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National tuberculosis prevalence surveys in Africa, 2008–2016: an overview of results and lessons learned

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Abstract

OBJECTIVE AND METHODS—Worldwide, tuberculosis (TB) is the leading cause of death from a single infectious agent. In many countries, national TB prevalence surveys are the only way to reliably measure the burden of TB disease and can also provide other evidence to inform national efforts to improve TB detection and treatment. Our objective was to synthesise the results and lessons learned from national surveys completed in Africa between 2008 and 2016, to complement a previous review for Asia.

RESULTS—Twelve surveys completed in Africa were identified: Ethiopia (2010–2011), Gambia (2011–2013), Ghana (2013), Kenya (2015–2016), Malawi (2013–2014), Nigeria (2012), Rwanda (2012), Sudan (2013–2014), Tanzania (2011–2012), Uganda (2014–2015), Zambia (2013–2014) and Zimbabwe (2014). The eligible population in all surveys was people aged ≥15 years who met residency criteria. In total 588 105 individuals participated, equivalent to 82% (range 57–96%) of those eligible. The prevalence of bacteriologically confirmed pulmonary TB disease in those ≥15 years varied from 119 (95% CI 79–160) per 100 000 population in Rwanda and 638 (95% CI 502–774) per 100 000 population in Zambia. The male:female ratio was 2.0 overall, ranging from 1.2 (Ethiopia) to 4.1 (Uganda). Prevalence per 100 000 population generally increased with age, but the absolute number of cases was usually highest among those aged 35–44 years. Of identified TB cases, 44% (95% CI 40–49) did not report TB symptoms during screening and were only identified as eligible for diagnostic testing due to an abnormal chest X-ray. The overall ratio of prevalence to case notifications was 2.5 (95% CI 1.8–3.2) and was consistently higher for men than women. Many participants who did report TB symptoms had not sought care; those that had were more likely to seek care in a public health facility. HIV prevalence was systematically lower among prevalent cases than officially notified TB patients with an overall ratio of 0.5 (95% CI 0.3–0.7). The two main study limitations were that none of the surveys included people <15 years, and 5 of 12 surveys did not have data on HIV status.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Sustainable Development Goals (SDGs): SDG 3 (good health and well-being)

*African TB Prevalence Survey Group members are listed in Box 1

CONCLUSIONS—National TB prevalence surveys implemented in Africa between 2010 and 2016 have contributed substantial new evidence about the burden of TB disease, its distribution by age and sex, and gaps in TB detection and treatment. Policies and practices to improve access to health services and reduce under-reporting of detected TB cases are needed, especially among men. All surveys provide a valuable baseline for future assessment of trends in TB disease burden.

Keywords

Tuberculosis; prevalence survey; Africa; epidemiology; public health

Introduction

Worldwide in 2018 an estimated 10.0 million people (range, 9.0–11.1 million) developed tuberculosis (TB). It was the leading cause of death from a single infectious agent with an estimated 1.2 million deaths (range, 1.2–1.3 million) among HIV-negative people and 251 000 deaths (range, 223 000–281 000) among HIV-positive people [1]. The African region accounted for 24% of global cases and 32% of deaths. It included countries with some of the severest TB epidemics in the world, especially those with a high prevalence of HIV in the general population.

During the period 2000–2015, global and national efforts to address the TB epidemic had the aim of achieving targets for reductions in the burden of TB disease (incidence, prevalence, mortality) that were set as part of the United Nations Millennium Development Goals (MDGs), WHO's Stop TB Strategy (2006–2015) and the Stop TB Partnership's Global Plan to Stop TB (2006–2015) [2-4]. Three targets were set, one of which was to halve TB prevalence by 2015 compared with 1990 levels.

The most accurate method for measuring prevalence in countries with a high burden of TB disease is a national population-based survey. Between 1990 and 2002, only four countries in Asia (Cambodia, China, Philippines, Republic of Korea) conducted such surveys [5]. As a result, in the mid-2000s, country-level TB prevalence could only be estimated indirectly, and with a high degree of uncertainty, as the product of estimated TB incidence and estimated average duration of disease [6].

In 2006, WHO established a Global Task Force on TB Impact Measurement, with the goal of ensuring that assessment of whether global TB targets set for 2015 were achieved was robust, rigorous and consensus-based [7]. In December 2007, the Task Force defined three strategic areas of work, one of which was national TB prevalence surveys in 22 global focus countries [7]. These were a prioritised subset of 53 countries considered eligible to implement a national survey, 13 in Africa (Figure 1) and nine in Asia [8]. At this time, no national TB prevalence survey had been conducted in Africa since the 1950s, with the sole exception of a survey in Eritrea in 2005 that was limited by the diagnostic methods used to detect cases (sputum smear microscopy only, without culture) [9, 10]. A few African countries had conducted subnational surveys in the 2000s [11-14].

In addition to providing more direct measurements of TB prevalence, repeat surveys, when conducted with intervals of about 10 years or more, are able assess trends to assess progress

towards national and global targets for reductions in the burden of TB disease [15-17]. These surveys can also help national TB programmes (NTPs) to better understand the epidemiology of TB disease (such as its distribution by age and sex), document healthcare-seeking behaviour in the public and private sectors, identify reasons for why TB cases were not previously diagnosed and/or officially reported to national authorities, and develop targeted strategies and interventions to reach more TB cases.

A previous paper has synthesised results and lessons learned from national TB surveys implemented in Asia [5]. Following national and global efforts to design and implement national TB prevalence surveys that started in 2008, our objective was to provide an overview of and describe lessons learned from national surveys that were completed in Africa between 2008 and 2016.

Methods

Identification of surveys

A literature search for the period January 2008 to April 2020, restricted to the English language, was conducted by one author (I.L.) in PubMed (April 2020) using the following search terms: ‘tuberculosis’ and ‘prevalence’ in the title and ‘survey’ as text word. Reference lists of identified studies were also examined. Studies that were not conducted in Africa, not nationally representative, that were about a subset of TB cases (e.g. drug-resistant TB, women only, healthcare workers, miners, prisons), TB infection rather than TB disease and risk factors for TB (e.g. diabetes, smoking) or bovine TB were excluded. Of 162 published papers, only seven were of relevance [18-24]. Grey literature, such as unpublished survey reports produced by national TB programmes, abstracts and presentations from international meetings, and routine progress updates collated by the WHO Global Task Force on TB Impact Measurement on the status of surveys since 2008, was also systematically reviewed [25-36].

We identified a total of 12 national TB prevalence surveys that were implemented between 2008 and 2016: Ethiopia (2010–2011), Gambia (2011–2013), Ghana (2013), Kenya (2015–2016), Malawi (2013–2014), Nigeria (2012), Rwanda (2012), Sudan (2013–2014), Tanzania (2011–2012), Uganda (2014–2015), Zambia (2013–2014) and Zimbabwe (2014). Of these, nine were global focus countries as defined by the WHO Global Task Force on TB Impact Measurement and the others were Gambia, Sudan and Zimbabwe.

All surveys were of the adult population (defined as aged ≥15 years) and focused on bacteriologically confirmed pulmonary TB (as opposed to clinically diagnosed TB), consistent with WHO guidance [8]. All surveys followed WHO recommendations for survey screening methodology, which is based on symptom screening and chest X-ray for all participants [8]. If participants reported symptoms suggestive of TB and/or had an abnormal chest X-ray, they were invited to submit sputum samples for TB diagnosis, using smear microscopy and at least one of culture, Xpert® MTB/RIF (Cepheid, Sunnyvale, CA, USA) or line probe assay (LPA) (Hain LifeScience GmbH, Nehren, Germany). Bacteriological confirmation was based on either a positive culture for *Mycobacterium tuberculosis* (MTB) and/or detection by Xpert MTB/RIF or LPA. All national and subpopulation prevalence

estimates (such as by age group and sex) were adjusted for sampling design effects, accounting for sampling probabilities, and using multiple imputation of missing data and inverse probability weighting to represent all eligible individuals including those who did not participate, according to previously published methods [37].

Identified surveys were assessed with a 10-criteria tool developed to assess the risk of bias in prevalence surveys [38]. The likelihood of non-response bias for the Nigerian survey was potentially high, and the case definition originally used in the Tanzanian survey was re-defined for this paper; all other surveys were assessed to have low risk of bias for all criteria (Table S1).

Data extraction and analysis

Key results to be identified, analysed and reported were based on a previous publication about national TB prevalence surveys in Asia [5].

Key characteristics of survey design and implementation were summarised for the 12 surveys. These included residency criteria; sampling design including the number of clusters, stratification and planned sample size; screening and diagnostic tests used; and duration of field operations.

Results from each survey were then summarised for the following process and outcome indicators: size of the eligible population; number of people screened and associated participation rate; number of people who screened positive; absolute number of smear-positive and bacteriologically confirmed pulmonary TB cases detected in the survey, both overall and disaggregated by sex and age group; prevalence of smear-positive and bacteriologically confirmed pulmonary TB per 100 000 population aged ≥15 years, both overall and disaggregated by sex and age group, and associated sex (male to female) ratio; the coefficient of variation (k) of the cluster-specific TB prevalence; pre- and post-survey estimates of prevalence (all forms, all ages); proportion of bacteriologically confirmed pulmonary TB cases who did not report TB symptoms; the ratio of prevalent to notified cases (P:N) per 100 000 population; number of bacteriologically confirmed pulmonary TB cases with known HIV status; HIV prevalence in TB survey cases compared with notified TB cases, expressed as a ratio; number of participants with at least one smear-positive sample who were not bacteriologically confirmed for MTB by culture, Xpert MTB/RIF or LPA; and type of healthcare facility used by participants who reported symptoms or were on TB treatment at the time of the survey.

