Title

Long-term risk of tuberculosis among migrants according to migrant status: a cohort study

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Key messages

- We established a longitudinal cohort including all migrants resettled in Denmark during 23 years to investigate the long-term risk of tuberculosis following immigration dependent on specific migrant status and region of origin.
- We found that the risk of tuberculosis was highest upon receiving residence for all migrant groups (year 1: incidence rate 275 per 100,000 person-years; 95% CI 249-305) followed by only a gradually decline over time.
- Following resettlement, the tuberculosis risk among migrants remained high for more than a decade, particularly among sub-Saharan African migrants, former asylum seekers, family-reunified to refugees, and quota refugees.
- This study underlines the importance of maintaining awareness of tuberculosis risk among migrants many years after immigration.
- Our study suggests that approaches to screening for tuberculosis should be adapted, with migrant populations benefiting from long-term and meaningful access to preventive health services.

Abstract

Background: Migrants comprise the majority of tuberculosis (TB) in low-incidence countries. Only few studies have assessed the long-term TB risk in migrants after immigration, and datasets have not considered this across a range of diverse migrant groups. This nationwide-study aimed to investigate long-term TB risk among migrants according to migrant status and region of origin.
Methods: Cohort study including all migrants≥18 years who obtained residence in Denmark from 1993-2015, with a mean follow-up of 10.8 years (SD 7.3). Migrants were categorised based on legal status of residence and region of origin. Incidence rates (IR) and rate ratios (IRR) were estimated by Poisson regression.
Results: 142,314 migrants were included. Across all migrants, the TB risk was highest during year one of residence (IR 275/100,000 person-years; 95% CI 249-305) followed by a gradual decline, though TB risk remained high for over a decade. Compared to Danish-born, the IRRs after 7-8 years were particularly higher among former asylum seekers (IRR 31; 95% CI 20-46), quota refugees (IRR 31; 95% CI 16-71), and family-reunified to refugees (IRR 22; 95% CI 12-44). Sub-Saharan African migrants also experienced elevated risk (IRR 75; 95% CI 51-109). The proportion of migrants with pulmonary TB was 52.4%.
Conclusion: All migrant groups experienced an initial high TB risk, but long-term risk remained high in key migrant groups. Most European countries focus TB screening on or soon after arrival. Our study suggests that approaches to TB screening should be adapted, with migrant populations benefiting from long-term access to preventive health services.

Keywords: tuberculosis, migrants, long-term risk, asylum seekers, immigration, refugees, screening

Introduction

Migration is an important factor for tuberculosis (TB) in low-incidence settings, where migrants from high-incidence countries often comprise more than 70% of TB cases(1). Therefore, improving TB prevention and care among migrants is a key public health priority towards TB elimination(2).

The TB risk among migrants is highest within 2-5 years after immigration, but remains high for over a decade following migration(3–8). However, migrants are a heterogeneous group and some migrants may experience higher TB rates than others. Migrants exposed to high TB rates in their country of origin are likely to be at increased TB risk, including several years following migration due to reactivation of latent TB infection (LTBI)(9,10). Some migrants, for instance refugees, may also be at high risk due to conditions related to migration such as overcrowded camps, poor nutrition and stress(11,12). Upon arrival, although many European countries have implemented TB screening(13), most of these programmes focus on TB among primarily asylum seekers, whereas other newly arrived migrant groups may be missed(3,14). After resettling, migrants may experience barriers to health services in the host country, which consequently can compromise access to care(15). Lastly, some migrants may be exposed to transmission during travels to TB-endemic countries(16).

Only few studies have assessed the long-term TB risk experienced by specific migrant groups based on legal grounds for residence following migration to a low-incidence country, since most studies have focused on country of origin(17). One study from the UK(3) assessed the TB risk among migrants screened before entry, and found that family-reunified migrants had the highest risk compared to students, resettlement-refugees and working migrants, but the study did not include asylum seekers.

More knowledge on the long-term TB risk among migrants is important in order to inform TB elimination strategies. The aim of the present study was to investigate the TB risk among migrants who acquired residence in Denmark according to migrant status and region of origin. In addition, we assessed the presentation of TB over time (pulmonary versus extrapulmonary TB).

Methods

Design and study population

This nationwide cohort study included all migrants ≥18 years who obtained residence in Denmark between January 1st 1993 and December 31st 2015. Migrants were included in the cohort from the date residence was granted. A Danish-born comparison group was identified through Statistics Denmark and matched 1:6 on age and sex. The cohort was established in 2005 and updated in 2016. The construction of the cohort including the matching procedure has previously been described in detail(18,19). Individuals with a TB diagnosis in Denmark between arrival and residence date were excluded. The current study cohort has previously been described(20).

