>
<td>Ecuador</td>
<td>Santiago basin</td>
<td>Community</td>
<td>VDRL and TPHA</td>
<td>52 (1118)</td>
<td>4·74 (3·57–6·16)</td>
</tr>
<tr>
<td>1993</td>
<td>Ecuador</td>
<td>Santiago basin</td>
<td>Community</td>
<td>VDRL and TPHA</td>
<td>68 (1926)</td>
<td>3·53 (2·75–4·45)</td>
</tr>
</tbody>
</table>

FTA-Abs=fluorescent treponemal antibody-absorption. MHA-TP=microhaemagglutination assay–Treponema pallidum. NCD=National Capital District. ND=not documented. RDT=rapid diagnostic test. RPR=rapid plasma reagin. TmpA EIA=enzyme immunoassay with TmpA antigen. TPHA=T pallidum haemagglutination. VDRL=Venereal Disease Research Laboratory. WB=western blot with T pallidum subspecies pallidum as antigen.

Table 1: Characteristics and outcomes of the 24 included studies of active and latent yaws prevalence.
study and had final responsibility for the decision to submit for publication.

**Results**

Our systematic review identified 103 records, from which we identified 23 eligible published articles that described 27 studies that met our inclusion criteria (figure I). We included data from an additional four studies identified from other sources (personal communications with country managers and yaws experts: Tabah EN, personal communication; Boua B, personal communication; Nsiire A, personal communication; Ayelo G, personal communication). The included studies covered 18 countries. Three of these countries—Guyana, Nigeria, and Wallis and Futuna—were classified by WHO as previously endemic countries with unknown status in 2012. Two countries—Ecuador and India—were reported to have eliminated yaws. The remaining 13 countries were classified as known endemic countries in 2012.

Among the 31 studies, 16 reported data on active yaws prevalence (table 1; Tabah EN, personal communication; Boua B, personal communication; Nsiire A, personal communication; Ayelo G, personal communication). Patients with suspected yaws skin lesions were further tested with syphilis serology, except in four studies in which diagnosis was made on the basis of clinical criteria only (Tabah EN, personal communication; Boua B, personal communication). After excluding one study from Ecuador in 1998 in which no clinical cases were detected, prevalence of active yaws lesions ranged from 0.31% in Sumatra, Indonesia, to 14.54% around the city of Port Moresby, Papua New Guinea.

<table>
<thead>
<tr>
<th>Country</th>
<th>Location</th>
<th>Target population</th>
<th>Case ascertainment</th>
<th>New cases (at-risk population)</th>
<th>Incidence, cases per 1000 population-years (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toure et al (2007)</td>
<td>2000 Côte d’Ivoire Nationwide</td>
<td>Children and adults</td>
<td>Clinical</td>
<td>9212 (15 882 758)</td>
<td>0.58 (0.57–0.59)</td>
</tr>
<tr>
<td>Konan et al (2013)</td>
<td>2011 Côte d’Ivoire Nationwide</td>
<td>Children and adults</td>
<td>Clinical</td>
<td>3 343 (22 594 232)</td>
<td>0.15 (0.14–0.15)</td>
</tr>
<tr>
<td>Edorh et al (1994)</td>
<td>1991 Togo Nationwide</td>
<td>School children</td>
<td>Clinical</td>
<td>3 750 (3 787 000)</td>
<td>0.99 (0.96–1.02)</td>
</tr>
<tr>
<td>Neunoka (2005)</td>
<td>1999-2001 Nigeria Enugu Hospital</td>
<td>Children and adults</td>
<td>Clinical</td>
<td>0 (2872)</td>
<td>0.00 (0.00–1.28)</td>
</tr>
<tr>
<td>Western Pacific</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manning and Ogle</td>
<td>2000-01 Papua New Guinea Port Moresby</td>
<td>Children and adults</td>
<td>RPR and TPHA</td>
<td>494 (20 000)</td>
<td>24.70 (22.59–26.95)</td>
</tr>
<tr>
<td>Ministry of Health</td>
<td>2012 Solomon Islands Nationwide</td>
<td>Children and adults</td>
<td>Clinical</td>
<td>12 372 (515 870)</td>
<td>23.98 (21.57–24.40)</td>
</tr>
</tbody>
</table>

RPR=rapid plasma reagin. TPHA=treponema pallidum haemagglutination.

