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Community-based strategies for tuberculosis control in migrant communities: how to integrate determinants of vulnerability into decision-making

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Abstract

Background Tuberculosis (TB) remains a major public health challenge, particularly among migrant populations, who face increased vulnerability due to social and structural determinants of health. In Catalonia, Spain, the Model of Community and Public Action (MACIP) programme was launched in 2023 to improve TB prevention and care through culturally adapted, community-based interventions delivered by community health workers (CHWs). This study aims to describe the vulnerability determinants among migrants diagnosed with TB and enrolled in the MACIP programme, and to present the community-based strategies implemented. The analysis was informed by a conceptual framework based on the social determinants of health, aimed at supporting people-centred, equity-oriented TB control and informing decision-making.

Methods A descriptive study was conducted among migrant TB patients included in the MACIP programme between January and December 2023. Sociodemographic, clinical, and migration-related variables were collected from the Epidemiological Registry of Catalonia, the Central Registry of Insured Individuals of Catalonia, and the digital data collection system used by CHWs. Vulnerability indicators and community-based interventions were analysed using descriptive statistics. Comparisons between regions of origin were performed using Chi-squared or Fisher's exact tests for categorical variables and the Kruskal–Wallis test for continuous variables.

Results Community-based interventions were implemented for 121 migrant patients. Most were men (67.8%) and originated from the Eastern Mediterranean (35.5%) and Southeast Asia (33.1%) regions. A high proportion (87.6%) had low or very low socioeconomic status, and 23.1% lacked a healthcare identification card at diagnosis. The median diagnostic delay among symptomatic pulmonary TB cases was 49 days [IQR 26–89]. The main reasons for referral to MACIP were language and cultural barriers (66.1%) and difficulties in contact identification and follow-up (54.5%). A total of 2,567 community-based activities were recorded. On average, 21.2 actions were carried out per participant.

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Conclusions Social and migration-related determinants significantly shape TB vulnerability among migrant communities. Integrating these determinants into community-based strategies such as MACIP may enhance equity, strengthen case management, and improve treatment outcomes. This approach aligns with global efforts to address TB through people-centred, culturally adapted public health interventions.

Keywords Tuberculosis, Migrants, Community health workers, Social determinants of health, Public health, Health equity, Community-based interventions

Background

Tuberculosis (TB) remains one of the leading infectious diseases causing mortality worldwide, as highlighted in the WHO Global Tuberculosis Report 2024 [1]. TB is closely related to social vulnerability, which complicates its prevention and control [2]. The complexity arises from the multitude of intersecting determinants, including biological, behavioural, social, structural, and migration-related, that shape TB risk and outcomes [3, 4].

For migrant populations specifically, the migration process itself constitutes a key structural determinant of health [3]. Migration-related social determinants of health such as legal status, precarious employment, housing instability, social exclusion, and limited access to healthcare further compound existing vulnerabilities. These determinants influence both exposure to TB and the ability to access timely diagnosis, adhere to treatment, and complete the full continuum of TB care [3, 5–7].

Catalonia is home to nearly 1.8 million foreign-born individuals, representing 22.5% of its 7.9 million inhabitants in 2023, the highest number of non-native inhabitants in any Spanish Autonomous Community [8, 9]. Although Spain is a high-income country with a low TB incidence rate, regional disparities within the country are significant [10–12]. Historically, Catalonia reached its peak TB incidence in the 1990s, reaching 52.9 cases per 100,000 inhabitants in 1992 [12]. A steady decline was observed until 2018, which was interrupted by the COVID-19 pandemic [12]. By 2023, the TB incidence rate in Catalonia remained above the low incidence threshold (< 10 per 100,000), with an overall rate of 13.2 cases per 100,000. While TB incidence has continued to decline among the native population, it has remained stable among migrant populations, reaching 36.1 per 100,000 in 2023 and accounting for 62.4% of all reported cases. This growing disparity underscores the persistent structural and social barriers to TB prevention and care faced by migrant communities and highlights the need for targeted and culturally adapted control measures [12]. Although Catalonia has a universal public healthcare system, migrant populations often continue to encounter substantial barriers to accessing care [13, 14].

The continuum of TB care in Catalonia illustrates how social, structural, and migration-related determinants pose paramount challenges for migrant populations

across all stages of care [15]. From the timely diagnosis of TB and treatment adherence to contact tracing and effective follow-up, underserved communities often encounter numerous obstacles before seeking medical attention or during the continuum of care [15, 16]. Legal status in the country, restrictive working conditions, language barriers, fear of stigma and discrimination, lack of means of transportation, poverty, and low educational status are some of the factors that have been widely identified as key barriers to accessing healthcare services and adhering to treatment [2, 3, 17]. These factors not only delay diagnosis and treatment initiation but also increase transmission risks and worsen health outcomes. Furthermore, institutional and structural barriers within healthcare systems, such as limited cultural sensitivity, administrative hurdles, and inadequate social support, exacerbate these challenges and contribute to the persistence of health disparities among migrant populations [15, 17].

In an effort to address some of the barriers contributing to health inequities, the outreach community service already present in Catalonia was expanded and launched as the “Model of Community and Public Action” (MACIP) in 2023 [18]. MACIP is a community-based initiative to advance the prevention and control of communicable diseases, with a focus on vulnerable migrant populations. It is implemented jointly by the Public Health Agency of Catalonia and the Public Health and Community team, eSPiC from here on (equip de Salut Pública i Comunitària) of the Drassanes International Health Unit – Vall d'Hebron. Through community health workers (CHWs), this programme provides a culturally sensitive and community-oriented approach, addressing specific vulnerabilities [18].