These variables were obtained from survey reports, published papers and available data sets (Text S1) provided by lead survey investigators. The other two sources were the WHO Global TB database for notification data and prevalence of HIV among notified TB cases; [39] and the United Nations Population Division for estimates of the total population in the main year of the survey [40], which were used for calculation of rates per 100 000 population.

For Tanzania, it was only possible to verify the number of smear-positive cases (and not the number of culture-positive, smear-negative cases). Therefore, the prevalence of

bacteriologically confirmed TB was estimated using the combined value for the ratio of bacteriologically confirmed to smear-positive TB in the neighbouring countries of Ethiopia, Malawi, Rwanda, Uganda and Zambia (ratio = 2.16:1 (standard deviation [SD]: 0.46)).

Meta-analyses were conducted for four indicators: sex ratio of bacteriologically confirmed prevalence per 100 000 population; proportion of bacteriologically confirmed TB cases that screened negative for symptoms; the ratio of prevalent to notified cases (P:N) per 100 000 population; and HIV prevalence in TB survey cases compared with notified TB cases, expressed as a ratio. These four indicators were summarised using a random-effects model. The *metafor* package in R (v3.5.2, R Foundation for Statistical Computing, Vienna, Austria) was used to estimate all ratios [41], and heterogeneity was assessed using the I^2 statistic [42]. A meta-analysis was not conducted for prevalence estimates because the countries were not considered representative of TB disease burden for the entire African region.

Ethical approval

All 12 prevalence surveys were approved by their respective national ethics committees. Protocols were also reviewed and approved by the WHO Global Task Force on TB Impact Measurement prior to implementation.

Results

Main survey characteristics

The main characteristics of the 12 surveys are shown in Table 1. All surveys were of adults aged ≥15 years who met residency criteria (typically living in the household for a period ranging from the last 2 weeks to the last month). The median duration of field operations was approximately 11 months (range 9–14). The number of clusters per survey ranged from 62 in Tanzania to 109 in Sudan. The sample size was usually in the range 40 000–60 000, with larger surveys in Ghana, Kenya and Sudan. Most surveys used stratified sampling to increase the precision and representativeness of the overall country estimate of TB prevalence; urban and rural were the most common strata defined by the national bureaus of statistics.

All survey participants were screened using both direct chest X-ray (CXR) and an interview about TB symptoms. The main symptom screening criterion was a cough for two or more weeks, but some countries had a broader definition. Four countries used conventional CXR technologies, and eight used digital systems. Individuals with findings suggestive of TB on CXR and/or symptoms suggestive of TB were eligible for sputum collection and examination. In eight countries, participants who declined or were exempt from having a CXR were also eligible for sputum submission (Table 1).

Sputum samples were tested for the presence of acid-fast bacilli (AFB) using smear microscopy, as well as by culture and/or Xpert MTB/RIF. Most countries examined direct smears (at least two per sputum-eligible participant) using Ziehl-Neelsen or fluorescent microscopy, apart from Ghana and Malawi, which used concentrated smears. Most countries conducted two culture examinations (performed on Löwenstein-Jensen, Ogawa solid media, or BACTEC Mycobacterial Growth Indicator Tube (MGIT) system (Becton Dickinson,

Franklin Lakes, NJ, USA)) for each sputum-eligible participant, except for Ethiopia and Tanzania, which only performed one culture test per participant [43, 44].

Testing with Xpert MTB/RIF was typically restricted to participants with sputum smear-positive results or contaminated cultures: this was the case for Ghana, Malawi, Uganda, Zambia and Zimbabwe. Kenya was the first country in Africa to test all submitted sputum samples from positively screened survey participants with Xpert MTB/RIF in addition to culture and smear microscopy. In Tanzania, DNA extracted from smear-positive slides was also tested using Xpert MTB/RIF in the supranational TB reference laboratory in Antwerp, Belgium, due to challenges with culture testing in this survey [45]. Smear-positive samples from Sudan were tested using LPA instead of Xpert MTB/RIF for diagnostic confirmation.

Size of eligible population, survey participation and screening outcomes

For each survey, the number of individuals eligible to participate, the participation rate and screening outcomes are shown in Table 2. The number of eligible individuals who were invited to participate was similar to the planned sample size for most countries. In Nigeria and Tanzania, 59% and 40% more people were invited to participate than planned, respectively, but the total number of participants was similar to the planned sample size.

In 12 surveys, 588 105 individuals participated, equivalent to 82% (range 57–96%) of those eligible. The median number of participants enrolled in a survey was 49 000 (range 31 579–83 079). The proportion of the eligible survey population that agreed to participate was ≥80% in eight surveys. The participation rate was lowest in Nigeria (57%) and 77–78% in Gambia, Tanzania and Zimbabwe. In general, participation was higher among females and older age groups than males and younger age groups (Figure 2).

Overall, the proportion of participants who had a positive TB symptom screen and/or an abnormal CXR was approximately 14% (range 11–21%) in the 12 countries. The proportion of participants that screened positive via CXR (i.e. CXR only, or symptom and CXR; median 8%, range 3.5–14%) was higher than the proportion of participants screened positive via symptoms (i.e. symptom only, or symptom and CXR; median 6.5%, range 3.2–9.7%) especially where the standard criteria of cough for two or more weeks were used. However, countries that used broader symptom screening criteria (i.e. Gambia, Malawi, Tanzania and Zambia) had greater yields from symptom screening than CXR. In Ghana, Sudan and Zimbabwe, more than 3% of participants were eligible to submit sputum samples based on exemption from (or declining) CXR examination.

Prevalence per 100 000 population

Prevalence results overall, and the proportion of bacteriologically confirmed cases that were smear-positive, are shown in Table 3. The prevalence of smear-positive pulmonary TB per 100 000 population aged ≥15 years varied from 74 (95% CI 48–99) in Rwanda to 319 (95% CI 232–406) in Zambia. The prevalence of bacteriologically confirmed pulmonary TB per 100 000 population aged ≥15 years ranged from 119 (95% CI 79–160) in Rwanda to 638 (95% CI 502–774) in Zambia. The proportion of bacteriologically confirmed cases who were smear-positive varied from 21% in Zimbabwe to 74% in Nigeria. Smear-negative,

bacteriologically confirmed cases were more common than smear-positive, bacteriologically confirmed cases in all countries except Nigeria, Rwanda, Sudan and Zambia.

Estimates of TB prevalence for all ages and all forms of TB (i.e. including children and extrapulmonary TB) published by WHO before the survey compared with updated estimates based on survey findings are shown in Figure 3. Post-survey, TB prevalence estimates were higher in Ghana, Kenya, Malawi, Nigeria, Tanzania, Uganda and Zambia, but lower in the other five countries. The post-survey range of uncertainty was outside the pre-survey bounds for Ghana, Gambia and Malawi. With the exception of Tanzania, post-survey estimates were much more precise (i.e. narrow uncertainty intervals).

Sex and age distribution of TB cases

Overall, men were more likely to have TB than women (sex ratio 2.0; 95% C.I. 1.6–2.5) (Figure 4). The male:female sex ratio of bacteriologically confirmed TB prevalence ranged from 1.2 in Ethiopia to 4.1 in Uganda.

The age distribution of cases varied considerably (Figure 5. In Ghana and Rwanda, the prevalence per 100 000 population increased steadily with age; in Malawi, Tanzania and Zimbabwe there was a general increase up to the age group 35–44 years, followed by a decrease in the next age group and then an increase to a peak in those aged ≥65 years; in other countries, there was an increase to a peak in young or middle-aged adults, with similar levels in older age groups. The absolute number of TB cases was highest among participants aged 35–44 years (Table S2) in most countries; the exceptions were Ghana, Malawi and Tanzania, where the absolute number of cases was highest among those aged ≥65 years.

Proportion of TB cases that screened negative for TB symptoms or had no symptoms

The mean proportion of bacteriologically confirmed TB cases that were eligible for sputum examination based on CXR results alone (i.e. they did not report any TB screening symptoms) was 44% (range 30–60%) (Figure 6 and Table S3). Of note, Malawi, Gambia, Tanzania, Zambia and Zimbabwe had more sensitive screening criteria than the other countries, which typically used a cough of two or more weeks and/or haemoptysis as screening criteria (Table 1). There was no difference in the proportion of symptom screening negative bacteriologically confirmed TB cases by HIV status in Kenya, Malawi and Uganda, where case-based data on HIV status were available.

Ratio of prevalence to notification

The mean prevalence to notification (P:N) ratio among smear-positive TB cases was 2.5, ranging from 0.62 in Gambia to 5.8 in Nigeria (Figure 7). Apart from Ethiopia, Gambia and Rwanda, all surveys had a P:N ratio of at least 2. Across all surveys, the P:N ratio was higher in men than women; the most noticeable difference was in Nigeria, where the P:N ratio was 7.3 for men and 4.6 for women (Figure S1a,b).

HIV status of participants and bacteriologically confirmed TB cases

HIV testing results from the survey, and/or the self-reported or previously documented HIV status of survey participants, were available for Kenya, Malawi, Rwanda, Tanzania, Uganda, Zambia and Zimbabwe.