**Table 2: Characteristics and outcomes of health-facility-based active yaws incidence studies**

![Figure 2: Annual absolute number of yaws cases by country](https://www.thelancet.com/lancetgh)
were very highly endemic (ie, >5000 cases within the 4-year reporting period), including the Eastern, Central, Volta, Western, Ashanti, and Brong-Ahafo regions. In Côte d’Ivoire, the regions of Fromager, Sud-Bandama, Haut-Sassandra, and Bas-Sassandra were highly endemic (ie, 1000–4999 cases within the 4-year reporting period). The East region in Cameroon, Likouala department in the Republic of Congo, and Lobaye prefecture in Central African Republic, which are close to one another, were all moderately endemic (ie, 100–999 cases within the 4-year reporting period).

Data from Central African Republic were limited to surveys in two regions and the situation of the rest of the country remains to be investigated.

Figure 4 shows the cumulative number of yaws cases in the WHO western Pacific and southeast Asia regions within the 4-year period, shown by subnational region. In Papua New Guinea, five provinces were very highly endemic (>5000 cases)—New Ireland, West New Britain, East New Britain, Madang, and Autonomous Region of Bougainville provinces—whereas seven provinces were highly endemic (1000–4999 cases). The Western province in Solomon Islands, and Tafea province in Vanuatu were also very highly endemic. In Indonesia, most cases were found in the province of Nusa Tenggara Timur, where 13 084 cases were reported during the 4-year period. No recent surveillance data have been reported from Timor-Leste, but the country is regarded as endemic according to WHO.

Table 3 summarises the estimates of the number of at-risk populations living in districts judged to be endemic (second administrative level; 2012).

**Table 3: Estimates of at-risk populations living in districts judged to be endemic (second administrative level; 2012)**

<table>
<thead>
<tr>
<th>Population of country*</th>
<th>Health districts reporting yaws (n/N [%])</th>
<th>Population living in endemic districts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benin</td>
<td>3,964,619</td>
<td>Minimum 632,488. Total not known</td>
</tr>
<tr>
<td>Cameroon</td>
<td>22,128,420</td>
<td>2,360,944</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>4,600,125</td>
<td>Minimum 434,521. Total not known</td>
</tr>
<tr>
<td>Republic of Congo</td>
<td>4,001,831</td>
<td>Minimum 1,555,513</td>
</tr>
<tr>
<td>Côte d’Ivoire</td>
<td>23,261,022</td>
<td>18,000,000</td>
</tr>
<tr>
<td>Democratic Republic of the Congo</td>
<td>75,507,000</td>
<td>Not known</td>
</tr>
<tr>
<td>Ghana</td>
<td>24,658,823</td>
<td>23,178,000</td>
</tr>
<tr>
<td>Togo</td>
<td>6,191,155</td>
<td>545,729</td>
</tr>
<tr>
<td>Western Pacific</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>7,145,240</td>
<td>6,201,393</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>515,870</td>
<td>515,870</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>234,023</td>
<td>234,023</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>241,692,190</td>
<td>34,588,881</td>
</tr>
<tr>
<td>Timor-Leste</td>
<td>120,1500</td>
<td>120,1500</td>
</tr>
</tbody>
</table>