Variables

A TB case was defined as all forms of active TB, including pulmonary and extrapulmonary TB. Diagnosis was either microbiologically confirmed or based on clinical and/or paraclinical findings suggestive of TB prompting TB treatment. Information on how TB cases were detected was not available. In Denmark, most TB cases are found based on reporting symptoms and few during contact investigations. There was no systematic TB screening among migrants during the study period. For the distribution between pulmonary and extrapulmonary TB, cases with both pulmonary and extrapulmonary TB were categorized as pulmonary TB.

Migrants were grouped according to legal grounds of residence in Denmark, defined as migrant status: i) former asylum seekers (in this paper, we refer to asylum seekers granted refugee status as former asylum seekers), ii) quota refugees, iii) family-reunified to Danish/Nordic citizens, iv) family-reunified to immigrants, and v) family-reunified to refugees(20). Migrants were grouped based on region of origin modified from the World Bank Group(21): 1) Eastern Europe + Central Asia, 2) Europe, North America + Oceania, 3) Latin America + Caribbean, 4) Middle East + North Africa, 5) South-East Asia + Pacific (referred to as South-East Asia), and 6) sub-Saharan Africa.

Data generation

All Danish-born are assigned a unique civil person registration number (CPR) at birth, whereas migrants receive a CPR and are registered in the CPR-registry at date of residence permission. The CPR can be used to track individuals through public registries at an individual level.

Data on immigration, emigration and death were obtained from Statistics Denmark. In this study, year one refers to the first year of receiving residence permission. For quota refugees and family-reunified migrants, who are granted residence overseas, this is immediate and aligns with day of arrival. For former asylum seekers, who apply for asylum in Denmark, the asylum-seeking process can take an average of 6-24 months, but may vary(22). Emigration is the date where an individual has given up residence and is deregistered in the CPR-registry(23). Age, sex, migrant status and country of origin were obtained from The Danish Immigration Service.

Data on culture-verified TB cases were retrieved from the International Reference Laboratory of Mycobacteriology, Statens Serum Institut (SSI), where TB diagnostics are centralized. By law, TB is a notifiable disease and data on all notified TB cases were retrieved from the National Surveillance Register, Department of Infectious Disease Epidemiology and Prevention, SSI to ensure we included culture-negative cases.

Data analysis

Descriptive analyses were carried out using chi-squared and t-test analyses. Poisson regression was used to calculate incidence rates (IR) per 100,000 person-years, and incidence rate ratios (IRR), both with 95% confidence intervals (CI), using the logarithm of follow-up time as offset. Follow-up time was calculated as time from receiving residence until one of the following events: i) TB diagnosis, ii) emigration, iii) death, or iv) study-end.

Consequently, follow-up time represents duration of residence and quantified the number of person-years at TB risk.

IR and IRR were estimated according to duration of residence with one-year intervals. We present IR and IRR stratified by migrant status and region of origin using Danish-born as reference group. As unadjusted IRR and adjusted IRR showed the same results, table 3 presents only adjusted IRR. We calculated reduction in risk per year by including duration of residence as a continuous variable calculated from the model as (1-exp(change per year on log scale))*100 = % reduction per year. We adjusted for age as a time varying covariate in 10-year intervals.

Results are reported according to STROBE guidelines(24). Analyses were performed in SAS version 9.4 (SAS Institute, Cary, NC, USA).

Ethical approval

This study was approved by the Danish Data Protection Agency (No. 2016-41-4576).

Results

A total of 142,314 migrants were included in the study with a mean follow-up of 10.8 years (SD 7.3) (Supplementary material). The control cohort consisted of 854,820 Danish-born with a mean follow-up of 12.4 years (SD 7.1). There were 1841 TB cases among migrants (table 1) with the majority of TB cases originating from sub-Saharan Africa (56.4%) and South-East Asia (26.2%). There were 398 TB cases among Danish-born. Among migrant TB cases, 84.5% were ≤40 years at residence date. Among migrants, the mean time from residence to TB diagnosis was 4.3 years (SD 4.1).

Among all migrants, the IR was highest in the first year of residence (year 1: IR 275/100,000 person-years; 95% CI 249-305) followed by a gradual decline over time (year 7-8: IR 84/100,000 person-years; 95% CI 71-98), corresponding to a decrease of 69% over eight years ($p<0.05$) (table 2).

