Tuberculosis in Canada and the United States: a review of trends from 1953 to 2015

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Abstract

Objectives To explore tuberculosis (TB) incidence in Canada and the United States from 1953 to 2015. In the most recent decade, the US incidence was lower than that of Canada. Since both countries are high income and have low TB incidence with similar TB surveillance programs, we hypothesized that rates should be similar.

Methods TB incidence data from 1953 to 2015 were retrieved for both countries. Joinpoint regression was performed to identify change points in the trend, and direct standardization of US rates using Canadian ethnic population distribution was calculated. Adjusted rate and average annual percent change (AAPC) were estimated.

Results Canada rates/100,000 were higher from 1953 to 1974 and similar from 1975 to 1985. This coincided with a change in US case definition in 1975. US rates were higher from 1986 to 1996. HIV/TB coinfection in the USA was 10.2% compared to that of Canada, 1.6%. Rates were similar from 1997 to 2004. Canada rates were again higher from 2005 to 2015. The Canada average AAPC rate in 1975–2015 was lower, –2.9%, compared to that of the USA, –4.1%. Foreign-born and Indigenous population proportions were 20.2% and 4.2% for Canada and 12.9% and 1.7% for the USA. The US rate adjusted to the Canada ethnic composition was 4.8 compared to the Canadian rate of 4.7.

Conclusion Case definition change and HIV coinfection contributed to the 1980 US rate increase. TB rates decreased in both countries from 1997, but more rapidly in the USA. The Canada proportion of foreign-born and Indigenous populations was higher. When US rates were standardized by Canada ethnic distribution, the national rates were similar. Further exploration of factors contributing to differences between these countries is needed.

Résumé

Objectifs Explorer l'incidence de la tuberculose au Canada et aux États-Unis de 1953 à 2015. Au cours des 10 dernières années à l'étude, l'incidence aux États-Unis a été plus faible qu'au Canada. Étant donné que ce sont deux pays à revenu élevé, à faible incidence de tuberculose et avec des programmes de surveillance de la tuberculose similaires, nous avons émis l'hypothèse que les taux devraient être similaires.

Méthode Nous avons obtenu les données sur l'incidence de la tuberculose de 1953 à 2015 pour les deux pays. Nous avons effectué une régression joinpoint pour repérer les points de changement dans les tendances et standardisé directement les taux américains en fonction de la répartition ethnique de la population canadienne. Les taux ajustés et le pourcentage de changement annuel moyen (PCAM) ont été estimés.

Résultats Les taux pour 100,000 du Canada ont été supérieurs à ceux des États-Unis de 1953 à 1974 et semblables à ceux des États-Unis de 1975 à 1985. Cela a coïncidé avec un changement dans la définition des cas aux États-Unis en 1975. Les taux américains ont été supérieurs de 1986 à 1996. Le taux de coinfection VIH/tuberculose aux États-Unis était de 10,2 %, contre 1,6 % au Canada. Les taux ont de nouveau été semblables de 1997 à 2004. Les taux canadiens sont redevenus supérieurs de 2005 à 2015. Le PCAM au Canada entre 1975 et 2015 a été inférieur à celui aux États-Unis (–2,9 % contre –4,1 %). Les proportions de

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personnes nées à l'étranger et d'Amérindiens étaient de 20,2 % et de 4,2 % au Canada et de 12,9 % et de 1,7 % aux États-Unis. Le taux américain ajusté selon la composition ethnique du Canada était de 4,8, comparativement à 4,7 pour le Canada.

Conclusion Le changement dans la définition des cas et la coïnfection par le VIH ont contribué à la hausse des taux américains dans les années 1980. Les taux de tuberculose ont diminué dans les deux pays à partir de 1997, mais plus rapidement aux États-Unis. Au Canada, la proportion de personnes nées à l'étranger et d'Amérindiens était plus élevée. Quand nous avons standardisé les taux américains pour tenir compte de la répartition ethnique du Canada, nous avons obtenu des taux nationaux similaires. Il faudrait néanmoins pousser l'étude des facteurs qui contribuent aux différences entre les deux pays.