ND = no data. *From 2012, except Ghana (2010) and Vanuatu and Indonesia (2009). 1 Accurate data were only available for two districts. The prevalence of yaws in the remaining 32 districts was not known. 2 Accurate data were only available for two districts. The prevalence of yaws in the remaining 22 districts was not known. 3 District-level data were not available to allow an accurate calculation of the population at risk.
**Figure 3: Cumulative number of yaws cases by subnational regions in the WHO Africa region**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cameroon</td>
<td>1–99</td>
</tr>
<tr>
<td>Gabon</td>
<td>1–99</td>
</tr>
<tr>
<td>Equatorial Guinea</td>
<td>1–99</td>
</tr>
<tr>
<td>Congo</td>
<td>1–99</td>
</tr>
<tr>
<td>Democratic Republic of the Congo</td>
<td>1–99</td>
</tr>
<tr>
<td>Angola</td>
<td>1–99</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>1–99</td>
</tr>
<tr>
<td>Chad</td>
<td>1–99</td>
</tr>
<tr>
<td>South Sudan</td>
<td>1–99</td>
</tr>
<tr>
<td>Sudan</td>
<td>1–99</td>
</tr>
<tr>
<td>Chad</td>
<td>1–99</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>1–99</td>
</tr>
<tr>
<td>Benin</td>
<td>1–99</td>
</tr>
<tr>
<td>Togo</td>
<td>1–99</td>
</tr>
<tr>
<td>Mali</td>
<td>1–99</td>
</tr>
<tr>
<td>Guinea</td>
<td>1–99</td>
</tr>
<tr>
<td>Guinea (Liberia)</td>
<td>1–99</td>
</tr>
<tr>
<td>Côte d’Ivoire</td>
<td>1–99</td>
</tr>
<tr>
<td>Ghana</td>
<td>1–99</td>
</tr>
<tr>
<td>Cameroon</td>
<td>1–99</td>
</tr>
<tr>
<td>Gabon</td>
<td>1–99</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>1–99</td>
</tr>
<tr>
<td>Democratic Republic of the Congo</td>
<td>1–99</td>
</tr>
<tr>
<td>Angola</td>
<td>1–99</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>1–99</td>
</tr>
<tr>
<td>Chad</td>
<td>1–99</td>
</tr>
<tr>
<td>South Sudan</td>
<td>1–99</td>
</tr>
<tr>
<td>Sudan</td>
<td>1–99</td>
</tr>
<tr>
<td>Chad</td>
<td>1–99</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>1–99</td>
</tr>
<tr>
<td>Benin</td>
<td>1–99</td>
</tr>
<tr>
<td>Togo</td>
<td>1–99</td>
</tr>
<tr>
<td>Mali</td>
<td>1–99</td>
</tr>
<tr>
<td>Guinea</td>
<td>1–99</td>
</tr>
<tr>
<td>Guinea (Liberia)</td>
<td>1–99</td>
</tr>
<tr>
<td>Côte d’Ivoire</td>
<td>1–99</td>
</tr>
<tr>
<td>Ghana</td>
<td>1–99</td>
</tr>
<tr>
<td>Cameroon</td>
<td>1–99</td>
</tr>
<tr>
<td>Gabon</td>
<td>1–99</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>1–99</td>
</tr>
<tr>
<td>Democratic Republic of the Congo</td>
<td>1–99</td>
</tr>
<tr>
<td>Angola</td>
<td>1–99</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>1–99</td>
</tr>
<tr>
<td>Chad</td>
<td>1–99</td>
</tr>
<tr>
<td>South Sudan</td>
<td>1–99</td>
</tr>
<tr>
<td>Sudan</td>
<td>1–99</td>
</tr>
<tr>
<td>Chad</td>
<td>1–99</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>1–99</td>
</tr>
<tr>
<td>Benin</td>
<td>1–99</td>
</tr>
<tr>
<td>Togo</td>
<td>1–99</td>
</tr>
<tr>
<td>Mali</td>
<td>1–99</td>
</tr>
<tr>
<td>Guinea</td>
<td>1–99</td>
</tr>
<tr>
<td>Guinea (Liberia)</td>
<td>1–99</td>
</tr>
<tr>
<td>Côte d’Ivoire</td>
<td>1–99</td>
</tr>
<tr>
<td>Ghana</td>
<td>1–99</td>
</tr>
<tr>
<td>Cameroon</td>
<td>1–99</td>
</tr>
<tr>
<td>Gabon</td>
<td>1–99</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>1–99</td>
</tr>
<tr>
<td>Democratic Republic of the Congo</td>
<td>1–99</td>
</tr>
<tr>
<td>Angola</td>
<td>1–99</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>1–99</td>
</tr>
<tr>
<td>Chad</td>
<td>1–99</td>
</tr>
<tr>
<td>South Sudan</td>
<td>1–99</td>
</tr>
<tr>
<td>Sudan</td>
<td>1–99</td>
</tr>
</tbody>
</table>

