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European guidelines for the management of tuberculosis screening procedures in migrants: A systematic review

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ABSTRACT

Background: This systematic review assesses the current available evidence across the WHO European region on the effectiveness and cost-effectiveness of the different approaches used for TB screening and also explores the facilitators and barriers that migrants face during screening programmes.

Methods: We conducted an extensive, comprehensive, and systematic literature search across multiple databases, including MEDLINE, Cochrane, Scopus, and ISI Web of Knowledge, without any restrictions on publication date or language. In addition, we reviewed grey literature and reports. The data were meticulously analysed with a focus on screening of TB active disease and infection effectiveness indicators, and cost-effectiveness economic analyses as a primary objective and the comprehension of barriers and facilitators of screening as a secondary objective.

Findings: Our review included 43 studies covering over 8 million migrants from 11 countries. The findings demonstrate that while screening uptake was high, coverage varied, and completion rates for preventive treatments were low. Economic analyses supported the high cost-effectiveness of the screening programmes, particularly when integrating both active TB and TBI screening strategies.

Interpretation: This review underscores the cost-effectiveness and public health importance of TB screening in migrant populations within Europe. However, the disparities in screening practices highlight the urgent need for standardisation at the European level.

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Cost-effectiveness; Europe; migrants; public health; screening

Introduction

Globally, the number of international migrants is rising, being particularly marked in European countries with a substantial impact on the health system.[1–3] Approximately 5.1% of Europe's population consists of migrants, with estimated 23 million non-EU citizens residing in the region.[4] Migrants in Europe suffer from a disproportionate burden of infectious diseases, including tuberculosis (TB), experiencing barriers and limitations in access to health systems.[5,6] Tuberculosis is still one of the main causes of morbimortality worldwide, being responsible in 2023 for 10.8 million cases, resulting in 1.25 million deaths and in 2019 for 1.85% (1.69–2.05%) of Disability Adjusted Life Years (DALYs) worldwide for all causes of diseases, at all ages and in both sexes.[7] TB is a mandatory notifiable disease, meaning that clinicians have a statutory duty to notify local authorities.[8] Delays in TB notification pose a public health challenge, potentially exacerbating patients' health outcomes and impeding timely diagnosis and contact tracing efforts.[9] The migratory phenomenon has had a growing impact on the local epidemiology of TB, with special relevance in Europe particularly in Western Europe.[10] Although the majority of TB cases in Europe occur in individuals born in the region, TB is an important cause of morbidity and mortality among migrant populations. Thus, in several European countries, migrants represent the largest proportion of TB patients in comparison to the native population, for example in Liechtenstein (100%) of the TB cases are in migrants, while in Malta (97.9%),

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Iceland (91.7%), Sweden (86.6%), Cyprus (86.1%), Luxembourg (85.3%), Israel (84.8%), Norway (81.3%), the Netherlands (72.4%), Denmark (72.1%), Switzerland (71.3%) and the United Kingdom (70.1%).[11] To address the incidence of TB among migrants from high-incidence countries, some low-incidence TB countries in Europe have implemented screening measures for high-risk populations in alignment with WHO guidelines. This includes screening migrants from high-incidence countries for TB.[12,13] The WHO recommendations focus on systematically screening migrants from high-incidence countries for active TB with chest X-ray, and screening for TBI (TB infection) with the tuberculin skin test or IGRA.[14] The European Centre for Disease Prevention and Control (ECDC) recommends screening for active disease with chest X-ray and screening for TBI with the tuberculin test or IGRA on arrival in the country of destination for the entire population from countries with a high incidence of TB (>120 cases/100,000).[11] After the arrival of the migrant population, screening can benefit the destination population by preventing onward transmission, often in minority communities, and at the same time provide a direct benefit to individuals by detecting active disease and preventing the progression from infection to active disease.[15,16] Nevertheless, the execution of screening initiatives encounters several hurdles. Existing literature on migrant populations lacks clarity on the target demographic for screening, the cost-effectiveness of different screening procedures, optimal time frames for test administration, and obstacles to implementation, such as insufficient training of healthcare personnel and cultural disparities.[16–19] Thus, considerable variations across Europe in terms of screening procedures for active TB and TBI detection and best practices for early detection and treatment exist in the migrant population.[20–22]

The aim of this systematic review is to evaluate the current evidence from the WHO European region on the effectiveness and cost-effectiveness of different TB screening strategies. Additionally, the review also investigates the facilitators and the main barriers of TB screening programmes. This comprehensive evaluation helps inform policy and programme development to improve TB screening outcomes, especially in migrant population.

Methods

Search strategy and selection criteria

This systematic review included studies focusing on the effectiveness of screening for active tuberculosis (TB) and TB infection (TBI). Primary outcomes measured included screening coverage, uptake, treatment completion for both infection and disease, number needed to screen (NNS), number needed to treat (NNT), acceptability, and cost-effectiveness. Secondary outcomes encompassed barriers, and facilitators of screening. The present systematic review was conducted under Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, being the search conducted from October to December 2023. Four electronic databases were searched including MEDLINE, Cochrane Database of Systematic Reviews, ISI Web of Science, and Scopus. Websites of the WHO, ECDC, and Centers for Disease Control and Prevention (CDC) were searched by keywords as per the search strategy. Grey literature was also searched, using OpenGrey and Google Scholar.

The search was performed with no publication date and language restriction. The keyword combinations were: *'(Tuberculosis OR Latent Tuberculosis OR TB OR Mycobacterium tuberculosis) AND (Transients and Migrants OR immigrant OR asylum OR foreign born OR refugee) AND (screening OR mass screening)'*. Additionally, papers were identified by backward and forward citation searching. Three independent review authors (MP, CV, MC) provided content expertise to identify important articles in the topic area. The PICO framework (population, intervention, comparator, and outcome) was used to formulate the eligibility criteria. Studies including active TB and TBI in different subgroups of the migrant population (*i.e.*, asylum seekers, refugees, undocumented migrants, labour migrants, and unaccompanied minors) were eligible for inclusion. The established inclusion and exclusion criteria are shown in Figure 1.

Quality assessment

Three reviewers (M, CV, MC) independently screened articles: first by title/abstract and then by full text for inclusion. Consensus decisions were made at each screening stage. Key papers were selected

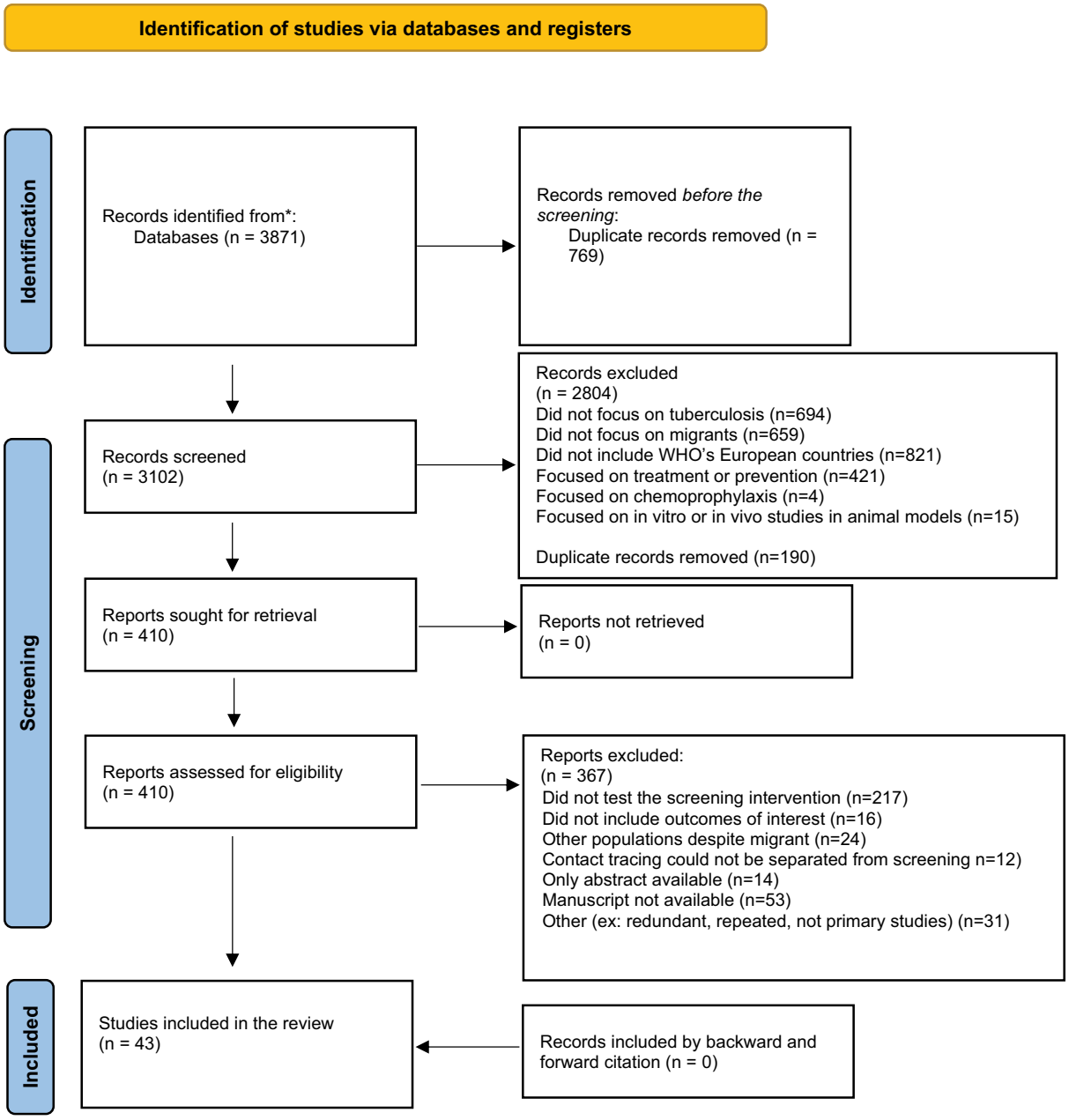

Figure 1. 2020 preferred reporting items for systematic reviews and meta-analyses flow diagram.