Keywords Joinpoint · Annual percent change · Tuberculosis · Epidemiology · Trends

Mots-clés Joinpoint · Pourcentage de changement annuel · Tuberculose · Épidémiologie · Tendances

Introduction

Tuberculosis (TB) is a preventable and treatable disease (World Health Organization 2018) that has not been eliminated in most parts of the world (Chiang et al. 2013), including Canada and the United States (Lönnroth et al. 2015). TB has a long history in North America dating back to the eighteenth and nineteenth centuries (Grzybowski and Allen 1999; Grigg 1958), for which national incidence reporting in Canada and the USA only commenced in 1924 and 1953 respectively (Gallant et al. 2014; Woodruff et al. 2015). There are TB-related similarities between these countries: high income (World Bank 2016), low TB incidence (Lönnroth et al. 2015), similar surveillance programs (Mor et al. 2008), isoniazid (INH) and rifampin (RMP) implemented at the same time (Menzies and Elwood 2014), treatment of latent TB infection (LTBI) implemented within a year (Mount and Ferebee 1961), and the majority of cases occurring in the foreign-born population (Public Health Agency of Canada 2015; Centers for Disease Control and Prevention 2017). There are some differences: the USA in 1993 (Centers for Disease Control and Prevention 2017) was several years ahead of Canada in 1997 (Public Health Agency of Canada 2000) for first reporting TB with HIV/AIDS nationally, Canada ranks 6th and the USA 14th for highest proportion of foreign-born population (OECD 2018) and 18th and 29th for the highest net positive immigration respectively (Index Mundi 2018). From 1953 to 1974, the US surveillance case definition included only new cases compared to Canada with new and previously reported cases (Gallant et al. 2014; Armstrong and Miramontes 2014). In 1975, the USA changed its surveillance case definition to include previously reported cases (Gallant et al. 2014; Armstrong and Miramontes 2014). In 1975, the USA changed its surveillance case definition resulting in an increase in annual surveillance numbers (Armstrong and Miramontes 2014). Considering this background, it was an unexpected observation over the last decade that TB rates in the USA declined more rapidly than in Canada (Public Health

Agency of Canada 2015; Centers for Disease Control and Prevention 2017).

Epidemiologically, time-trend analysis is a graphical procedure used to assess changes in disease patterns over time (Kim et al. 2000). Birnbaum likened the analysis of trends which involve time as a major component to a screening tool needed to “decide whether a more intensive investigation into underlying causes is justified” (Birnbaum et al. 1997). This highlights the need for exploring incidence trends as the first step in carrying out in-depth investigations of disease drivers to guide national and global goals in TB control. Explicit comparison of TB incidence rates over time between Canada and the USA has not been published. To better understand some of the differences, we proposed to explore TB incidence rates in Canada and the USA over time and compare the national trends.

Methods

Incidence data

This study used retrospective national annual TB incidence rate data from 1953 to 2015 retrieved from the Public Health Agency of Canada (PHAC) and Centers for Disease Control and Prevention (CDC) USA (Gallant et al. 2014; Centers for Disease Control and Prevention 2017; Gallant et al. 2017). 2015 was the last year for which Canadian data were available. Population data were obtained from the Canada quinquennial census and US decennial census data (Statistics Canada 2011; Grieco et al. 2012).

The TB rate in Canada from 1953 to 2015 included new and previously reported cases. In the USA from 1953 to 1974, it included new active cases only and from 1975 to 2015, new and previously reported cases (Gallant et al. 2014; Armstrong and Miramontes 2014). Data on implementation of treatment drugs and treatment of LTBI, TB program funding cuts, case definition change, first reports of HIV, percent of HIV/TB coinfection, percent foreign-born population, and percent

Table 1 Sources of data list by reference number

Metric	Country	Year and %	Source
Implementation date INH	Canada and USA	1952	Menzies and Elwood (2014)
Implementation TLBTI	Canada and USA	1961	Mount and Ferebee (1961)
Implementation date RMP	Canada and USA	1968	Menzies and Elwood (2014)
TB program funding cuts	USA	1970	United States Congress (1993)
Surveillance case definition change	USA	1975	Armstrong and Miramontes (2014)
First national reported TB/HIV	Canada	1997	Public Health Agency of Canada (2000)
	USA	1993	Centers for Disease Control and Prevention (2017)
% foreign-born population	USA	2010 and 12.9%	Grieco et al. (2012)
	Canada	2011 and 20.6%	Statistics Canada (2011)
% Indigenous population	USA	2010 and 1.7%	Norris et al. (2012)
	Canada	2011 and 4.2%	Statistics Canada (2011)
% cases with HIV/TB coinfection	USA	2012 and 7.2%	Centers for Disease Control and Prevention (2017)
	Canada	2012 and 8.0%	Public Health Agency of Canada (2015)

INH isoniazid, TLBTI treatment of latent TB infection, RMP rifampin

Indigenous population were obtained as listed in Table 1. Foreign-born was defined by birth outside of Canada (Statistics Canada 2011) or the USA (United States Census Bureau 2010); Indigenous was defined by self-identification in Canada (Statistics Canada 2011) and the USA (United States Census Bureau 2010). Ethics approval was obtained from the University of Saskatchewan ethics review board (U of S BIO#16-329).