When stratified by migrant status and region of origin, the IR generally decreased with increased time since residence (figure 1 and figure 2). According to migrant status, the IR was persistently highest from year one to year 7-8 among former asylum seekers, family-reunified to refugees, and quota refugees (table 2). According to region of origin, the IR was persistently highest among sub-Saharan African migrants throughout time (year 1: IR 1373/100.000 person-years; 95% CI 1212-1556, year 7-8: IR 304/100.000 person-years; 95% CI 238-389) (table 2).

Compared to Danish-born, the IRR remained higher beyond 13 years of residence among all migrant groups (table 3). According to migrant status, the IRR after 7-8 years were particularly higher among former asylum seekers (IRR 31; 95% CI 20-46), quota refugees (IRR 31; 95% CI 16-71) and family-reunified to refugees (IRR 22; 95% CI 12-44). The reduction in risk per year was more pronounced among family-reunified to immigrants

(19.7%), family-reunified to refugees (20.7%), and former asylum seekers (15.5%), whereas a minor reduction was observed for family-reunified to Danish/Nordic citizens (11.4%) and quota refugees (11.5%) ($p<0.05$).
According to region of origin, the IRR after 7-8 years were especially higher among migrants from sub-Saharan Africa (IRR 75; 95% CI 51-109) and South-East Asia (IRR 31; 95% CI 21-47). The reduction in risk per year was more pronounced among migrants from sub-Saharan Africa (19.7%), whereas a minor reduction was seen among migrants from South-East Asia (11.5%), from the Middle East and North Africa (14.2%), and from Eastern Europe and Central Asia (9.9%).

Overall, among Danish-born TB cases, a greater proportion were pulmonary TB (87.4%) than among migrants (52.6%) ($p<0.05$). This distribution did not change over time (figure 3).

Discussion

The findings show that the TB risk among migrants remains high for over a decade of residence with only a gradual decline in risk over time. TB risk was found to be associated with migrant status and region of origin. The highest risk both initially and long-term was observed among former asylum seekers, family-reunified to refugees and quota refugees, and migrants from sub-Saharan Africa, whereas family-reunified to immigrants and family-reunified to Danish/Nordic citizens had lower risk.

Overall, our findings are similar to previous studies reporting a high TB incidence soon after immigration as well as many years after(5–8). The initial IR in our migrant population was 275/100,000 person-years (95% CI 249-305) decreasing to 84/100,000 person-years (95% CI 71-98) over eight years. This was slightly higher than the IR among refugees, asylum seekers and persons migrating for work in Norway, decreasing from 210/100,000 person-years (95% CI 190-230) to 50/100,000 person-years (95% CI 30-70) over seven years(6). This study did not stratify by migrant status. The gradual decrease seen in our study was unlike the sharp decline from the first to the second year in the Norwegian study. First, this could be explained by the lack of arrival screening in our cohort. In Norway, mandatory radiographic TB screening is performed upon arrival for all refugees and for migrants from high-incidence TB countries. Thus, the drop in incidence from the first to the second year in Norway could likely be explained by a high TB detection rate during the screening process, in contrast to our study population without systematic TB screening. In Denmark, asylum seekers were offered a voluntary general health assessment on arrival, but this did not include systematic TB screening before 2017. Quota refugees and family-reunified migrants were not offered health assessment or TB screening(20). Prior to arrival in Denmark, only quota refugees are required to attend TB screening, but these data or data on TB/LTBI treatment were not available. Second, migrants from high-incidence TB countries aged 15-35 years were screened for LTBI upon arrival in Norway. If they were treated for LTBI (not reported), this would lower the risk of reactivation also partly explaining the sharp decline(25). A lower risk was also seen in a study among immigrants (not further specified) and refugees who were granted permanent residence in Canada: The IR was 63/100,000 person-years in the first two years after arrival decreasing to 14/100,000 person-years in years 11-16(8). The lower IR upon arrival may be

because migrants in Canada must undergo radiographic TB screening overseas before being granted residence, and those with active TB are treated before arrival. The Canadian study identified the highest risk-group as migrants from countries with IR ≥100/100,000 person-years, but did not stratify by migrant status.

