National tuberculosis prevalence surveys in Asia, 1990–2012: an overview of results and lessons learned

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Abstract

OBJECTIVE AND METHODS  In many countries, national tuberculosis (TB) prevalence surveys are the only way to reliably measure the burden of TB disease and monitor trends. They can also provide evidence about the current performance of TB care and control and how this could be improved. We developed an inventory of Asian surveys from 1953 to 2012 and then compiled and analysed a standard set of data for all national surveys implemented between 1990 (the baseline year for 2015 global TB targets) and 2012.

RESULTS  There were 21 surveys in 12 countries between 1990 and 2012; published results were available for 18. The participation rate was at least 80% and often much higher except for two surveys in Thailand. The prevalence of bacteriologically-positive TB disease among adults aged ≥15 years varied widely among countries (1.2 per 1000 population in China in 2010 to 15 per 1000 population in Cambodia in 2002), but age and sex distribution patterns were consistent with a progressive increase in rates of disease by age, and men accounting for 66–75% of prevalent cases. A high proportion of cases (40–79% across all surveys) did not report TB symptoms that met screening criteria (generally cough of 2–3 weeks or more, and blood in the sputum) and were only detected due to chest X-ray screening of all survey participants; this proportion increased over time in countries with repeat survey data. The ratio of prevalent cases to cases notified to national TB programmes was typically around two, but was as high as three in Lao PDR and Pakistan even after the internationally recommended TB control strategy had been implemented nationwide for several years. Four countries (China, Cambodia, the Republic of Korea and the Philippines demonstrated declines in smear or culture-positive pulmonary TB prevalence of approximately 50% over 10 years.

CONCLUSIONS  National TB prevalence surveys in Asia show that large reductions in the prevalence of TB disease can be achieved within a decade, that men bear much more of the burden than women and that the epidemic is ageing. Comparisons among countries show that more can be achieved in TB control in some countries with existing strategies and technologies. However, with many prevalent cases not reporting classic TB symptoms, all countries face the challenge of defining and implementing strategies that will result in earlier detection and treatment of cases.

keywords tuberculosis, prevalence survey, Asia, epidemiology, public health

Introduction

Measuring the burden of tuberculosis (TB) and monitoring time trends are critical for planning TB control interventions, assessing their impact on population health and for evaluation of whether global targets for reductions in disease burden are achieved. Current global targets are set for 2015: the target in the Millennium Development Goals (MDGs) is that TB incidence should be falling by 2015; the Stop TB Partnership targets set within the context of the MDGs are to halve TB prevalence and death rates by 2015 compared with 1990.

Ideally, nationwide disease surveillance systems should provide direct measurements of the number of TB cases and deaths from TB. However, most countries with a high TB burden do not yet have notification systems that capture all cases. In particular, cases diagnosed in the private sector may not be reported, and health systems in many countries lack the reach and quality required to ensure that all (or virtually all) cases are diagnosed. This includes most, if not all, of the 22 high TB burden countries that account for about 80% of the world’s estimated cases. Vital registration systems with sufficient coverage and quality to allow direct measurement of TB mortality exist in 124 of WHO’s 194 member states, but most of
these are in Europe and Latin America (China, which ranks second globally in terms of numbers of TB cases, is a notable exception).

Given these gaps in routine surveillance, the only way to obtain an unbiased estimate of the burden of TB disease in many TB-endemic countries, and to monitor trends, is to conduct population-based national surveys of the prevalence of TB disease. Such surveys can also be used to better understand TB epidemiology (e.g. the distribution of disease by age, sex and geographical variation), to produce more precise estimates of TB incidence, to understand why people with TB disease have not been diagnosed by health providers and notified to national TB control programmes (NTPs) and to make associated changes to policies and strategies for TB care and control. When repeat surveys are implemented with intervals of approximately 10 years, trends can be assessed. Nonetheless, nationwide TB prevalence surveys are large studies that are expensive and logistically challenging to implement. In 2007, the WHO Global Task Force on TB Impact Measurement (hereafter the Task Force) developed a set of criteria to identify countries where surveys would be justified. These criteria are described in detail elsewhere [63]. A total of 53 countries met the criteria and from these a set of 22 global focus countries that would receive priority attention and support from the Task Force and partners were selected. A total of 20 national surveys will be implemented between 2009 and 2015, including in 15/22 global focus countries.

In the 1990s and 2000s, most surveys were implemented in Asia. This study provides a historical listing of national TB prevalence surveys completed between 1953 and 2012 and synthesises the major results and lessons learned from surveys completed between 1990 and 2012.

Methods
Identification of surveys conducted in Asia (1953–2012)
All national TB disease prevalence surveys conducted in Asia since the 1950s were identified using information previously compiled by WHO (for surveys conducted up to 2008, PubMed was searched using the terms: ‘tuberculosis’, ‘prevalence’ and ‘surveys’), documents with regular updates on TB prevalence surveys produced by the Task Force since 2008 [64] and discussions with NTPs during WHO regional meetings in Asia. A total of 49 national TB prevalence surveys conducted in 16 Asian countries between 1953 and 2012 were identified (Table 1). For the purposes of maintaining relevance to current efforts in TB care and control, and given that 1990 is the baseline year for 2015 global TB targets, we focused our attention on surveys conducted between 1990 and 2012.

Standard variables used to summarise survey results
Key characteristics of survey design, implementation, analysis and reporting (for example, the eligible population, the target sample size and number of clusters, screening strategy, laboratory tests performed and statistical methods used to analyse data) and a standard set of results (variables defined in Box 1) were summarised for 18 of the 21 surveys conducted in 1990–2012. The three surveys that were excluded were Malaysia (2003), as uptake of facility-based chest X-ray screening was low and results have not been published; Thailand (2006), due to low coverage of specimen collection among those considered eligible for sputum examination by chest X-ray screening; and Indonesia (2010), because the survey was implemented as part of a general health survey that did not include either TB screening or systematic use of culture examinations. Trend data were summarised for four countries that had repeat survey data since 1990 and comparable survey methods: Cambodia, China, Republic of Korea and the Philippines.

Box 1 Standard variables used to summarise survey results
The variables used to summarise results from the 18 surveys for which results have been published in reports or papers were as follows:

- the size of the eligible population;
- the number of people who participated in survey operations and associated participation rate;
- the absolute number of smear-positive and bacteriologically-positive cases that were identified (overall and disaggregated by sex and age group);
- the prevalence rate for smear-positive and bacteriologically-positive TB, per 1000 population (overall and disaggregated by sex and age group);
- the sex ratio (male to female) of prevalence;
- the proportion of smear-positive and bacteriologically-positive cases that did not report TB symptoms that met NTP screening criteria;
- the prevalence to notification (P:N) ratio for smear-positive TB;
- drug susceptibility test results;
- healthcare-seeking test results;
- healthcare-seeking behaviour among TB cases that reported symptoms;
- place of treatment for individuals on TB treatment at the time of the survey.
| National surveys | Number of surveys | Year       | References                                      |
|------------------|------------------|------------|-------------------------------------------------|
| Bangladesh       | 4                | 1964       | Ministry of Health – Bangladesh [17]            |
|                  |                  | 1987       | Ministry of Health – Bangladesh [18]            |
|                  |                  | 2007–09    | Zaman K et al. [68]                             |
|                  |                  | 2015*      | –                                                |
| Cambodia         | 2                | 2002       | Ministry of Health – Cambodia [19]              |
|                  |                  | 2011       | Mao et al. [16]                                 |
| China            | 5                | 1979       | Ministry of Public Health – China [37]         |
|                  |                  | 1984       | Ministry of Public Health – China [38]         |
|                  |                  | 1990       | Ministry of Public Health – China [39]         |
|                  |                  | 2000       | Ministry of Public Health – China [40]         |
|                  |                  | 2010       | Wang et al. [59]                                |
| Taiwan, China    | 4                | 1958–59    | Quo 1959 [46], Lin et al. [15]                 |
|                  |                  | 1962–63    | Lin et al. [15]                                 |
|                  |                  | 1967–68    | Lin et al. [15]                                 |
|                  |                  | 1972–73    | Lin et al. [15]                                 |
| DPR Korea        | 1                | 2016*      | –                                                |
| Indonesia        | 4                | 1979–82    | Aditama [1]                                     |
|                  |                  | 2004       | Ministry of Health – Indonesia [21], Soemantri et al. [48] |
|                  |                  | 2010       | Ministry of Health – Indonesia [22]             |
|                  |                  | 2013–14    | To be published                                 |
| Japan            | 5                | 1953       | Yamaguchi [67], Omura et al. [45]              |
|                  |                  | 1958       | Ministry of Health and Welfare – Japan [36], Omura et al. [45] |
|                  |                  | 1963       | Wakamatsu [58]                                  |
|                  |                  | 1968       | Muranaka [41]                                   |
|                  |                  | 1973       | Shimao [47]                                     |
| Lao PDR          | 1                | 2010–11    | Ministry of Health – Lao PDR [23]              |
| Malaysia         | 2                | 1970       | Chia and Huang [3]                              |
|                  |                  | 2003       | Dye [8]                                         |
| Mongolia         | 1                | 2014–15*   | –                                                |
| Myanmar          | 3                | 1972       | Thein Nyunt et al. [51]                         |
|                  |                  | 1994       | Ministry of Health – Myanmar [24]               |
|                  |                  | 2009–10    | Ministry of Health – Myanmar [25]               |
| Nepal            | 1                | 2015*      | –                                                |
| Pakistan         | 3                | 1959       | Dolin [6]                                       |
|                  |                  | 1987       | Dolin [6]                                       |
| Philippines      | 3                | 1981       | National Institute of Tuberculosis – Philippines [42], Department of Health – Philippines [5] |
|                  |                  | 1997       | Tropical Disease Foundation Inc and Department of Health [53], Tupasi et al. [56], Tupasi et al. [57] |
|                  |                  | 2007       | Tropical Disease Foundation Inc and Department of Health [54], Tupasi et al. [55] |
| Republic of Korea| 7                | 1965       | Ministry of Health & Social Affairs and the Korean National Tuberculosis Association [29] |
|                  |                  | 1970       | Ministry of Health & Social Affairs and the Korean National Tuberculosis Association [30] |
|                  |                  | 1975       | Ministry of Health & Social Affairs and the Korean National Tuberculosis Association [31] |
|                  |                  | 1980       | Ministry of Health & Social Affairs and the Korean National Tuberculosis Association [32] |
|                  |                  | 1985       | Ministry of Health & Social Affairs and the Korean National Tuberculosis Association [33] |
Data sources and statistical analysis

The main sources of data were survey reports and articles published in peer-reviewed journals. In a few instances where these did not include the required information, data were obtained directly from lead survey investigators. When the coefficient of variation (k) of the cluster-specific TB prevalences was not reported, it was derived from the design effect (DEFF) or the confidence interval of the overall TB prevalence in surveys where the DEFF was not known [52, 63]. 95% confidence intervals for the proportion of isolates detected as MDR-TB were derived using the exact binomial approach, using the number of cases found with MDR-TB strains out of the total number of prevalent cases tested for drug susceptibility and assuming that missing data (prevalent cases not tested for drug susceptibility) were missing completely at random. The prevalence: notification (P:N) ratio was calculated as the smear-positive TB prevalence measured in the survey divided by the notification rate for smear-positive TB among those aged ≥15 years in the main year of the survey. Notification rates were calculated using notification data reported to WHO and United Nations population estimates (2012 revision) for the main year of the survey. The P:N ratio for bacteriologically-positive TB could not be calculated because notification data for smear- and culture-positive TB combined were not routinely compiled by most NTPs prior to 2014.

We did not conduct any meta-analyses to provide summary results across all surveys, as our objective in this study was rather to provide a comprehensive summary of the results from individual surveys and a synthesis of the lessons learned based on common findings in multiple surveys. However, meta-analyses using the data presented in this study (e.g. on male:female ratios or the age distribution of cases) could be the subject of future publications.

Ethical approval

All 18 prevalence surveys used in the final analysis were approved by in-country ethics committees. For surveys implemented since 2009, protocols were also reviewed by the WHO Global Task Force on TB Impact Measurement, including to ensure that ethical issues were appropriately addressed.

Results

Main survey characteristics

The main characteristics of the 18 surveys for which detailed results were available are shown in Table 2 (see Table S1 for a fuller summary).

The number of participants enrolled varied widely from 12 850 (the Philippines, 1997) to 1 461 190 (China, 1990) people, but was usually in the range 20 000–65 000 from 40 to 95 clusters. Surveys with a planned sample size of over 100 000 people were restricted to China, Pakistan and Viet Nam, and the number of clusters only exceeded 100 in China, Indonesia, the Republic of Korea and Thailand (1991 only). Most surveys used stratified sampling; urban (and/or the capital) and rural (and/or remote) were the most common strata used. Nine of the surveys were restricted to those aged ≥15 years (all surveys since 2009), five were restricted to those aged ≥10 years, two surveys in the...
| Country       | Main year | Age of eligibility (Years unless specified) | Planned sample size/participants | Geographical area excluded* | Number of clusters | Stratified sampling | Screening strategy† | Bacteriology |
|---------------|-----------|---------------------------------------------|----------------------------------|----------------------------|--------------------|---------------------|---------------------|--------------|
| China         | 1990      | ≥3 months                                   | Not reported /1 461 190         | Non-mainland ‡             | 928                | Province            | Not done           | Fluoroscopy if abnormal then CXR § |
| Republic of Korea | 1990      | ≥5                                          | Not reported /48 976            | None                       | 190                | Urban/Rural         | Not done           | Abnormal     |
| Thailand      | 1991      | ≥10                                         | 35 800                          | None                       | 133                | Urban/Rural/Bangkok | Abnormal            | 2 smear from 1 sputum |
| Myanmar       | 1994      | ≥10                                         | 36 100/37 424                  | Unknown                    | 41                 | Yangon/Urban/Rural  | TB-suspected symptoms | 3 N/A only inner Yangon |
| Republic of Korea | 1995      | ≥5                                          | Not reported /64 713            | None                       | 203                | Urban/Rural         | Not done           | Abnormal     |
| Philippines   | 1997      | ≥10                                         | 15 905/12 850                  | Unclear due to replacement after selection (two provinces, one municipality and a few clusters) | 36                 | Manila/Urban/Rural  | Not done           | TB suggestive |
| China         | 2000      | ≥3 months                                   | 418 456/365 097                | Non-mainland ‡             | 257                | Province            | Cough/expectoration ≥3 weeks or haemoptysis | 3 N/A only limited clusters |
| Cambodia      | 2002      | ≥10                                         | 21 098/22 160                  | 4/24 provinces, <3% of population | 42                 | Urban/Rural         | Cough 3 weeks and/or haemoptysis | 2 smear from 1 sputum |
| Indonesia     | 2004      | ≥15                                         | 62 000/50 154                  | None                       | 1250 census blocks | Urban/Rural         | Any duration of productive cough/sputum ± blood within a month | 3 N/A only in limited clusters |
| Philippines   | 2007      | ≥10                                         | 30 000/20 625                  | 18 barangays               | 50                 | Manila/Urban/Rural  | Not done           | Abnormal     |
| Viet Nam      | 2007      | ≥15                                         | 105 000/94 179                 | None                       | 70                 | Urban/Rural/Remote  | Cough ≥2 weeks     | TB suggestive |
| Country   | Main year | Age of eligibility (Years unless specified) | Planned sample size/participants | Geographical area excluded* | Number of clusters | Stratified sampling | Screening strategy† | Bacteriology |
|-----------|-----------|---------------------------------------------|---------------------------------|-----------------------------|--------------------|---------------------|-------------------|--------------|
| Bangladesh| 2008      | ≥15                                         | 50 000/52 098                   | 3/64 districts              | 40                 | Urban/Semi-urban/Rural | No screening      | No screening  |
| Myanmar   | 2009      | ≥15                                         | 49 690/51 367                  | 32/325 townships            | 70                 | States/Divisions Province | Cough ≥3 weeks   | Abnormal     |
| China     | 2010      | ≥15                                         | 264 000/252 940               | Non-mainland ‡             | 176                | Abnormal            | Abnormal         | 3            |
| Cambodia  | 2011      | ≥15                                         | 39 680/37 417                  | None                        | 62                 | Abnormal            | Abnormal         | 2            |
| Lao PDR   | 2011      | ≥15                                         | 40 000/39 212                  | None                        | 50                 | Not stratified      | Abnormal         | 2            |
| Pakistan  | 2011      | ≥15                                         | 133 000/105 913                | Unsecured zones, 6.5% of the national population | 95 | Not stratified | Abnormal         | 2            |
| Thailand  | 2012      | ≥15                                         | 78 840/62 536                  | Bangkok                     | 83, number of PSU: 24 provinces | Urban/Rural | Clinical scoring¶ | Abnormal     |