HIV testing during field operations was only conducted in four countries: Zambia offered HIV testing (Alere Determine™ HIV-1/2 then Uni-Gold™ HIV) to all participants, whereas Rwanda (Alere Determine™ HIV-1/2 then Uni-Gold™ HIV), Tanzania (SD BIOLINE HIV-1/2 then Alere Determine™ HIV-1/2, changing to Alere Determine™ HIV-1/2 then Uni-Gold™ HIV) and Uganda (Alere Determine™ HIV-1/2, HIV 1/2 STAT-PAK® and Uni-Gold™ HIV) offered to test only those who were eligible for sputum examination. In Zambia, among participants who were tested for HIV infection, 6.7% (2062/30 584) were HIV-positive. In Rwanda, Uganda and Tanzania, of those eligible for sputum examination and tested for HIV infection, 4.9% (218/4445), 9.6% (422/4386) and 5.0% (318/6302) were HIV-positive, respectively.

In Malawi, all participants were asked if they had ever been tested for HIV and were invited to disclose their status; verbal acknowledgement of HIV status was known in 19 703 (62.4%) participants and 1840 (9.3%) of them reported to be HIV-positive. In Kenya and Zimbabwe, the HIV status of TB cases was obtained from records that were routinely linked as part of HIV treatment and care programmes; 17% (41/245) and 51% (42/83) of TB cases were HIV-positive, respectively.

Data on HIV status were available (tested or self-reported) for 51–100% of bacteriologically confirmed TB cases, and of these, the median HIV-positive proportion was 27%, ranging from 3% in Rwanda to 51% in Zimbabwe. For these seven surveys, the proportion of prevalent TB cases co-infected with HIV was found to be systematically lower than the proportion of newly notified TB cases with HIV. The HIV prevalence ratio (i.e. TB/HIV prevalent survey cases over notified TB cases with HIV for the main year of the survey) was 0.47 (95% CI 0.34–0.65) (Figure 8).

Smear-positive results not classified as TB

A positive sputum smear microscopy result was found to be poorly predictive of TB in several surveys. A large proportion of participants with smear-positive results were not confirmed to have TB by Xpert MTB/RIF (or LPA) or culture (Table 4). A high proportion of smear-positive samples tested in Ghana (70%), Malawi (62%), Zambia (62%) and Zimbabwe (89%) were negative and thus not bacteriologically confirmed as MTB.

Health care-seeking behaviour of participants

All surveys collected data on healthcare-seeking behaviour related to participants who reported symptoms (Table 5). Among participants who reported symptoms and had sought care, the majority (median 82%, range 70–93%) initially sought care in a public health facility. Outside the public sector, private health facilities were more commonly visited in Ethiopia and Malawi, whereas pharmacy visits were more common in Ghana, Nigeria and Uganda. In Rwanda, Tanzania and Zambia, symptomatic participants who sought care were

asked which diagnostic tests were performed: 48%, 37% and 12% had sputum collected for examination, respectively, and 28% and 14% had a CXR performed in Tanzania and Zambia [46-48]. A large proportion (median 46%, 13–68%) of symptomatic participants had not sought care prior to the survey, and the main reasons given included their perception that their symptoms were not serious enough and, to a lesser extent, the costs related to seeking care.

Nine surveys collected data about the current place of treatment for participants who self-reported to be on TB treatment (Table S4). The proportion of participants on TB treatment at the time of the survey varied from 0.04% to 0.25%. The majority of those on treatment at the time of the survey were being treated in the public sector, although place of treatment was unknown for at least a quarter of those on treatment in Kenya, Sudan and Zambia. Overall, the proportion of TB patients on treatment in the private sector at the time of the survey was low except for Ghana (10%) and Nigeria (6.1%).

Discussion

During 2008–2016, 12 nationally representative TB prevalence surveys were completed in Africa in countries that collectively accounted for 48% of the regional burden of TB [39]. The prevalence of bacteriologically confirmed pulmonary TB among individuals aged ≥15 years ranged from 119 per 100 000 population in Rwanda to 638 per 100 000 population in Zambia. Surveys conducted in Ghana, Kenya, Malawi, Nigeria, Tanzania, Uganda and Zambia found a higher burden of TB disease than previously estimated, whereas it was similar to or lower than pre-survey estimates in Ethiopia, Gambia, Rwanda, Sudan and Zimbabwe. Apart from Gambia, Ghana and Malawi, estimates were within the uncertainty bounds of previous estimates, and with the exception of Tanzania, all post-survey estimates were more precise (i.e. narrower uncertainty bounds).

Consistent with routine notification data and with the results of prevalence surveys from Asia, the prevalence of TB was higher in men than women across all African surveys [5]. Men of 35 years and above accounted for a significant proportion of all prevalent cases in Africa, highlighting the need to target this group for intervention. The highest absolute number of prevalent TB cases and the prevalence per 100 000 population were found in older age groups in Ghana, Malawi, Rwanda and Tanzania showing that the epidemic is a progressively ageing one in these countries, similar to previous findings from surveys in Asia [5]. The age distribution of cases also indicates that transmission is declining in these four countries, since more cases in older people suggest an increasing contribution of reactivation of past (rather than recent) TB infection to total TB cases. However, in most other African countries, prevalence plateaued across the middle to older age groups and peaked in those aged 25–54 years, suggesting transmission in the community is still widespread despite many years of implementing first the DOTS and then Stop TB strategies recommended by WHO [4, 49]. In Malawi, Zambia and Zimbabwe, where more than 50% of routinely notified TB patients are co-infected with HIV, the significant peaking of TB prevalence in younger age groups likely reflects the effect of the HIV epidemic in these communities [50].

The acceptance of reporting HIV status and/or testing was high in countries that reported data; presumably, because HIV testing is an acceptable and widespread part of routine health care. Five surveys did not have data on HIV status (this included Ethiopia and Nigeria which are high TB/HIV burden countries). Nonetheless, the pattern was still quite striking: HIV infection among TB cases identified in these surveys was consistently lower than in routinely notified TB cases. This finding probably reflects three factors: (i) the duration of illness with TB among people living with HIV is shortened by higher case fatality ratios, compared with people with TB who are HIV-negative; (ii) the severity of disease among people with TB who are HIV-positive may prompt them to seek health care more rapidly; (iii) HIV programmes are improving the detection of TB/HIV co-infected individuals relative to those who are HIV-negative. Scaling-up collaborative TB/HIV activities and joint TB and HIV programming can promote synergies between TB and HIV programmes [51]. At the same time, it is important to give attention to targeted interventions and approaches for people with TB who are HIV-negative, especially given that the overall burden of TB in this population is much higher.

All surveys revealed limitations in the TB screening and diagnostic algorithms used in routine health care settings. A large proportion of survey TB cases were not identified by symptom screening, even when the range of symptoms considered was expanded beyond those typically used in routine healthcare settings (e.g. cough for ≥2 weeks, haemoptysis, weight loss, fever, night sweats). Approximately one-third of smear-positive and half of bacteriologically confirmed TB cases were symptom-screen negative and were detected via CXR only.

CXR is not a routine part of TB diagnosis in most African countries, and therefore, survey findings indicate that many people with TB remain in the community for a long time unless their disease progresses or it is opportunistically detected while accessing the health system for other reasons (e.g. during an examination for another illness, antenatal services, HIV care). Expanding the use of CXR may improve case finding, but at the cost of increased diagnostic testing [52].

Many survey TB cases (and participants) who reported symptoms suggestive of TB did seek health care for their symptoms, but were not initially diagnosed. This indicates a need to strengthen health systems by improving access to TB diagnostic services (especially in the healthcare facilities where the population is most likely to initially seek care) and raising awareness of TB symptoms among healthcare workers. The high proportion of participants who reported symptoms but had not gone to a health facility also suggests geographical and financial barriers to accessing care that need to be addressed. In addition, as previously observed in the context of national TB prevalence surveys in Asia, it is possible that people with TB in older age groups tolerate their symptoms for longer if they already have a chronic health condition [5].

Although a sizeable proportion of symptomatic participants and cases did not seek care, most of those who did sought care in the public sector. Unlike in Asia, the private sector currently plays a small role in TB case management in Africa [5]. However, some health providers, such as pharmacies (which are often the first point of contact), could play an

important role in healthcare referrals especially in Ghana, Nigeria and Uganda [53, 54]. Engaging with and raising awareness in the community in general and among all healthcare providers could help to increase case detection in Africa.

Smear microscopy remains the backbone of TB diagnosis in many African countries. In some surveys, close to two-thirds of smear-positive samples did not have MTB detected by culture or Xpert MTB/RIF (or LPA); of these, most were culture or Xpert-negative, and non-tuberculous mycobacteria (NTM) was not uncommon [55]. The lower positive predictive value of smear microscopy in the context of prevalence surveys highlights its limitations as a diagnostic tool in the context of active case finding in the general population.