The proportion of migrants recently infected either in the country of origin or during migration is likely to contribute to the high risk in the early years after migration, as the risk of reactivating LTBI is highest within the first 2-5 years after infection(10). Former asylum seekers, quota refugees, and family-reunified to refugees had the highest TB risk after one year since residence was granted. Former asylum seekers and family-reunified to refugees also had a steeper reduction in risk compared to family-reunified to Danish/Nordic citizens. Soon after immigration, former asylum seekers and family-reunified to refugees might be a high-risk group compared to other migrant groups due to the potential high risk of TB transmission during migration. Typically, asylum seekers leave their home under critical circumstances, spend time in overcrowded camps or travel in perilous conditions favouring TB transmission(11). Although family-reunified to refugees migrate under different legal terms than asylum seekers, they are also likely to be highly vulnerable to TB since they are often fleeing under just as critical circumstances(15). Additionally, the high rates could also reflect risk factors favouring LTBI reactivation such as stress or poor nutrition(26).

The high TB rates according to region of origin are consistent with previous studies where migrants from TB-endemic countries have an increased risk following migration, largely driven by LTBI reactivation(3,5,9). In our population, the risk after eight years of residence was still 75 and 32 times higher among sub-Saharan African and South-East Asian migrants, respectively, compared to Danish-born. One important aspect is that the majority of TB cases among former asylum seekers (71.4%) and family-reunified to refugees (75.4%) were from sub-Saharan Africa, largely contributing to the high IR observed in these migrant groups. E.g. the total IR among former asylum seekers and family-reunified to refugees were 156 (95% CI 146-167) and 199 (95% CI 179-221), respectively, whereas the total IR among sub-Saharan African former asylum seekers and family-reunified to refugees were 790 (95% CI 732-853) and 707 (95% CI 624-801), respectively(20). Even though originating from a TB-endemic region is a highly important risk factor, migrant status may contribute to the TB risk through other well-known TB risk factors during migration such as impaired living conditions, malnutrition etc.(27). For instance, 60.3% of South-East Asian migrants were family-reunified to Danish/Nordic citizens, and are likely to have arrived directly from their country of origin, travelled under less stressful means, and arrived within a support system. However, differences may also reflect differences in socio-economic status in the country of origin.

After resettlement, migrants might acquire new infections through TB transmission in the host country or during travels to TB high-risk areas. Studies indicate a low degree of transmission between migrants and the host-population in low-incidence countries(28). Family-reunified to Danish/Nordic citizens may have a higher level of travels to their country of origin than family-reunified to refugees and former asylum seekers, whose countries of origin may be in unstable conditions, however whether travel is a risk factor was not explored in this study.

The high TB proportion among migrants ≤40 years at residence partly reflects the overall age distribution in our migrant cohort, with mostly younger people migrating to Denmark. The total TB risk was lower among migrants ≤40 years than migrants ≥65 years, but there was no difference when stratified according to duration of residence, possibly due to the low TB numbers among migrants ≥65 years (n=61). This was unlike the Canadian study, where migrants ≥65 years at arrival maintained a higher risk than younger migrants throughout post-migration(8). The higher risk with ageing possibly reflects increased LTBI reactivation from risk factors and comorbidities increasing with age(29,30).

The high proportion of extrapulmonary TB among migrants is consistent with previous studies(31,32), and attributed to the large proportion of Somali migrants with extrapulmonary TB in our cohort(33). We did not observe changes in the distribution between pulmonary and extrapulmonary TB over time. This is in contrast to the Norwegian study(6), where the higher proportion of pulmonary TB during the first year probably was due to CXR screening upon arrival. From a public health perspective, extrapulmonary TB is less important for the TB transmission, but extrapulmonary TB is often attributed to reactivation(34) which emphasizes the need to consider LTBI screening among migrants.

Strengthening screening for active TB at arrival can potentially reduce the high TB risk following immigration, particularly among migrants at highest risk i.e. migrants from sub-Saharan Africa, family-reunified to refugees, former asylum seekers and quota refugees. However, given the long-term TB risk related to reactivation of LTBI(3,10), LTBI screening and treatment could be important tools to reduce subsequent reactivation among the high-risk groups(35–37). Recently in the UK(37), pre-entry screening for active TB among migrants combined with post-entry LTBI screening and treatment was associated with a decrease in incidence following resettlement. As LTBI treatment is effective and short-term regimes of only month rifapentine and isoniazid become increasingly available(38,39), we may come closer towards TB elimination. However, strategies to increase follow-up and treatment completion are crucial for LTBI screening programmes to be effective(25,40). Furthermore, as many TB cases develop years after arrival, long-term access to preventive healthcare should be prioritized so TB signs of can be spotted and diagnostics initiated.