CXR, Chest X-ray. S+, smear-positive. PSU, primary sampling unit.
*Although some surveys excluded certain geographical areas from their sampling frames, national surveys were included when most populations were covered.
†Criteria for eligibility of sputum examination.
‡Excluded Hong Kong Special Administrative Region, Macao Special Administrative Region, and Taiwan, China.
§In China 1990 & 2000, tuberculin skin tests performed in 0–14 years, and if positive, then fluoroscopy was undertaken.
¶A participant was screened positive when the clinical scoring was 3 or more points. The symptoms included cough of at least 2 weeks (Yes: 3 points); coughing up blood over the past month (3 points); cough of less than 2 weeks (2 points); unintentional body weight loss in the past month (1 point); fever 1+ weeks within the last 2 weeks (1 point); drenching night sweats in the past month (1 point).
Republic of Korea included those aged ≥5 years, and two surveys in China included all those aged ≥3 months.

The most common screening strategy during the 1990s was a chest X-ray, either a mass miniature X-ray or fluoroscopy, for the entire eligible population; those screening X-ray positive (any lung shadows or signs pathognomonic of TB) were then considered eligible for sputum examination. Between 2000 and 2008, surveys used a variety of screening and diagnostic methods, prompting WHO to produce standardised guidance on these and other survey methods [62]. In addition to chest X-ray screening, an interview with each participant that included questions about TB symptoms was introduced during the 2000s (using the NTP’s definition of ‘TB suspect’, typically an individual with a chronic cough for more than 2–3 weeks and/or blood in the sputum). Since 2009, all surveys participants were screened using both direct chest X-ray (using either conventional or digital technologies) and an interview about symptoms, with participants who screened positive on either or both considered eligible for sputum examination.

In 15 surveys, participants eligible for sputum examination were tested using both smear microscopy and culture. In Indonesia (2004) and Myanmar (1994), testing included smear microscopy, but culture examination was not systematically performed. In Bangladesh, culture examinations were restricted to participants with sputum smear-positive results. Except for Viet Nam, all surveys used a simple inoculation method without centrifuging for primary culture.

Size of eligible population, survey participation rates and prevalence rates

The size of the eligible population, the participation rate, the number of prevalent cases identified and prevalence rates are shown in Table 3. The percentage of the eligible survey population that agreed to participate was ≥80% in 15 surveys and ≥90% in 9 of these. The participation rate could not be assessed for one survey (Myanmar, 1994) because a complete census of the population to enumerate those eligible to participate in the survey (i.e. the denominator) and those not eligible was not carried out. In general, participation rates were higher for females, middle and older age groups and rural residents, compared with males, younger age groups and urban residents.

The smear-positive TB prevalence per 1000 population aged ≥15 years varied from 0.66 (95% C.I. 0.53–0.79) in China (2010) to 4.4 (95% C.I. 3.5–5.6) in Cambodia (2002). The prevalence of bacteriologically-positive TB per 1000 population aged ≥15 years varied from 1.2 (95% C.I. 1.0–1.4) in China (2010) to 15 (95% C.I. 12–18) in Cambodia (2002). The proportion of bacteriologically-positive cases that were smear-positive varied widely, from 30% in Cambodia (2002) to 68% in Pakistan.

Age and sex distribution of cases

For 17 surveys, data on the prevalence of smear-positive TB cases disaggregated by sex were available (Figure 1). The male:female ratio of prevalence rates ranged from 1.7 in Pakistan to 5.1 in Viet Nam. In surveys for which culture results were also available, the male:female ratio of the prevalence of bacteriologically-positive TB varied from 1.5 in Pakistan to 4.5 in Viet Nam.

In 14 surveys that used chest X-ray screening, data on the prevalence of smear-positive TB disaggregated by age were available (Figure 2). In most surveys, TB prevalence rates increased progressively with age. In all countries, the most recent survey showed that TB prevalence rates peaked in the oldest age group of ≥65 years old. The pattern was similar for the absolute number of cases in most recent surveys (data not shown), with the notable exceptions of Myanmar (2011) and Viet Nam in which the absolute number of cases was highest in those aged 35–44 years.

Percentage of survey cases that screened negative for TB symptoms or had no symptoms

For 12 surveys, it was possible to assess the proportions of cases that met survey symptom screening criteria or whether they had any symptoms (Figure 3). The proportion of smear-positive cases that did not screen positive based on reported TB symptoms (typically a cough of more than 2–3 weeks duration and/or blood in the sputum) ranged from 34% in Lao PDR to 68% in Viet Nam. Among bacteriologically-positive TB cases, the proportion of cases that did not screen positive based on reported TB symptoms was higher still, ranging from 40% in Pakistan to 79% in Myanmar (2009).

In three repeat surveys that asked all participants about TB symptoms, the percentage of smear-positive TB cases that did not meet the symptom screening criteria or did not report any TB-related symptoms increased substantially compared with earlier surveys. In Cambodia, the percentage that screened negative for symptoms rose from 38% in 2002 to 56% in 2011; in the Republic of Korea, the percentage who did not report any symptoms rose from 39% to 60% between 1990 and 1995; and in China, the percentage of asymptomatic cases rose from 6% to 26% between 2000 and 2010 [20, 35, 40].
Table 3 Summary of the eligible population, participation rates and the number of prevalent cases identified