The P:N ratio is an approximate indicator (expressed in years) of case detection by the NTP [56]. The higher the ratio, the longer the time taken for a prevalent case to be notified to the NTP. Some cases may exit the pool of prevalent cases without being notified, for example because they self-cure or die, or because they are detected and treated by providers not linked to official reporting systems. The overall P:N ratio for smear-positive TB was greater than two, highlighting major gaps in detection and/or official reporting (to national authorities) of TB cases. These ratios were systematically higher in men, suggesting that women may be accessing available diagnostic and treatment services more effectively [57]. Strategies to reduce this gender gap, informed by operational research to understand the reasons for it in different contexts, are required. More positively, it is likely that these gaps could be reduced by improving reporting mechanisms. Inventory studies can be used to assess the degree to which detected TB cases are under-reported [58]. The ratio of <1 in Gambia may reflect a high level of case detection and a relatively short duration of disease prior to diagnosis (if the duration of disease is less than one year and notifications are a good proxy for incidence, the P.N ratio will be less than one).

The survey data have several limitations: (i) children <15 years were excluded from all surveys as per WHO recommendations [59], meaning that extrapolation of estimates to all ages relied on country-specific child TB surveillance or research data; (ii) low culture confirmation among smear-positive cases (<80%) in a few countries (notably Ethiopia which only used one culture, plus Gambia, Nigeria and Rwanda) suggests there was some under-diagnosis of smear-negative TB cases and that reported overall prevalence estimates may be conservative; (iii) although all surveys followed the essential elements of the screening and diagnostic algorithm recommended by WHO, there was some variation in the symptoms used for screening and in the number and specific type of diagnostic tests; (iv) while estimates of prevalence were adjusted for non-participation in the analysis, it was necessary to assume that those who did not participate were the same as those that did for a given age and sex; (v) none of the surveys covered key affected populations such as migrants and prisoners; and (vi) standardisation of healthcare-seeking behaviour data was insufficient and it was necessary to recategorize healthcare facilities to make the data as consistent and comparable as possible. More generally, it was not possible to identify the exact reasons for some of the differences in survey results among countries (e.g. the absolute level of TB prevalence, sex ratio, P:N ratio). Plausible explanations include the past history of efforts in TB control, the overall performance, governance and financing of the health system, and broader determinants of TB (e.g. levels of undernutrition, smoking, HIV, diabetes, poverty,

social protection, income per capita). Quantifying and disentangling the relative contribution of these factors is, however, difficult to do and was not the primary purpose of our study. Further cross-country analyses as well as new quantitative and qualitative research at country level are necessary to further unpick the differences observed among surveys.

A study strength is that it is the largest analysis of national TB prevalence survey data from Africa known to date and provides important knowledge about the epidemiology of TB in the region. It also highlights the benefits of these surveys beyond the primary objective of estimating prevalence. Results from surveys completed in 2019–2020 in four high TB/HIV burden countries of southern Africa (Eswatini, Lesotho, Mozambique and South Africa) will provide further evidence in the near future.

Besides the survey results themselves and their implications for policy for programmatic action, the experience of implementing the first wave of surveys in Africa for more than 50 years generated important lessons for future surveys in terms of both successes and challenges. Successes included use of prevalence survey data to inform national strategic plans and associated goals, targets, advocacy and resource mobilisation; building capacity within NTPs and survey implementing agencies, for example, in terms of staff skills and availability of equipment that could be used after the survey was finished; and fostering country–country collaboration. The major challenges were data management, achieving high participation especially in urban areas, ensuring the quality of culture testing, and delays in reporting and disseminating results (Tables S5 and S6).

In 2016, the MDGs (2000–2015) and WHO's Stop TB Strategy (2006–2015) were succeeded by a new era of Sustainable Development Goals (2016–2030) and the WHO End TB Strategy, which include the overall goal of ending the TB epidemic and targets to reduce incidence (per 100 000 population) and the number of TB deaths by 80% and 90%, respectively, by 2030, compared with 2015 [60, 61]. The prevalence surveys completed in Africa between 2008 and 2016 show the scale of the diagnostic and treatment gaps that need to be closed to make progress towards these targets, and the nature of the interventions required. These include policies and practices to find new TB cases by improving access to health and diagnostic services, and reduce under-reporting of detected TB cases, especially among men. The surveys also provide important national baselines, which were not previously available in any African country, for monitoring of progress in reducing the burden of TB disease in the next decade.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

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2000–2013 and who was the surveillance officer within EMRO's TB unit 2007–2013. She supported the national TB prevalence surveys of Pakistan and Sudan.

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Box 1

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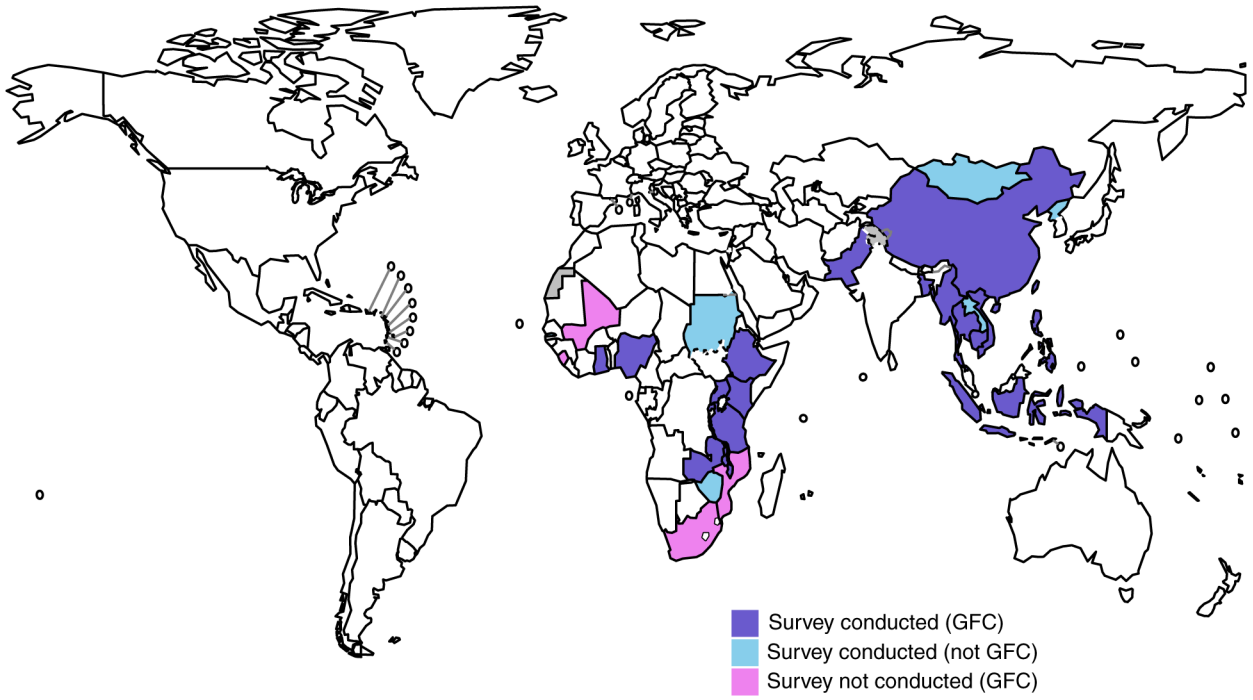

Figure 1.

[a] The WHO Global Task Force on TB impact Measurement selected 22 global focus countries (GFC) to undertake a national TB prevalence survey during the period 2008- 2015. Of the 13 GFCs in Africa, nine completed a survey (violet) between 2010-2016. The other four GFCs that did not conduct a survey during 2010-2016 were Mali, Mozambique, Sierra Leone and South Africa (pink). DPR Korea, Gambia, Lao PDR, Mongolia, Sudan and Zimbabwe completed a survey during the period 2010-2016 but were not GFCs (skyblue). Grey, not applicable.

Countries that completed a national TB prevalence survey, 2008–2016[a].