The cultural adaptation of MACIP is based not only on the participation of CHWs who share migration backgrounds and cultural and linguistic proximity with the target populations, but also on the use of community-based strategies coordinated by the eSPiC team [18]. The programme includes a tailored approach to case management that considers the cultural norms, values, and lived experiences of patients. This involves supporting patients in accepting the diagnosis, reinforcing treatment adherence, and empowering them to engage with health services. CHWs also adapt communication strategies and consider the social and cultural patterns of each community to facilitate culturally sensitive contact tracing,

helping to identify additional transmission settings and improve follow-up. These strategies aim to overcome barriers to healthcare access, improve case management and contact tracing, and enhance trust, reduce stigma, and increase the effectiveness of TB control efforts among migrant populations [18].

To better understand and address the health disparities affecting migrant populations with TB, we propose a conceptual framework grounded in the social determinants of health and informed by a syndemic perspective. In recent years, the syndemic approach has been increasingly used to explore how the interaction between

health conditions and social, structural, and behavioural factors can intensify disease burden, particularly among underserved populations [3, 4]. In Catalonia, the routine TB surveillance system, complemented by the additional data collected through the MACIP programme, already collects variables related to these social determinants of health. These variables were used to develop a structured, people-centred conceptual framework (Fig. 1). This framework integrates biological, behavioural, migratory, and structural factors that influence TB vulnerability and impact access to care and treatment outcomes, offering

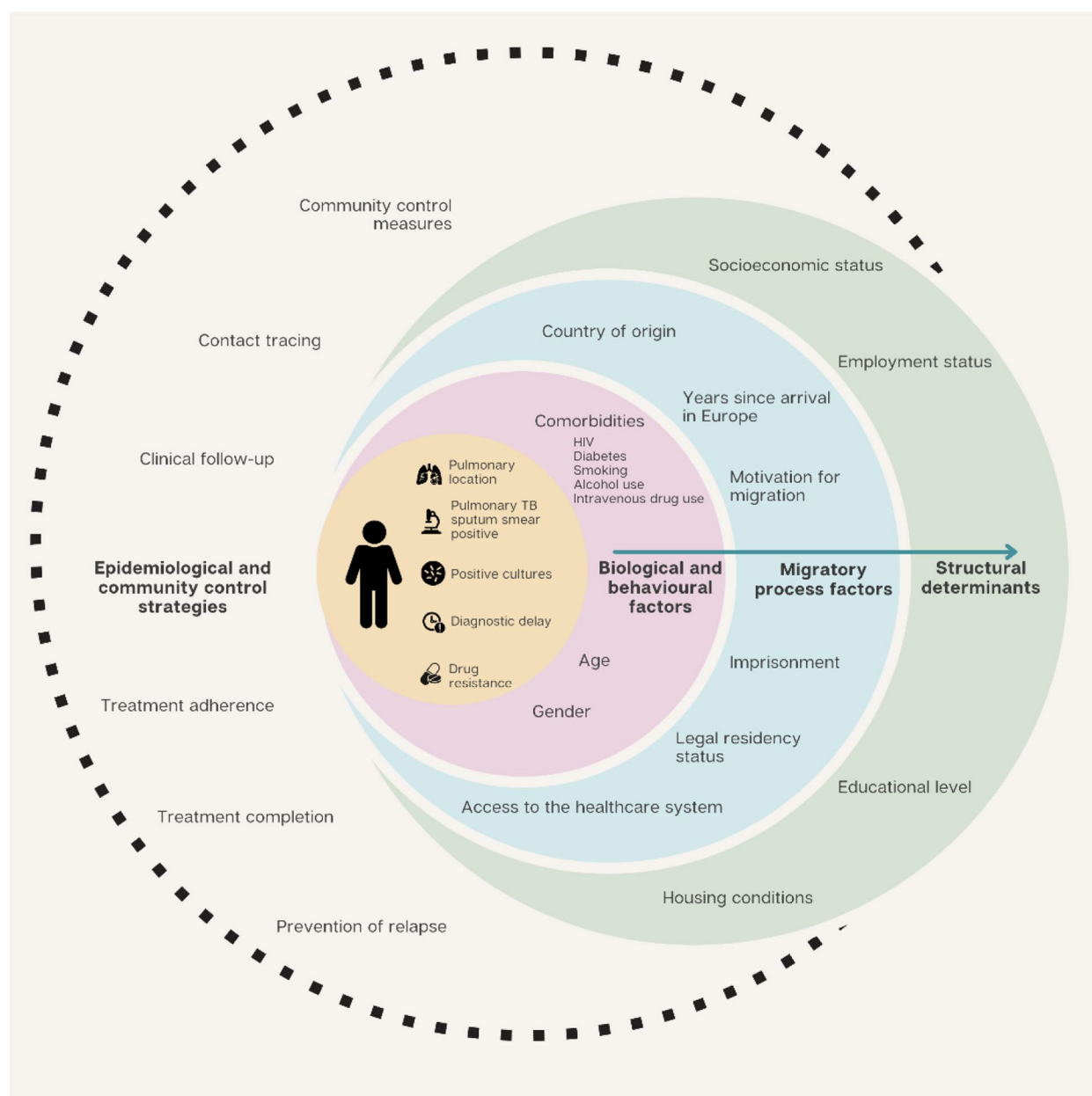


Fig. 1 Conceptual framework of social health determinants of TB vulnerability in migrant communities, based on a syndemic-informed approach

a practical perspective to guide people-centred strategies and community-based interventions.