Data analysis

A time-trend analysis comparing TB incidence rates between Canada and the USA from 1953 to 2015 was performed using Microsoft Excel 2016. The US TB rate in 2010 was directly standardized to the 2011 Canadian

ethnic population distribution. Thus, the crude US rate was multiplied by the Canadian proportion of ethnic population. The TB rate share which is the proportion of the annual rate contributed by ethnic group was calculated by multiplying the ethnic crude TB rate by the percent total population. In addition, the joinpoint/segmented regression model was applied to identify points (years) with a statistically significant log linear trend in TB case rates from 1975 to 2015. Joinpoint regression based on inferential permutation tests identifies where distinct segments in trends change in direction or magnitude and are more robust than single summary trend statistics (Kim et al. 2000; Qiu et al. 2009). The method has been applied in several fields of research, including TB and cancers (Kim et al. 2000; Baker et al. 2016). The annual percent change

Fig. 1 Tuberculosis incidence rates/100,000 in Canada and the USA from 1953 to 2015. Canada, solid black line; USA, interrupted black line

Fig. 2 Tuberculosis incidence rates/100,000 in Canada and the USA from 1997 to 2015. The period of interest is 2004–2015. Canada, solid black line; USA, interrupted black line

(APC) with 95% confidence intervals (CIs) was estimated from the models, and p values <0.05 were considered a statistically significant joinpoint.

Results

Trend of tuberculosis incidence rates from 1953 to 2015

Figure 1 shows a comparison of TB incidence rates from 1953 to 2015. It shows that from 1953 to 1974, rates in Canada were higher compared to those in the USA. From 1975 to 1985, rates were similar for both countries. From 1974 to 1975, the US rate increased 12.8% (case definition change) equalling the Canadian rate. During 1986–2000, rates in Canada continued to decline while an increase was observed in the USA. Between 2001 and 2004, rates were again similar. From 2004 to 2015, rates in Canada appeared to plateau whereas in the USA they decreased. Important events which were expected to influence rates are highlighted in Fig. 1 and listed in Table 1. Figure 2, an expanded view of rates from 1997 to 2015, shows that the

Canadian rate declined throughout this period but at a significantly slower pace than that in the USA.

Comparing tuberculosis incidence rates, 2010 and 2011

Table 2 lists the population, percent total population and rate of TB by ethnicity for both countries. The total crude rate was 4.7 for Canada and 3.6 for the USA. The Canadian rate share shows the Indigenous crude TB rate, 21.6, contributed 0.9% to the total annual rate; in the USA, the crude rate was 2.9 and contributed 0.05% to the annual rate. Table 3 shows that the US rate adjusted to the Canadian ethnic composition was 4.8 compared to the Canadian rate of 4.7. It also shows that when the US rate was standardized by Canadian ethnic group individually, the rate was highest for foreign-born, lower for non-Indigenous, and lowest for Indigenous standardization. Table 4 shows similar results ten years earlier in 2000 and 2001. The foreign-born and Indigenous percent total populations were lower and rates were higher in both countries. The non-Indigenous percent total population was higher and rates were higher in both countries. The crude US rate/100,000, 5.8, was similar to that of Canada, 5.7. Table 5 shows that the US rate adjusted to the Canadian ethnic composition was 7.4.

