The Brazilian Journal of
INFECTIOUS DISEASES

www.elsevier.com/locate/bjid

Original article

Relationship between climatic factors and air quality with tuberculosis in the Federal District, Brazil, 2003–2012

Fernanda Monteiro de Castro Fernandes[a,*], *Eder de Souza Martins*[b], *Daniella Melo Arnaud Sampaio Pedrosa*[a], *Maria do Socorro Nantua Evangelista*[a]

[a] *Universidade de Brasília (UNB), Programa de Pós-graduação em Enfermagem, Brasília, DF, Brazil*
[b] *Universidade de Brasília (UNB), Programa de Pós-graduação em Geografia, Brasília, DF, Brazil*

ARTICLE INFO

Article history:
Received 3 July 2016
Accepted 27 March 2017
Available online 23 May 2017

Keywords:
Tuberculosis
Seasonality
Air pollution

ABSTRACT

Introduction: Despite the high rate of tuberculosis indicators in Brazil, the Federal District shows a low prevalence of the disease.
Objective: To analyze the relationship between climatic factors and air quality with tuberculosis in the Brazilian Federal District.
Methodology: This was an ecological and descriptive study comparing 3927 new cases of Tuberculosis registered at the Federal District Tuberculosis Control Program with data from the National Institute of Meteorology, Brazilian Institute of Geography and Statistics, Brazilian Agricultural Research Institute, Brasilia Environmental Institute, and the Federal District Planning Company.
Results: From 2003 to 2012, there has been a higher incidence of Tuberculosis (27.0%) in male patients in the winter (27.2%). Patients under 15 years of age (28.6%) and older than 64 years (27.1%) were more affected in the fall. For youth and adults (15–64 years), the highest number of cases was reported during winter (44.3%). The disease was prevalent with ultraviolet radiation over 17 MJ/m^2 (67.8%; p = <0.001); relative humidity between 31.0% and 69.0% (95.8% of cases; p = <0.00); 12 h of daily sunlight or more (40.6%; p = 0.001); and temperatures between 20 °C and 23 °C (72.4%; p = <0.001). In the city of Taguatinga and surrounding area, pollution levels dropped to 15.2% between 2003 and 2012. Smoke levels decreased to 31.9%. In the Sobradinho region, particulate matter dropped to 13.1% and smoke to 19.3%, coinciding with the reduction of Tuberculosis incidence rates during the same period.
Conclusion: The results should guide surveillance actions for Tuberculosis control and elimination and indicate the need to expand observation time to new climate indicators and air quality.

* *Corresponding author.*
E-mail address: fcastrojuju@gmail.com (F.M. Fernandes).
http://dx.doi.org/10.1016/j.bjid.2017.03.017

Introduction

Although Brazil is among the 22 countries with the highest TB burden (35.4/100,000 inhabitants), the Brazilian Midwest Region (MW) presents a low-tuberculosis burden scenario (24.1/100,000 inhabitants). The Federal District (FD) features 13 cases per 100,000 inhabitants and an annual decrease of 2.2%, indicating a trend toward pre-elimination of the disease.[1]

Social limitations,[2] vitamin D deficiency,[3–6] comorbidities,[7] and limited access to health services[8] are risk factors for developing TB. In addition, ecological studies conducted in countries where the incidence of TB was high relate the magnitude of TB to climatic summer factors – Spain[9,10]; Peru[3]; India[10,11]; Cape Town, South Africa[12]; United Kingdom, Wales and Scotland[4,10,13]; and South Africa, Kuwait, Ireland and Mongolia.[10] In Hong Kong, TB reports were high in sputum-smear or culture positive patients in the summer.[10,14] TB cases increased in spring in New York[15] and in the rainy season in Cameroon.[16] In Japan, the seasonality of TB varied according to clinical form and age, being higher in the spring among AFB+ ganglionar TB young patients (late spring to summer) and in AFB+ elderly in summer.[17] In Cape Town, South Africa, TB affected more children in the spring,[12] whereas in Spain was in the winter.[18] In addition, studies revealed that the less ultraviolet light exposure, the more frequent is TB, as verified in Australia[5,19] because of vitamin D deficiency.[20] In contrast, in Peru the development of TB was higher in the summer due to the rainy period with low sunlight incidence.[3]