for studies with multiple publications. The Mixed Methods Appraisal Tool (MMAT) was used to assess the risk of bias. MMAT used in our study contained three sets of criteria according to the type of study: quantitative, qualitative, and mixed methods studies. The MMAT requires reviewers to assess the extent to which a study meets relevant criteria for the study design, with ratings of 'yes', 'no', and 'can't tell' generated for each criterion. Discrepancies in quality assessment between reviewers related primarily to how findings related to researchers' influence and sampling strategy of quantitative data and were settled through consensus.[23] Data was pooled and quantitatively synthesised using the median and interquartile range. Qualitative studies require clear research questions, appropriate data collection and analysis methods, and minimal bias. A narrative summary using a content analysis approach was chosen. The review is registered within PROSPERO (CRD42023471616) and received ethical approval from the Ethics Committee of the Institute of Public Health of the University of Porto (CE24260).

Data extraction and synthesis

MP conducted data extraction from selected articles using an extraction table, with each data item verified by two additional reviewers (CV and MC). To facilitate the comparison of data from the included records, the authors developed an extraction table with the following categories: first author, publication year, title of the publication, country of arrival, country of origin, study design, period of study, sample size, population, time of screening, TB type, tests, settings, primary outcome, and secondary outcome. Data from each included record was collated and summarised in Table 1. A narrative synthesis was conducted on the included studies, and the main findings are reported in the following section of the review under the following divisions: Effectiveness of TB screening in migrants; Effects of setting, target population, and disease; Cost-effectiveness of screening; Barriers of Screening; Facilitators of screening. Primary data was recorded and categorised according to the primary outcomes and general characteristics of studies, description of the interventions, effectiveness indicators, and secondary outcomes, namely barriers and facilitators of TB screening (Table 1). Migrant populations were divided into eight subgroups, namely all international migrants (foreign-born); refugees and asylum seekers; labour migrants; undocumented migrants; pregnant migrants; and foreign students. The barriers and facilitators of the screening were narratively and qualitatively described. Considering the variation between studies, the percentages were aggregated to represent the median and range for each indicator. Due to the substantial variability among studies, heterogeneous outcomes and the limited reporting of standard errors, conducting a meta-analysis of effectiveness was not considered appropriate.

Results

Database and grey literature searches yielded 3871 publications, of which the full texts of 3102 publications were screened and 43 were included[24–66] in the systematic review (Figure 1), and organised according to the date of publication from 2006 to 2023 (Table 1). Supplementary Table S1 details the results of the quality assessment. Thirty-four of the 43 studies were quantitative non-randomised studies. The main quality concerns were that in approximately 65% ($n = 22$) quantitative non-randomised studies fail to consider potentially confounders in the design and analysis. Studies were conducted in 11 countries, across the European region: the UK ($n = 13$), Italy ($n = 11$), Germany ($n = 5$), the Netherlands ($n = 4$), Norway ($n = 3$), Sweden ($n = 3$), Switzerland ($n = 1$), Malta ($n = 1$), Cyprus ($n = 1$), Finland ($n = 1$), Portugal ($n = 1$), and 2 studies were performed in a set of different countries of EU/EEA.[42,43] The majority of the studies establish the screening for TB by migrants based on country of origin. In this case, the criteria are usually the high incidence of TB but in the majority of the cases, the countries do not define the cut-off established to consider a TB high-incidence country. Some countries have a list of target countries and perform the screening, independently of the incidence of TB. In the studies that met the inclusion criteria, the majority were retrospective cohort ($n = 12$), cost-effectiveness ($n = 9$), prospective cohort ($n = 9$), cross-sectional ($n = 5$), quasi-experimental studies ($n = 3$), qualitative studies ($n = 2$), case–control ($n = 1$), and mix-method study ($n = 1$). The median period of study length in months is 24 months and the inter-quartile range (IQR) is 36 months. The total number of migrants included in this study is approximately 8 million (Table 1). The screening was performed for both TBI and active TB in a substantial proportion of the studies ($n = 19$), while some studies assessed the screening for active TB ($n = 12$), or TBI ($n = 12$) individually. From the included papers, migrants screened included all migrants ($n = 22$), asylum seekers ($n = 15$), refugees ($n = 5$), undocumented migrants ($n = 2$), and unaccompanied minors ($n = 1$). The screening occurs mainly at the post-entry in the host countries ($n = 23$) but also occurs upon entry ($n = 12$), and pre-entry ($n = 1$). In some studies, the screening occurred at different moments, namely at entry and post-entry ($n = 3$), pre-upon, upon and post-entry ($n = 2$), and pre- and post-entry ($n = 1$). The main tests used in the screening of TB are chest radiography ($n = 21$), IGRA ($n = 25$), symptom-based screening ($n = 16$), and TST ($n = 16$). Other tests that are used include nucleic acids amplification ($n = 4$), microscopy and culture ($n = 1$), histology ($n = 1$), a questionnaire of symptoms using a smartphone application ($n = 1$), and E-detect App based on questionnaire of symptoms combined with fast molecular tests ($n = 1$). Regarding the settings of the screening, the majority occur at the public health centre ($n = 10$), primary care ($n = 9$), hospital level ($n = 6$), in migration settings ($n = 4$), such as Refugee Health Care Centers, at the community level ($n = 1$) and may also occur at the different

Table 1. Descriptive summary of included studies.

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1°	Outcome 2°
Brewin	2006	24	UK	Several countries	qualitative	36	n = 53	Active TB	asylum seekers	post-entry	• not reported	Hospital, Primary care, and Community level	• not reported	• Facilitators: improving communication and information. Screening should be offered in a range of different settings to maximise uptake.
Harling	2007	25	UK	Not reported	prospective cohort	12	n = 8258	Active TB and LTBI	asylum seekers	post-entry	• TST • symptom-based screening • chest radiography	Primary care	• Uptake of screening = 94%. • Active TB = 2.2%. • The one-year cost of the service was £350 000 in total: around £40 per migrant screened and £30 000 per suspected case of active disease detected.	
Bodenmann	2008	26	Switzerland	Latin America (51.2%), Sub-Saharan Africa (19.2%) and other countries	prospective cohort	6	n = 161	LTBI	undocumented migrants	post-entry	• IGRA	Hospital	• LTBI positive = 19.2%. • Active TB = 1.6%. • Preventive treatment completed = 21%. • Acceptance of screening = 81.4%.	• not reported
Erkerns	2008	27	Netherlands	non-Western countries that stay longer than 3 months	prospective cohort	29	n = 70173	Active TB	migrants	upon-entry and post-entry	• chest radiography	Migration settings	• Coverage of screening = 34–59%.	• not reported
Hardy	2010	28	UK	countries with TB incidence > 200/100000	prospective cohort	12	n = 280	LTBI	migrants	post-entry	• IGRA	Not reported	• Uptake of screening = 32%. • The total cost to screen 280 immigrants was £9781.82 (£34.94 per immigrant) and identified 105 cases of LTBI (£93.16). • NICE protocol would have cost an estimated total of £13346.75 (£47.67 per immigrant) and would have identified 83 cases of LTBI (£160.81 per case identified).	• not reported

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1º	Outcome 2º
Orlando	2010	29	Italy	Several countries	cross-sectional	24	n = 1130	LTBI	migrants	post-entry	• TST • IGRA	Hospital	• LTBI positive = 36.04 versus 29.82% (intention-to-treat) and 45.27 versus 30.22% (per protocol), respectively for tuberculin and quantiFERON® test.	• not reported
Pareek	2011	30	UK	Indian subcontinent (60%), Sub-Saharan Africa (20%), Other Asia (13%), Europe, Americas (4%), Middle East, North Africa (2%)	cost-effectiveness	31	n = 1229	Active TB and LTBI	migrants	upon-entry	• symptom questionnaire • IGRA	Primary care	• LTBI positive = 20%, 95% CI 18–22% (*n* = 245 individuals). • NNS = 165.5–231.9. • NNT = 42.0–42.7. • The two most cost-effective strategies were: to screen individuals from countries with a TB incidence of more than 250 cases per 100 000 (incremental cost-effectiveness ratio [ICER] was £17 956 [£1=US$1·60] per prevented case of tuberculosis) and at more than 150 cases per 100 000 (including immigrants from the Indian subcontinent), which identified 92% of infected immigrants and prevented an additional 29 cases at an ICER of £20 819 per additional case averted.	• not reported
Pace-Asciak	2013	31	Malta	Sub-Saharan Africa (66%), Northern Africa (22%), Western Asia (9%), Southern Asia (3%)	retrospective cohort	48	n = 4570	Active TB	migrants	entry	• chest radiography	Public Health	• Screening coverage = 85%. • Active TB = 0.44% (*n* = 20).	• Facilitators: free access to TB health care; including cultural mediators in TB screening. • Barriers: relative inaccessibility of the health services due to lack of information; language; and cultural barriers.