**Figure 4: Cumulative number of yaws cases by subnational regions in the WHO southeast Asia and western Pacific regions**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>0</td>
</tr>
<tr>
<td>Myanmar (Burma)</td>
<td>0</td>
</tr>
<tr>
<td>Laos</td>
<td>0</td>
</tr>
<tr>
<td>Vietnam</td>
<td>0</td>
</tr>
<tr>
<td>Cambodia</td>
<td>0</td>
</tr>
<tr>
<td>Thailand</td>
<td>0</td>
</tr>
<tr>
<td>Malaysia</td>
<td>0</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0</td>
</tr>
<tr>
<td>Timor-Leste</td>
<td>0</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>0</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>0</td>
</tr>
<tr>
<td>Australia</td>
<td>0</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>0</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>0</td>
</tr>
</tbody>
</table>

**Previously endemic countries with present status unknown**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>0</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>0</td>
</tr>
</tbody>
</table>

**No data available**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>No data available</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>No data available</td>
</tr>
</tbody>
</table>

**Previously endemic countries with present status unknown**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>0</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0</td>
</tr>
<tr>
<td>Timor-Leste</td>
<td>0</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>0</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>0</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>0</td>
</tr>
</tbody>
</table>

**No data available**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>No data available</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>No data available</td>
</tr>
</tbody>
</table>

**No data available**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>No data available</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>No data available</td>
</tr>
</tbody>
</table>

**Previously endemic countries with present status unknown**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>0</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0</td>
</tr>
<tr>
<td>Timor-Leste</td>
<td>0</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>0</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>0</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>0</td>
</tr>
</tbody>
</table>

**No data available**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>No data available</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>No data available</td>
</tr>
</tbody>
</table>

**No data available**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>No data available</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>No data available</td>
</tr>
</tbody>
</table>

**Previously endemic countries with present status unknown**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>0</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0</td>
</tr>
<tr>
<td>Timor-Leste</td>
<td>0</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>0</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>0</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>0</td>
</tr>
</tbody>
</table>

**No data available**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>No data available</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>No data available</td>
</tr>
</tbody>
</table>

**No data available**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>No data available</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>No data available</td>
</tr>
</tbody>
</table>

**Previously endemic countries with present status unknown**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>0</td>
</tr>
<tr>
<td>Indonesia</td>
<td>0</td>
</tr>
<tr>
<td>Timor-Leste</td>
<td>0</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>0</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>0</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>0</td>
</tr>
</tbody>
</table>

**No data available**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>No data available</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>No data available</td>
</tr>
</tbody>
</table>

**No data available**

<table>
<thead>
<tr>
<th>Country</th>
<th>Absolute number of cases, 2010–13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon Islands</td>
<td>No data available</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>No data available</td>
</tr>
</tbody>
</table>
Discussion

Our data show that about 65,000 yaws cases per year occurred in 13 endemic countries and that in at least 19 countries the incidence of yaws is unknown; thus, there has been limited progress since the last systematic review on yaws epidemiology in 1992 (85,000 yaws cases in 33 endemic countries). In 1953, Hackett estimated there were 50–150 million cases of yaws in 90 countries. A substantial decrease in the prevalence of yaws was brought about by the implementation of mass treatment campaigns and subsequent surveillance activities in the 1950s and 1960s. In many countries, yaws control and surveillance activities stopped after 1970, with a subsequent resurgence of yaws, particularly in parts of west and central Africa and in southeast Asia. Little activity to control the infection has been undertaken since 1990. The scarcity of political will, inadequate funding, and weaknesses in primary health-care systems in affected countries have been the biggest obstacles to the reduction of the burden of yaws in the past two decades.