Methods

Aim of the study

The aims of this study are to describe the social, structural, and migration-related determinants of vulnerability among migrants diagnosed with TB in Catalonia and enrolled in the MACIP programme during 2023, and to present the different community actions implemented through the programme following a people-centred approach.

Study design

This descriptive study included clinical, epidemiological, sociodemographic, and migration-related data from migrants diagnosed with TB in Catalonia who were included in the MACIP programme for case management and control from January 1, 2023, to December 31, 2023. This design was chosen to capture the complexity of vulnerability determinants and intervention contexts in a real-world setting. Although the absence of a control group limits the assessment of intervention effectiveness, the approach is appropriate for characterising syndemic patterns and informing context-specific strategies.

Study setting

This study was conducted in Catalonia, Spain. TB control in Catalonia is managed by the Epidemiological Surveillance Network, which includes nine Territorial Epidemiological Surveillance Services responsible for case notification and contact tracing. The MACIP programme integrates CHWs to address barriers to TB care through culturally adapted, community-based interventions. The identification and enrolment of TB cases in the MACIP programme follow a structured pathway: (1) TB cases are first detected in the healthcare system; (2) TB patients are notified of the Territorial Epidemiological Surveillance Services; (3) the vulnerability criteria are assessed; and (4) TB patients are referred to the eSPiC for CHW allocation and tailored interventions if necessary. The programme operates across Catalonia, except in Barcelona Metropolitan City, where a separate TB management model exists [19].

Community-based strategies

As part of the MACIP programme, a structured community-based approach was implemented to support TB cases and contact management among migrant populations through CHWs. This strategy aimed to overcome structural and social barriers to healthcare access by combining remote and in-person interventions tailored to the specific needs of each patient and their contacts.

The intervention included three main types of actions:

1. Phone-based support (calls and WhatsApp messaging): Used for initial outreach, appointment reminders, treatment follow-up, and addressing patient concerns related to TB care.
2. In-person visits and healthcare mediations: CHWs conducted on-the-spot visits, informal meetings, and healthcare mediations to overcome language barriers and provide health education.
3. Orientation and guidance: Patients and their contacts received support with administrative procedures, sociolegal issues, and other essential formalities. This guidance aimed to facilitate healthcare system navigation, access to TB services, and broader social support, reinforcing the programme's holistic strategy.

The implementation of these community-based actions was tailored to the specific epidemiological and sociocultural characteristics of different migrant groups, based on the experience of CHWs familiar with the cultural and linguistic context of each group.

Study population

Participants were eligible for inclusion if they were enrolled in the MACIP programme. All the participants faced social vulnerability related to their migrant status and increased epidemiological risk due to factors such as heightened exposure to infectious diseases, delayed diagnosis, difficulties in contact tracing, and challenges in adhering to preventive and therapeutic measures.

Data collection

Data were obtained primarily from the HSUS (Health Survey System) database, a digital tool developed in collaboration with the Polytechnic University of Catalonia to facilitate real-time monitoring and evaluation of community interventions. This system, already in use within the MACIP programme, records TB case management actions, from referral and inclusion in the programme to community-based interventions such as phone calls, visits, and workshops.

Sociodemographic data and information related to community-based strategies were sourced from the HSUS and cross-referenced with the Epidemiological Registry of Catalonia for epidemiological information. Additional data on socioeconomic status, access to healthcare, and legal residency status were obtained from the Central Registry of Insured Individuals of Catalonia.

Variables

The study included sociodemographic, clinical, and epidemiological variables. Additionally, data related to the community-based strategy were collected, including the type of community action implemented and the reasons

for referral to the MACIP programme. Barriers to contact identification and follow-up were recorded when contacts could not be identified, located, or appropriately followed up, according to the assessment by the epidemiological surveillance services or the CHW team involved in the MACIP programme.

The number of actions per participant was defined as the total number of community-based activities carried out by community health workers (CHWs) and recorded during follow-up, including home visits, phone calls, accompaniment to healthcare services, and support for contact tracing. Each participant may have received multiple actions, as CHWs provided several interventions per individual depending on their needs.

Clinical information, including comorbidities such as HIV, diabetes, and renal disease, as well as behavioural factors such as smoking, alcohol use disorders, and intravenous drug use, were extracted from medical records. Diagnostic delay was defined as the time (in days) between the onset of TB-related symptoms and the date of TB notification in the epidemiological surveillance system. This variable was analysed among patients with symptomatic pulmonary TB.

The classification of countries of origin, socioeconomic position, healthcare accessibility, and legal residency status is detailed in the following subsections.

Country and region of origin

The country of origin refers to the country of birth and was retrieved from the HSUS database. For children under 15 years of age born in Spain to parents with a migrant background, parental information was used to determine the family's country of origin and the number of years since their arrival in Spain.

Countries were grouped into regions based on the official WHO regional classification [20]. One adaptation was made for Pakistan, which is officially part of the Eastern Mediterranean Region but was included in the

South-East Asia Region in this study. This decision was based on cultural and linguistic similarities with India and Bangladesh, as well as on operational considerations: the same CHW provided interventions for all three communities. Additionally, one participant in the study was born in China, a country officially classified within the Western Pacific Region. For presentation purposes, China was grouped under the South-East Asia Region in this study. A detailed table of country-to-region classifications is provided in Table 1.