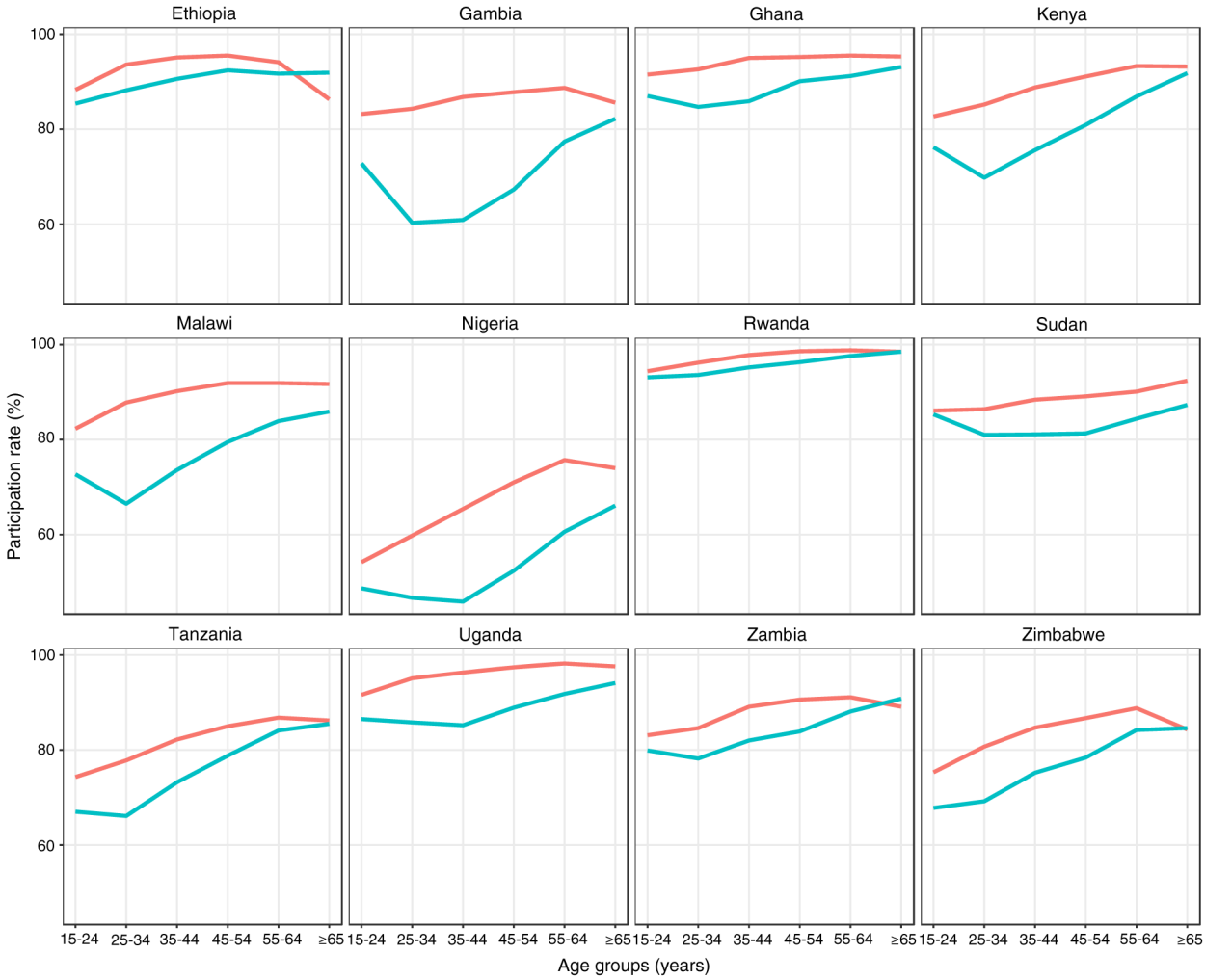

Figure 2.

Participation rate by sex and age group in national TB prevalence surveys implemented in Africa, 2008–2016. Female (red), Male (green).

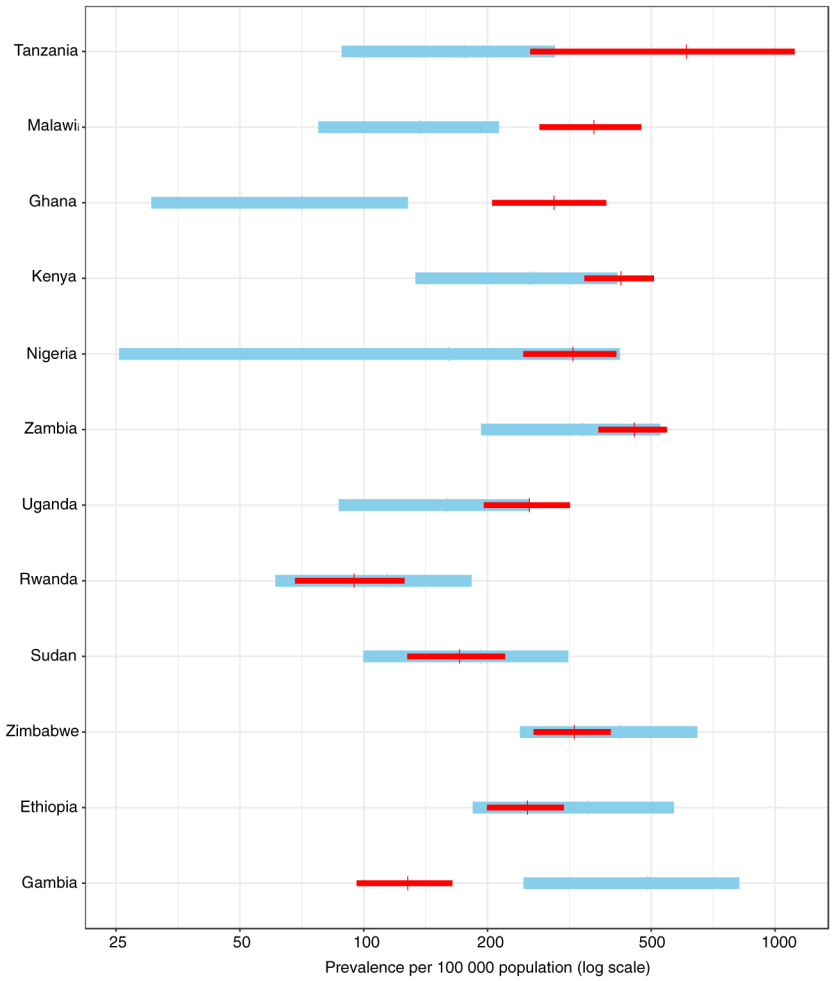

Figure 3.

[a] Countries are listed in decreasing order according to the before-after difference. The vertical line denotes the best estimate of prevalence and its range (depicted as a 95% uncertainty interval). These prevalence estimates were indirectly derived from estimates of incidence and the duration of disease previously published by WHO, adjusted to the year of the prevalence survey using previously published trends in incidence.

Estimates of TB prevalence (all ages, all forms of TB) for 12 surveys, before (in blue) and after (in red) results from national TB prevalence surveys implemented in Africa, 2008–2016[a].

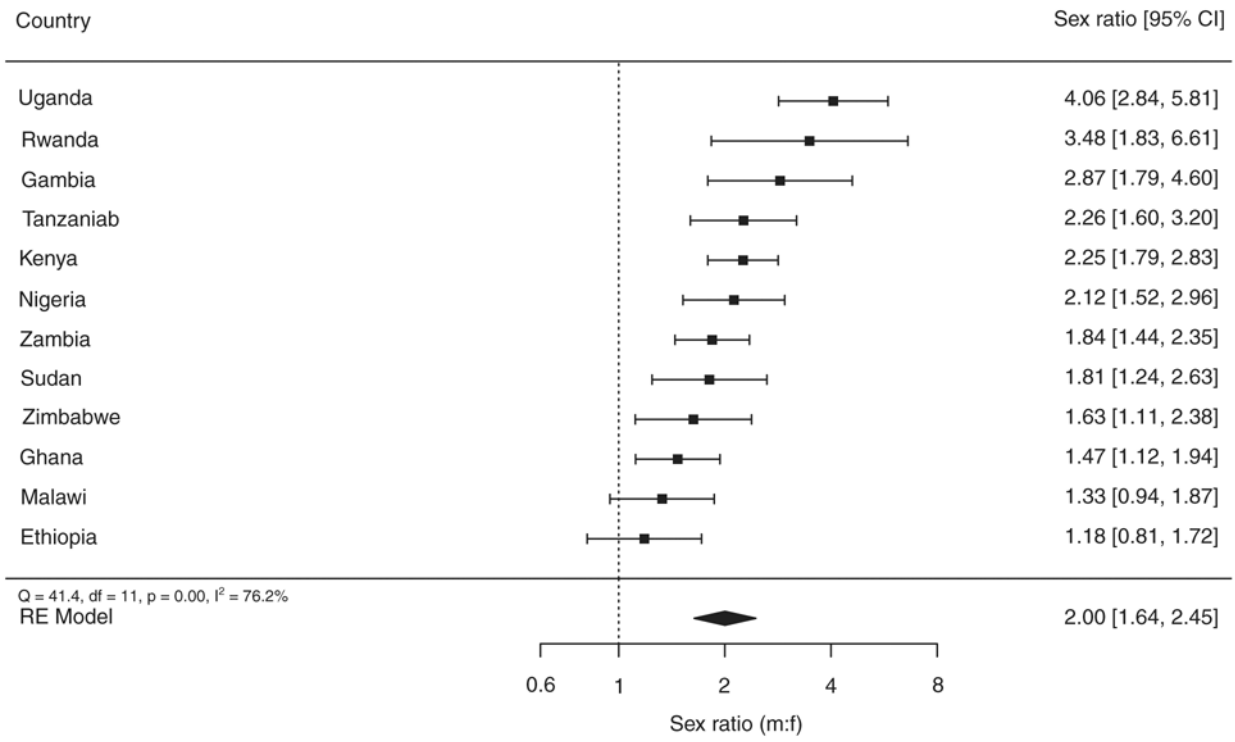

Figure 4.

[a] The size of the best estimate (black square) is proportional to the model's weights (inverse variance).

[b] The sex ratio of smear-positive TB prevalence is shown for Tanzania.

The sex ratio (male to female) of bacteriologicallyconfirmed pulmonary TB cases detected in national TB prevalence surveys implemented in Africa, 2008–2016[a].