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1º	Outcome 2º
Pareek	2013	32	UK	Asian countries (excluding the Indian subcontinent) (42.4%) and the Indian subcontinent (21.2%)	cost-effectiveness	21	n = 306	Active TB and LTBI	migrants	upon-entry	• symptom-based screening • TST • IGRA • T-SPOT.TB screening CxR	Primary care	• LTBI positive = 30.3% for TST (*n* = 70), 16.6% using QFN-GIT (*n* = 38) and 22.5% (*n* = 52) using T-SPOT.TB). • Acceptation of screening = 80.9% (*n* = 187); • The two most cost-effective screening strategies were: no port-of-entry CXR and screen with single-step QFN-GIT at 250/100 000 per year (incremental cost-effectiveness ratio (ICER)) £21 565.3/case averted); and no port-of-entry CXR and screen with single-step QFN-GIT at 150/100 000 per year (averted additional 7.8 TB cases; ICER £31 867.1/case averted).	• not reported
Kruijshaar	2013	33	UK	Nigeria, India, Uganda, Bangladesh, Pakistan, Philippines, Somalia, Kenya, Zimbabwe, South Africa	retrospective cohort	60	Not reported	LTBI	migrants (≥35 years)	post-entry	• IGRA	Not reported	• NNS = 16 and 83, respectively for Somalia and Uganda. NNS < 200 for Pakistan, Kenya, Zimbabwe, and India. NNS = 1242 and 500 for South Africa and Philippines. • NNT = 4 and 23, respectively for Somalia and Uganda; <50 for for Pakistan, Kenya, Zimbabwe, and India; 348 and 90 for South Africa and Philippines.	• not reported
Panchal	2014	34	UK	48% from countries with a high TB incidence; cut-off >150/100 000	retrospective cohort	132	n = 59007	LTBI	migrants	upon-entry	• Not reported	Primary care	• NNS = 65 (95% CI 57–74).	• not reported

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1[a]	Outcome 2[a]
Harstad	2014	35	Norway	Not reported	case-control	11	n = 257	Active TB and LTBI	asylum seekers and refugees	post-entry	• chest radiography • TST • IGRA	Migration settings	• not reported	• Facilitators: Increased collaboration between the municipal and specialist health care can improve the follow-up of positive TB screening results.
Aldridge	2016	36	UK	TB high-incidence countries (*n* = 15)	cross-sectional	108	n = 476 455	Active TB	migrants	pre-entry	• chest radiography • sputum testing	Public Health and Migration settings	• NNS = 1087 and 444 (migrants from countries with a prevalence of 150–349 per 100 000 population) Ccost pilot screening program = £1·1 million • cost per individual US $50–70.	• not reported
Schepisi	2016	37	Italy	Several countries (especially Sub-Saharan Africa (34.8%), Asia (28%), and Northern Africa (14.8%)	quasi-experimental	53	n = 6347	Active TB	migrants	post-entry	• symptom-based screening	Primary care	• Acceptation of screening = 53.5% (*n* = 292). • Active TB = 0.17% (*n* = 11).	• Facilitators: simplification of the screening procedures with no resources (laboratory and imaging); including cultural mediators in TB screening; legal status, length of stay in the host country, and access to public healthcare. • Barriers: irregular legal status, unstable access, and link to public healthcare.
Zannetos	2016	38	Cyprus	Several countries with high incidence of TB; cut-off not reported	cost-effectiveness	12	n = 7786	Active TB and LTBI	migrants	post-entry	• TST • chest radiography	Not reported	• Net Present Value was €3,188,653.	• not reported
Usdin	2017	39	UK	Several countries with high incidence of TB; cut-off >40, >100 and > 200 cases per 100 000 population	prospective cohort	24	n = 588	Active TB and LTBI	migrants	upon-entry and post-entry	• symptom-based screening • IGRA	Community level	• LTBI positive = 16% (*n* = 71). • Active TB = 0.45% (*n* = 2). • Uptake of screening = 75% • Preventive treatment completed = 85%. (*n* = 45).	• not reported
Berg	2017	40	Netherlands	China (13%), Turkey (11%), India (8%), Morocco (6%) and Indonesia (5%)	retrospective cohort	60	n = 117389	Active TB	migrants (excluding asylum seekers)	upon-entry	• chest radiography	Public Health	• Coverage of screening = 47% in the first round (after 6 months), and decreased to 28%, 21%, and 21% in the subsequent screening rounds.	• not reported

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1°	Outcome 2°
Haukaas	2017	41	Norway	Not reported	cost-effectiveness	120	n = 20000	Active TB and LTBI	migrants (<35 years)	upon-entry	• TST • IGRA	Not reported	• Costs of treating LTBI and TB disease = €1938 and €15,489 per case, respectively. • Screening all immigrants with IGRA requires the highest threshold (€28,400). • Expected value of perfect information = €5 per screened immigrant. • Costs cohort follow-up = €12.2 million for the algorithm 'screening and treatment for TB disease but no LTBI screening', • Cost cohort follow-up= €14 million for "screening all immigrants for both TB disease and LTBI with IGRA.	Not reported
Guthmann	2018	42	31 countries of EU/EEA	Several countries	cross-sectional	4	not reported	Active TB and LTBI	migrants	upon-entry and post-entry	• not reported	Public Health	• not reported	• Barriers: lacking knowledge about TB, low motivation to adhere to treatment among vulnerable/high-risk groups, and low motivation to seek treatment among vulnerable/ high-risk groups • Facilitators: reaching vulnerable population groups, screening for active TB in high-risk population groups, implementing electronic TB case registries.

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1º	Outcome 2º
Greenaway	2018	43	EU/EEA countries	Several countries	cost-effectiveness	192	n > 6 million	Active TB and LTBI	migrants	pre-entry, upon-entry and post-entry	• symptom-based screening • chest radiography • smear and GeneXpert • TST • IGRA	Not reported	• Acceptance of screening = 85%; range: 55–96%) • NNS = 5076 (3,175–9,709) (countries with a TB incidence between 50 and 149 per 100,000); NNS = 602 (514–714)(countries with a TB incidence 150–249 per 100,000); NNS = 749 (631–903) (countries with a TB incidence of 250–349 per 100,000); NNS = 298 (254–353) (countries with a TB incidence greater than 350 per 100,000) • CXR screening of migrants was cost-effective compared with no screening (evidence low-to-moderate).	• Facilitators: including the right to healthcare access for all and programs tailored to address unique needs.
Barcellini	2019	44	Italy	North African countries (Central Mediterranean route)	prospective cohort	24	n = 3787	Active TB	refugees	upon-entry	• smartphone application (symptom-based screening) • fast molecular test	Hospital	• not reported	• Facilitators: the use of a phone application standardised data collection, allowed screening in the 'field' and transfer of patients information directly to the referral hospital.
Berrocal-Almanza	2019	45	UK	TB High-incidence TB countries	qualitative	6	not reported	Active TB and LTBI	migrants	post-entry	• IGRA	Primary care and Community level	• not reported	• Facilitators: promote awareness of the importance of LTBI testing; provide a bridge between the community and primary care services; make tests routine and use groups familiar within communities.
Berrocal-Almanza.	2019	46	UK	TB High-incidence TB (*n* = 66)	retrospective cohort	48	n = 224234 in interventional group (screened); *n* = 118738 in group (2) (not screened)	LTBI	migrants	pre-entry and post-entry	• not reported	Primary care	• LTBI positive = 17%. • Active TB = 0%.	• Barriers: fear; stigma.

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1º	Outcome 2º
Bonvicini	2019	47	Italy	Not reported	retrospective cohort	24	n = 368	Active TB and LTBI	undocumented migrants	post-entry	• chest radiography • histology • TST	Hospital	• Uptake of screening = 90.22% (active TB) and 87.33% for LTBI • Disease treatment completed = 100%.	• Facilitators: availability of cultural mediators, having a network between the different health services, and the presence of dedicated nursing staff and free-of-charge services. TB screening at the point of arrival is more (3)table for the migrant population.
Pontarelli	2019	48	Italy	Mainly originating from the African continent (86.9%)	retrospective cohort	24	n = 2904	Active TB and LTBI	asylum seekers	post-entry	• symptom-based screening • TST	Public Health	• LTBI positive = 36.6% of LTBI cases (843/2303) using TST. • Coverage of active TB screening = 88.4% (*n* = 2567) and LTBI screening = 89.7% (*n* = 2302). • Uptake of screening = 49.0% (*n* = 413) completed the screening for LTBI. • Preventive treatment completed = 10.8% (*n* = 91).	• Facilitators: communication was facilitated by the use of cultural mediators as appropriate. • Barriers: increased demand for poorly resilient services; hard-to-reach populations.