Socioeconomic status (SES)

SES was categorised on the basis of the pharmacy copayment system in Catalonia, which determines the cost of medications according to the individual's income or social security benefits [14]. The following SES groups were considered [13]: a) very low SES, which comprises individuals receiving universal benefits, those no longer receiving unemployment benefits, and those who have exhausted unemployment benefits; b) low SES, including individuals receiving unemployment benefits, those employed with an annual income below €18,000, and foreign individuals residing in Catalonia for over three months without official registration; c) medium–high SES, which includes employed individuals with an annual income ranging from €18,000 to €100,000; and d) high SES, which includes individuals with an annual income exceeding €100,000. Children were assigned the SES of their parents, and pensioners were classified according to their preretirement copayment levels [13].

Access to the healthcare system

In Catalonia, universal health coverage (UHC) legislation ensures that all residents can access health services without charge at the point of care, except for prescription medications [21]. Each resident is issued a healthcare identification card (ID), which enables tracking of health service utilisation and dispensed medications. The ID also allocates individuals and families to a specific primary care centre through an empanelment system [13].

For TB patients without a healthcare ID at the time of diagnosis, a temporary card is issued to ensure timely access to health services. For the present study, access to the healthcare system was assessed on the basis of whether the individual had a healthcare ID at the onset of TB symptoms or, for asymptomatic patients, prior to TB diagnosis.

Legal residency status

Legal residency status was determined on the basis of the type of identification document held by the individual. Those with a NIE (foreigner identification number) or DNI (national identity document) were classified as having legal residency. Conversely, individuals who held only

Table 1 Country-to-region classification used in this study (adapted from WHO regional classification)

WHO Region	Countries in this study
Africa	Democratic Republic of the Congo, Gambia, Ghana, Guinea, Mali, Senegal
Americas	Bolivia, Colombia, Peru, Venezuela
Eastern Mediterranean	Morocco
Europe	Armenia, Russia, Ukraine
South-East Asia (adapted)	Bangladesh, China*, India, Pakistan†

*Originally part of the Western Pacific Region
†Reassigned from the Eastern Mediterranean Region to South-East Asia based on cultural/linguistic similarity with India and Bangladesh, and shared community health worker interventions

Table 2 Sociodemographic characteristics of the participants

Characteristics	N with factor/N with f available	%
Biological and behavioural factors		
Age (years)*	33	[IQR 25; 47]
Gender		
Woman	39/121	32.2%
Man	82/121	67.8%
Comorbidities		
HIV	4/119	3.4%
Diabetes	15/120	12.5%
Smoking	42/119	35.3%
Alcohol use disorder	14/118	11.9%
Intravenous drug use	4/119	3.4%
Renal disease	2/121	1.7%
Migratory process factors		
Years since arrival in Spain†		
< 2 years	31/121	25.6%
2 to 5 years	31/121	25.6%
> 5 years	59/121	48.8%
Motivation for migration		
Economic opportunities	80/108	74.1%
Family reunification	24/108	22.2%
Refugee	3/108	2.8%
Education	1/108	0.9%
Imprisonment	3/79	3.8%
Irregular migrant	41/121	33.9%
No healthcare ID‡	28/121	23.1%
Structural determinants		
Socioeconomic status		
Very low	13/121	10.7%
Low	106/121	87.6%
Medium – High	2/121	1.7%
Employment status		
Unemployed	51/91	56.0%
Short-term and casual employees	20/91	22.0%
Permanent employees	20/91	22.0%
Education level		
Incomplete primary education	20/78	25.6%
Primary education	45/78	57.7%
Secondary education	12/78	15.4%
University level	1/78	1.3%
Housing conditions		
Shared with family/friends	90/98	91.8%
Shelter/temporary accommodation	3/98	3.1%
Illegal accommodation	2/98	2.0%
Homeless	3/98	3.1%

*Age is presented as median and interquartile range [IQR]; all other variables are shown as n/N (%), where N corresponds to the number of participants with available data

†Four participants were children born in Catalonia, but we used the information of year of arrival of their relative index case

‡At the onset of TB symptoms or, for asymptomatic cases, prior to TB diagnosis

a passport or who were undocumented were classified as having irregular residency status.

Statistical methods

A descriptive analysis was conducted to examine vulnerability variables, TB transmission dynamics, and community-based activities implemented for the follow-up of all TB patients included in the study. Categorical variables are presented as frequencies and proportions, while numerical variables are shown as medians and interquartile ranges due to their non-normal distributions. Comparisons between regions were performed using Chi-squared or Fisher's exact tests for categorical variables, and the Kruskal–Wallis test for continuous variables.

All statistical analyses and most figures were generated using RStudio software [22]. A Sankey diagram of migration flows was created via SankeyMATIC [23].

Results

Community-based interventions were carried out for 121 patients diagnosed with TB in 2023 as part of the MACIP programme. The median age of the participants was 33 years [IQR 25; 47]. A total of 3.3% (4 participants) were children under 5 years of age, while 46.3% (56 participants) were older than 35 years. The majority of the participants were men (67.8%) (Table 2).

According to the Territorial Epidemiological Surveillance Service, the highest proportion of participants resided in *Barcelonès Nord i Maresme* (28.1%), *Barcelona Sud* (21.5%), and *Catalunya Central* (16.5%).

In terms of country of origin, more than one-third of the individuals were born in the Eastern Mediterranean Region (35.5%), followed by Southeast Asia (33.1%), Africa (18.2%), the Americas (9.9%), and Europe (3.3%). The country-specific communities with the highest participation in the programme were Morocco (35.5%) and Pakistan (24.8%). Figure 2 presents a Sankey graphic illustrating migration flows between countries of birth and the Territorial Epidemiological Surveillance Service according to their place of residence.