Table 2 Population and TB rates by ethnicity, Canada and USA, 2010 and 2011

Ethnicity	Canada 2011				USA 2010			
	Population	Population % total	Rate	Rate share	Population	Population % total	Rate	Rate share
Foreign-born	6,775,800	20.2	16.3	3.3	39,900,000	12.9	17.1	2.2
Indigenous	1,400,685	4.2	21.6	0.9	5,200,000	1.7	2.9	0.05
Non-Indigenous	25,200,203	75.6	0.7	0.5	263,600,000	85.4	1.6	1.4
Total	33,476,688	100	4.7	4.7	308,700,000	100	3.6	3.6

Table 3 Adjusted US TB rate share using Canada % population and US crude rate by ethnicity. The last three columns show rate share and total rate when adjusting for foreign-born, Indigenous, and non-Indigenous separately

Ethnicity	Canada % population	Crude US rate	Adjusted US rate share	Adjusted US rate share		
				Foreign-born only	Indigenous only	Non-Indigenous only
Foreign-born	20.2	17.1	3.45	3.45	2.2	2.2
Indigenous	4.2	2.9	0.1	0.05	0.1	0.05
Non-Indigenous	75.6	1.6	1.2	1.4	1.4	1.2
Total	100	3.6	4.8	4.9	3.7	3.9

Joinpoint trend in tuberculosis incidence rate, 1975–2015

The models of TB incidence rates were broken into six segments in the USA (1975, 1985, 1992, 2000, 2007, 2011) and four segments in Canada (1987, 1993, 2003, 2015), corresponding to where changes in the trend line occurred (Table 6). A decrease in APC was identified in all four segments in Canada, whereas in the USA an increase of 1.9% was observed in 1985–1992. In Canada, the 1987–1992 segment decrease was not significant, whereas in the USA, for all six segments, the APC were significant. The average APC in rate from 1975 to 2015 for Canada was significantly lower, –2.9%, compared to that of the USA, –4.1% (Table 6).

Discussion

This is the first extended published comparison of TB incidence rate trends between two North American low-incidence countries with similar national TB surveillance programs, Canada and the USA. Similarity of surveillance programs was based on the difference of two of 33 points of comparison that Mor reviewed in low-incidence countries, process and penalty for not reporting (Mor et al. 2008). The expectation, possibly biased, was that rates and trends would be similar. The data showed that there were differences over six decades. The joinpoint intervals assigned by the regression model

presented unequal intervals. All but the 1985–1992 US breakpoints showed a significant decline. All but the 1987–1993 Canada breakpoints showed a significant decline. This interval quantified the line graph result. The US average annual percent decline was significantly greater than that of Canada over the 41-year interval, 4.1% compared to 2.9%. This compares to the US-designated 2015–2020 target of 53% (3 to 1.4/100,000) reduction over the 5 years or 10% per year and compares to the Canadian designated 1990–2015 target of 50% reduction (7.0 to 3.6/100,000) over 25 years or 2% per year (Public Health Agency of Canada 2014; Centers for Disease Control and Prevention 2015). The Canadian and US targets compare to the WHO designated 2015–2025 target of 50% reduction or 5% per year (World Health Organization 2014).

One of the advantages of using joinpoint was identifying intervals for which the difference was significant. It also quantified and compared the trend for more precise comparison. This was preferred to single summary trend statistics that provides trends without identifying differences (Qiu et al. 2009). Joinpoint assumptions allow for modelling homogeneous or heterogeneous rates as log function. The log transformation of rates ensured that normality assumptions were met.

The overall trend for the 63-year interval (1953–2015) showed that Canadian rates were higher between 1953 and 1974. Part of this difference, possibly 10–15%, was due to Canada including new and previously reported

Table 4 Population and TB rates by ethnicity, Canada and USA, 2000 and 2001

Ethnicity	Canada 2001				USA 2000			
	Population	Population % total	Rate	Rate share	Population	Population % total	Rate	Rate share
Foreign-born	5,448,500	18.1	20.6	3.73	31,100,000	11.1	24.5	2.72
Indigenous	976,305	3.3	31.2	1.03	4,100,000	1.46	5.5	0.08
Non-Indigenous	23,582,289	78.6	1.2	0.94	246,200,000	87.4	3.4	2.97
Total	30,007,094	100	5.7	5.7	281,400,000	100	5.8	5.8

Table 5 Adjusted US TB rate share using Canada % population and US crude rate by ethnicity, 2000 and 2001

Ethnicity	Canada % population	Crude US rate share	Adjusted US rate share
Foreign-born	18.2	24.5	4.5
Indigenous	3.3	5.5	0.2
Non-Indigenous	78.6	3.4	2.7
Total	100	5.8	7.4

cases compared to the USA reporting new cases only (Gallant et al. 2014; Armstrong and Miramontes 2014). This was based on the US percent increase in 1975 due to previously reported cases. Further explanation is speculative since age, ethnicity, origin of birth, and gender were not available before 1970 (personal communication, Adam Langer, CDC, Feb 13, 2017, with permission).