Other climatic factors such as temperature,[21] precipitation, and humidity can influence the development of *Mycobacterium tuberculosis*.[22] Air quality is affected by atmospheric pollution, where carbon monoxide induces bacillary reactivation[23] and increases the incidence of tuberculosis.[24] In addition, large seasonal amplitudes of TB often occur in upland regions with temperate mountain climate and low annual average temperature.[21] Therefore, findings described in the literature confirm the relevance of conducting a study to better understand how climate and air quality can influence TB development in the Federal District. The objective of this study was to analyze the relationship between climatic factors and air quality with tuberculosis in the Federal District of Brazil (2003–2012). Through this analysis, we suggest improvements in the accuracy of the monitoring system and in the planning and allocation of resources to activities of the TB control program, taking into consideration the global climate change context.

Methodology

The study was conducted in the Federal District (FD), the capital city of Brazil, located in the Midwest region. The FD has an area of 5,778,999 km^2 and is divided into 31 administrative regions[25] (AR), with the health sector distributed into 15 Health Districts. The public service is responsible for 79.9% of all health actions[26] and is the only entity to provide TB treatment.

The FD has a population of 2,957,954 inhabitants,[25] 96.6% of whom are living in urban areas.[26] High-altitude tropical climate prevails in the region, with wet and rainy summers, dry and cold winters, and relative humidity of ≤20.0%. The average annual temperature is 21 °C, with an average high of 35.8 °C and an average low of 16 °C. From 2003 to 2012, solar ultraviolet radiation in the FD showed a variation of 17–20 MJ/m^2.[27] The region has little cloudiness and an average 75.0% days of sunshine during the year. During the period analyzed in our study, in general air quality in the FD was considered good.[28]

We analyzed 3927 TB cases (pulmonary, extrapulmonary, and pulmonary + extrapulmonary) of patients in the FD registered under the information system of health events (SINAN/TB), part of the Federal District Health Department (DF). We excluded non-residents and cases without address identification (0.4% excluded). Health Centers in the FD are 70.0% public and free-of-charge,[1] and 67.3% of the Centers manage tuberculosis cases.[1]

We analyzed climate variables, air quality indicators, and demographic data from 2003 to 2012. Secondary data was obtained from the National Institute of Meteorology – INMET,[29] Brazilian Agricultural Research Corporation – EMBRAPA,[27] Brasilia Environmental Institute – IBRAN,[28] Brazilian Institute of Geography and Statistics – IBGE,[25] and the Federal District Planning Company – CODEPLAN.[30]

The variables included demographic data (gender, age, educational level, and race/skin color), climate (temperature), solar radiation levels, relative humidity, and TB incidence. Regarding air quality and pollution, four regions in the FD were analyzed: Taguatinga, Sobradinho, the North Wing, and the South Wing. Pollution monitoring sampling points were defined by IBRAN in order to prioritize areas with high traffic and population density.

A case was defined as direct smear and/or culture proven TB medium with histopathology confirmation or clinical and epidemiological findings suggestive of TB.[1] We used the Köppen classification model[31] for climate analysis and the national standards established by the CONAMA Resolution for air quality assessment (No. 3 of 28, 1990).[28]

Statistical analyses were performed using Pearson's chi-square test to check the dependence or independence of the variables[32] with a 5% significance level. The study was approved by the Ethics Committee of the University of Brasilia, Opinion No. 1,098,421.

Results

The Federal District Health Department reported 4017 new cases of TB to SINAN-TB between 2003 and 2012. Out of the 4017 cases a total of 3927 were selected; 0.4% excluded: 52 had no address information and 38 for being residents of other states.

Among the demographic variables, there was a predominance of males (63.6% of cases). The most frequent age group was 15–64 years (53.7%), the most common level of education was primary school (40.2%), and the predominant race was mulatto (44.0%) (Table 1).

In the 10 years examined, the highest incidence of tuberculosis was in the winter (27.0%), followed by fall (25.0%), spring (24.7%), and summer (23.3%). Male patients showed higher

Table 1 – Demographic characteristics of new cases of tuberculosis per season from 2003 to 2012. Federal District, Brazil.