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1º	Outcome 2º
Spruijt	2019	49	Netherlands	Countries with high TB incidence; cut-off >200 per 10000 population	mix-methods	14	n = 738	LTBI	asylum seekers	post-entry	• symptom-based screening • IGRA	Public Health	• Coverage of screening = 97% (*n* = 719). • Preventive treatment completed = 87% of migrants (*n* = 129).	• Facilitators: planning the screening in collaboration with the health workers; health workers could help locate migrants in case of no-show; allowing migrants to call and invite friends or family eligible for LTBI screening; the use of professional interpreters, and the LTBI treatment support given to migrants by TB nurses; the use of alarms on mobile phones, WhatsApp contact between nurses and migrants (using emoticons, spoken messages and very simple text messages), and week boxes for medication. • Barriers: stigma misinformation and gossip about the amount of blood collected for the blood test.
Thee	2019	50	Germany	Afghanistan, Syria, Lebanon and Iran	quasi-experimental	3	n = 301	LTBI	unaccompanied minors	post-entry	• IGRA	Public Health and Community level	• LTBI positive = 13.9% (*n* = 42). • Uptake of screening (*n* = 40) = 95%. • Preventive treatment completed = 89% of the patients (*n* = 34).	• not reported
Winje	2019	51	Norway	Countries with high TB incidence; cut-off >150 and 200 per 10000 population	prospective cohort	48	not reported	LTBI	asylum seekers	upon-entry	• IGRA	Migration settings	• NNS for Thailand (NNS 585 [413–887], and for Somalia (NNS 99 [70–150]). • NNT for Thailand (NNT 111 [79–116], and for Somalia (NNT 27 [19–41]).	• not reported

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1º	Outcome 2º
Grecchi	2020	52	Italy	Several countries, especially Sub-Saharan Africa (82.2%)	prospective cohort	31	n = 726	Active TB and LTBI	asylum seekers	post-entry	• symptom-based screening • chest radiography • nucleic acids amplification (smear and GeneXpert) • TST • IGRA	Public Health and Hospital	• LTBI positive = 31.3%. • Active TB = 0.84%. • Uptake of screening = 98.2%. • Preventive treatment completed = 97.1%.	• not reported
Räisänen.	2020	53	Finland	Iraq, Afghanistan, and Somalia	retrospective cohort	24	n = 38134	Active TB	asylum seekers	post-entry	• symptom-based screening • chest radiography	Public Health	• Active TB = 0.25% (*n* = 96/38134). • NNS = 552.	• not reported
Tewes	2020	54	Germany	Several countries	retrospective cohort	2	n = 705	Active TB	refugees and asylum seekers	upon-entry	• chest radiography	Public Health	• Active TB = 0.001%.	• Barriers: language barriers; quickly transferring of the screening population to a different accommodation site before screening results are finished; lack of stringent administration. • Facilitators: better care provision with standard-operating procedures
Wahedi	2020	55	Germany	Several countries	retrospective cohort	168	n = 84505	Active TB	asylum-seekers	upon-entry	• symptom-based screening • chest radiography	Public Health	• ICERs of screening from countries with an incidence of 50 to 250/100,000 = 15,000–17,000€. ICER for screening asylum-seekers from countries with an incidence < 50/100,000 = 112,000€ per additional case found.	• Barriers: language barriers and restricted access to health care. • Facilitators: understanding asylum-seekers as a heterogeneous population with complex health needs and risks and changing population dynamics.
Goscé	2021	56	Italy	TB High-incidence countries	cost-effectiveness	96	n = 3787	Active TB and LTBI	asylum seekers	upon-entry	• E-DETECT (app-based symptoms screening with Xpert MTB/RIF Ultra assay)	Public Health	• Active TB = 0.40% (*n* = 15). • Average cost per recruited patient = €11.05 • Cost per true positive case = €2,788.55.	• not reported
Pampaloni	2021	57	Italy	África	quasi-experimental	24	n = 33676	Active TB	migrants	upon-entry	• symptom-based screening • chest radiography • sputum testing	Migration Settings and Hospital	• Active TB = 0.16% (*n* = 55). • Disease treatment completed = 100% (*n* = 55).	• not reported

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1[a]	Outcome 2[a]
Shedrawy.	2021	58	Sweden	Several countries	cost-effectiveness	48	n = 5470	Active TB and LTBI	migrants	post-entry	• IGRA • TST • chest radiography	Hospital	• ICER in the age group 13–19 years had the lowest ICER, 300,082 Swedish Kronor (SEK)/QALY, which is considered cost-effective in Sweden. • ICER in the age group 20–34 was 714,527 SEK/QALY (moderately cost-effective). • ICER in all age groups above 34 was above 1,000,000 SEK/QALY (not cost-effective). • ICER decreased with increasing TB incidence in the country of origin.	• not reported
Marx	2021	59	Germany	Several countries	cost-effectiveness	24	Not reported	Active TB and LTBI	asylum seekers (15–34-years)	upon-entry	• symptom-based screening • chest radiography • IGRA	Public Health	• LTBI positive = 17.5% (95% uncertainty interval: 14.2–21.6%). • Introducing LTBI screening/TB preventive treatment above 250 per 100,000 country-of-origin TB incidence would gain 7.3 (2.7–14.8) QALYs for €51,000 (€18,000–€114,100) per QALY. Lowering the threshold to ≥ 200 would cost an incremental €53,300 (€19,100–€122,500) per additional QALY gained relative to the ≥ 250 threshold scenario. • Incremental cost-effectiveness ratios for the ≥ 150 and ≥ 100 thresholds were €55,900 (€20,200–€128,200) and €62,000 (€23,200–€142,000), respectively.	• not reported

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1º	Outcome 2º
Öhd.	2021	60	Sweden	Several countries	retrospective cohort	36	n = 14173	LTBI	asylum seekers	post-entry	• TST • IGRA	Primary care	• Coverage of screening = 39%. • LTBI positive = 25%. • Preventive treatment completed = 16%.	• not reported
Berrocal-Almanza	2022	61	UK	TB High-incidence countries (*n* = 55)	retrospective cohort	96	n = 368 097	LTBI	migrants	post-entry	• IGRA	Primary care	• LTBI positive = 17.8%. • Preventive treatment completed = 26.2%.	• Barriers: language facils, self-perceived low risk of LTBI or active TB, stigma, mistrust, and fear of deportation or immigration status.
Marchese	2022	62	Italy	Several countries	prospective cohort	17	n = 1356	Active TB and LTBI	asylum seekers	post-entry	• symptom-based screening • chest radiography • TST • IGRA	Migration settings	• LTBI positive = 18.5%. • Active TB = 4.2%. • Uptake of screening = 98.6% in the centralised delivery method and 74.5% in the decentralised model	• Barriers: large numbers of migrants may overwhelm the capacity of the staff in hosting centres. Booking and performing health consultations may be challenging (i.e., risk of overlapping the appointments, lack of vehicles), reducing the effectiveness of the screening. • Facilitators: All steps of the screening were performed by the same multidisciplinary team, possibly contributing to improved trust in the system and a better relationship with the patients, both affecting the overall acceptance and completion of the screening.
Menezes	2022	63	Italy, Netherlands, Sweden, UK	Several from Asia and Africa	cross-sectional	156	n = 2107016	Active TB	asylum seekers	pre-entry, upon-entry and post-entry	• symptom-based screening • chest radiography • TST • IGRA	Primary care and Migration settings	• Active TB = 0.072% (72.0 (95% CI: 68.6–75.6) per 100,000 persons screened	• not reported
Ferro	2023	64	Portugal	Ukraine	cross-sectional	1	n > 48 000	Active TB and LTBI	refugees	post-entry	• chest radiography • TST • IGRA	Primary care	• not reported	• Barriers: difficulties in the mobility of refugees to another city, refusal to perform chest radiography, linguistic barrier, lack of human resources.

(*Continued*)

Table 1. (Continued).