The methods proposed for assessing yaws burden have not changed substantially since 1953; however, unlike in the previous review by Hackett, who sent a questionnaire to all countries in Africa and carefully analysed the replies, or in the review by Meheus and Antal, who compiled original data from country reports submitted to WHO, we also extracted and synthesised a large amount of data from published studies, and complemented this with data from grey literature.

An important finding of our work is that almost 85% of all infections occurred in three countries—Ghana, Papua New Guinea, and Solomon Islands. The results of individual studies in these countries, which showed high prevalence and incidence rates, are consistent with integrated surveillance data. An overall low number of cases have been reported in national surveillance programmes in other countries in central Africa. However, we have shown that focal indigenous populations (ie, Pygmies) in the Central African Republic, Cameroon, Republic of Congo, and Democratic Republic of the Congo are affected by yaws, with prevalence of active disease ranging between 3% and 11% (Boua B, personal communication). The main risk factor for these groups, as for in other settings in which yaws is highly endemic, is the scarcity of access to health care and poor personal hygiene.

Among the 13 known endemic countries, we estimated that a maximum of about 89 million people were living in yaws-endemic areas. In view of the focal nature of the disease, the size of the population at risk, in particular in Ghana, Côte d'Ivoire, and Indonesia, is uncertain. This global estimate of at-risk individuals would probably be revised down if community-based surveys were used to guide the implementation of mass treatment.

The major limitation of our study is the weakness of routinely reported data. Yaws is not a notifiable disease and the use of national routine surveillance data is likely to result in an underestimation of the real number of cases because yaws predominantly occurs in rural communities with poor access to health facilities, whereas available data are primarily from health facilities. The limited reliability of clinical diagnoses of yaws and the recognition that other organisms can cause clinically similar skin lesions in yaws-endemic countries causes problems for clinical case reporting. The weakness of reported data shows the limitations of the present data and supports the need for surveys as per the WHO strategy.

We did not undertake a meta-analysis for several reasons. First, the studies that we included were primarily implemented in settings where yaws is endemic and no random sampling from a general population was done. Hence, the prevalence estimates are not representative of a given district, province, or an entire country. Second, the number of studies from each WHO region was limited. Third, the inclusion and diagnostic criteria varied markedly between studies, with both children and adults and both clinical and serological definitions of yaws included. These factors make direct comparison of the survey findings difficult.

The results of this systematic review contribute to the epidemiological knowledge needed to guide the preliminary estimation of resources that are necessary for a successful eradication programme. The inability of several countries to undertake more active surveillance and surveys is a major obstacle to achieving the WHO 2020 eradication target. The weaknesses of routinely reported data shows the need to establish a strict and sensitive surveillance system similar to other eradication programmes (eg, for Guinea worm and poliovirus) in a way that enables regionalisation of cases to make the decision about which communities need mass treatment and other control interventions.

Contributors
OM, MM, and KA had the original idea for the study. DJPK, GA, BB, WH, YK, ENT, AN, DO, FT, RD, and ZZ were involved in data gathering and analysis. OM, MM, and CG-B wrote the first draft of the report, with revisions and input from JU, LSV, QB, and KA. All authors contributed to revisions and approved the final version.

Declaration of interests
We declare no competing interests.

Acknowledgments
MM is supported by a Wellcome Trust Clinical Research Fellowship (WT102807). QB has received a fellowship from the programme Miguel Servet of the ISCIII (Plan Nacional de I + D + I 2008–2011, grant number CP11/00269). ZZ, LSV, and KA are staff members of WHO. The authors alone are responsible for the views expressed in this article and they do not necessarily represent the decisions or policies of the institutions they represent. We are grateful to Alexei Mikhailov for image editing.

References