Variables	Seasons								Total	
	Spring		Summer		Fall		Winter			
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Sex										
Male	643	25.8	572	22.9	602	24.1	680	27.2	2497	63.6
Female	337	23.6	343	24.0	382	26.7	368	25.7	1430	36.4
Age group										
<15 years	42	26.1	33	20.5	46	28.6	40	24.8	161	4.1
15–34 years	368	26.2	320	22.8	337	24.0	378	26.9	1403	35.7
35–64 years	476	24.6	456	23.5	486	25.1	520	26.8	1938	49.4
65 or older	94	22.1	106	24.9	115	27.1	110	25.9	425	10.8
Race/skin color										
White	354	26.2	261	19.3	345	25.5	390	28.8	1350	34.3
Black	92	20.7	90	20.3	104	23.4	157	35.4	443	11.2
Yellow	13	20.6	9	14.2	24	38.0	17	26.9	63	1.6
Mulatto	398	23.0	362	20.9	470	27.1	499	28.8	1729	44.0
Indigenous	3	17.6	3	17.6	5	29.4	6	35.2	17	0.4
Unknown	–	–	–	–	–	–	–	–	325	8.2
Education										
Illiterate	54	29.0	41	22.0	48	25.8	43	23.1	186	4.7
Elementary	383	24.3	368	23.3	398	25.2	428	27.1	1577	40.2
High School	193	26.3	159	21.7	193	26.3	188	25.6	733	18.7
University	95	27.2	74	21.2	79	22.6	101	28.9	349	8.9
Unknown	–	–	–	–	–	–	–	–	1082	27.6

Table 2 – Climatic conditions per season during the study period of 2003–2012. Federal District, Brazil.

Variables	Seasons								Total		*p*-Value[a]
	Spring		Summer		Fall		Winter				
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Temperature											
<20 °C	66	10.5	58	9.2	177	28.3	324	51.8	625	15.9	
20–23 °C	661	23.3	780	27.5	792	27.9	600	21.1	2833	72.1	<0.001
24 °C or more	253	53.9	77	16.4	15	3.1	124	26.4	469	11.9	
Radiation											
<11 MJ/m^2	102	44.3	66	28.6	49	21.3	13	5.6	230	5.8	
11–16 MJ/m^2	265	26.4	254	25.3	302	30.1	182	18.1	1003	25.5	<0.001
≥17 MJ/m^2	613	22.7	595	22.0	633	23.4	853	31.6	2694	68.6	
Humidity											
≤30%	26	55.3	0	0.0	1	2.1	20	42.5	47	1.1	
31–69%	377	20.2	122	6.5	408	21.8	958	51.3	1865	47.4	<0.001
≥70%	577	28.6	793	39.3	575	28.5	70	3.4	2015	51.3	
Pollutants											
Smoke mg/m^3											
North Wing	132.2	20.7	175	27.5	184.4	28.9	144.6	22.7	636.2	25.6	
South Wing	15.4	24.1	15.3	24.1	7.5	12.0	23.8	38.7	62	2.4	<0.001
Taguatinga	188.3	19.2	328.6	33.6	214.3	21.9	244	25.0	975.2	39.2	
Sobradinho	92.6	11.4	75.6	9.3	109	13.4	531.3	65.7	808.5	32.5	
TSP mg/m^3											
North Wing	152.7	21.9	119	17.2	182.1	26.3	237.2	34.2	691	19.2	
South Wing	68.8	23.8	93.9	32.5	53.2	18.3	73.2	25.2	289.1	8	<0.001
Taguatinga	282.1	29.0	256	26.3	175.5	18	257.2	26.4	971	27	
Sobradinho	266.2	16.1	278.5	16.8	555.7	33.7	545.5	33.1	1646	45.7	

TSP, total supended particulate matter.

[a] *p*-Value = Pearson's chi-square test with a 5% significance.

Table 3 – Characteristics of air quality per season during the study period of 2003–2012. Federal District, Brazil.

Variables	Seasons								Total		*p*-Value[a]
	Spring		Summer		Fall		Winter				
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	
Pollutants											
Smoke mg/m³											
North Wing	132.2	20.7	175	27.5	184.4	28.9	144.6	22.7	636.2	25.6	
South Wing	15.4	24.1	15.3	24.1	7.5	12.0	23.8	38.7	62	2.4	<0.001
Taguatinga	188.3	19.2	328.6	33.6	214.3	21.9	244	25.0	975.2	39.2	
Sobradinho	92.6	11.4	75.6	9.3	109	13.4	531.3	65.7	808.5	32.5	
TSP mg/m³											
North Wing	152.7	21.9	119	17.2	182.1	26.3	237.2	34.2	691	19.2	
South Wing	68.8	23.8	93.9	32.5	53.2	18.3	73.2	25.2	289.1	8	<0.001
Taguatinga	282.1	29.0	256	26.3	175.5	18	257.2	26.4	971	27	
Sobradinho	266.2	16.1	278.5	16.8	555.7	33.7	545.5	33.1	1646	45.7	

TSP, total supended particulate matter.