Author	Year	Reference	Country of arrival (EU)	Country of origin	Study design	Period of study (month)	Sample size	TB type	Population	Time of screening	Methods	Setting	Outcome 1º	Outcome 2º
Russo	2023	65	Italy	Countries with high TB incidence; cut-off >150 per 10000 population	cost-effectiveness	36	n = 595	LTBI	migrants	post-entry	• IGRA • TST	Hospital	• LTBI positive = 30%. • Uptake of screening = 89.1% (*n* = 530). • Preventive treatment completed = 18.2–19% (*n* = 52–65).	• not reported
Häcker	2023	66	Germany	Ukraine	cross-sectional	8	n = 26196	Active TB and LTBI I	refugees (>15 years)	post-entry	• chest radiography • IGRA	Not reported	• LTBI positive = 13%. • Active TB = 0.2. • NNS = 545.	• not reported

Study	Reference	Country	Number Screened	Target Population	Tests Employed	Findings for LTBI – costs associated	Findings for TB Disease – costs associated
Harling et al.	25	UK	n = 8258	asylum seekers	Induction centre TB screening services	LTBI screening at induction centre: £40 per migrant screened, £30,000 per suspected case of active disease detected.	Active TB screening: £40 per migrant screened, £30,000 per suspected case of active disease detected.
Hardy et al.	28	Not specified	n = 280	migrants	QuantiFERON® test	QuantiFERON® test (IGRA): £34.94 per immigrant screened, identified 105 cases of LTBI (£93.16 per case identified)	Not applicable
Pareek et al.	30 and 32	UK	n = 1229	migrants	Not specified	LTBI screening program: Most cost-effective strategy screened individuals from countries with TB incidence > 250 cases per 100,000 (ICER of £17,956 per prevented case of TB)	Not applicable
Zannetos et al.	38	Cyprus	n = 7786	migrants	Thresholds for effective screening TST, chest radiography	Thresholds for effective screening: Screening at 40/100,000 per year with specific tests was cost-effective Screening program in Cyprus: Net Present Value €3,188,653. Screening all migrants, including those from high-prevalence European countries not currently screened, was cost-saving.	Not applicable Not applicable
Haukaas et al.	41	Norway	n = 20000	migrants	IGRA, TST	LTBI screening in migrants: Screening all migrants with IGRA was most costly. Cost for cohort of 20 000 immigrants ranged from €12.2 million to €14 million over 10 years.	TB disease screening in migrants: Cost for cohort of 20 000 immigrants ranged from €12.2 million to €14 million over 10 years.
Greenaway et al.	43	EU/EEA	n = 192	migrants	chest radiography	CXR screening of migrants in EU/EEA countries: Cost-effective compared with no screening.	Not applicable
Wahedi et al.	55	Germany	n = 84505	asylum seekers	Symptom questionnaire, X-ray	Not applicable	Active TB screening program: ICERs ranged from €15,000–17,000 per additional case found, depending on TB incidence.
Goscé et al.	56	Italy	n = 3787	asylum seekers	E-DETECT	Screening of asylum seekers in Italy: E-DETECT screening reported an average cost per recruited patient of €11.05. Cost per true positive case was €2,788.55.	Not applicable
Shedrawy et al.	58	Sweden	n = 5470	migrants	IGRA, TST, chest radiography	LTBI screening program in Stockholm: Cost-effective for age group 13–19 years (300,082 SEK/QALY) and moderately cost-effective for age group 20–34 (714,527 SEK/QALY). Cost-effectiveness varied.	TB disease screening program in Stockholm: Moderately cost-effective for KONI_A_2484880age group 20–34 (714,527 SEK/QALY). Not cost-effective for age groups above 34 (ICER >1,000,000 SEK/QALY). Cost-effectiveness varied.
Marx et al.	59	Germany	Not specified	asylum seekers (15–34-years)	symptom-based screening, chest radiography, IGRA	LTBI screening and preventive treatment in asylum seekers in Germany: Cost per QALY gained ranged from €51,000 to €62,000 depending on country-of-origin TB incidence thresholds.	Not applicable
Russo et al.	65	Italy	n = 595	migrants	IGRA-only strategy, sequential strategy	TB screening strategies in Italy: IGRA-only strategy had higher completion rate and lower completion time compared to sequential strategy. Cost-effectiveness was higher for sequential strategy.	Not applicable

List of abbreviations: CI: confidence interval; CXR: chest X-ray; E-DETECT: early detection and integrated management of tuberculosis in Europe; EU: European Union; EEA: European economic area; ICER: incremental cost-effectiveness ratio; IGRA: interferon gamma release assay; LTBI: latent tuberculosis infection; NICE: national institute for health and care excellence; NNS: number needed to screen; NNT: number needed to treat; PHS: public health services; QALY: quality-adjusted life year; SEK: Swedish kronor; TB: tuberculosis; TBI: tuberculosis infection; TST: tuberculin skin test; UK: United Kingdom; WHO: World health Organization.

combinations, namely at primary care and migration's settings ($n = 1$), primary care and community ($n = 1$), public health and migrations' settings ($n = 1$), public health and hospital ($n = 1$), public health and community level ($n = 1$), hospital and migration's setting ($n = 1$), and hospital, primary care and community ($n = 1$).

Effectiveness of TB screening in migrants

Different indicators of the effectiveness of screening, including the percentage (%) of active TB diagnosis, TBI diagnosis, acceptability, coverage, uptake, and preventive treatment completed, are represented in Figure 2a. The number of individuals who were screened (NNS) among migrants to identify one person with TB and the number of individuals who need to be treated (NNT) with TBI chemoprophylaxis to prevent one TB case in the migrant screening programme is depicted in Figure 2b. The indicators of the effectiveness of the screening are also listed in Table 1.

From the analysis of Figure 2 and Supplementary Table S2, it is possible to notice that the infection was detected in (19.2%, IQR 13.7) ($n = 15$) of the screened cases, and the active disease in (0.33%, IQR 0.68) ($n = 14$) of migrants. The coverage of the screening from the included studies was (65.8%, IQR 50.1) ($n = 6$). The screening uptake was (88.8%, IQR 32.5) ($n = 9$). Of the migrants that tested positive for the infection, only (26.2%, IQR 70.4) ($n = 9$) completed treatment for TBI, while the migrants who tested positive for active TB (100%, IQR 0) ($n = 2$), completed the treatment. The number needed to screen (NNS) was (231, IQR 1022) ($n = 8$), being the number needed to treat (NNT) calculated (69, IQR 61) ($n = 3$). Regarding the acceptability of the screening, some studies ($n = 4$) calculated the acceptance of migrants' screening (81.2%, IQR 53.9) ($n = 4$) and one ($n = 1$) evaluated the acceptability qualitatively. All the previous studies concluded that the screening is considered acceptable from both migrants' perspectives.

Study-specific results were desegregated and stratification was made according to the effects of settings, target population, disease, and tests on the indicators of screening effectiveness that are most frequent in the included studies, namely coverage, uptake, and treatment completion are depicted in Table 2. Stratification was conducted to investigate the impact of setting, target population, and disease type (active TB versus TB infection) on screening effectiveness. Screening coverage was medium for migrants at (46.5%, IQR 53.0) ($n = 3$) and higher for asylum seekers and refugees at (89.1%, IQR 58.0) ($n = 3$). Uptake was higher in asylum seekers at (91.4%, IQR 32.5) ($n = 4$), unaccompanied minors (95.0%, IQR 0), undocumented migrants at (90.2%, IQR 0) ($n = 1$), being lower in general migrants at (75.0%, IQR 57.1) ($n = 4$). Preventive treatment completion was higher for asylum seekers and refugees at (87.0%, IQR 86.3) ($n = 4$), but lower for migrants at (22.2%, IQR 8.8) $n = 3$) undocumented migrants at (21.0%, IQR = 0) ($n = 1$) and unaccompanied minors

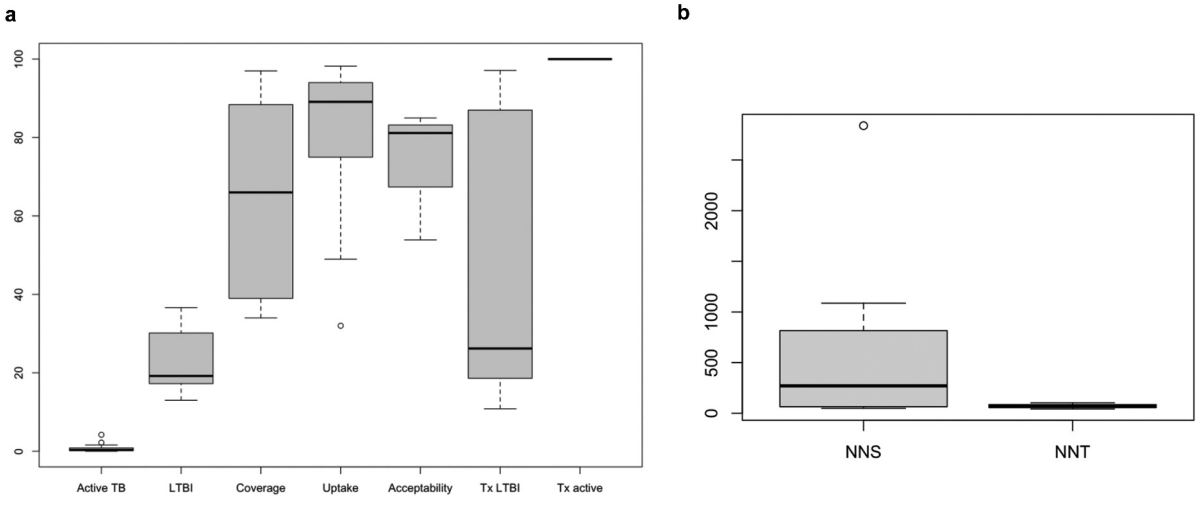

Figure 2. Boxplot representation of the indicators of screening effectiveness(% of active TB, % of LTBI detection, coverage, uptake, acceptability, treatment prevention completion and treatment active TB completion (1A), NNS, and NNT (1B). List of abbreviations: LTBI: latent tuberculosis infection; NNS: number needed to screen; NNT: number needed to treat; TB: tuberculosis; Tx: treatment.