Strengths and limitations

Major strengths of this study were the large cohort size and duration of follow-up. Utilizing the unique Danish CPR registry, we could identify and follow all migrants who received residence in the study period on a nationwide, individual level with high-quality data on TB, emigration and mortality. This enabled us to estimate the TB risk for over a decade. We believe our data reflect the long-term TB risk among migrants following resettlement in a low-incidence country. Still, there were limitations. Some migrants (n=191) were diagnosed with TB in Denmark between arrival and obtaining residence. Large uncertainties were associated with information on specific arrival date and were not available for all migrants. We therefore based inclusion on residence date as the CPR is assigned here allowing for exact follow-up through registries. A consequence of this approach is an underestimation of TB on arrival in our migrant population, particularly among former asylum seekers. Second,

migrants <18 years were not included. Children were received differently at arrival in Denmark with regards to social support and health assessment, thus to minimize potential bias only adults were included.

Conclusion

Following immigration, the TB risk remained high for more than a decade, particularly among sub-Saharan African migrants, former asylum seekers, family-reunified to refugees, and quota refugees. Most European countries focus on TB screening upon arrival. Our study underlines the importance of maintaining awareness of TB risk among migrants many years after immigration, and suggests that approaches to TB screening should be strengthened and adapted with migrant populations benefiting from long-term access to preventive health services, including LTBI screening.

Pernille Ravn has a patent on IP-10 for LTBI diagnosis. The authors declare no other conflict of interests.

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TABLE 1 Baseline characteristics among tuberculosis cases[1] by migrant status (n = 2239)

	Danish-born	Migrants	Former asylum seekers	Quota refugees	Family-reunified to Danish/Nordic citizens	Family-reunified to immigrants	Family-reunified to refugees
Sex							
Female	39.2 (156)*	53,3 (982)*	42.8 (395)*	25.6 (32)*	71.5 (266)*	52.2 (48)	73.2 (241)*
Male	60.8 (242)	46,7 (859)	57.2 (528)	74.4 (93)	28.5 (106)	47.8 (44)	26.8 (88)
Age at residency[2]							
≤ 40 years	76.4 (304)	84.5 (1555)	82.3 (760)	88.0 (101)	90.3 (336)	85.9 (79)	84,8 (279)
41-64 years	22.4 (89)	12.2 (225)	13.1 (121)	17.6 (22)	8.8 (33)	13.0 (12)	11.3 (37)
≥ 65 years	1.3 (5)	3.3 (61)	4.6 (42)	1.6 (2)	0.8 (3)	1.1 (1)	4.0 (13)
Time to diagnosis, years[3]	8.8 (5.6)	4.3 (4.1)	4.3 (4.2)	4.3 (3.8)	4.6 (4.1)	4.4 (4.2)	3.9 (3.9)
Age at diagnosis, years[4]	41.1 (33.6-49.3)	32.9 (27.8-40.2)	33.1 (27.8-40.9)	33.7 (26.8-41.6)	33.1 (28.9-38.5)	30.9 (25.6-38.6)	32.1 (27.5-39.5)
Region of origin							
Eastern Europe + Central Asia	N/A	10.7 (197)	14.6 (135)	0 (0)	7.0 (26)	34.8 (32)	1.2 (4)
Latin America + Caribbean	N/A	0.3 (6)	0.1 (1)	0 (0)	1.3 (5)	0 (0)	0 (0)
Europe, North America + Oceania	N/A	0.8 (15)	0.2 (2)	0 (0)	2.4 (9)	2.2 (2)	0.6 (2)
Middle East + North Africa	N/A	5.5 (102)	5.5 (51)	10.4 (13)	3.5 (13)	7.6 (7)	5.5 (18)
South-East Asia	N/A	26.2 (483)	8.1 (75)	51.2 (64)	66.1 (246)	44.6 (41)	17.3 (57)
Sub-Saharan Africa		56.4 (1038)	71.4 (659)	38.4 (48)	19.6 (73)	10.9 (10)	75.4 (248)
Country of origin[5]							
Afghanistan	N/A	4.7 (86)	6.2 (57)	3.2 (4)	0.3 (1)	0 (0)	7.3 (24)
Former Yugoslavia	N/A	7.5 (138)	12.2 (113)	0 (0)	2.4 (9)	13.0 (12)	1.2 (4)
Pakistan	N/A	3.7 (69)	0.1 (1)	0 (0)	12.9 (48)	18.5 (17)	0.9 (3)
Somalia	N/A	47.1 (873)	66.9 (617)	9.6 (12)	1.3 (5)	5.4 (5)	71.1 (234)
Thailand	N/A	4.6 (85)	0 (0)	0 (0)	21.2 (79)	6.5 (6)	0 (0)

Data are presented as % (n) unless otherwise stated. 1. All forms of active tuberculosis. 2. For Danish-born age at inclusion. 3. Mean (standard deviation). 4. Median (interquartile range). 5. Five most frequent countries of origins among tuberculosis cases. *p<0.01 for the difference between sex.