[a] *p*-Value = Pearson's chi-square test with a 5% significance.

incidence in winter (27.2%) and females in the fall (26.7%). There was a higher incidence in infants and children under 15 years in the fall (28.6%). Youth and adults (15–64 years of age) became ill more often in the winter (44.3%) while patients over 64 years in the fall (27.1%) (Table 1).

Considering climate variables in the FD, tuberculosis was more prevalent with ultraviolet radiation conditions (UVR) above 17 MJ/m^2 (67.8%; $p = <0.001$); relative humidity between 31.0% and 69.0% (95.8%; $p = <0.001$); precipitation values less than 1 mm (71.7%; $p = <0.001$); daily sunlight exposure over 12 h (40.6%; $p = 0.001$); and temperature between 20 °C and 23 °C (72.4%; $p = <0.001$) (Table 2).

In relation to air quality, the two main pollutants were smoke (CO_2, CO, SO_2 and NO_2) and total suspended particulate matter (TSP). Among the regions covered by the study (Taguatinga, Sobradinho, North Wing, and South Wing), pollution levels were the highest in Taguatinga and Sobradinho regions, both with hazardous levels of health concern – TSP ≥ 375 mg/m^3 and smoke ≥ 250 mg/m^3. We identified a greater amount of pollutants in the spring in Taguatinga region (38.5%), and in the winter in Sobradinho (50.0%) (Table 3). During the study period a drop of TSP and smoke rates in Taguatinga (−15.2% and −31.9%, respectively) was observed. Similarly, TSP and smoke levels reduced in Sobradinho (−13.1% and −9.3%, respectively). These decreases in pollution and smoke levels were associated with lower incidence rates (IR) of TB in the same period, with a reduction of 46% in Taguatinga and of 66.5% in Sobradinho. These findings suggest that the decrease of pollutants was associated with the reduction of TB cases in the region.

Discussion

Regarding the demographic profile, the highest incidence of TB in the FD occurred in young adult male patients, with elementary education, and of mulatto race. Likewise, 67.0% of the Brazilian TB patients were young adult males.[1] In Cameroon, TB was significantly more prevalent in males (12.6%) compared to females (10.7%).[16] Peru,[3] China,[23] Spain,[18] and the United States[21] showed similar results.

In the present study, the highest incidence of cases in children under 15 years of age in the FD occurred in the fall, a season characterized by mild temperatures and long periods without rain. The result is similar to that reported in the United States, where there was a peak of childhood TB from spring to late fall.[21] The studies suggest a season interval for the transmission of TB from adults to children since, in general, childhood TB peaks in the next season following adult TB peak.[12] Youth and adults (15–64 years of age) develop more TB in the winter (53.7%) and patients over 64 in the fall (27.1%). This is somewhat similar to what happened in China, where the incidence was 15.7% in children under 15 years of age and 34.0% in the age range of 15–64 years, predominantly during the winter and fall.[33] In this study, children under 15 years of age developed less TB, despite their physiological disadvantages, such as decreased cardiac output, accelerated metabolism, developing immune system, and other forms of age-level developmental characteristics.[34] Out of TB patients in China 50.3% were older than 64, where life expectancy is 75.7 years.[33] Similar events were observed in Japan,[4] United Kingdom[14] and the United States,[21] where life expectancies were 83, 81, and 78 years, respectively.

Several authors underscore an association of low education level and TB.[2,35,36] One study in Spain indicated that 53.8% of the patients had not completed primary education.[37] In China,[38] patients with less than six years of schooling had a risk of relapse 3.4 times higher, and a risk of defaulting 4.3 times greater in newly treated TB cases. In the FD, TB was more prevalent in the least educated group (<8 years of education; 44.9%), reinforcing the association of lower level of education and the disease, highlighting that 27.6% of the responses were ignored. Considering race in Brazil,[25] mulatto was the most frequent race seen in TB patients of the FD.