(89.0%, IQR 0.0) ($n = 1$). For disease type, screening coverage was higher for TBI at (89.1%, IQR 58.0) ($n = 3$), and lower in active TB at (65.8%, IQR 57.1) ($n = 4$). Uptake was also similar for TBI at (86.8%, IQR 32.5) ($n = 9$) compared with active TB at (87.7%, IQR 34.1) ($n = 6$). Treatment of infections was lower (26.2%, IQR 70.4) ($n = 9$) in TBI, compared with active TB, where all the cases were treated (100%, IQR 0) ($n = 2$). By test type, screening coverage was higher for symptom questionnaires at (93.1%, IQR 8.0) ($n = 2$), being lower for TST at (64.0%, IQR 50.1) ($n = 2$), IGRA at 68.0% (IQR 58.0) ($n = 2$), and X-ray at (46.5%, IQR 53.0) ($n = 3$). Screening uptake was higher for GeneXpert (98.2%, IQR 0) ($n = 1$),[52] TST at (89.7%, IQR 8.3) ($n = 6$), histology (90.2%, IQR 0) ($n = 1$), IGRA at (86.6%, IQR 23.2) ($n = 5$), X-ray at (87.6%, IQR 66.2) ($n = 4$), and symptoms questionnaire at (86.6%, IQR 34.1) ($n = 5$), but lower for QuantiFERON at (32.0%, IQR 0 ($n = 1$)). Preventive treatment completion was higher for GeneXpert (97.1%, IQR 0) ($n = 1$) and for symptom questionnaires (86.0%, IQR 71.0) ($n = 4$), medium for IGRA at (56.5%, IQR 68.4) ($n = 6$), and lower for TST at (16.0%, IQR 86.3) ($n = 3$) and X-ray (18.6%, IQR 81.1) ($n = 3$). Taking into account the screening settings, the coverage was higher for public health (85.0%, IQR 57.1) ($n = 4$), and medium in migration settings (46.5%, IQR 0) ($n = 1$), and lower in the case of primary care (39.0%, IQR 0.0) ($n = 1$). The uptake was higher for public health (95.0%, IQR 49.2) ($n = 3$), primary care (94.0%, IQR 0) ($n = 1$), being lower in the case of the hospital (89.1%, IQR 9.4) ($n = 3$), migration settings (86.6%, IQR 0) ($n = 1$), and community (85.0%, IQR 0.0) ($n = 1$). Preventive treatment completion was higher for public health (88.0%, IQR 78.2) ($n = 4$) and community (87.0%, IQR 4.0) ($n = 2$), being lower in hospital (21.0%, IQR 78.5) ($n = 3$), and primary care (21.1%, IQR 10.2) ($n = 2$).

Cost-effectiveness of screening

Cost-effectiveness data from the included studies ($n = 11$) of TB screening among migrants in EU countries show promising results (Table 1). For instance, Harling et al. found that TB screening for asylum seekers in the UK costs £350,000 annually, with £40 per migrant screened and £30,000 per active case detected.[25] Hardy et al. study on QuantiFERON® (IGRA) testing showed £34.94 per migrant screened, identifying 105 TBI cases.[28] Pareek et al.[30] identified cost-effective strategies targeting migrants from high TB incidence countries. Zannetos et al.[38] suggested screening all migrants in Cyprus could save costs. Haukaas et al.[41] study in Norway showed varying costs for TBI and TB disease screening, concluding that increasing the proportion of IGRA-positive migrants who are treated decreases the costs per avoided case substantially. Greenaway et al.[43] found that CXR screening in EU/EEA countries of migrants is cost-effective compared with no screening. Wahedi et al.[55] found in Germany that using symptom questionnaire and X-ray for active TB screening programme conducts to an incremental cost-effectiveness ratio (ICER) of €15,000–17,000 per additional case found, depending on TB incidence. Goscé et al.[56] study in Italy suggested that app-based screening was cost-effective. Shedrawy et al. study in Stockholm showed age group differences in cost-effectiveness.[58] Marx et al.[59] in a study in Germany suggested that TBI screening was cost-effective above certain TB incidence thresholds. Russo et al.[65] found that a sequential screening strategy in Italy was cost-effective. Overall, tailored TB screening strategies for migrants show promise in cost-effectiveness.

Barriers to screening

Following a theoretical framework for analysing the content of articles, and given their descriptive content, we organised the data inductively following the thematic analysis protocol. From the included studies, 11 studies reported barriers to screening (Figure 3). The barriers to screening were categorised into three primary types: barriers related to health services, cultural and individual barriers among migrants and barriers associated with stigma, xenophobia, discrimination and policies.

Health services barriers

Affordability is the main challenge for migrants seeking TB screening. Despite subsidised healthcare in countries like the UK and Portugal, migrants' access to these services is less compared to the general population. For instance, in Italy, Bonvicini et al.[47] highlighted costs as a barrier, while Schepisi et al.[37] noted unstable access to public healthcare. Pontarelli et al.[48] found that high demand for fragile services hampers screening. In Germany, Wahedi et al.[55] identified restricted healthcare access as a significant barrier.

Table 2. Effectiveness of TB screening in migrants considering the effects of settings, the population, the type of disease and tests.

	Coverage			Uptake			TBI treated		
	Observations (N)	Median (IQR)	Median range	Observations (N)	Median (IQR)	Median range	Observations (N)	Median (IQR)	Median range
Population									
All migrants	3	46.5 (53.0) %	32.0–85.0%	3	75.0 (57.1) %	32.0–89.1%	3	22.2 (8.8) %	18.6–85.0%
Asylum seekers and refugees	3	89.1 (58.0) %	39.0–97.0%	4	91.4 (32.5) %	49.0–98.2%	4	87.0 (86.3) %	10.8–.97.1%
Undocumented migrants	0	–	–	1	90.2 (0) %	90.2–90.2%	1	21.0 (0%)	21.0–21.0
Unaccompanied minors	0	–	–	1	95.0 (0) %	95.0–95.0%	1	89.0 (0%)	89.0–89.0
Type of Disease									
TBI	3	89.1 (58.0) %	32.0–97.0%	8	86.8 (32.5) %	32.0–98.2%	9	26.2 (70.4) %	10.8–97.1%
Active TB*	4	65.8 (57.1) %	32.0–89.1%	6	87.7 (34.1) %	49.0–98.2%	4	100 (0) %	100–100%
Tests									
X-ray	3	46.5 (53.0) %	32.0–85.0%	4	87.6 (66.2) %	86.6–98.2%	3	18.6 (81.1)	16–97.1%
Symptoms	2	93.1 (8.0) %	89.1–97.0%	5	86.6 (34.1) %	49.0–98.2%	4	86.0 (71.0)	16.0–97.1
IGRA	2	68.0 (58.0) %	39.0–97.0%	6	86.6 (23.2) %	75.0–98.2%	6	56.5 (68.4) %	16.0–97.1%
TST	2	64.0 (50.1) %	39.0–89.1%	6	89.7 (8.3) %	49.0–98.2%	3	16.0 (86.3) %	10.8–97.1%
GeneXpert	0	–	–	1	98.2 (0) %	98.2–98.2%	1	97.1 (0)	97.1–97.1
Histology	0	–		1	90.2 (0) %	90.2–90.2%	–	–	–
Settings									
Public Health	4	85.0 (57.1) %	32.0–97.0%	3	95.0 (49.2) %	49.0–98.2%	4	88.0 (78.2) %	10.8–97.1%
Hospital	0	–	–	3	89.1 (9.4) %	89.1–98.2%	3	21.0 (78.5) %	18.6–97.1%
Primary care	1	39.0 (0) %	39.0–39.0%	1	94.0 (0) %	94.0–94.0%	2	21.1 (10.2) %	16.0–26.2%
Community level	0	–	–	2	85.0 (0) %	75.0–95.0%	2	87.0 (4) %	85.0–89.0%
Migration settings	1	46.5 (0) %	46.5–46.5%	1	86.6 (0.0) %	86.6–86.6%	0	–	–

List of abbreviations: IGRA: interferon gamma release assay; NA: Not applicable. TB: tuberculosis; TBI: tuberculosis infection; TST: tuberculin skin test. *In this case the column corresponds to the active TB treated.