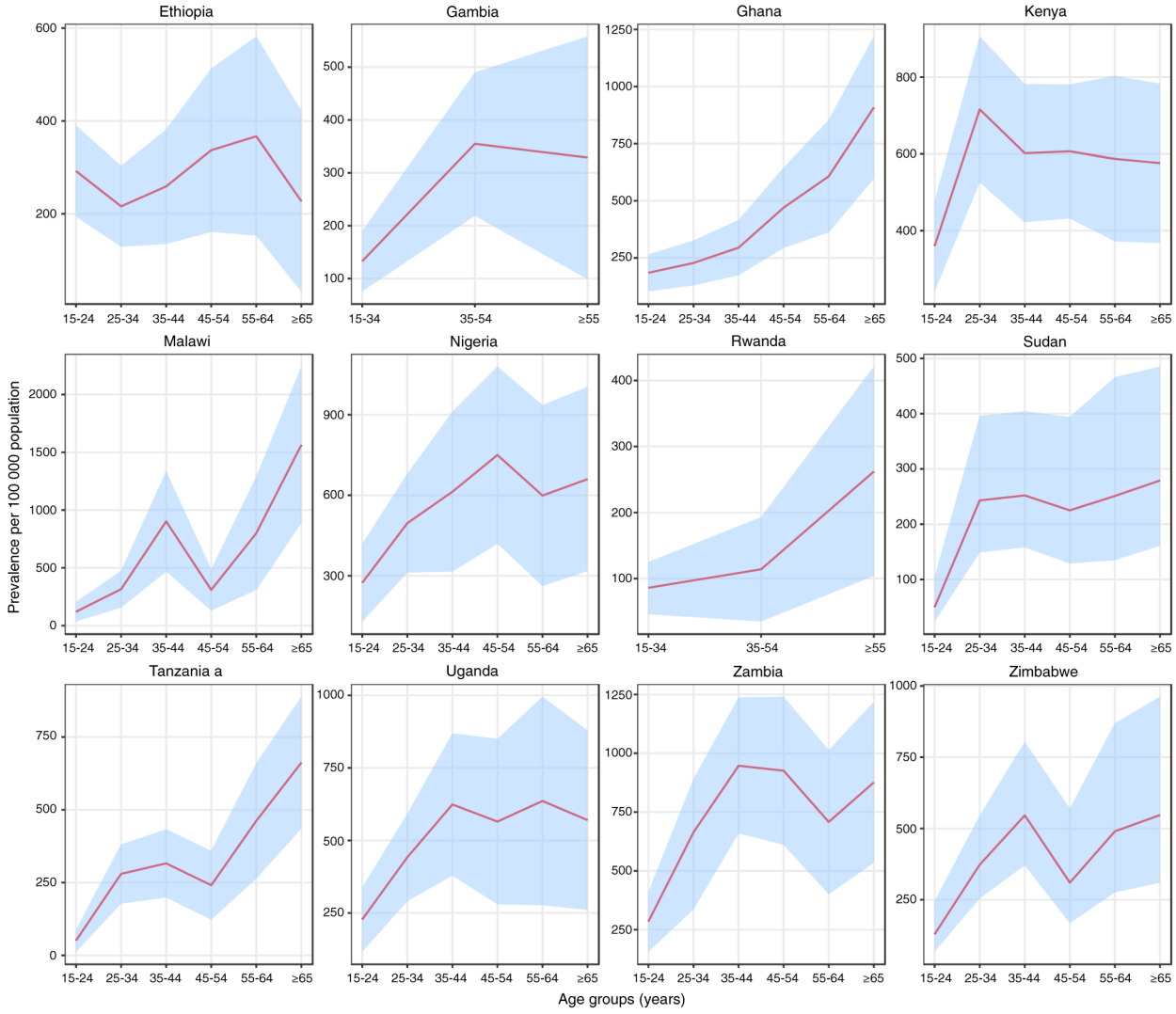

Figure 5.

[a] Bacteriologically-confirmed TB cases could not be verified, so the value for smear-positive TB is shown instead.

Estimated age-specific prevalence of bacteriologically-confirmed pulmonary TB in national TB prevalence surveys implemented in Africa, 2008–2016. The pink line denotes the best estimate and the blue shaded areas are the 95% confidence intervals.

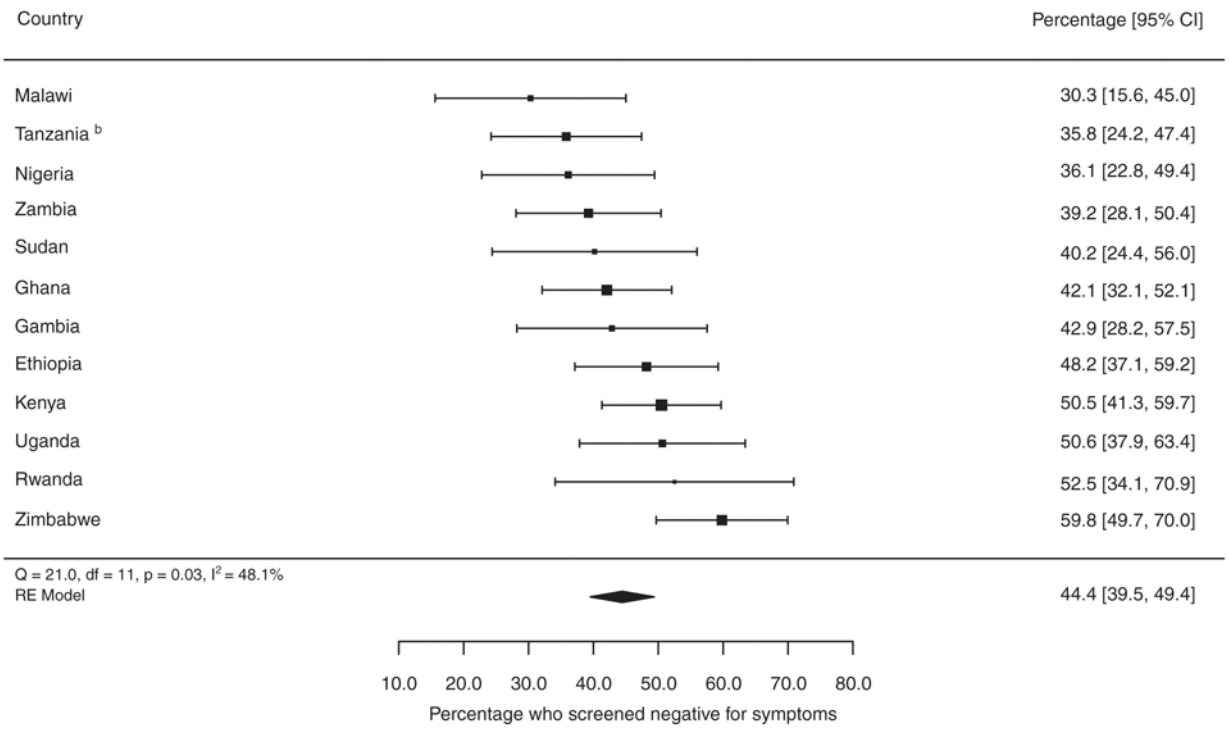

Figure 6.

[a] The size of the best estimate (black square) is proportional to the model's weights (inverse variance).

[b] Bacteriologically-confirmed TB cases could not be verified for Tanzania, so the value for smear-positive TB is shown instead.

Percentage of bacteriologically-confirmed pulmonary TB cases who screened symptom negative in national TB prevalence surveys completed in Africa, 2008–2016[a].

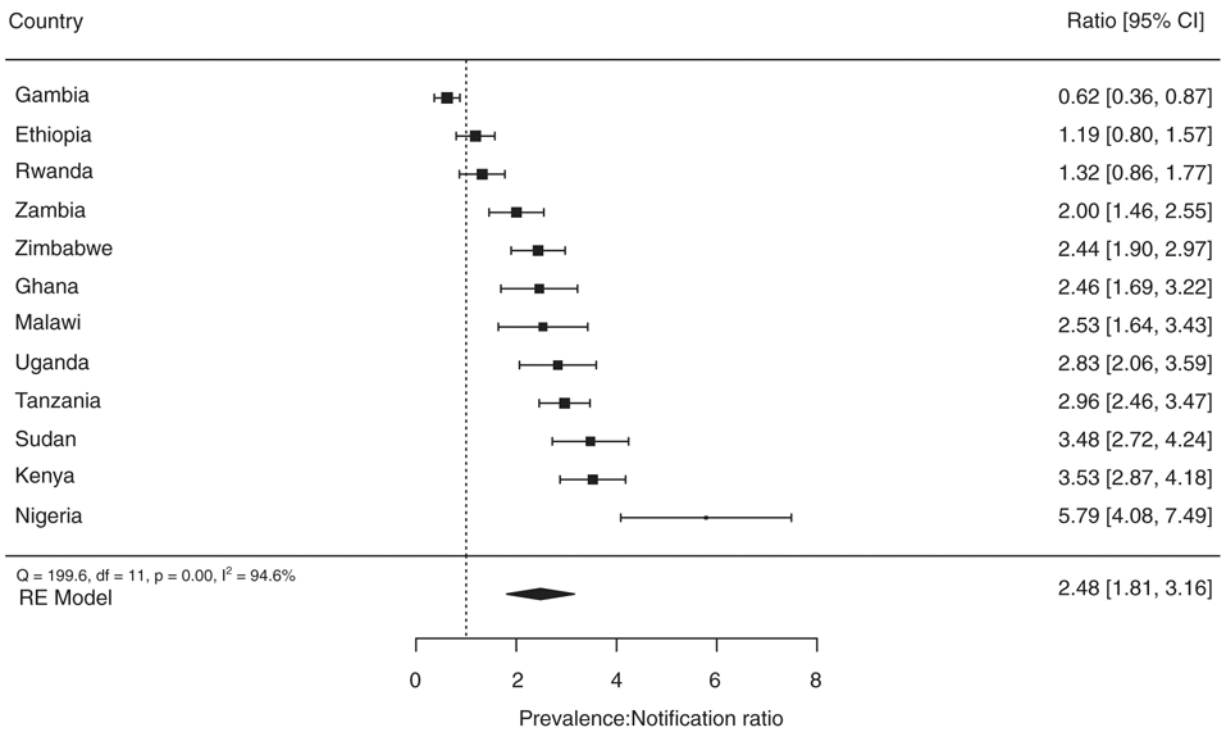

Figure 7.