| Country       | Year | Age of eligibility (years unless specified) | Eligible population | Number (%) of participants identified in survey operations | Number of smear-positive cases | Number of bacteriologically-positive cases | Proportion of smear-positive in bacteriologically-positive cases | Prevalence per 1000 (95% C.I.) smear-positive cases | Prevalence per 1000 (95% C.I.) bacteriologically-positive cases |
|---------------|------|--------------------------------------------|---------------------|----------------------------------------------------------|-------------------------------|-------------------------------------------|---------------------------------------------------------------|-------------------------------------------------------------|---------------------------------------------------------------|
| Bangladesh    | 2008 | ≥15                                        | 63 716              | 52 098 (82)                                              | 33                            | 33†                                       | N/A                                            | 0.79 (0.47–1.3)                                              | 1.58* (N/A N/A N/A)                                          |
| Cambodia      | 2002 | ≥10                                        | 23 084              | 22 160 (96)                                              | 81                            | 271                                       | 30                                             | 3.62 (2.8–4.6)                                               | 0.28 (12‡ 10–15 0.47)                                        |
| Cambodia      | 2011 | ≥15                                        | 40 423              | 37 417 (93)                                              | 103                           | 314                                       | 33                                             | 2.71 (2.1–3.5)                                               | 0.59 (83† 71–98 0.54)                                        |
| China         | 1990 | ≥3 months                                  | 1 493 334           | 1 461 190 (98)                                           | 1827                          | 2389                                      | 76                                             | 1.35 (1.2–1.4)                                               | 0.93 (1.8† 1.7–1.9 0.79*)                                    |
| China         | 2000 | ≥3 months                                  | 375 599             | 365 097 (97)                                             | 447                           | 584                                       | 77                                             | 1.2** (1.1–1.4)                                              | 0.57* (1.6 1.4–1.8 0.68*)                                    |
| China         | 2010 | ≥15                                        | 263 281             | 252 940 (96)                                             | 188                           | 347                                       | 54                                             | 0.66 (0.53–0.79)                                             | 0.88 (1.2 1.0–1.4 0.48)                                      |
| Indonesia     | 2004 | ≥15                                        | 53 155              | 50 154 (94)                                              | 80                            | Not done                                  | N/A                                            | 1.5 (0.94–2.0)                                               | N/A (N/A N/A N/A)                                            |
| Lao PDR       | 2011 | ≥15                                        | 46 079              | 39 212 (85)                                              | 107                           | 237                                       | 45                                             | 2.8†† (2.0–3.6)                                              | 0.74 (6.0†† 4.6–7.3 0.68)                                    |
| Myanmar       | 1994 | ≥10                                        | Not known           | 37 424                                                   | 39                            | Not done                                  | N/A                                            | 1.0 (0.7–1.4)                                               | 0.92* (N/A N/A N/A)                                         |
| Myanmar       | 2009 | ≥15                                        | 57 607              | 51 367 (89)                                              | 123                           | 311                                       | 40                                             | 2.4† (1.9–3.2)                                               | 0.82 (6.1† 5.0–7.5 0.69)                                     |
| Pakistan      | 2011 | ≥15                                        | 131 329             | 105 913 (81)                                             | 233                           | 341                                       | 68                                             | 2.7†† (2.2–3.2)                                              | 0.68 (4.0†† 3.3–4.6 0.55)                                    |
| Philippines   | 1997 | ≥10                                        | 15 905              | 12 850 (81)                                              | 47                            | 127                                       | 37                                             | 3.6 (2.8–4.5)                                               | Undefined (9.6 7.5–12 0.44*)                                 |
| Philippines   | 2007 | ≥10                                        | 22 867              | 20 625 (90)                                              | 60                            | 151                                       | 40                                             | 2.6**§§ (1.7–3.6)                                             | 0.79 (6.6§§ 5.1–8.1 0.55)                                    |
| Republic of Korea | 1990 | ≥15                                        | 50 960              | 48 976 (97)                                              | 76                            | 118                                       | 59                                             | 1.4 (known Not known)                                        | Not known (2.4 1.8–3.0 1.18*)                                |
| Republic of Korea | 1995 | ≥5                                         | 73 194              | 64 713 (88)                                              | 60                            | 142                                       | 42                                             | 0.93 (known Not known)                                       | Not known (2.2 1.8–2.6 0.57*)                                |
| Thailand      | 1991 | ≥10                                        | 47 046              | 35 844 (76)                                              | 73                            | 101                                       | 72                                             | 1.7 (known Not known)                                        | Not known (2.4 Not known Not known)                         |
| Viet Nam      | 2002 | ≥15                                        | Not known           | Not known                                                | Not known                    | Not known                                  | Not known                                        | 1.0††*** (0.56–1.8)                                          | 1.27* (2.4††*** 1.8–3.2 0.52*)                                |
| Viet Nam      | 2007 | ≥15                                        | 103 924             | 94 179 (91)                                              | 174                           | 269                                       | 65                                             | 2.0 (1.5–2.4)                                               | 0.79 (3.1 2.5–3.7 0.62)                                      |

*a k is the coefficient of variation of the cluster-specific TB prevalences. For these marked countries, k of the cluster-specific TB prevalences was not reported and derived from the confidence interval of the overall TB prevalence in surveys where the design effect (DEFF) was not known [52, 63].†The survey in Bangladesh only undertook culture examination from those individuals whose specimens were positive for acid-fast bacilli, that is no cultures were examined from individuals that were smear-negative.‡Imputation analyses were undertaken but as participation rates were high and imputed estimates were close to that derived from cluster-level models, the latter method was officially reported.§The estimated smear-positive and bacteriologically-positive prevalence for TB, adjusted for participants who were ≥15 years of age is 4.4 per 1000 (95% C.I. 3.5–5.6) and 15 per 1000 (95% C.I. 12–18), respectively.¶The survey in Bangladesh only undertook culture examination from those individuals whose specimens were positive for acid-fast bacilli, that is no cultures were examined from individuals that were smear-negative.§§The estimated smear-positive and bacteriologically-positive prevalence for TB, adjusted for participants who were ≥15 years of age is 1.37 per 1000 (95% C.I. 1.23–1.53) and 7.8 per 1000 (95% C.I. 6.0–9.5), respectively.***Not analysed at the cluster level but at the area (urban/rural) level.
Prevalence to notification ratios

For 11 surveys in which chest X-ray screening was carried out, the ratio of smear-positive prevalence to smear-positive notifications (P:N) could be calculated (Figure 4). This ranged from 1.7 in Cambodia (2011) and China (2010) to 7.6 in China (2000). However, surveys conducted since 2007 typically had P:N ratios of around 2 (range: 1.4–3.2), with higher values for surveys in Lao PDR and Pakistan. In most countries, the ratio tended to be narrower in younger age groups and wider in older ones (data not shown). Except for the Philippines in 2007, the P:N ratio was higher in males compared with females. The P:N ratio for male and female smear-positive cases was as low as 1.1 for female cases in Cambodia (2002). Since 2007, the most noticeable discrepancy between men and women was in Viêt Nam, where the P:N ratio for men was almost twice as that for women (2.8 vs. 1.6).

False-positive smear results

Although the isolation of non-tuberculous mycobacteria from smear-positive samples was very limited in seven surveys with available data, between 3% (Pakistan) and 43% (Lao PDR) of participants with a smear-positive result were not counted as TB cases because they did not fulfil the survey case definition of smear-positive TB, that is they did not show any culture isolates of MTB and/or their chest X-ray showed no signs of TB disease.

Drug susceptibility test results and the prevalence of MDR-TB

For 14 surveys in which drug susceptibility testing was performed for rifampicin and isoniazid, most countries tested more than 50% of MTB isolates and MDR-TB was detected in 0–11% of them (Table 4). Four countries had repeat survey data, allowing trends in the burden of MDR-TB and the numbers of people in the population in need of second-line TB treatment to be assessed. Striking findings included a large fall in the absolute number of prevalent cases of MDR-TB in China (and an approximate halving of numbers in need of expensive second-line treatments) and very low levels of drug resistance among TB cases in Cambodia.