Rates were similar beginning in 1975 when the US case definition changed and was similar to the Canadian definition. US rates rose in the mid-1980s coincident with a sizable proportion of cases resulting from HIV+/TB coinfection. The effect of TB program funding cuts beginning in 1970 also contributed (United States Congress 1993: pages III, 12, 13). Designated federal TB grants were converted to block grants to be used by the states according to need. Effectively, TB grants disappeared from 1972 to 1980. By 1986, case rates began to rise unrelated to HIV infection (Reichman 1991). Canadian rates declined more slowly during this interval, probably related to HIV+/TB coinfection (Tables 4 and 5), but with a lower proportion compared to those of the USA and less impact.

TB rates declined more rapidly thereafter in the USA; by 2005 they were lower than those in Canada. This trend

continued to the end of the observation period. Much of the difference was related to the proportion of the foreign-born population: 20.6% in Canada (2011 census year) and 12.9% in the USA (2010 census year) (Statistics Canada 2011; Grieco et al. 2012). The majority of cases in both countries were foreign-born, with comparable rates (Public Health Agency of Canada 2015; Centers for Disease Control and Prevention 2017). The US rate when standardized to Canadian ethnic distribution was similar to that of Canada. A similar rate was the hypothesized outcome for two high-income low-incidence countries with similar surveillance programs.

The proportion of foreign-born population with the accompanying TB cases mostly explains the lower US rate in the last decade since the difference in HIV+ TB cases narrowed. The rate share confirmed that it was the major contributor to the total rate. Canada's Indigenous rate was 38 times the non-Indigenous Canadian-born rate in 2010 but contributed only 19% to the annual rate (Public Health Agency of Canada 2015). The non-Indigenous Canadian-born contribution was 11% (Public Health Agency of Canada 2015). When the US rates were standardized individually to Canadian ethnic distribution, the highest contribution was due to foreign-born and

Table 6 Annual percent change in TB case rates/100,000, Canada and USA, 1975–2015

USA						Canada					
Segment	Breakpoint		Incidence rate			Segment	Breakpoint		Incidence rate		
	Lower end point	Upper end point	APC	95% CI			Lower end point	Upper end point	APC	95% CI	
				Lower CI	Upper CI					Lower CI	Upper CI
1	1975	1985	−5.1^	−5.7	−4.6	1	1975	1987	−5.5^	−5.9	−5.0
2	1985	1992	1.9^	0.7	3.3	2	1987	1993	−0.4	−2.1	1.3
3	1992	2000	−7.1^	−8.1	−6.2	3	1993	2003	−3.4^	−4.1	−2.7
4	2000	2007	−3.7^	−5.0	−2.5	4	2003	2015	−1.0^	−1.5	−0.6
5	2007	2011	−6.9^	−10.3	−3.3						
6	2011	2015	−3.5^	−5.8	−1.2						
Full range	1975	2015	AAPC	95% CI		Full range	1975	2015	AAPC	95% CI	
			−4.1	−4.7	−3.6				−2.9	−3.2	−2.5

APC annual percent change, AAPC average annual percent change, CI confidence interval

[^]Significantly different from zero alpha = 0.05

the lowest was due to Indigenous. The 2000 and 2001 data for both countries showed similar results. When the US rate was standardized to the Canadian ethnic composition, the rate was 7.4, higher than the Canadian rate of 5.7. The main contribution was also the foreign-born population.

A different TB risk for different population groups is another possible cause of divergent trends in TB case rates between Canada and the USA. This and age-specific rates require more detailed investigations to quantify the effects of all the factors. Country of origin is reported by the USA, while Canada reports origin by WHO Region. Neither country reports year of arrival. This is another area that requires more study.

Strengths and limitations

The strength of the data was based on a six-decade interval of annual reports by Canada and the USA. From 1975 onward, the case definition for both countries was the same. In a national context, Canada and the USA are comparable countries for high income and low TB incidence with similar epidemiological influences.

There were weaknesses. Non-Indigenous Canadian- and US-born populations are not homogeneous. Canadian cases were not stratified beyond non-Indigenous Canadian-born as they were in the USA, as Canada does not break down non-Indigenous ethnicity in Canadian-born cases. In the USA, the 2010 TB cases and incidence rates for Asian-American, African-American, and Hispanic-American were significant in proportion to total US cases and rates.