TABLE 2 Incidence rates of tuberculosis[1] according to duration of residency among migrants by migrant status and region of origin[2] compared to Danish-born (n = 997,134)

	Duration of residency						
	1 year	2 years	3-4 years	5-6 years	7-8 years	9-12 years	+ 13 years
	IR/100,000 person-years (95% CI)						
Danish-born	3 (2-4)	4 (3-6)	4 (3-5)	3 (2-4)	4 (3-5)	4 (3-4)	4 (4-5)
Migrants	275 (249-305)	253 (226-282)	209 (190-229)	135 (120-152)	84 (71-98)	56 (48-65)	33 (28-39)
Former asylum seekers	416 (363-476)	344 (292-404)	282 (247-323)	177 (148-211)	121 (97-151)	77 (63-94)	37 (29-47)
Quota refugees	333 (212-521)	386 (252-592)	275 (190-399)	315 (219-453)	137 (76-248)	95 (54-167)	36 (14-86)
Family-reunified to							
- Danish/Nordic citizens	129 (102-162)	105 (80-137)	96 (78-118)	69 (53-90)	52 (37-71)	36 (27-49)	22 (15-32)
- immigrants	220 (143-337)	165 (99-273)	122 (80-188)	87 (51-147)	34 (14-81)	27 (13-56)	24 (13-46)
- refugees	375 (286-490)	552 (437-698)	452 (372-548)	209 (155-280)	91 (57-144)	53 (34-83)	57 (38-87)
Region of origin							
Eastern Europe + Central Asia	62 (40-95)	61 (40-95)	71 (53-95)	59 (43-83)	43 (29-64)	24 (16-35)	19 (13-28)
Middle East + North Africa	67 (44-101)	75 (48-116)	40 (25-63	27 (15-49)	24 (29-64)	20 (11-34)	12 (6-23)
South-East Asia	258 (207-321)	243 (193-307)	219 (183-263)	182 (147-226)	123 (92-163)	84 (64-110)	48 (34-68)
Sub-Saharan Africa	1374 (1213-1557)	1282 (1114-1476)	1048 (932-1180)	558 (470-663)	304 (238-389)	216 (173-271)	126 (97-165)

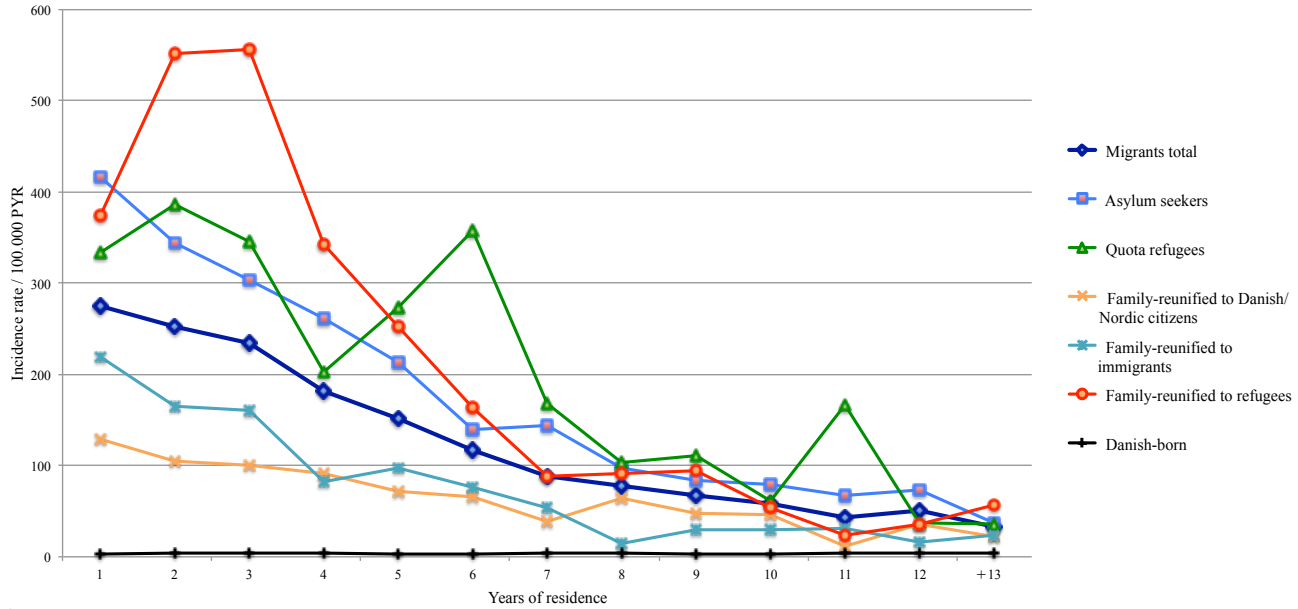
IR: Incidence rates; CI: Confidence interval; 1. All forms of active tuberculosis. 2. Latin America + Caribbean, and Europe, North America + Oceania region of origin are not included for analysis due to insufficient power.