[a] The comparison is for smear-positive pulmonary TB for all countries except Kenya, Uganda and Zimbabwe, for which the comparison is for bacteriologically confirmed pulmonary TB. The size of the best estimate (black square) is proportional to the model's weights (inverse variance).

Prevalence to notification (P:N) ratio for TB cases in national TB surveys implemented in Africa, 2008–2016[a].

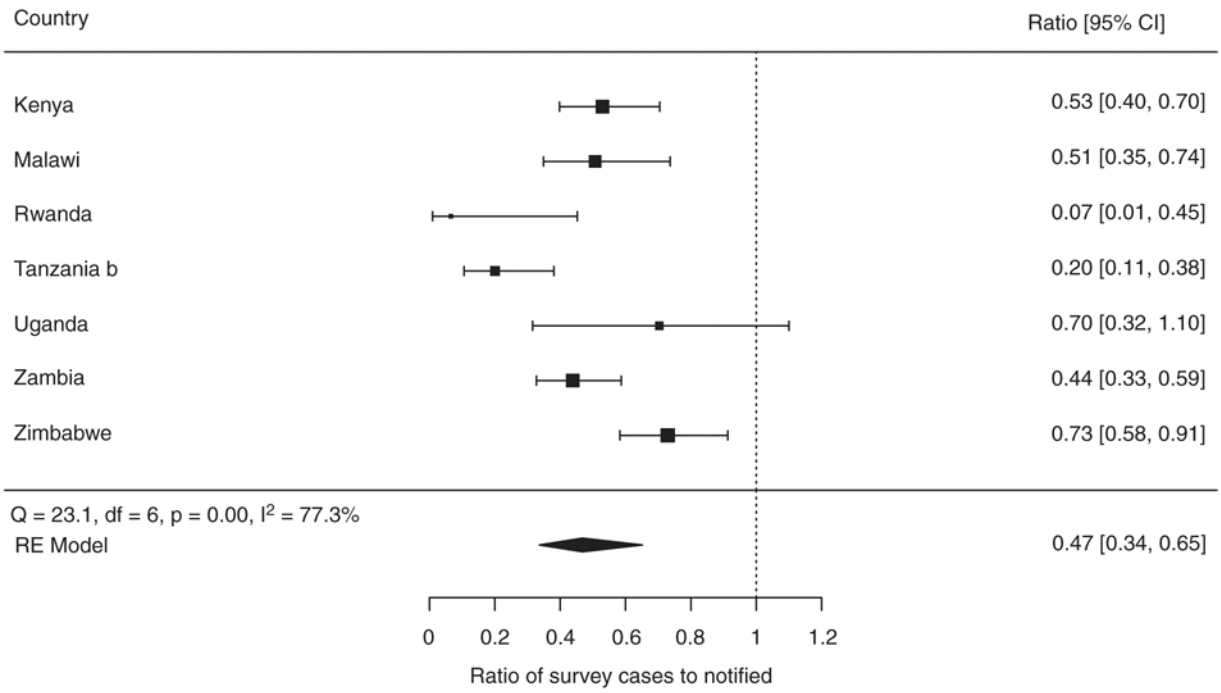

Figure 8.

[a]The proportions of TB survey cases with known HIV status and notified TB cases that were HIV-positive, respectively, were as follows: Kenya (0.17, 0.31), Malawi (0.28, 0.55), Rwanda (0.03, 0.26), Tanzania (0.08, 0.37), Uganda (0.27, 0.44), Zambia (0.27, 0.61) and Zimbabwe (0.51, 0.69). The size of the best estimate (black square) is proportional to the model's weights (inverse variance).

[b] Bacteriologically-confirmed TB cases could not be verified for Tanzania, so the value for smear-positive TB is shown instead.

HIV prevalence in TB survey cases compared with notified TB cases, expressed as a ratio, in national TB prevalence surveys implemented in Africa, 2008–2016[a].

Table 1

Main characteristics of national TB prevalence surveys completed in Africa, 2008-2016

Country and year	Residency criteria	Geographical area excluded†	Number of clusters	Stratified sampling	Planned sample size	Screening strategy¶		Diagnostic tests			Duration of field operations (months)
						Symptoms interview	Chest X-ray	Smear	Culture	Xpert MTB/RIF	
Ethiopia 2010-2011	Permanent residents who stayed in the household at least one night during the 14 days prior to the census day. Temporary visitors who stayed in the household at least 14 days prior to the census day.	37/810 woredas excluded from the sampling frame due to security and logistical challenges.	85	Urban/ Rural/ Pastoralist	46 514	Cough 2 weeks or more	Lung abnormality‡‡	2 FM	1 LJ	No	9
Gambia 2012	Residents who spent at least one night in the household in the last 4 weeks before the census. Visitors who arrived in the household 4 weeks or more before the census.	None	80	No	55 281	(i) Cough 2 weeks or more (ii) Any participant with a cough lasting <2 weeks and 2 or more other symptoms (iii) Any participant without a cough AND 3 or more other symptoms ††	Abnormal and suggestive of TB for any abnormality in lung field or mediastinum‡‡	2 FM	2 MGIT	No	14
Ghana 2013	Residents who have not been away for 2 weeks or more.	None	98	Urban/ Rural	64 000	Cough 2 weeks or more	Lung abnormality‡‡	2 ZN§§	2 MGIT	Smear-positive or contaminated cultures	10
Kenya 2015-2016	Residents who lived in the household for a minimum of 30 consecutive days prior to the census.	One cluster excluded due to security issues	99≠	Urban/ Rural	72 000	Cough 2 weeks or more	Lung abnormality‡‡	2 FM	2 LJ	At least one Xpert test for all participants who screened positive	12
Malawi 2013	Residents who spent at least 14 days in the household before the census.	None	74	Urban/ Semi-urban/Rural	37 200	Any symptom for 7 days or longer: cough, cough with sputum, blood stained sputum, chest pain, body weight loss, night sweat, fatigue/ malaise, fever, shortness of breath	Lung abnormality	2 FM¶¶	2 LJ	Smear-positive or contaminated cultures	11

Country and year	Residency criteria	Geographical area excluded[†]	Number of clusters	Stratified sampling	Planned sample size	Screening strategy[¶]		Diagnostic tests			Duration of field operations (months)
						Symptoms interview	Chest X-ray	Smear	Culture	Xpert MTB/RIF	
Nigeria 2012	Slept in the household for 14 days or more.	Three clusters replaced due to security issues	70	Zonal [6]	49 000	Cough 2 weeks or more	Lung abnormality	2 ZN	2 LJ	No	9
Rwanda 2012	Residents who lived in the household for at least 1 month prior to interview.	None	73	No	44 500	Cough (any duration)	Lung abnormality	2 FM	2 LJ	No	10
Sudan 2013-2014	Household resident or visitor for at least 3 weeks.	Four clusters were excluded due to security issues	109[§]	Urban/ Rural (Nomadic)	91 131	Cough 2 weeks or more; currently on TB treatment	Lung abnormality[‡‡]	2 FM	2 Ogawa	No	12
Tanzania 2012	A person having slept for the last 2 weeks in the household	None	62	Urban/ Rural/Semi-urban/ Zanzibar	46 792	Cough 2 weeks or more, haemoptysis, fever for more than 2 weeks, weight loss, and excessive sweating	Any abnormality in the lung fields or mediastinum	3 FM	1 LJ	No (Smear-positive slides examined retrospectively)	11
Uganda 2014-2015	Individuals who have resided in the household in the survey cluster for at least 14 days before the census day.	None	70	Urban/ Rural	40 180	Cough 2 weeks or more	Lung abnormality[‡‡]	2 ZN	2 LJ	Smear-positive or contaminated cultures	10
Zambia 2013-2014	Individuals who have slept in the household in the previous 24 h prior to census.	None	66	Urban/ Rural	54 400	Cough or fever or chest pains for 2 weeks or more	Lung abnormality or chest X-ray indeterminate[‡‡]	2 ZN	2 MGIT	Smear-positive or contaminated cultures	11
Zimbabwe 2014	Permanent residents who had spent a night at the household. Visitors who were residing in the selected cluster for 14 days or more before the survey.	Two clusters were replaced due to logistical issues.	75	Urban/ Rural	44 951	Cough of any duration, drenching night sweats, and/or haemoptysis	Lung abnormality[‡‡]	2 FM	2 MGIT	Smear-positive or contaminated cultures	12

C, Conventional radiology; CXR, Chest X-ray; DR, Digital radiology; FM, Fluorescence microscopy; LJ, Löwenstein-Jensen; MGIT, Mycobacterial growth indicator tube; MOH, Ministry of Health; N/A, Not applicable; NTP, National TB Programme; ZN, Ziehl-Neelsen stain.

[†]Although some surveys excluded certain geographical areas from their sampling frames, we included national surveys when most populations were covered.

[‡]In Kenya, 1 cluster was excluded from the original 100.