Divergent rates resulting from program performance could not be excluded. The comparison between programs in this study was WHO surveillance reports by country. Comparison of program outcomes was beyond the scope of this study. Such a comparison would include percent of TB treatment completion, extent of drug resistance including multidrug-resistant (MDR) TB, relapse, screening, and uptake of treatment of LTBI. MDR was unlikely to have influenced the rate difference since the rate of MDR in Canada in 2011 was 1.25% (Public Health Agency of Canada 2012) and that of the USA in 2010 was 1.3% (Centers for Disease Control and Prevention 2011).

For comparative purposes, the US cases were standardized to Canadian ethnic categories in 2011. Since the proportions of ethnic categories change over time, the results of standardizing TB incidence rates could vary over time.

Conclusion

Canadian and US TB incidence rates have been different for longer intervals over the last six decades than they have been the same. This was unexpected since both are low-incidence

and high-income countries, with similar TB surveillance programs. Surveillance case definition, TB program funding, HIV/TB coinfection, and TB in foreign-born persons were the main contributors to the differences. Higher TB rates in the Canadian Indigenous population were a smaller contribution to the annual rate since the Indigenous proportion of the total population was small. From 2004 to 2015, the lower US rates were mainly due to a larger proportion of foreign-born persons in Canada. Incidence rates decreased in both countries from 1997 but significantly more rapidly in the USA. Further exploration of contributing factors such as foreign-born country of origin and date of arrival, adjusting for age-specific rates and age composition in both populations, is needed.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

- Armstrong, L. R., & Miramontes, R. (2014). Public health surveillance for tuberculosis. In N. M. M'ikanatha & J. K. Iskander (Eds.), *Concepts and methods in infectious disease surveillance* (pp. 147–159). Chichester: John Wiley & Sons Ltd..
- Baker, B. J., Winston, C. A., Liu, Y., France, A. M., & Cain, K. P. (2016). Abrupt decline in tuberculosis among foreign-born persons in the United States. *PLoS One*, 11(2), e0147353.
- Birnbaum, D., Ely, J. W., Dawson, J. D., Lemke, J. H., & Rosenberg, J. (1997). An introduction to time-trend analysis. *Infect Control Hosp Epidemiol*, 18(4), 267–274.
- Centers for Disease Control and Prevention. (2015). *TB program objectives & performance targets for 2020*. <https://www.cdc.gov/tb/programs/evaluation/indicators/default.htm>. Accessed 5 May 2018.
- Centers for Disease Control and Prevention. (2011). *MMWR*, 61(11), 181–185. <https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6111a2.htm>. Accessed 17 May 2019.
- Centers for Disease Control and Prevention (CDC). (2017). *Reported tuberculosis in the United States* (p. 2016). Atlanta: US Department of Health and Human Services.
- Chiang, C. Y., Van Weezenbeek, C., Mori, T., & Enarson, D. A. (2013). Challenges to the global control of tuberculosis. *Respirology*, 18(4), 596–604.
- Gallant, V., Ogunnaike-Cooke, S., & McGuire, M. (2014). Tuberculosis in Canada: 1924–2012. *Can Commun Dis Rep*, 40(6), 99–108.
- Gallant, V., Duvvuri, V., & McGuire, M. (2017). Tuberculosis in Canada—summary 2015. *Can Commun Dis Rep*, 43(3–4), 77–82.
- Grieco, E. M., Acosta, Y. D., De la Cruz, G. P., Gambino, C., Gryn, T., Larsen, L. J., et al. (2012). *The foreign-born population in the United States: 2010*. <https://www.census.gov/prod/2012pubs/acs-19.pdf>. Accessed 13 May 2018.
- Grigg, E. R. (1958). The arcana of tuberculosis; with a brief epidemiologic history of the disease in the USA III. *American Review of Tuberculosis*, 78(3), 426.
- Grzybowski, S., & Allen, E. A. (1999). Tuberculosis: 2. History of the disease in Canada. *Can Med Assoc J*, 160(7), 1025–1028.
- Index Mundi (2018) *Net migration rate top 100 countries*. <https://www.indexmundi.com/map/?t=0&v=27&r=xx&l=en>. Accessed 12 June 2018.