Trends in prevalence rates in countries that have implemented repeat surveys

Four countries had repeat survey data since 1990 that allowed trends in the prevalence of smear-positive and
bacteriologically-positive TB to be assessed: Cambodia, China, the Philippines and the Republic of Korea. Large reductions in TB prevalence were demonstrated in all repeat surveys (Figure 5). Repeat surveys were also implemented between 1990 and 2012 in Myanmar (1994, 2009) and Thailand (1991, 2006, 2012). However, changes to screening and/or diagnostic methods in the most recent survey preclude an unbiased comparison of results. In Thailand, the 2012 survey used direct chest X-ray screening on-site as opposed to miniature mass radiography (MMR) in the 1991 and 2006 surveys; MMR is less sensitive than full-size chest X-ray and likely led to underestimation of the number of culture-positive TB cases in 1991. In Myanmar, the 1994 survey did not include chest X-ray screening or culture examination. Nonetheless, a reduction in the prevalence of smear-positive TB was documented in Thailand (1.7 per 1000 in 1991 to 1.0 per 1000 in 2012) despite an increase in TB due to HIV in the 1990s, and a 35% reduction in the prevalence of those who screened symptom-positive and had smear-positive TB occurred in Myanmar between 1994 and 2009 [25].

Health care-seeking behaviour and notification of diagnosed cases to the NTP
All surveys except Thailand (1991) and Myanmar (1994) reported health care-seeking behaviour data. Although behaviour among participants reporting a chronic cough was studied in most recent surveys, the most complete (8 surveys) and standardised data were about the current place of treatment for survey participants who were on TB treatment (Table 5). In six countries, around 80% or more of those on TB treatment were being treated in the public sector; the exceptions were Republic of Korea (1995) and Lao PDR, for which figures were around 50% (however, in Lao PDR the place of treatment was unknown for half of those on treatment). The proportion of TB patients being treated in the private sector halved between 2002 and 2011 in Cambodia, and in the most
Figure 3  Proportion symptom screen negative among prevalent TB cases. There were no available data from Bangladesh (2008), China (1990, 2000), Indonesia (2004), Myanmar (1994) or Thailand (1991). Surveys conducted by the Republic of Korea (1990 and 1995) and the Philippines (1997 and 2007) did not use symptom screening; however, symptom-related data were collected from all detected TB cases.

Figure 4  TB prevalence (smear-positive) to TB case notification (new smear-positive) ratio. Notification data were calculated using smear-positive TB country notifications to WHO and the UN population estimates (2012 revision) for the main year of the survey. Notification data not available from China (1990), the Republic of Korea (1990), Myanmar (1994), the Philippines (1997) or Thailand (1991). Data were not shown for Bangladesh (2008) because estimated prevalence was likely to be underestimated.
recent survey in China (2010), the number of patients reporting treatment in the private sector was almost negligible. The proportion of those on TB treatment who were bacteriologically-positive at the time of the survey was almost always very low (3–4%).

Information about whether TB patients had been notified to the NTP (or national TB surveillance system) was scarce. Verification using a case-based electronic national surveillance system was only possible in China, where 72% of people on TB treatment at the time of the survey had been notified through the national infectious diseases reporting system. Similar analyses using local registration data found under-reporting of approximately 20% in Viet Nam, Myanmar (2009) and Thailand (2012), assuming that all TB cases in local registries were notified to the NTP.

Table 4 Drug sensitivity testing of *Mycobacterium tuberculosis* isolates from detected cases

| Country     | Main year | Number of bacteriologically-positive TB cases detected by the survey | Number (%) of MTB isolates tested | Number (%, 95% C.I.) of isolates with MDR-TB detected* |
|-------------|-----------|--------------------------------------------------------------------|-----------------------------------|--------------------------------------------------------|
| Bangladesh  | 2008      | 33†                                                                | 29 (88)                           | 1 (3.4, 0.1–17.8)                                      |
| Cambodia    | 2002      | 271                                                                | 245 (90)                          | 0 (0, 0–1.5)                                           |
| Cambodia    | 2011      | 314                                                                | 193 (61)                          | 0 (0, 0–1.9)                                           |
| China       | 1990      | 2389                                                               | 1595 (67)                         | 36 (2.3, 1.6–3.1)                                      |
| China       | 2000      | 584                                                                | 392 (67)                          | 42 (11, 7.8–14.2)                                      |
| China       | 2010      | 347                                                                | 280 (81)                          | 19 (6.8, 4.1–10.4)                                     |
| Lao PDR     | 2011      | 237                                                                | 226 (95)                          | 2 (0.9, 0.1–12.5)                                      |
| Pakistan    | 2011      | 341                                                                | 182 (53)                          | 5 (2.7, 0.9–6.3)                                       |
| Philippines | 1997      | 127                                                                | 55 (43)                           | 2 (3.6, 0.4–12.5)                                      |
| Philippines | 2007      | 151                                                                | 130 (86)                          | 5 (3.8, 1.3–8.7)                                       |
| Republic of Korea | 1990 | 118                                                                | 113 (96)                          | 8 (7.1, 3.1–13.5)                                      |
| Republic of Korea | 1995 | 142                                                                | 131 (92)                          | 7 (5.3, 2.2–10.7)                                      |
| Thailand    | 2012      | 142                                                                | 130 (92)                          | 0 (0, 0–2.8)                                           |
| Viet Nam    | 2007      | 269                                                                | 212 (79)                          | 10 (4.7, 2.3–8.5)                                      |

*95% confidence intervals were derived using the exact binomial approach based on the number of cases found with MDR-TB strains out of the total number of prevalent cases tested for drug susceptibility, assuming that missing data (prevalent cases not tested for drug susceptibility) were missing completely at random.

†The survey in Bangladesh only undertook culture examination from those individuals whose specimens were positive for acid-fast bacilli, that is no cultures were examined from individuals that were smear-negative.

Figure 5 Trends in TB prevalence – four countries with repeat survey data.
Prevalence rates refer to survey cases who were ≥15 years from China and Cambodia. For survey cases from the Republic of Korea and the Philippines, prevalence rates refer to survey cases who were ≥5 or ≥10 years, respectively. Standard errors and confidence intervals were not reported for smear-positive data in the three surveys from the Republic of Korea.
For prevalent TB cases not on TB treatment, available data on health care-seeking behaviour varied markedly (see supplementary material, Table S2 for a summary). Key findings included that a variable proportion (range, 27–66%) of those who screened symptom-positive during surveys reported having previously sought some form of care in a medical facility, that visits to private health facilities, pharmacies and self-medication were common and that a large proportion of TB cases (with or without reported symptoms) had not sought care at all (range 10–56%).

### Discussion

Our summary of results from national TB prevalence surveys in Asia shows that the burden of TB disease remains high in many countries, while also varying considerably. Surveys in Asia show that the burden of TB disease remains high in many countries, while also varying considerably. Our summary of results from national TB prevalence surveys in Asia shows that the burden of TB disease remains high in many countries, while also varying considerably.