Seasonality analysis revealed that TB was more prevalent in the winter in the FD, similarly that observed in other regions of the country.[39] In the United Kingdom,[4] reduced sun exposure in the winter could decrease the host's defense to the tubercle bacillus because of vitamin D deficiency. Temperatures in the winter in the Midwest region of Brazil vary from 12 °C to 27 °C. It is worth noting that in Brazil the four seasons are not markedly different as they are in other regions in the world. A seasonal pattern of TB with a predominant peak during the fall was observed in the FD. A similar pattern was verified in Peru,[3] where the diagnosis of tuberculosis increases in late summer and early fall because of the rainy characteristics of those seasons. High humidity and absence of direct sunlight due to cloudiness are similar characteristics of the Brazilian autumn.

A high level of UV radiation was observed in the FD, averaging 17 MJ/m^2 with 12 h/day of incident sunlight (40.6%; $p = 0.001$). This probably occurs due to geographical aspects of the FD – plateau relief with smooth topography – that facilitate the penetration of sunlight. This fact should justify the lower TB incidence rates in the region compared to other areas of the country.[1] TB incidence peaks in the winter in Peru coincide with the low sunlight periods due to vitamin D deficiency.[3,5,6,40,41] In England,[13] low levels of vitamin D in post-winter might result in an impairment of cellular immunity leading to reactivation of mycobacterial infection after a period of latency.

In the FD, 95.8% of TB cases occurred with relative humidity between 31.0% and 69.0% and precipitation values less than 1 mm (71.7%; $p = <0.001$). It is noteworthy that European humidity is high (70.0% average) due to high rainfall caused by winds that bring moisture from the ocean to the continent almost all year round.[4] In Cameroon, more TB cases were recorded in the rainy season, with a significant difference as compared to other seasons.[16] Similarly, a greater incidence of TB in Mongolia occurs in wet seasons.[22]

Possible explanations for seasonal variations in the incidence of TB include decreased vitamin D levels in winter,[6,40–42] which leads to depression of immune response and consequent reactivation of TB. Another risk factor for TB in winter is household crowding,[15] which may be found in the poorest areas in the FD. It is noteworthy that direct sunlight is present during 75.0% of the days in the FD.[29] High solar radiation may explain the lower incidence of tuberculosis in the region compared to other areas of the country.

More cases of TB were reported in the FD when the temperature was between 20 °C and 23 °C (72.4% of cases), in line with several studies carried out in different places, including: New York (20–25 °C)[15]; Spain (16–24 °C)[9]; Cape Town, South Africa (13–23 °C)[41]; UK (11.7° C and 21.1 °C)[4]; and Peru.[3] However, TB was also diagnosed at higher temperatures: 39 °C in Cameroon[16]; 21–39 °C in Northern India[11]; and 20–38 °C in Kuwait.[43] Lower temperatures have been identified in Japan (5 °C)[44] and Mongolia (−5° C to 9 °C).[22] In general, TB incidences were higher in milder temperatures, similar to conditions reported in the FD.

In relation to air quality, two main pollutants were identified in the FD: smoke (CO_2, CO, SO_2, and NO_2) and total suspended particulate matter (TSP), especially in Taguatinga and Sobradinho. In Sobradinho TB notifications were higher in winter; in Taguatinga in spring. Although the FD has 15 health districts, only four points could be sampled for air quality analysis: the South Wing, the North Wing, Taguatinga, and Sobradinho. It is important to mention that air quality improved in the FD as a result of a Resolution (CONAMA No. 242/1998) that regulates modes of transportation and actions issued by the National Council for the Environment to control air quality (provided in CONAMA Resolution No. 436/2011 prohibiting the emission of pollutants in the federal capital by industries). Despite the limitation of air quality monitoring equipment in the FD (only four), the data seem to indicate that air pollution is directly related to TB incidence. Studies in the US and Russia also suggest a link between concentrations of smoke and total suspended particulate matter and tuberculosis, especially considering the amounts of NO_2 and CO_2.[24,45] Air pollution generated by traffic in Taiwan – caused by sulfur dioxide, ozone, and carbon monoxide – was associated with culture-confirmed TB.[46] Likewise, a study in South Korea revealed that long-term exposure to ambient SO_2 increased the risk of TB by 7.0% in males.[47]