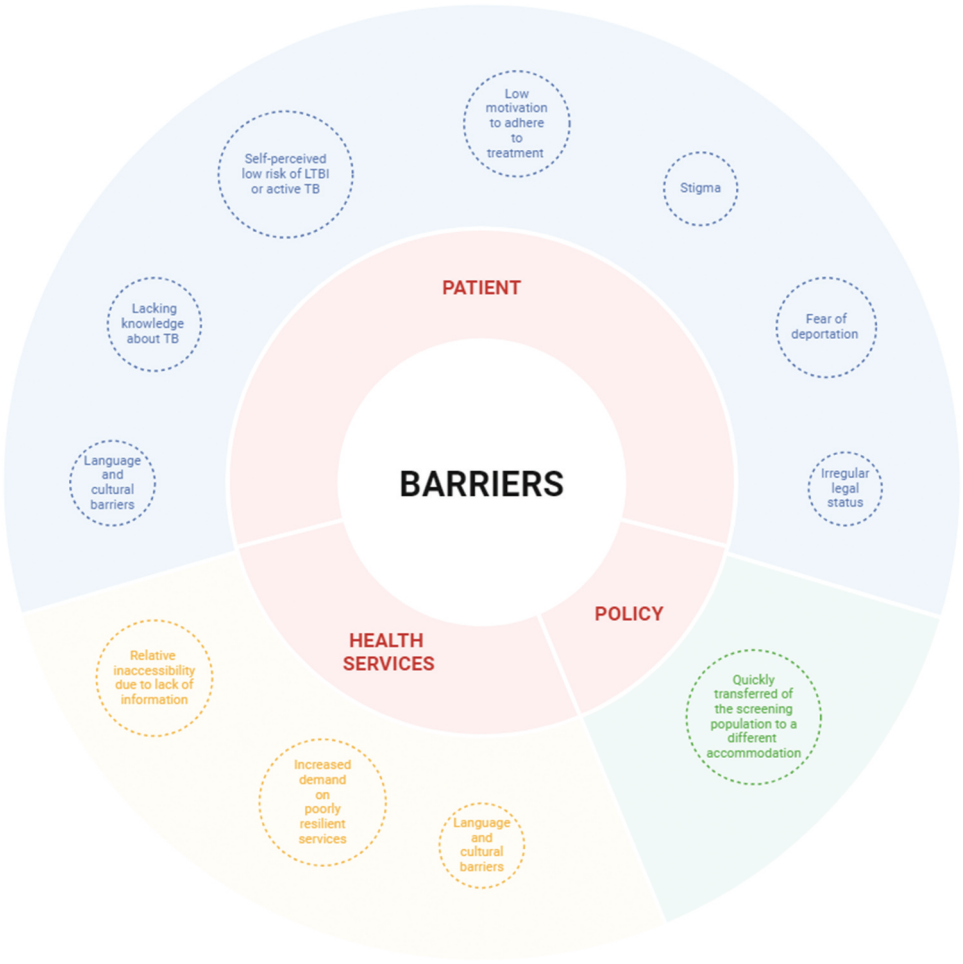

Figure 3. Representation of the main barriers to the screening of tuberculosis. Figure created with BioRender.com.

Marchese et al.[62] mentioned logistical issues like appointment scheduling and transportation as challenges. This former study also pointed out that healthcare systems often cannot handle large numbers of migrants. Additionally, a shortage of health workers and insufficient specialised training for working with migrants are significant barriers. Ferro et al.[64] study in Portugal noted a lack of professional resources for TB screening among Ukrainian refugees.

Cultural and individual barriers

Cultural and language barriers significantly hinder TB screening among migrants. In Malta, Pace-Asciak et al.[31] found that lack of information, language, and cultural differences impede access to TB screening. Similarly, studies in the UK (Berrocal-Almanza et al.),[61] Germany (Wahedi et al.),[55] and Portugal (Ferro et al.)[64] identified language barriers as a major issue. Migrants' fear and insensitivity towards screening, along with a low perception of TB risk and lack of preventive health behaviours, also pose serious obstacles. In this context, Guthmann et al.[42] study across 31 EU/EEA countries highlighted migrants' lack of TB knowledge and low motivation for diagnosis and treatment. Pontarelli et al.[48] noted that asylum seekers in Italy are particularly hard to reach for screening. Additionally, misinformation and gossip, such as misconceptions about blood tests, further hinder TB screening, as identified by Spruijt et al.[49]

Stigma, xenophobia, and discrimination barriers

Stigma, xenophobia, and discrimination are significant barriers to migrants accessing health systems. In the UK, Berrocal-Almanza et al.[61] identified stigma, mistrust, and fear of deportation or immigration status as major obstacles to TB screening. In the Netherlands, Spruijt et al.[49] found that stigma not only hinders TB screening but also TBI treatment.

Policy barriers

Regarding the physical and geographical barriers to screening services, Ferro et al.[64] study in Portugal highlighted the challenges Ukrainian refugees face in travelling to another city for TB screening.

Facilitators of screening

To address the screening barriers, EU countries have developed and proposed various strategies to facilitate TB screening, which can significantly increase participation. Thirteen studies reported facilitators to screen. Similar to barriers, these facilitators can exist at the participant level and at the system level, and can be categorised into service provider facilitators, professional facilitators, technology facilitators, and others (Figure 4).

Service provider facilitators

Multiple screening venues, such as primary care, public health, and hospitals, are recognised as key facilitators. Brewin et al. study emphasised screening across various levels, advocating for diverse settings to maximise participation. Pace-Asciak et al.[31] study on boat migrants in Malta highlighted free TB healthcare

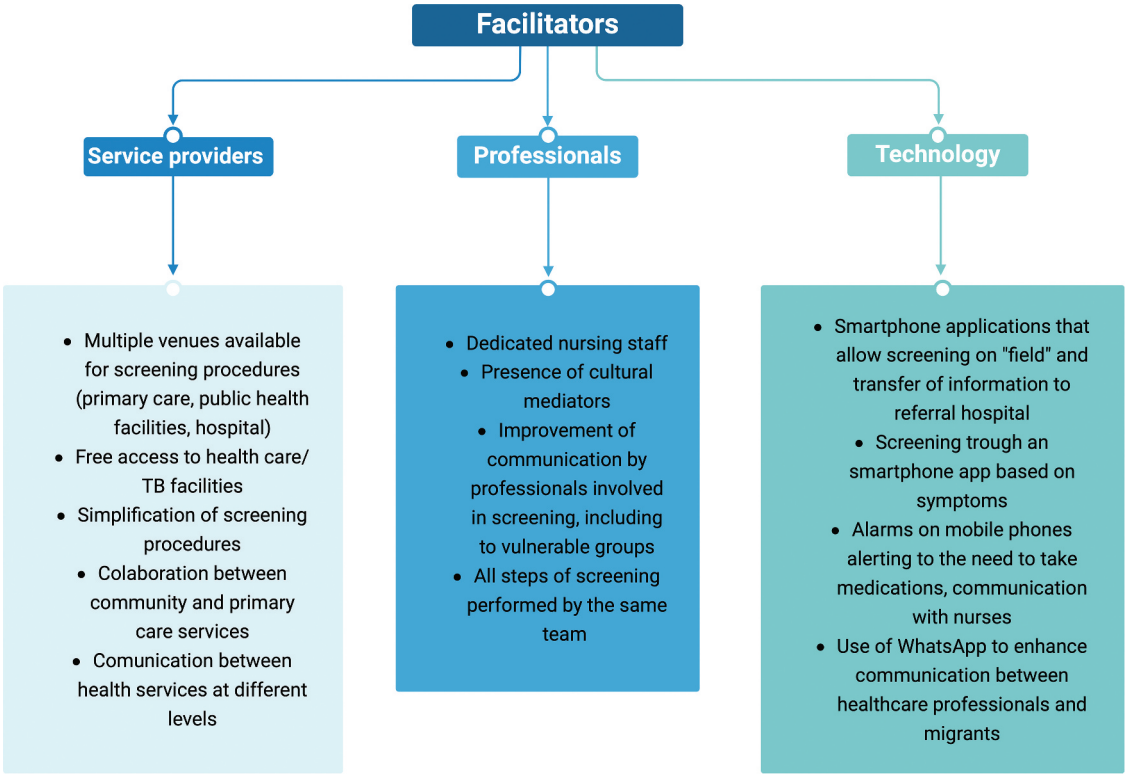

Figure 4. Representation of the main facilitators for the screening of tuberculosis. Figure created with BioRender.com.

access and cultural mediators as enablers. Schepisi et al.[37] study underscored simplified procedures as screening facilitators. Enhanced collaboration between municipal and specialist health services, as found by different authors,[35,36] demonstrates an improvement in the follow-up for positive TB cases. Berrocal-Almanza et al.[46] highlighted the importance of linking community and primary care services for screening. Bonvicini et al.[47] emphasised network connectivity between health service levels and universal accessibility as screening priorities. Tewes et al.[54] study on refugees in Germany emphasised standardised care provision. Geographical proximity, as noted by Berrocal-Almanza et al.[45] in the UK facilitates screening for migrants.

Professionals' facilitators – from cultural to a multidisciplinary team approach

Several studies have identified professional facilitators to improve TB screening accessibility for migrants. In Italy, Bonvicini et al.[47] emphasised the role of cultural mediators and dedicated nursing staff in enhancing access to TB and TBI screening for migrants in an irregular situation. Other studies, including those by Schepisi et al.[37] and Pontarelli et al.,[48] also highlighted the importance of cultural mediators. In the UK, Berrocal-Almanza et al.[45] found that health promotion and the involvement of general practitioners significantly facilitated TBI screening. Improved communication and information dissemination by health professionals were noted as facilitators in the studies by Brewin et al.,[24] and Pontarelli et al.[48] Spruijt et al.[49] concluded that collaborative planning with health workers during mandatory reporting helped ensure migrant participation, locate no-show individuals, and increase screening and treatment adherence through professional interpreters and TB nurses. Marchese et al.[62] compared centralised and decentralised screening models in Italy and found that a multidisciplinary team performing all screening steps fostered trust in the system and improved patient relationships, enhancing screening acceptance and completion.

Technology facilitators

Technology has proven effective in TB screening. Barcellini et al.[44] developed a phone application for standardised data collection, enabling field screening and direct transfer of patient information to referral hospitals. This app-based tool was used for active TB screening of newly arrived migrants in Italy. Spruijt et al.[49] identified additional technological facilitators, such as mobile phone alarms, WhatsApp communication between nurses and migrants (using emoticons, voice messages, and simple texts), and medication boxes.