Table 5 Health care-seeking behaviour among participants on TB treatment at the time of the survey, and detected TB cases

| Country       | Year | Number of bacteriologically-positive TB cases detected by the survey | Number (%) of survey participants currently on TB treatment | Number (%) of survey participants currently on TB treatment in the public sector | Number (%) of survey participants currently on TB treatment in the private sector | Number (%) of survey participants currently on TB treatment: unknown sector | Detected TB cases on treatment (%) reported to NTP at the time of the survey |
|---------------|------|---------------------------------------------------------------|-----------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Cambodia      | 2002 | 271                                                           | 11 (4)                                                    | 42                                                                             | 34 (81)                                                                        | 8 (19)                                                                         | 0 (0)                                                                   | 34 (81)                                                                 |
| Cambodia      | 2011 | 314                                                           | 6 (2)                                                     | 80                                                                             | 72 (90)                                                                        | 6 (8)                                                                          | 2 (3)                                                                  | 72 (90)                                                                 |
| China         | 2010 | 347                                                           | Not known                                                | 123                                                                           | 122 (99)                                                                       | 1 (1)                                                                          | 0 (0)                                                                  | 99 (72)                                                                 |
| Republic of Korea | 1995 | 142                                                           | 6 (4)                                                     | 71                                                                             | 34 (48)                                                                        | 33 (47)*                                                                        | 4 (6)                                                                  | Not known                                                                      |
| Myanmar       | 2009 | 311                                                           | 11 (4)                                                    | 79                                                                             | 63 (80)                                                                        | 15 (19)                                                                        | 1 (1)                                                                  | 63 (80)                                                                 |
| Lao PDR       | 2011 | 237                                                           | 6 (3)                                                     | 42                                                                             | 21 (50)                                                                        | 0 (0)                                                                          | 21 (50)                                                               | 21 (50)                                                                 |
| Thailand      | 2012 | 142                                                           | 6 (4)                                                     | 60                                                                             | 48 (80)                                                                        | 3 (5)                                                                          | 9 (15)                                                                | 48 (80)                                                                 |
| Viet Nam      | 2007 | 269                                                           | 39 (22)†                                                  | 407†                                                                           | 324 (80)                                                                       | 29 (7)                                                                         | 54 (13)                                                               | ¬ (80–93)§                                                             |

*In the Republic of Korea, 12 of the 33 cases were treated in the hospital sector which at the time may or may not have reported to the NTP.

†These data refer to the 174 smear-positive cases detected in the survey. These 39 cases refer to those currently on treatment or had been treated for ≥1 month.

‡Those reported to have been recently treated for TB within two years including those currently on treatment.

§Total detected TB cases reported to the NTP were not in the reference. Only a percentage was reported in the reference that was derived from imputation methods (Hoa et al. [12]).
decentralised beyond hospitals to include health centres [16, 55, 59]. The low proportion of bacteriologically-positive cases on treatment among survey cases in almost all recent surveys conducted several years after DOTS implementation also suggests an increase in the quality of TB treatment over time. In turn, earlier conversion to bacteriologically negative status could have helped to cut transmission.

As transmission declines, most incident cases will arise from past rather than recent infection. The average latency period between acquisition of infection and onset of disease increases as the age distribution of cases shifts towards older age groups; a tendency amplified by an ageing population. The TB epidemic in Asia is a progressively ageing epidemic; in most countries, the highest rates and absolute numbers of cases are now found in the oldest age groups.

All surveys reinforce other evidence (for example, from routinely reported case notification data and research studies [2, 44]) that the burden of TB disease in men is two to three times higher than in women, with sex ratios (male:female) ranging from 1.7 in Lao PDR and Pakistan to 5.1 in Viet Nam. This means that, overall, men account for about two-thirds to three-quarters of the burden of TB disease in Asia. Survey results about the proportion of cases with MDR-TB are also consistent with national surveys of drug resistance [65].

One of the most striking and consistent findings is that a high percentage of people with bacteriologically-positive TB did not report symptoms that met screening criteria. Among surveys conducted since 2007, the percentage of prevalent TB cases that screened symptom negative was typically in the range 40–60%. In all repeat surveys, this proportion increased over time. These observations have important implications. First, many people with bacteriologically-positive TB, including a large proportion of smear-positive cases, are unlikely to seek health care unless they suffer from another condition and will be a source of ongoing transmission in the community until symptoms worsen. Second, even if they do seek care, it is unlikely (with existing screening criteria) that they would be referred for further laboratory testing and a resulting TB diagnosis on the basis of reported symptoms. Third, as basic TB care services improve, most TB cases with ‘classic’ TB symptoms should be detected, but as the proportion of cases without such symptoms increases a prompt diagnosis becomes, on average, harder to make. Furthermore, a large share of TB cases was only identified in these surveys because the entire eligible survey population was screened using chest X-ray. Updated control strategies that enable earlier diagnosis and treatment, such as widening the current screening criteria and more systematic use of chest X-ray screening, along with raised awareness of healthcare providers about the magnitude and characteristics of TB cases in the community, are required.

More encouragingly, cross-country comparisons of the P:N ratio show that in several countries, it should be possible to achieve much more with strategies and technologies for TB care and control that are already available. The overall P:N ratio in Cambodia (2011), China (2010), the Philippines (2007) and Thailand (2012) was less than two, suggesting that countries with higher ratios (especially Lao PDR and Pakistan) have scope to improve. Comparisons by sex reinforce this conclusion: systematically lower P:N ratios for women show considerable potential to lower this ratio among men. While the burden of TB disease is much higher in men, P:N ratios indicate that women are probably accessing available diagnostic and treatment services in primary care more effectively. They also indicate that cases among older age groups tend to be detected less effectively; explanations may include lower access to health care for financial or other reasons and that TB symptoms are tolerated for longer as older individuals are more prone to have chronic health conditions, leading to delayed investigations.

Standardised survey data from multiple countries on patterns of healthcare-seeking behaviour could help to identify actions that NTPs and/or health services in general could take to shorten the time to TB diagnosis and to ensure prompt provision of high-quality care. Unfortunately, data collected in Asian surveys up to 2012 are relatively limited and not well standardised. However, they do show that, in at least some settings, a large share of people with bacteriologically-positive TB and who reported symptoms had sought care at private healthcare facilities or at pharmacies/drug sellers. This reinforces the need for continuous engagement with the full range of healthcare providers in the public and private sectors, especially in Asian countries in which a large share of total health expenditures and usage of first-line TB drugs occur in the private sector [60, 66]. In the future, efforts are needed to standardise the data that are collected on healthcare-seeking behaviour as part of surveys and to ensure that under-reporting of detected cases to NTPs is measured so that routine TB surveillance can be strengthened if necessary.

Challenges and failures during surveys implemented in the 2000s prompted WHO and technical partners to publish guidance that included standardised survey methods and examples of best practices [63]. Lessons learned about the process of preparing, implementing and reporting on surveys from the Asian surveys described in this
Box 2 Important lessons for other countries and future TB prevalence surveys regarding how to design, prepare, implement and report results

- The time needed to procure the necessary equipment, especially X-ray equipment, is often underestimated. Countries have different rules and regulations for the procurement of equipment and consumables, which must be fully understood when survey preparations are initiated.
- Laboratories must be prepared for the required increase in capacity. Surveys typically require 5 000–10 000 primary cultures to be examined in 6–12 months, in addition to those from routinely collected sputum specimens. Therefore, the annual increase in the number of specimens to be processed for culture is approximately 50–100% for small or mid-sized countries. Efficient scheduling, human resource and procurement capacity should be carefully assessed for the duration of the survey so that a laboratory can process routine and survey specimens without compromising the quality of laboratory work. It may be necessary to involve more than one laboratory if services can be standardised and quality assured.
- Eligibility criteria must be clearly enforced. Individuals should be enrolled only if they are resident in the survey site for a clearly defined and context-appropriate period of time (typically 2–4 weeks), to avoid enrolment bias due to people moving to the survey site for free chest X-ray screening.
- Exclusions of specific geographical areas must be done at the time of protocol development. Exceptions can be considered but these should be for truly exceptional situations that cannot be anticipated in advance, such as a natural disaster or new developments that affect the personal security of the survey team.
- Community engagement is essential but should not be done too early. Smooth enrolment of participants and high participation rates are strongly enabled by early involvement of community leaders. Raising awareness about the survey should not be carried out prematurely, however, because this can encourage people from neighbouring areas to move to survey clusters, in particular to benefit from free chest X-ray screening.
- The optimal cluster size is 500–800 people. This corresponds to the number of people who can be screened by chest X-ray in one week, which is the maximum time that a survey site can be kept operational. The typical number of clusters will range from 50 to 70.
- Data management must be given high priority. In many surveys, one of the weakest aspects of implementation has been data management (especially in the laboratory), which in turn has delayed analysis and dissemination of results. The necessary people with appropriate expertise and experience as well as other resources must be identified before protocol development to ensure that data management is carried out according to best practices.
- Data analysis must be given high priority. The analysis of survey data, especially adjustments for intercluster variability and multiple imputation of missing values should be carried out by experts familiar with and able to implement best practices [9]. This requires support from qualified statisticians. Holding a workshop to discuss results and their interpretation shortly after survey completion is very helpful for facilitating prompt consensus about and wide dissemination of results.
- Chest X-ray screening in communities with immediate feedback of screening results facilitates participation and high sputum collection rates. The failure of surveys in Malaysia, 2003 (in which participants were invited to a separate facility to undergo X-ray examination rather than screening being performed in the field) and Thailand, 2006 (delayed feedback of X-ray examination results) provided evidence that strongly supported the use of on-site radiological screening. This has been adopted in every survey in Asia since 2009.
- A smear-positive result does not always mean TB. In more recent surveys, for case management purposes and survey case definitions, detected smear-positive specimens are being tested with Xpert MTB/RIF or LPA to ensure accurate diagnosis of cases for whom smear results and clinical findings are inconsistent.
- Achieving high participation rates becomes more challenging as countries become more urbanised, and as overall income levels rise. Participation rates in almost all Asian surveys have been high. However, achieving high participation rates has been harder in urban areas and also in wealthier areas as well as in young people (especially men). Once access to health services is very good, there is little incentive to access free services (especially chest X-ray screening) provided during surveys.