With respect to migration history, nearly half of the migrants (48.8%) had been in Spain for more than five years, whereas 25.6% had migrated within the last two years. The primary motivation for migration was economic opportunities (74.1%), followed by family reunification (22.2%). A total of 33.9% of the participants were classified as irregular migrants, and 3.8% reported a history of imprisonment. Regarding access to healthcare, 23.1% had not obtained a healthcare ID at the time of TB diagnosis or symptom onset (Table 2).

Overall, 3.4% of patients were co-infected with HIV, and 12.5% had a history of diabetes mellitus. With respect to behavioural risk factors, 35.3% of the participants

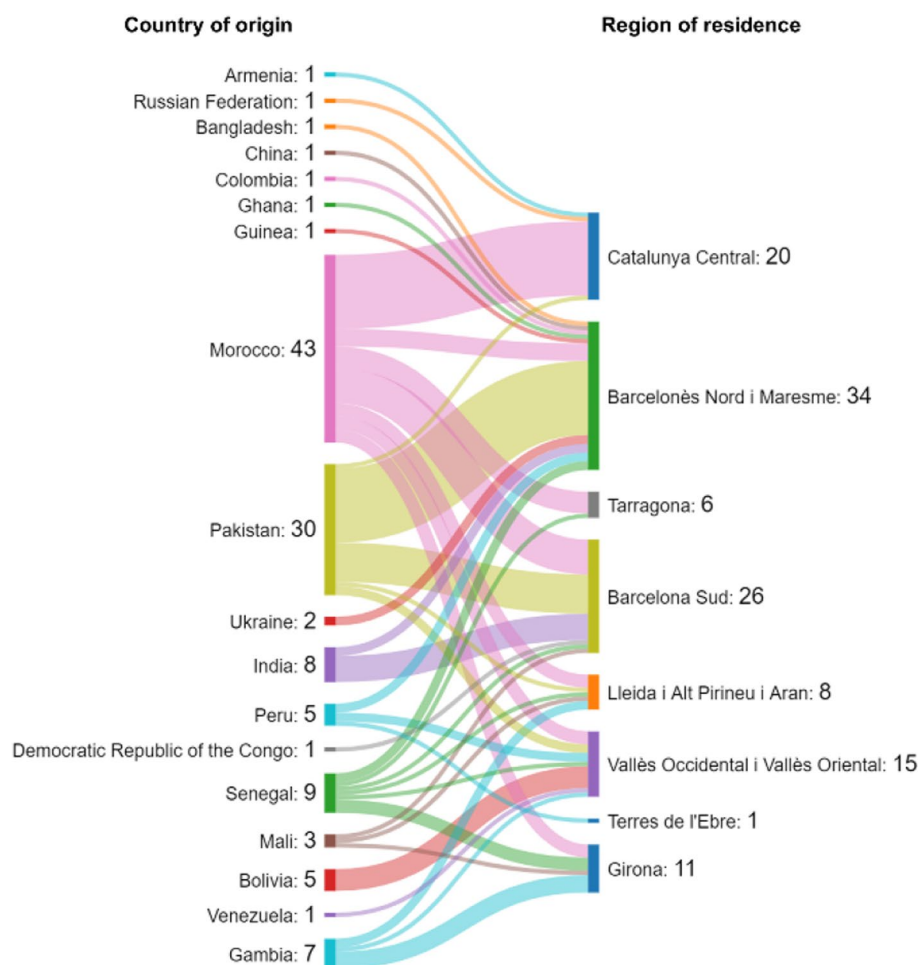


Fig. 2 Migration flows from the country of origin to the current region of residence in Catalonia ($n = 121$)

reported being smokers, whereas 11.9% reported having alcohol use disorders. The prevalence rates of intravenous drug use and renal disease were 3.4% and 1.7%, respectively.

Among participants with available data on education level, a large proportion had incomplete primary education (25.6%) or attained primary education as their highest level (57.7%). Only 1.3% had a university-level education. Employment data were available for 91 participants, with 56.0% unemployed and 22.0% working in short-term or unstable jobs.

With respect to housing conditions, most participants (91.8%) lived with family or friends, while 3.1% were housed in shelters or temporary accommodations, 3.1% were homeless, and 2.0% lived in illegal accommodations. However, information on housing arrangements was missing for 23 individuals.

Almost all patients were classified as having low SES (87.6%) or very low SES (10.7%), with no participants belonging to the highest category of SES.

In terms of the anatomic location of TB disease, 71.1% of the patients presented with pulmonary TB, whereas 28.9% presented with extrapulmonary TB. Among those with pulmonary TB, 54.7% were sputum smear positive (SS+).

The overall median diagnostic delay was 49 days [IQR 26; 89]. The longest delays were observed in patients from the Eastern Mediterranean region (61 days [IQR 32; 95]) and Africa (60 days [IQR 27; 108]).

With respect to drug resistance, 19.8% of culture-positive TB patients were resistant to antituberculosis drugs. All four patients from Europe had drug-resistant TB.

In the context of contact tracing involving CHWs, the overall median number of close contacts was 4 per case [IQR 2; 5]. A total of 14.9% of patients were identified as part of a notified TB outbreak, with the highest proportions observed among individuals from the Americas (83.3%) and Southeast Asia (15.4%). Table 3 presents the main TB transmission characteristics, including diagnostic delay, drug resistance, and outbreak-related data.