[§]In Sudan, 5 clusters were excluded from the original 114; one for protocol violation and four for security reasons.

[¶] Criteria for eligibility of sputum examination.

[††] In Gambia, other symptoms included chest pain, fever, haemoptysis, night sweats, shortness of breath, loss appetite and weight loss.

[‡‡] Other criteria were used especially if a participant was exempt or refused to have a chest X-ray. Please see supplementary file (Text S2) for details.

[§§] In Ghana, Zield-Neelsen smears used the concentrated method

[¶¶] In Malawi, FM smears used the concentrated method.

Table 2

Summary of sampling population, survey participants and screening outcomes

				Survey participants		Number and percentage of participants eligible for sputum examination													
Country	**Timeframe of field operations**	**Planned sample size**	**Number of people eligible to participate**	**Number**	**Participation rate (%)**	**Symptom positive, chest X-ray positive**	**%**	**Symptom positive, chest X-ray negative/ N/A**	**%**	**Symptom negative, chest X-ray positive**	**%**	**Other†**	**%**	**Any symptom positive**	**%**	**Any chest X-ray positive**	**%**	**Total eligible**	**%**
Ethiopia	2010–2011	46 514	51 667	46 697	90%	806	1.7%	2220	4.8%	3013	6.5%	41	0.09%	3026	6.5%	3819	8.2%	6080	13%
Gambia	2011–2013	55 281	55 832	43 100	77%	1026	2.4%	2436	5.7%	2384	5.5%	102	0.24%	3462	8.0%	3410	7.9%	5948	14%
Ghana	2013	63 905	67 757	61 726	91%	771	1.2%	1198	1.9%	4387	7.1%	1942	3.1%	1969	3.2%	5158	8.4%	8298	13%
Kenya	2015–2016	72 000	76 291	63 050	83%	1241	2.0%	2896	4.6%	5184	8.2%	394	0.62%	4137	6.6%	6425	10%	9715	15%
Malawi	2013–2014	37 200	39 026	31 579	81%	381	1.2%	2334	7.4%	717	2.3%	N/A	N/A	2715	8.6%	1098	3.5%	3432	11%
Nigeria	2012	49 000	77 797	44 186	57%	746	1.7%	1720	3.9%	2222	5.0%	N/A	N/A	2466	5.6%	2968	6.7%	4688	11%
Rwanda	2012	44 500	45 058	43 128	96%	545	1.3%	2092	4.9%	2107	4.9%	3	0.01%	2637	6.1%	2652	6.1%	4747	11%
Sudan	2013–2014	91 131	96 979	83 202	86%	1823	2.2%	840	1.0%	9838	12%	5040	6.1%	2663	3.2%	11 661	14%	17 541	21%
Uganda	2014–2015	40 180	45 293	41 154	91%	552	1.3%	2162	5.3%	2298	5.6%	130	0.32%	2714	6.6%	2850	6.9%	5142	12%
Tanzania	2011–2012	46 792	65 664	50 447	77%	804	1.6%	3459	6.9%	2039	4.0%	N/A	N/A	4263	8.5%	2843	5.6%	6302	12%
Zambia	2013–2014	54 400	54 830	46 099	84%	1505	3.3%	2948	6.4%	2255	4.9%	N/A	N/A	4453	10%	3760	8.2%	6708	15%
Zimbabwe	2014	44 951	43 478	33 736	78%	628	1.9%	1205	3.6%	2803	8.3%	1184	3.5%	1833	5.4%	3431	10%	5820	17%
Total					83%		1.8%		4.7%		6.2%		1.7%		6.5%		8.0%		14%

N/A, not applicable.

† Other refers to criteria used to ascertain if a participant was eligible for sputum collection other than via symptom or chest X-ray screening. See Text S2 for specific details.

Table 3

Summary of prevalent TB cases and the prevalence of pulmonary TB per 100 000 population aged ≥15 years

	Smear-positive pulmonary TB				Bacteriologicallyconfirmed pulmonary TB				
Country	**Number of cases**	**Prevalence per 100 000 population aged ≥ 15 years†**	**95% confidence interval**	***k*‡**	**Number of cases**	**Prevalence per 100 000 population aged ≥ 15 years†**	**95% confidence interval**	***k*‡**	**Proportion of bacteriologically confirmed cases that were smear-positive**
Ethiopia	4	108	73–143	0.7	110	277	208–347	0.4	39
Gambia	34	90	53–127	1.3	77	212	152–272	0.7	42
Ghana	64	111	76–145	0.9	202	356	288–425	0.7	31
Kenya	123	230	174–286	0.7	305	558	455–662	0.7	41
Malawi	62	220	142–297	1.1	132	452	312–593	1.1	49
Nigeria	107	318	225–412	0.9	144	524	378–670	0.7	61
Rwanda	27	74	48–99	N/A§	40	119	79–160	0.7	62
Sudan	57	87	52–121	1.3	112	183	128–238	1.3	48
Uganda	66	174	111–238	0.9	160	401	292–509	0.8	43
Tanzania¶	134	275	232–326	0.6	N/A	N/A	N/A	N/A	N/A
Zambia	135	319	232–406	0.8	265	638	502–774	0.7	50
Zimbabwe	23	82	47–118	N/A§	107	344	268–420	0.3	24

N/A, not applicable.

†Estimates based on the use of robust standard errors with missing value imputation and inverse probability weighting for all countries except for Tanzania for which a cluster-level analytical model was used.

‡*k* is the coefficient of variation of the cluster-specific TB prevalences. When the coefficient of variation (*k*) of cluster-specific TB prevalence was not reported, it was derived from the reported design effect.

§*k* could not be calculated because the design effect was less than one.

¶The number of bacteriologically confirmed cases could not be verified for the estimation of prevalence by WHO. The smear-positive and bacteriologically confirmed prevalence reported by the Tanzanian survey team was 249 per 100 000 (95% CI: 192–305) and 293 per 100 000 (95% CI: 228–358) population, respectively [22].

Table 4

Percentage of survey participants with smear-positive results that were not confirmed TB. Results shown for surveys in which specimens were tested using smear microscopy, rapid molecular tests and culture[†]

Country	Number of participants with at least one smear-positive specimen	Participants with smear-positive specimens excluded as a TB case	
		Number	%
Ghana	198	138	70%
Kenya	141	18	13%
Malawi	163	101	62%
Sudan	61	4	6.6%
Uganda	91	25	27%
Zambia	356	221	62%
Zimbabwe	206	183	89%

[†]Results are shown for surveys in which specimens were systematically tested using smear microscopy and rapid molecular tests. All surveys used Xpert MTB/RIF except Sudan which used line probe assays (LPAs). Kenya used both culture and Xpert MTB/RIF whereas other surveys used Xpert (or LPA) to confirm smear-positive specimens only.

Table 5

althcare-seeking behaviour among participants who were symptom-screen positive

untry	Participants who were symptom-screen positive	Location of care sought																					
		No action taken	%	Consulted medical facility	%	Type of facility																	
						Public facility	%	Private facility	%	Other facility	%	Pharmacy	%	Traditional	%	Other	%	Unspecified	%	Self-treated	%	Unknown	%
hiopia	3026	1932	64%	848	28%	628	74%	199	23%	21	2.5%	40	1.3%	3	0.10%	N/A	N/A	55	1.8%	N/A	N/A	148	4.8%
mbia	3462	1424	41%	1706	49%	1398	82%	220	13%	88	5.2%	17	0.49%	14	0.40%	24	0.69%	N/A	N/A	N/A	N/A	277	8.0%
hana	1969	264	13%	793	40%	695	88%	61	7.7%	37	4.7%	324	17%	20	1.0%	N/A	N/A	N/A	N/A	567	29%	1	0.10%
nya†	4137	2763	67%	1257	30%	1047	N/A	198	N/A	3	N/A	56	N/A	9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	117	2.8%
alawi	2715	1096	40%	1280	47%	901	70%	379	30%	N/A	N/A	32	1.2%	41	1.5%	4	0.15%	N/A	N/A	236	8.7%	26	0.96%
geria	2466	604	24%	800	32%	628	79%	172	21%	N/A	N/A	319	13%	11	0.45%	9	0.36%	3	0.12%	680	28%	40	1.6%
wanda†	2855	1934	68%	921	32%	941	N/A	48	N/A	38	N/A	101	N/A	54	N/A	N/A	N/A	N/A	N/A	0	0	N/A	N/A
dan	2663	575	22%	1308	49%	1077	82%	90	6.9%	141	11%	52	2.0%	49	1.8%	N/A	N/A	69	2.6%	N/A	N/A	610	23%
ganda	2714	1059	39%	1201	44%	1038	86%	146	12%	17	1.4%	421	16%	11	0.41%	N/A	N/A	N/A	N/A	22	0.81%	0	0%
nzania	3388	1688	50%	481	14%	445	93%	36	7.5%	N/A	N/A	147	4.3%	11	0.32%	257	7.6%	155	4.6%	N/A	N/A	649	19%
mbia	4453	2534	57%	1829	41%	1680	92%	75	4.1%	74	4.0%	16	0.36%	1	0.02%	N/A	N/A	N/A	N/A	N/A	N/A	73	1.6%
mbabwe†	1833	1130	62%	486	26%	438	N/A	45	N/A	N/A	N/A	17	N/A	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	217	12%

, not applicable.

Kenya, Rwanda and Zimbabwe participants could select more than one category.