study, to complement those arising from actual survey results, are summarised in Box 2. These include the importance of clearly enforcing eligibility criteria, when to define any geographical areas to exclude from the survey, the optimal cluster size, the role and magnitude of community engagement and the need to give high priority...
to and mobilise the right expertise for data management and data analysis.

There are several limitations to the survey data presented in this study. Most data are for adults only, due to well-recognised problems with the inclusion of children in surveys with currently available screening and diagnostic technologies. HIV testing was not performed in any survey, primarily for logistical reasons and concerns about the impact on survey participation rates. In three surveys (Myanmar, 1994; Bangladesh, 2008; Indonesia, 2004), the only laboratory test used to diagnose TB in most participants was smear microscopy and chest X-ray screening was not provided, leading to a probable underestimation of TB prevalence. Analysis of the 1994 Myanmar survey did not account for clustering, and we were unable to establish whether the analyses performed for four other surveys (China 1990, 2000; Republic of Korea 1990, 1995) did so.

There is also one major geographical gap in the coverage of national TB prevalence surveys in Asia: no national survey has been conducted in India, even though the country accounts for about 24% of the global TB burden. Surveillance data in India are not yet reliable enough to provide a direct measure of disease burden (there are no vital registration data with accurate coding of cause of death to measure mortality; and under-reporting of cases from the private sector as well as underdiagnosis mean that notification data are not a good proxy for TB incidence). A national TB prevalence survey would be very valuable for providing reliable population-based data about the burden of TB disease in the country.

**Conclusions**

National TB prevalence surveys in Asia show that TB prevalence is still high in most countries, that large reductions in TB burden can be achieved with well-implemented TB control strategies, that more men than women have TB disease in this region and that TB epidemics are ageing. Comparisons between countries show that more can be achieved in TB control in most countries. However, with many prevalent cases not reporting classic TB symptoms, all countries face the challenge of defining and implementing strategies that will result in effective detection and treatment of cases with milder forms of the disease.

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**References**

1. Aditama TY. Prevalence of tuberculosis in Indonesia, Singapore. Brunei Darussalam Philippines Tuberculosis 1991: 72: 255–260.
2. Borgdorff MW, Nagelkerke NJ, Dye C et al. Gender and tuberculosis: a comparison of prevalence surveys with notification data to explore sex differences in case detection. Int J Tuberc Lung Dis 2000: 4: 123–132.
3. Chia M & Huang J. Report on the prevalence survey in West Malaysia (1970). Regional office for the Western Pacific (WHO), 1971.
4. Daramas S, Konjanart S, Sunaknorn B. The second national tuberculosis survey in Thailand. Thai J Tuberc Chest Dis 1981: 1: 179–191.
5. Department of Health – Philippines. Risk of tuberculosis infection in the Philippines. (August–October 1992, 1992.
6. Dolin P. Report of a visit to Pakistan, December 25–19, 1997 (WHO report). Geneva, Switzerland, 1997.
7. Donald PR & starke JR. Tuberculosis in Children and Adolescents. Oxford University Press: USA, 2015 (To be published).
8. Dye C. Epidemiology and control of tuberculosis in Malaysia: A provisional analysis of survey and surveillance data (WHO report). Geneva, Switzerland, 2004.
9. Floyd S, Sismanidis C, Yamada N et al. Analysis of tuberculosis prevalence surveys: new guidance on best-practice methods. Emerg Themes Epidemiol 2013: 10: 10.
I. Onozaki et al. National TB prevalence surveys in Asia