Other factors facilitating TB screening accessibility

Schepisi et al.[37] identified the legal status of migrants and their length of stay in the host country as key facilitators for post-entry active TB screening in Italy. Other facilitators include routine use of TB tests, as suggested by Berrocal-Almanza et al.,[45] and conducting TB screening at the point of arrival, which Bonvicini et al.[47] found to be more acceptable to migrants. Wahedi et al.[55] emphasised the importance of understanding asylum-seekers as a heterogeneous population with diverse needs and adjusting strategies accordingly to enhance screening effectiveness in Germany.

Discussion

This systematic review encompasses 43 studies[24–66] investigating the effectiveness of screening for TB infection (TBI) and active TB within the migrant population. No randomised clinical trials were identified in this field, with the majority of the included studies being cohort or survey-based. Overall, these studies collectively underscore the gains in the health outcomes of screening for infection and active TB within the migrant population. However, due to the high heterogeneity of the included studies, it was not possible to conduct a meta-analysis. Furthermore, despite the included studies highlighting the cost-effectiveness of screening for infection and active TB, the recommendations remain unclear, inconsistent, and ambiguous. Consequently, there is an urgent need at the health service level to educate healthcare professionals regarding the safety and effectiveness of TB screening in the target population.

Across the studies (Figure 2, Supplementary Table S2), the infection detection of TB was high, identified in 19.2% (range 2.2–35.3%) of screened migrants.

Active disease was present in 0.33% (range 0.0–4.2%) (Figure 2). The coverage of screening by migrants was 65.75%, being variable (range 32–97%). The coverage was higher in the group of asylum seekers (median 89.1%, range 39.0–97.0%) in comparison with migrants as a whole (median 46.5%, range 32.0–85.0%). In contrast to coverage, the uptake of screening was independent of the migrants' subgroup (median 88.8%, range 32.0–98.6%). The uptake was found to be higher in asylum seekers (median 96.1%, range 49.0–98.6%), and undocumented migrants (median 89.1%, range 81.4–90.2%) compared to the migrants as a whole (median 83.9%, range 32.0–90.0%). The overall evidence supports that the screening is accepted by the migrant population (median 81.2%, range 53.9–85%) with a high uptake obtained. The pooled data highlighted a low treatment completion in migrants (26.2%, range 10.8–97.1%). In the case of active TB, the scenario is different with a treatment completion of 100% in the included studies. The large disparities of migrants with TBI who complete treatment after screening have already been documented in a previous study.[5] Taking into account the screening settings, when the public health was the service responsible for the screening the coverage was higher (85.0%, range 32.0–97.0%), uptake (90%, range 49.0–98.2), and preventive treatment completion (88%, 10.8–97.1) were higher.

The data on cost-effectiveness included in this study (Table 1) was substantial ($n = 11$) and pointed to a moderate/high cost-effectiveness of migrant screening, independently of the disease targeted (infection vs active) and independently of the migrant group. Consistent with previous research, the results are heterogeneous. However, the overall results point out that to obtain a higher cost-effective screening, the individuals should come from countries with a high incidence of TB. The cut-off studies generally range from 50 to 250 cases/100 000, and the heterogeneous results are not surprising since the incidence of TB in the host country by itself is not sufficient to predict the cost-effectiveness of TB screening as demonstrated elsewhere.[67] These findings fully align with a systematic review by Gogichadze et al. spanning 16 years and highlighting the importance of TB screening implementation in Europe as a collaborative and cost-effective public health policy.[68] Regarding the tests used in the screen, the X-ray has some limitations as a diagnostic tool since it has a reduced specificity and also has limitations in inter-observer variability.[16] On the other hand, and in comparison, with questionnaires of symptoms, an X-ray is an effective approach for diagnosing asymptomatic patients with active TB that would be missed by symptom-based screening. In the case of active TB, ECDC recommends screening for active TB using CXR soon after arrival for migrants from high-TB-incidence. According to ECDC, the unit costs of CXR are between 37.08 and 62.66 euros, while the culture test costs between 30.80 and 52.08 euros.[69] In the case of infection, ECDC considers that TBI screening for migrants at entry using either IGRA or TSA is cost-effective, and that the cost-effectiveness of screening migrants increases when the TB incidence in the country of origin is higher. According to ECDC, the average cost of IGRA by unit cost ranges from 54.09 to 91.41 euros, while the TST cost is between 28.14 and 47.55 euros.[69] However, TST requires more than one visit to the health services, and the reading is based on a subjective interpretation of the health professional. Moreover, TST shows cross-reactivity with BCG vaccination and exposure to non-tuberculous mycobacteria.[70] The use of IGRA has been described to be the most cost-effective method since IGRA compared with the other methods to detect TBI has a higher specificity and sensitivity, only requires one visit to the health facilities but, it requires a more specialised laboratory, and infrastructure.[49,70] Recently, new tuberculin skin tests (TBST) have been recognised by the WHO as viable alternatives to the TST or IGRA. These tests show promise in detecting TB infection due to their high sensitivity, specificity, and favourable safety profile. However, additional clinical trials focusing on specific population groups and relevant clinical scenarios are necessary to accelerate the broader implementation of these promising diagnostic tools.[71]

The research demonstrates that infection screening and treatment costs are small compared to the treatment of active TB disease. For instance, the study of Haukaas et al.[41] calculated that the cost of treating an active case of TB would cost 8 times more than treating a TBI case. The evidence also advocates that introducing TBI screening/TB preventive treatment has gains in quality of life, namely in quality-adjusted life years (QALYs). In this context, the study of Marx et al.[59] also showed that the screening above 250 per 100,000 country-of-origin TB incidence would gain 7.3 (2.7–14.8) QALYs for €51,000 (€18,000–€114,100) per QALY. Thus, taking into account that the evidence reinforces that TBI

screening for migrants that came from intermediate to high-incidence countries is cost-effective, several European countries test migrants on arrival, including the UK Health Security Agency, as a strategy to reduce the TB burden in their country.

This systematic revision highlights the high prevalence of TBI compared with the European population (estimated at 13.7%)[72] and the insufficient coverage and particularly the low completion of treatment. These findings underscore strong arguments for increased endeavours to identify, screen and treat individuals eligible for screening upon arrival. From the enrolled studies, some studies have explored the target population's perspectives on the screening acceptability of the screening, and concluded that the screening is perceived as well-accepted. This study also investigates numerous barriers to screening within this highly mobile population. Many of these barriers stem from service providers and primarily concern accessibility and associated costs, which can contribute to stigma and discrimination against this population. Ultimately, overcoming these barriers hinges on political and financial decisions made by host countries. Restricting healthcare access for migrants, including undocumented migrants, across Europe is likely to result in poorer health outcomes for both migrant and local populations. To enhance screening effectiveness, it is crucial to identify barriers from the perspective of migrants and also from the perspective of the various stakeholders involved, along with recognising facilitators. These facilitators, aligned with previous research on TB and other infectious diseases in migrant populations, should include staff trained in preventive health and screening promotion tailored to this specific population. Similar results were also described by Braga *et al*covering 11 years in a scoping review that explored the barriers to TB screening and highlighted the physical, professional and cultural barriers.[73] This study is the first systematic review that provides a comprehensive overview of TB screening interventions across 11 countries, incorporating a large sample size ($n > 8$ million migrants). However, this study also presents several limitations that should be highlighted and discussed in detail.

The focus on screening within Europe limits the applicability of findings to countries on other continents, particularly those with differing screening policies and healthcare infrastructures. The overrepresentation of studies from the UK further narrows the generalisability to other European countries with varying healthcare systems and TB control strategies. Additionally, the high heterogeneity in interventions, as well as the diverse primary and secondary outcomes measured, complicates direct comparisons of the effectiveness of different screening components both within and across studies. Variability in the methodological quality of the included studies may also undermine the robustness and reliability of the findings. One important variable that was not studied is the type of screening (voluntary *vs* mandatory), which may impact screening effectiveness indicators (e.g., coverage and uptake). The review's consideration of migration to Europe from a wide range of countries with differing TB incidences introduces further challenges, as the definition of high-incidence countries varies widely – ranging from more than 40 to over 200 cases per 100,000 population. In some cases, screening criteria are based on specific lists of countries or regions, irrespective of TB incidence, adding complexity to the analysis and interpretation of results. Finally, certain effectiveness indicators rely on a limited number of studies, which reduces the strength of the evidence base for those metrics. In conclusion, the present research shows that screening for both infection and active TB has positive health outcomes, but there is inconsistency in recommendations and gaps in understanding cost-effectiveness. Overall, there is a need for better education for healthcare professionals about TB screening for migrants. The data also highlight high rates of TBI but low treatment completion. Despite challenges, screening is accepted by migrants, especially asylum seekers. Cost-effective screening methods vary, with IGRA testing preferred for TBI. TBI screening is beneficial, especially in countries with high TB rates, prompting many European countries to screen migrants upon arrival. In conclusion, there is a need for ongoing efforts to improve screening strategies and ensure migrants receive necessary care. Finally, we advocate that policymakers, researchers, and society should be involved with global public health to ensure a longer-term view on improving health outcomes in the migrant population as they fully integrate into health systems.

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