TABLE 3 Incidence rate ratios of tuberculosis[1] according to duration of residence among migrants by migrant status and region of origin[2] compared to Danish-born (n = 997,134)

	Duration of residency							
	1 year	2 years	3-4 years	5-6 years	7-8 years	9-12 years	+ 13 years	Reduction/ year[3]
	IRR[4] (95% CI)							
Danish-born[5,6]	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Migrants	99 (58-167)	62 (39-99)	57 (38-86)	47 (29-76)	20 (13-32)	15 (10-24)	7 (5-10)	15.5
Former asylum seekers	153 (100-237)	87 (59-129)	79 (56-112)	63 (42-96)	31 (20-46)	21 (15-31)	8 (5-11)	15.5
Quota refugees	121 (65-223)	96 (55-169)	76 (45-128)	110 (64-191)	34 (16-71)	26 (13-53)	7 (2-21)	11.5
Family-reunified to								
- Danish/Nordic citizens	46 (28-73)	26 (16-40)	26 (18-38)	24 (15-38)	13 (7-20)	10 (7-16)	5 (3-9)	11.4
- immigrants	75 (41-136)	38 (21-72)	32 (18-56)	28 (14-57)	8 (3-22)	7 (3-17)	6 (3-13)	19.7
- refugees	133 (81-218)	134 (87-206)	121 (83-177)	71 (44-117)	22 (12-44)	15 (8-27)	16 (9-27)	20.7
Region of origin								
Denmark[5,6]	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Eastern Europe + Central Asia	22 (12-39)	15 (8-26)	19 (12-28)	20 (12-32)	10 (6-17)	6 (4-10)	4 (3-6)	9.9
Middle East + North Africa	23 (13-42)	18 (10-32)	11 (6-18)	9 (5-19)	6 (3-12)	5 (3-10)	3 (1-6)	13.2
South-East Asia	95 (60-151)	61 (40-93)	62 (44-86)	65 (44-97)	31 (21-47)	24 (17-35)	12 (8-18)	11.5
Sub-Saharan Africa	488 (305-779)	313 (207-475)	284 (209-386)	194 (134-282)	75 (51-109)	61 (43-86)	29 (21-40)	19.7

IRR: Incidence rate ratios; CI: Confidence interval; 1. All forms of active tuberculosis. 2. Latin America and Europe, North America + Oceania region of origin are not included for analysis due to insufficient power. 3. Reduction in TB risk per year e.g. (1-exp(slope coefficient))*100 = (1-exp(-0.1686))*100 = 15.5% reduction per year. 4. Adjusted for age and sex. 5. Danish-born form the reference group. 6. All IRR listed are different from the Danish-born reference group ($p<0.01$).

FIGURE 1 Tuberculosis incidence rates by years of residence among migrants stratified by migrant status, Denmark, 1993-2015 (n = 997,134)