10. Hoa NB, Sy DN, Nhun NG et al. National survey of tuberculosis prevalence in Viet Nam. Bull World Health Organ 2010: 88: 273–280.
11. Hoa NB, Tiemersma EW, Sy DN et al. Health-seeking behaviour among adults with prolonged cough in Vietnam. Trop Med Int Health 2011a: 16: 1260–1267.
12. Hoa NB, Cobelens FGJ, Sy DN et al. Diagnosis and treatment of tuberculosis in the private sector, Vietnam. (Correspondence). Emerg Infect Dis 2011b: 17: 562–564.
13. Hong YP, Kim SJ, Kwon DW et al. The sixth Nationwide Tuberculosis Prevalence Survey in Korea, 1990. Tuber Lung Dis 1993: 74: 323–331.
14. Hong YP, Kim SJ, Lew WJ et al. The seventh nationwide tuberculosis prevalence survey in Korea, 1995. Int J Tuberc Lung Dis 1998: 2: 27–36.
15. Lin TM, Chang AB, Tsu YC et al. Analysis of the four tuberculosis prevalence surveys in Taiwan. Taiwan Yi Xue Hui Za Zhi 1976: 75: 707–718.
16. Mao TE, Okada K, Yamada N et al. Cross-sectional studies of tuberculosis prevalence in Cambodia between 2002 and 2011. Bull World Health Organ 2014: 92: 573–581.
17. Ministry of Health – Bangladesh. Report of the tuberculosis survey in Bangladesh, 1964–1966. Ministry of Health: Dha- ka, Bangladesh, 1967.
18. Ministry of Health – Bangladesh. Report on the national prevalence survey on tuberculosis in Bangladesh, 1987–1988. Ministry of Health: Dhaka, Bangladesh, 1989.
19. Ministry of Health – Cambodia. Report of the national TB prevalence survey, 2002, Ministry of Health: Cambodia, 2005.
20. Ministry of Health – Cambodia. Report of the second national tuberculosis prevalence survey, 2011. Ministry of Health: Cambodia, 2012.
21. Ministry of Health – Indonesia. Report of the health survey (Surkesnas): tuberculosis prevalence survey, 2004. Ministry of Health: Jakarta, Indonesia, 2005.
22. Ministry of Health – Indonesia. Report of the basic health research survey (Riset kesehatan dasar – riskesdas), 2010. Ministry of Health: Jakarta, Indonesia, 2010a.
23. Law I, Sylvanah P, Bounmala et al. The first national tuberculosis prevalence survey of Lao PDR (2010–2011). Trop Med Int Health. 2015 May 5. [Epub ahead of print].
24. Ministry of Health – Myanmar. Sputum positive point prevalence survey. Ministry of Health: Myanmar, 1994.
25. Ministry of Health – Myanmar. Report on national TB prevalence survey 2009–2010. Yangon: Myanmar, 2010.
26. Ministry of Health – Singapore. Report of the 1975 tuberculosis prevalence survey. Ministry of Health: Singapore, 1975
27. Ministry of Health – Thailand. Third tuberculosis prevalence survey in Thailand, 1991–1992. Ministry of Health: Bangkok, Thailand, 1993.
28. Ministry of Health – Thailand. Fourth tuberculosis prevalence survey in Thailand, 2012. Ministry of Health: Bang- kok, Thailand, 2015 (To be published)
29. Ministry of Health & Social Affairs and the Korean National Tuberculosis Association. Report on the tuberculosis prevalence survey in Korea, 1965. Seoul, Korea, 1965.
30. Ministry of Health & Social Affairs and the Korean National Tuberculosis Association. Report on the second tuberculosis prevalence survey in Korea, 1970. Seoul, Korea, 1970.
31. Ministry of Health & Social Affairs and the Korean National Tuberculosis Association. Report on the third tuberculosis prevalence survey in Korea, 1975. Seoul, Korea, 1976.
32. Ministry of Health & Social Affairs and the Korean National Tuberculosis Association. Report on the fourth tuberculosis prevalence survey in Korea, 1980. Seoul, Korea, 1981.
33. Ministry of Health & Social Affairs and the Korean National Tuberculosis Association. The second report on the fifth tuberculosis prevalence survey in Korea, 1985. Seoul, Korea, 1986.
34. Ministry of Health & Social Affairs and the Korean National Tuberculosis Association. Report on the 6th Tuberculosis Prevalence Survey in Korea. Seoul, Korea, 1990.
35. Ministry of Health & Social Affairs and the Korean National Tuberculosis Association. Report on the 7th tuberculosis prevalence survey in Korea, 1995. Seoul, Korea, 1996.
36. Ministry of Health and Welfare – Japan. Survey of tuberculosis prevalence in Japan. Ministry of Health and Welfare: Tokyo, Japan, 1958.
37. Ministry of Public Health – China. Nationwide random survey for the epidemiology of tuberculosis in 1979. Ministry of Public Health: Beijing, China, 1979.
38. Ministry of Public Health – China. Nationwide random survey for the epidemiology of tuberculosis in 1985. Ministry of Public Health: Beijing, China, 1985.
39. Ministry of Public Health – China. Nationwide random survey for the epidemiology of tuberculosis in 1990. Ministry of Public Health: Beijing, China, 1990.
40. Ministry of Public Health – China. Nationwide random survey for the epidemiology of tuberculosis in 2000. Ministry of Public Health: Beijing, China, 2000.
41. Muranaka T. Tuberculosis prevalence survey in Japan in 1981. Kekkaku 1981: 56: 713–720.
42. National Institute of Tuberculosis – Philippines. Report on a national tuberculosis prevalence survey in the Republic of the Philippines (1981–1983). National Institute of Tuberculosis: Philippines, 1984
43. National TB control program – Pakistan. Prevalence of pulmonary tuberculosis among the adult population of Paki- stan, 2010–2011. Islamabad, Pakistan, 2013.
44. Neyrolles O, Quintana–Marci L. Sexual inequality in tuberculosis. PLoS Med 2009: 6: e1000199.
45. Omura T, Oka H, Kamabe H et al. The trend of tuberculosis in Japan during the period 1953–58. Comparison of the results of tuberculosis prevalence surveys. Bull World Health Organ 1962: 26: 19–45.
46. Quo S. Statistical summary report on a sample survey of tuberculosis prevalence in Taiwan, July 1957–June 1958, 1959.
47. Shimao T. Tuberculosis prevalence survey in Japan. Kekkaku 2009: 84: 713–720.
I. Onozaki et al. National TB prevalence surveys in Asia

48. Soemantri S, Senewe FP, Tjandrarini DH et al. Three-fold reduction in the prevalence of tuberculosis over 25 years in Indonesia. Int J Tuberc Lung Dis 2007; 11: 398–404.

49. Sriyabhaya N, Chanachaiviboonwat D, Wangprasertkul W et al. Intensification of tuberculosis case-finding by sputum microscopy and short course chemotherapy through primary health care in Yasothon Province, Thailand. (Poster presentation and abstract). World congress on Tuberculosis. Bethesda, Maryland, November 16-19, 1992.

50. Sunakorn B. The epidemiology of tuberculosis in Thailand. J Med Assoc Thai 1969: 52: 127–162.

51. Thein Nyunt U, Ko Gyi U, Kahn G et al. Tuberculosis baseline survey in Burma in 1972. Tubercle 1974: 55: 313–325.

52. Thomson A, Hayes R, Cousens S. Measures of between-cluster variability in cluster randomized trials with binary outcomes. Stat Med 2009: 28: 1739–1751.

53. Tropical Disease Foundation Inc and Department of Health. Final report of the national tuberculosis prevalence survey 1997. Navotas City, Philippines, 1997.

54. Tropical Disease Foundation Inc and Department of Health. Final report of the nationwide tuberculosis prevalence survey 2007. Navotas City, Philippines, 2008.

55. Tupasi TE, Radhakrishna S, Chua JA et al. Significant decline in the tuberculosis burden in the Philippines ten years after initiating DOTS. Int J Tuberc Lung Dis 2009: 13: 1224–1230.

56. Tupasi TE, Radhakrishna S, Pascual ML et al. BCG coverage and the annual risk of tuberculosis infection over a 14-year period in the Philippines assessed from the Nationwide Prevalence Surveys. Int J Tuberc Lung Dis 2000: 4: 216–222.

57. Tupasi TE, Radhakrishna S, Rivera AB et al. The 1997 Nationwide Tuberculosis Prevalence Survey in the Philippines. Int J Tuberc Lung Dis 1999: 3: 471–477.

58. Wakamatsu E. Tuberculosis Prevalence Survey in Japan in 1963. Kokkaku 1964: 39: 257–265.

59. Wang L, Zhang H, Ruan Y et al. Tuberculosis prevalence in China, 1990–2010: a longitudinal analysis of national survey data. Lancet 2014: 383: 2057–2064.

60. Wells WA, Ge CF, Patel N et al. Size and usage patterns of private TB drug markets in the high burden countries. PLoS ONE 2011: 6: e18964.

61. WHO. Report on tuberculosis baseline survey in Ceylon (WHO report). New Delhi, India, 1971.

62. Western Pacific Regional Office/WHO. Assessing tuberculosis prevalence through population–based surveys. Manila, Philippines, 2007.

63. WHO. Tuberculosis prevalence surveys: a handbook. WHO/HTM/TB/2010.17: Geneva, Switzerland, 2011.

64. WHO. Global Task Force on TB impact measurement, 2014 (Available from: http://www.who.int/tb/advisory_bodies/impact_measurement_taskforce/partners/en/) [20 November 2014].

65. WHO. Global Tuberculosis Report. Geneva, Switzerland, 2014. (WHO/HTM/TB/2014.08).

66. WHO. Health Accounts, 2014. (Available from: www.who.int/nha) [20 November 2014].

67. Yamaguchi M. Survey of tuberculosis prevalence in Japan, 1953. Bull World Health Organ 1955: 13: 1041–1073.

68. Zaman K, Hossain S, Banu S et al. Prevalence of smear-positive tuberculosis in persons aged >15 years in Bangladesh: results from a national survey, 2007–2009. Epidemiol Infect 2012: 140: 1018–1027.

Supporting Information

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

Table S1 Surveys in Asia 1990–2012 and their main characteristics.

Table S2 Healthcare-seeking behaviour among symptomatic participants and detected TB cases.

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