Table 3 TB transmission characteristics

Characteristics	Overall N = 121 ¹	Africa N = 22 ¹	Americas N = 12 ¹	Eastern Mediterranean N = 43 ¹	Europe N = 4 ¹	Southeast Asia N = 40 ¹	p – value ²
Location of disease							0.3
Extrapulmonary exclusive	35/121 (28.9%)	7/22 (31.8%)	0/12 (0%)	15/43 (34.9%)	1/4 (25.0%)	12/40 (30.0%)	
Pulmonary	86/121 (71.1%)	15/22 (68.2%)	12/12 (100%)	28/43 (65.1%)	3/4 (75.0%)	28/40 (70.0%)	
Pulmonary TB SS +	47/86 (54.7%)	9/15 (60.0%)	4/12 (33.3%)	18/28 (64.3%)	3/3 (100%)	13/28 (46.4%)	0.1
Symptomatic pulmonary TB	76/86 (88.4%)	15/15 (100%)	8/12 (66.7%)	23/28 (82.1%)	3/3 (100%)	27/28 (96.4%)	0.2
Diagnostic delay in symptomatic pulmonary TB (days)	49 [26, 89]	60 [27, 108]	39 [27, 59]	61 [32, 95]	49 (25, 59)	41 [19, 84]	0.48
Positive cultures	86/121 (71.1%)	16/22 (72.2%)	8/12 (66.7%)	33/43 (76.7%)	4/4 (100%)	25/40 (62.5%)	0.42
Drug-resistance in positive culture cases	17/86 (19.8%)	1/16 (6.3%)	3/8 (37.5%)	3/33 (9.1%)	4/4 (100%)	6/25 (24.0%)	
TB outbreak-related cases	18 (14.9%)	0 (0%)	10 (83.3%)	2 (4.7%)	0 (0%)	6 (15.0%)	< 0.001
Number of contacts per case*	4 [2, 5]	2.5 [2, 4]	4 [3.5, 6]	3 [2, 4]	6 [4, 13]	4 [4, 6]	< 0.001

¹ n (%); Median (IQR)² Chi-squared, Fisher's exact, or Kruskal–Wallis tests were performed as appropriate

SS + : Sputum smear positive

*Includes only cases with contact tracing conducted

Table 4 Reasons for referral to MACIP programme

Reasons for referral	Overall N = 121 ¹
Language and cultural barriers	80 (66.1%)
Barriers to contact identification and follow-up	66 (54.5%)
Lack of epidemiological information	65 (53.7%)
Missing information of the case	48 (39.7%)
Lost follow-up during treatment	12 (9.9%)
Medication abandonment	7 (5.8%)
Patient not localised**	7 (5.8%)
Medical conflict	5 (4.1%)
Resurvey for epidemiological clusters	1 (0.8%)
Other reasons†	3 (2.5%)

¹ n (%). The value in % is the number of referrals for that specific reason, divided by the total of TB cases

**Patient lost before start of treatment or contact tracing

†Other reasons includes referrals for active index case follow-up and health promotion activities

Table 4 presents the reasons for referral to the MACIP programme. Language and cultural barriers were the most frequently reported (66.1%), followed by barriers to contact identification and follow-up (54.5%), insufficient epidemiological data (53.7%), and patient loss at different stages, including patients lost to follow-up during treatment (9.9%), not localised before initiating treatment or contact tracing (5.8%), and medication abandonment (5.8%).

Throughout 2023, a total of 2.567 actions were carried out as part of the community-based interventions implemented through the MACIP programme. These actions included phone calls, WhatsApp communications, in-person visits, healthcare mediations, informal meetings

and education workshops, and orientations toward administrative procedures, as well as social and health-related resources. Figure 3 illustrates the proportion of each community intervention and the total number of actions implemented across regions.

Phone calls made by CHWs were the most frequently used action, accounting for 48.3% of all activities. WhatsApp messaging was the second most utilised strategy, representing 34.6% of all actions, with Southeast Asia communities relying on it the most, where it represented over 50% of all activities conducted for this community. In contrast, the Americas region presented the highest proportion of CHW-guided healthcare mediations (16.6%). In-person visits represented a smaller proportion of total activities but were predominantly utilised for communities from Southeast Asia and the Eastern Mediterranean, which together accounted for nearly 80% of all in-person visits. On average, each individual enrolled in the MACIP programme generated 21.2 actions, with the Southeast Asia region reporting the highest number, 1.123 actions, accounting for 43.7% of the total actions.

Discussion

This study offers a detailed description of the social, structural, and migration-related determinants shaping TB vulnerability among migrant populations in Catalonia, southern Europe. By applying a social determinants of health framework, we describe multiple layers of vulnerability that may influence both exposure to TB and treatment outcomes. While our analysis is primarily descriptive and does not aim to demonstrate causal or interaction effects between determinants, it provides