In this study, Taguatinga and Sobradinho showed levels of great health concern; i.e., TSP pollution $\geq$375 mg/m^3 and smoke $\geq$250 mg/m^3. A higher amount of pollutants was reported in Taguatinga (38.5%) in spring and in Sobradinho in winter (50.0%). In South Korea, the exposure to high concentrations of suspended particles in the atmosphere increased at 1.27 times the incidence of TB[48] and the exposure to fine particulate matter (PM 2.5) was associated with increased risk of the disease.[49] In Taiwan, exposure suspended particles increased the rate of TB by 4.0% and interfered with smear results. The chronic exposure to $\geq$50 μg/m^3 PM 10 may prolong the sputum culture conversion of TB patients with sputum-positive culture.[38]

Among the limitations of the study is the use of secondary bases of SINAN-TB since the information can be inconsistent due to incomplete records and/or missing data leading to methodological bias. Other limitations were the lack of more effective air pollution assessments in different regions of the FD and the analysis of air quality restricted to smoke and to certain particulate matter.

In summary, the results suggest that the incidence of TB appears to have been affected not only by climatic factors – seasons and climatic variables, solar radiation, temperature, humidity, and air quality – but also by social and demographic factors – age, gender, race, and education. However, we underscore the need for further studies so that the role of other environmental variables can be clarified. Air-quality observation time should also be increased so that we can better understand the relationship of TB with the weather.

Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

1. Ministério da Saúde (BR). Secretaria de Vigilância em saúde. Bol Epidemiol. 2016;47:13.
2. Viana PVS, Gonçalves MJF, Basta PC. Ethnic and racial inequalities in notified cases of tuberculosis in Brazil. PLOS ONE. 2016;11.