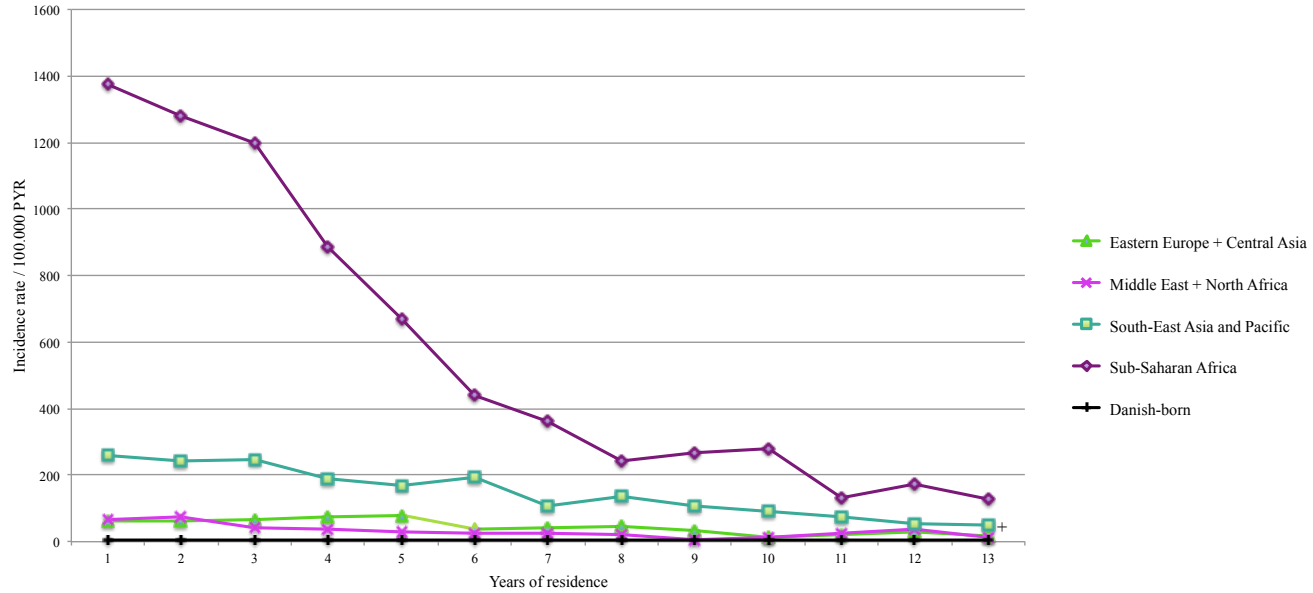


Migrants per year, n

TB cases	373	307	263	191	153	112	81	67	56	46	32	35	124
Population	142,314	127,532	116,573	108,462	102,993	98,470	93,116	88,489	84,333	79,775	75,894	72,363	69,013

PYR: Person-years

FIGURE 2 Tuberculosis incidence rates by years of residence among migrants stratified by region of origin, Denmark, 1993-2015 (n = 997,134)



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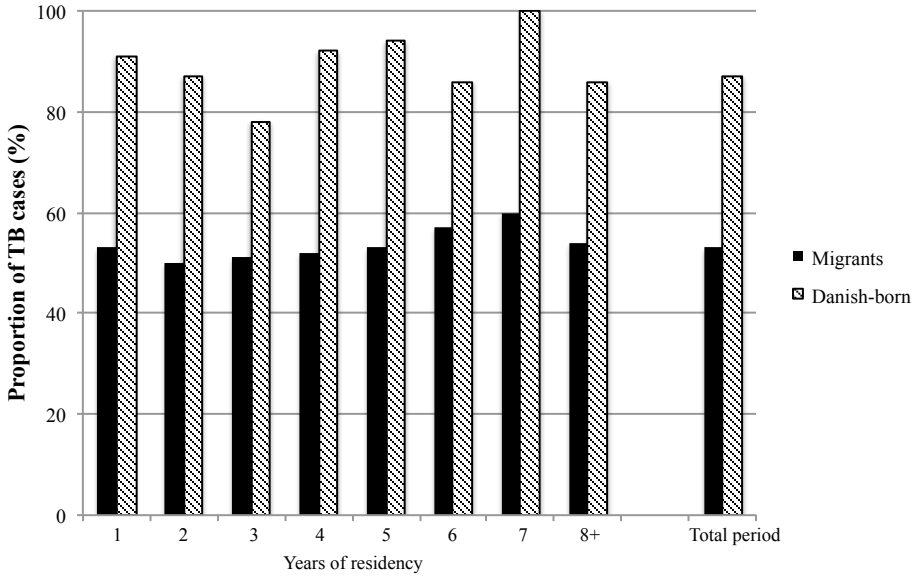
PYR: Person-years

FIGURE 3 Proportion of pulmonary tuberculosis by years of residence among migrants and Danish-born, Denmark, 1993-2015 (n = 997,134)



TB: tuberculosis; Cases with both pulmonary TB and extrapulmonary TB are categorised as pulmonary TB.