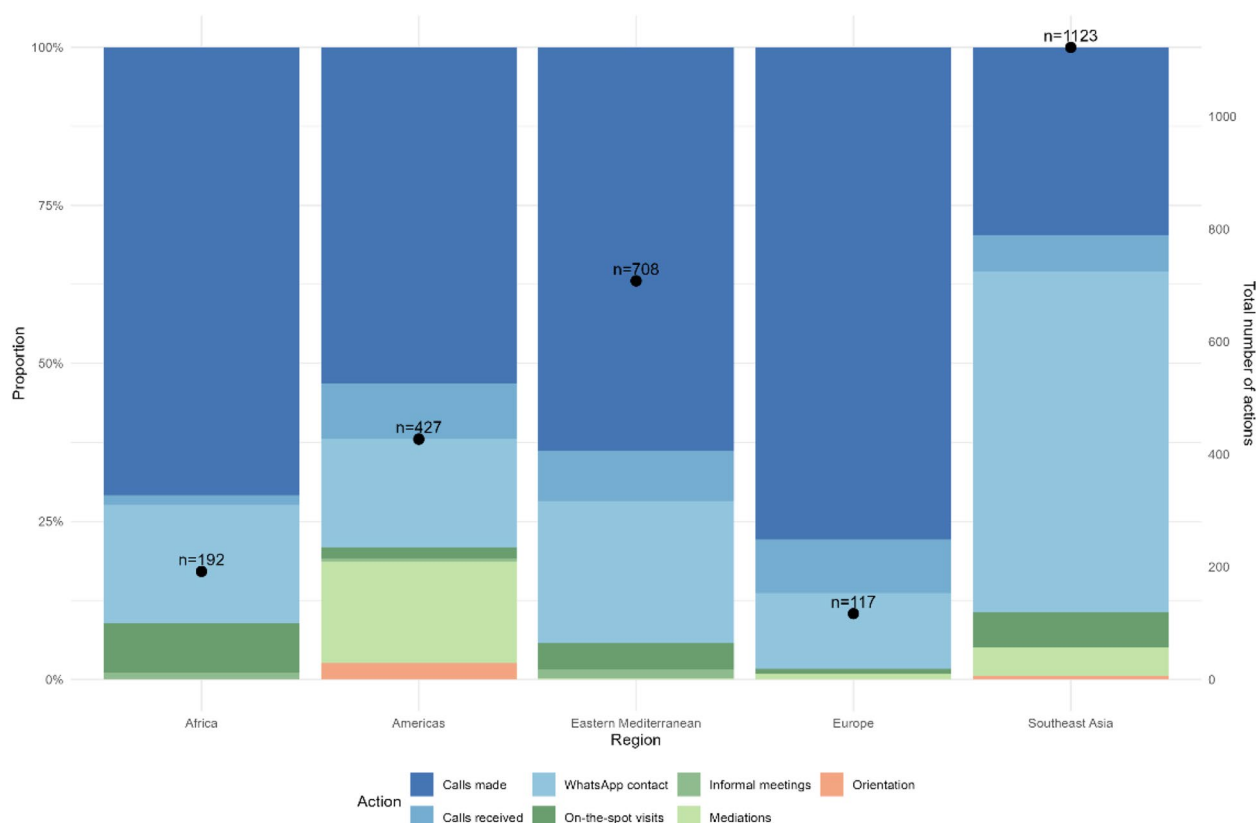


Fig. 3 Distribution of community-based actions by migrants' region of origin

valuable groundwork for future research exploring syndemic dynamics. In particular, our findings highlight how structural and social inequalities shape TB risk across diverse migrant communities, an aspect often under-represented in TB control strategies. This approach offers valuable insights for designing culturally adapted, equity-oriented interventions such as MACIP, capable of responding to the complex realities faced by migrant populations.

Biological factors and comorbidities such as HIV and diabetes, along with behavioural factors such as smoking, alcohol use disorders, and intravenous drug use, are associated with poorer TB outcomes and complicated treatment adherence and recovery [24, 25]. Sociodemographic characteristics like gender and age further shape these patterns [26, 27]. In our study, we observed how these individual-level vulnerabilities were present in conjunction with social determinants such as precarious employment, housing instability, and healthcare access barriers. Although our data do not allow us to establish causal links, these observations are consistent with prior evidence highlighting the compounding nature of disadvantage in TB care [28, 29]. For instance, women, particularly those in informal employment, may face additional obstacles due to caregiving responsibilities and sociocultural constraints [30, 31], whereas young men in

precarious jobs often delay seeking care due to economic pressures [28]. These gendered dynamics may contribute to delays in diagnosis and challenges in treatment adherence, further reinforcing TB-related health inequities [30].

The migratory process itself constitutes another key determinant of TB vulnerability [32–34]. Nearly one-third of the participants in this study were undocumented, which is associated with increased barriers to healthcare access and poorer health outcomes [14]. Moreover, while some migrants had recently arrived in Spain, nearly half had been living in Catalonia for more than five years. This suggests that TB risk is not only related to recent migration but also shaped by long-term structural vulnerabilities such as precarious employment and social exclusion [2, 5, 35]. This observation aligns with the “migrant paradox”, which posits that migrants often arrive in good health but experience worsening health outcomes over time due to socioeconomic marginalisation [36, 37]. Addressing TB in migrant populations therefore requires not only early screening strategies but also long-term social policies that reduce health disparities beyond the initial phase of migration [38].

Structural determinants represent a significant component of TB vulnerability among migrant populations [39]. Nearly 90% of our participants were classified as having

low or very low SES, and over half were unemployed or had precarious jobs. These factors, alongside housing instability and limited access to social protection mechanisms, create conditions that facilitate TB transmission and hinder treatment adherence [2, 15, 38, 40, 41]. Additionally, despite the existence of UHC policies in Catalonia, barriers to healthcare access persist. Nearly a quarter of the participants in this study did not have a healthcare ID at the time of diagnosis, indicating that administrative obstacles continue to delay access to TB services for vulnerable populations [5, 14]. According to the Migrant Integration Policy Index, Spain ranks relatively high in healthcare accessibility for migrants compared with other European countries, yet gaps remain in administrative requirements and effective implementation, which may contribute to delays in TB diagnosis and treatment [42, 43].