- Kim, H. J., Fay, M. P., Feuer, E. J., & Midthune, D. N. (2000). Permutation tests for joinpoint regression with applications to cancer rates. *Statistics Medicine*, 19(3), 335–351.
- Lönnroth, K., Migliori, G. B., Abubakar, I., D'Ambrosio, L., De Vries, G., Diel, R., et al. (2015). Towards tuberculosis elimination: an action framework for low-incidence countries. *European Respiratory Journal*, 45(4), 928–952.
- Menzies, D., & Elwood, K. (2014). Treatment of tuberculosis disease. In D. Menzies (Ed.), *Canadian tuberculosis standards* (7th ed., pp. 97–123). Ottawa: Public Health Agency of Canada.
- Mor, Z., Migliori, G. B., Althomsons, S. P., Loddenkemper, R., Trnka, L., & Iademarco, M. F. (2008). Comparison of tuberculosis surveillance systems in low-incidence industrialised countries. *European Respiratory Journal*, 32(16), 16–24.
- Mount, F. W., & Ferebee, S. H. (1961). Preventive effects of isoniazid in the treatment of primary tuberculosis in children. *New England Journal of Medicine*, 265(15), 713–721.
- Norris, T., Vines, P. L., Hoeftel, E. M. (2012). *The American Indian and Alaska Native population: 2010 census briefs*. <https://www.census.gov/prod/cen2010/briefs/c2010br-10.pdf>. Accessed 25 March 2018.
- Organisation for Economic Co-operation and Development (OECD). (2018). *Foreign-born population (indicator)*. <https://data.oecd.org/migration/foreign-born-population.htm#indicator-chart>. Accessed 23 Jan 2018.
- Public Health Agency of Canada. (2000). *Tuberculosis in Canada 1997*. Centre for <http://publications.gc.ca/collections/Collection/H49-108-1997E.pdf>. Accessed 11 July 2018.
- Public Health Agency of Canada. (2012). *Tuberculosis in Canada 2011*. <http://www.phac-aspc.gc.ca/tbpc-latb/pubs/tbcan12/assets/pdf/tbcan12-eng.pdf>. Accessed 17 May 2019.
- Public Health Agency of Canada. (2014). *Tuberculosis prevention and control in Canada: a federal framework for action*. Ottawa:Canada. <http://www.phac-aspc.gc.ca/tbpc-latb/pubs/tpc-pct/assets/pdf/tpc-pcta-eng.pdf>. Accessed 10 May 2018.
- Public Health Agency of Canada. (2015). *Tuberculosis in Canada 2012*. Ottawa (Canada): Minister of Public Works and Government Services Canada <https://www.canada.ca/content/dam/phac-aspc/migration/phac-aspc/tbpc-latb/pubs/tbcan12/assets/pdf/tbcan12-eng.pdf>. Accessed 31 July 2018.
- Qiu, D., Katanoda, K., Marugame, T., & Sobue, T. (2009). A joinpoint regression analysis of long-term trends in cancer mortality in Japan (1958–2004). *International Journal of Cancer*, 124(2), 443–448.
- Reichman, L. B. (1991). The U-shaped curve of concern. *American Review Respiratory Disease*, 144, 741–742.
- Statistics Canada. (2011). *2011 national household survey*. <http://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/dt-td/Rp-eng.cfm?LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GID=0&GK=0&GRP=0&PID=105470&PRID=0&PTYPE=105277&S=0&SHOWALL=Yes&SUB=0&Temporal=2013&THEME=95&VID=0&VNAMEE=&VNAMEF=>. Accessed 30 March 2018.
- United States Census Bureau 2010. <https://www.census.gov/topics/population/foreign-born.html>. Accessed 15 May 2019.
- United States Congress. Office of Technology Assessment. (1993). *The continuing challenge of tuberculosis*. Washington, DC: United States Government Printing Office OTA-H-574. <http://ota.fas.org/reports/9347.pdf>. Accessed 10 May 2018.
- Woodruff, R. S. Y., Pratt, R. H., & Armstrong, L. R. (2015). The US national tuberculosis surveillance system: a descriptive assessment of the completeness and consistency of data reported from 2008 to 2012. *JMIR Public Health Surveillance*, 1(2), 1.
- World Bank. (2016). *New country classifications by income level: 2016–2017*. <https://blogs.worldbank.org/opendata/new-country-classifications-2016>. Accessed 2 July 2018.
- World Health Organization. (2014). *The end TB strategy 2015*. http://www.who.int/tb/strategy/End_TB_Strategy.pdf. Accessed 6 April 2018.
- World Health Organization. (2018). *Tuberculosis*. <http://www.who.int/news-room/fact-sheets/detail/tuberculosis>. Accessed 5 May 2018.

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