TB transmission dynamics vary across different migrant communities and are influenced by social structures, housing conditions, and migration patterns [44]. In this study, notable differences emerged regarding disease presentation, diagnostic delay, and drug resistance. The Latin American population had the highest proportion of TB outbreak-related cases, suggesting close-contact transmission within family and community clusters. In contrast, other migrant communities, such as sub-Saharan Africans, often share housing with individuals from the same cultural background, leading to different social dynamics. These variations highlight the need for community-specific TB prevention strategies that account for social organisation and living conditions. While intensified contact tracing may be particularly relevant for Latin American clusters, where household transmission is more prevalent, broader outreach efforts are needed in communities with more dispersed social networks to ensure effective case detection and follow-up [45].

In our descriptive analysis, migrants from the Eastern Mediterranean region showed the longest diagnostic delay, which may reflect barriers to early healthcare access. Administrative hurdles, unfamiliarity with the healthcare system, limited access to culturally appropriate healthcare information, distrust in healthcare services, and fear of stigma may contribute to delays in seeking care and receiving a timely diagnosis [46, 47]. All TB cases detected among Eastern European migrants in our study were drug resistant, reinforcing the critical need for systematic and early screening [48]. These disparities emphasise the importance of integrating sociological insights into TB prevention strategies to better understand healthcare-seeking behaviours, relationship dynamics within different migrant communities, and potential barriers to early diagnosis [2, 16, 49].

Community-based interventions play a fundamental role in mitigating migrant-related vulnerabilities [40,

50]. CHWs have been particularly effective in addressing linguistic and cultural barriers and facilitating contact tracing and case management [51, 52]. Digital tools, such as WhatsApp messaging, emerged as a strong component of community engagement, facilitating rapid and low-barrier communication and improving treatment adherence. The successful use of digital communication strategies in diverse settings has been associated with increased engagement and adherence [53]. However, it is essential to identify which community interventions are most effective for each community on the basis of their specific sociocultural characteristics. Tailoring interventions to align with the preferences and practices of each community is crucial for maximising their impact and acceptability.

Despite these strengths, this study has several limitations. Data collection was affected by missing information, as some participants might hesitate to share sensitive details due to administrative barriers, job insecurity, stigma, and distrust in public health services. These factors highlight the importance of community-based approaches in fostering trust and ensuring safe spaces for engagement. Another limitation was that referral decisions to the MACIP programme were subjective and varied across surveillance services, underscoring the need for standardised criteria to ensure equitable access. Additionally, migrant TB cases from Barcelona Metropolitan City, managed through a separate community-based programme, were not included in this study, which may limit the representativeness of our findings given the specific social and housing challenges faced by migrants residing in the city. Finally, the proposed framework was developed based on the available study variables and grounded in the social determinants of health approach, which may not fully capture all relevant dimensions of vulnerability.

Efforts in integrating vulnerability diagnostics into TB management must be accompanied by broader social protection policies that address housing, employment conditions, and access to legal and social support systems [14, 29]. A health-in-all-policies approach that fosters intersectoral collaboration is essential to ensure that TB control strategies are not only clinically effective but also socially just and sustainable [38, 54]. Recognising the interplay of structural, social, and biological determinants is fundamental to reducing health disparities. Strengthening these approaches and integrating syndemic-informed decision-making will maximise the impact of TB programmes, fostering more effective, equitable, and people-centred disease control efforts in migrant communities [55].

Conclusions

The vulnerabilities associated with TB in migrant populations are shaped by multiple determinants. Applying a framework that integrates migration and social determinants of health provides a comprehensive perspective to reinterpret traditional epidemiological surveillance data and better understand the roots of vulnerability. This approach can inform people-centred TB control strategies, in line with current WHO recommendations.

Strengthening community-based interventions and systematically incorporating social determinants into TB decision-making may enhance the impact and equity of TB prevention and care.

Future research should explore how to operationalise the concept of syndemic vulnerability within public health strategies in order to better address the complex needs of migrant communities.

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Authors' contributions

H.M.A., J.P.G. and L.G.M. led the conceptualisation and design of the study. H.M.A., V.P.M. and G.T.P. conducted the data analysis and prepared the figures. H.M.A., V.P.M. and L.G.M. drafted the original manuscript. J.P.G., H.O.E., A.G.C., E.S.T., M.L.E., J.M.P. and L.G.M. critically revised the manuscript and contributed to the development of the conceptual framework. All authors reviewed and approved the final version of the manuscript.

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Data availability

The datasets analysed during the current study contain sensitive information collected through public health surveillance and community-based interventions. To protect participant confidentiality and comply with institutional and legal data protection requirements, the datasets are not publicly available. However, anonymised and aggregated data may be shared upon reasonable request to the corresponding author, for non-commercial scientific purposes, and in accordance with applicable ethical and institutional policies.

Declarations

Ethics approval and consent to participate

Ethics approval for this study was obtained from the Ethics Committee of the Vall d'Hebron Research Institute (Reference: PR(AG)03/2023), in accordance with the principles expressed in the Declaration of Helsinki. Before participation, all individuals received oral information about the intervention and provided oral informed consent. The procedure for obtaining oral informed consent was explicitly approved by the Clinical Research Ethics Committee (CEIm) of the Vall d'Hebron University Hospital. All patient data were codified and analysed anonymously.

Competing interests

The authors declare no competing interests.

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