3. Wingfield T, Schumacher SG, Sandhu G, et al. The seasonality of tuberculosis, sunlight, vitamin D, and household crowding. J Infect Dis. 2014;210:774–83.
4. Koh GCKW, Hawthorne G, Turner AM, Kunst H, Dedicoat M. Tuberculosis incidence correlates with sunshine: an ecological 28-year time series study. PLOS ONE. 2013;8.
5. Maclachlan JH, Lavender CJ, Cowie BC. Effect of latitude on seasonality of tuberculosis, Australia, 2002–2011. Emerg Infect Dis. 2012;18:1879–81. PMID: 23092594.
6. Visser DH, Schoeman JF, VAN Furth AM. Seasonal variation in the incidence rate of tuberculous meningitis is associated with sunshine hours. Epidemiol Infect. 2013;141:459–62. PMID: 22647556.
7. Fox GJ, Barry SE, Britton WJ, Marks GB. Contact investigation for tuberculosis: a systematic review and meta-analysis. Eur Respir J. 2012;41:140–56.
8. Souza MSPL, Aquino R, Pereira SM, et al. Fatores associados ao acesso geográfico ao serviço de saúde por pessoas com tuberculose em três capitais do Nordeste brasileiro. Cad Saude Publica. 2015;31:111–20.
9. Luquero F, Sanchez-Padilla E, Simon-Soria F, Eiros JM, Golub JE. Trend and seasonality of tuberculosis in Spain, 1996–2004. Int J Tuberc Lung Dis. 2008;12:221–4. PMID: 18230258.
10. Fares A. Seasonality of tuberculosis. J Glob Infect Dis. 2011;3:46–55.
11. Thorpe LE, Frieden TR, Laserson KF, et al. Seasonality of tuberculosis in India: is it real and what does it tell us? Lancet. 2004;364:1613–4.
12. Schaaf HS, Nel ED, Beyers N, et al. A decade of experience with *Mycobacterium tuberculosis* culture from children: a seasonal influence on incidence of childhood tuberculosis. Tuber Lung Dis. 1996;77:43–6.
13. Douglas AS, Ali S, Bakhshi SS. Does vitamin D deficiency account for ethnic differences in tuberculosis seasonality in the UK? Ethn Health. 1998;3:247–53.
14. Leung CC, Yew WW, Chan TY, et al. Seasonal pattern of tuberculosis in Hong Kong. Int J Epidemiol. 2005;34:924–30.
15. Parrinello CM, Cross A, Harris TG. Seasonality of tuberculosis in New York City, 1990–2007. Int J Tuberc Lung Dis. 2012;16:32–7.
16. Ane-Anyangwe IN, Akenji TN, Mbacham WF, Penlap VN, Titanji VP. Seasonal variation and prevalence of tuberculosis among health seekers in the South Western Cameroon. East Afr Med J. 2006;83:588–95.
17. Nagayama N, Ohmori M. Seasonality in various forms of tuberculosis. Int J Tuberc Lung Dis. 2006;10:1117–22.
18. Rios M, Garcia JM, Sanchez JA, Perez D. A statistical analysis of the seasonality in pulmonary tuberculosis. Eur J Epidemiol. 2000;16:483–8.
19. Ralph AP, Lucas RM, Norval M. Vitamin D and solar ultraviolet radiation in the risk and treatment of tuberculosis. Lancet Infect Dis. 2013;13:77–88.
20. Jeevan A, Sharma AK, McMurray DN. Ultraviolet radiation reduces resistance to *Mycobacterium tuberculosis* infection. Tuberculosis (Edinb). 2009;89:431–8.
21. Willis MD, Winston CA, Heilig CM, Cain KP, Walter ND, MacKenzie WR. Seasonality of tuberculosis in the United States, 1993–2008. Clin Infect Dis. 2012;54:1553–60.
22. Naranbat N, Nymadawa P, Schopfer K, Rieder HL. Seasonality of tuberculosis in an Eastern-Asian country with an extreme continental climate. Eur Respir J. 2009;34:921–5.
23. Trembla GA. Historical statistics support a hypothesis linking tuberculosis and air pollution caused by coal. Int J Tuberc Lung Dis. 2007;11:722–32.
24. Shilova MV, Glumnaia TV. Influence of seasonal and environmental factors on the incidence of tuberculosis. Probl Tuberk Bolezn Legk. 2004:17–22.
25. Instituto Brasileiro de Geografia e Estatística. Censo Demográfico 2010. Características da população e dos domicílios: resultados do universo. Rio de Janeiro: IBGE; 2016. Available from: http://www.ibge.gov.br/home/estatistica/populacao/censo2010/características_da_populacao/resultados_do_universo.pdf
26. Cohn A, organizador. Questionando conceitos: o público e o privado na saúde no século 21. In: Cohn S, Rodrigues N, Amarante P. Gestão pública e relação público privado na saúde. Rio de Janeiro: Cebes; 2010. p. 324.
27. Ministério da Agricultura, Pecuária e Abastecimento (BR). Estações climáticas. EMBRAPA; 2015.
28. Instituto Brasília Ambiental. Qualidade do ar, relatórios anuais de monitoramento. IBRAN; 2012.
29. Ministério da Agricultura, Pecuária e Abastecimento (BR). Instituto Nacional de Meteorologia. INMET; 2015.
30. Companhia de Planejamento do Distrito Federal – CODEPLAN, PDAD – Pesquisa Distrital por Amostra de Domicílios 2015.
31. Koeppen W. Climatologia: con um estudio de los climas de la tierra. Mexico: Fondo de cultura economica; 1948, 478 pp.
32. Bussab WO, Morettin PA. Estatistica Básica. 8th ed. São Paulo: Saraiva; 2013.
33. Li X-X, Wang L-X, Zhang H, et al. Seasonal variations in notification of active tuberculosis cases in China, 2005–2012. PLOS ONE. 2013;8:e68102.
34. Mori T. Recent trends in tuberculosis, Japan. Emerg Infect Dis. 2000;6:566–8.
35. Costa JSD, Gonçalves H, Menezes AMB, et al. Controle epidemiológico da tuberculose na cidade de Pelotas, Rio Grande do Sul, Brasil: adesão ao tratamento. Cad Saúde Pública. 1998;14:409–15.
36. Mascarenhas MDM, Araújo LM, Gomes KRO. Perfil epidemiológico da tuberculose entre casos notificados no município de Piripiri, Estado do Piauí, Brasil. Epidemiol Serv Saúde. 2005;14:7–14.
37. Martin Sacnhes V, Alvarez-Guisasola F, Cayla JA, Alvarez JL. Predictive factors of mycobacterium tuberculosis infection and pulmonary tuberculosis in prisoners. Int J Epidemiol. 1995;24:630–6.
38. Wang J, Shen H. Review of cigarette smoking and tuberculosis in China: intervention is needed for smoking cessation among tuberculosis patients. BMC Public Health. 2009;9:292.
39. Franco JF, Moraes JR, Santander LAM, et al. Relação entre a ocorrência de tuberculose e um conjunto de fatores sócioeconômicos, demográficos e de saúde da população brasileira usando a PNAD; 2003.
40. Sita-Lumsden A, Lapthorn G, Swaminathan R, Milburn HJ. Reactivation of tuberculosis and vitamin D deficiency: the contribution of diet and exposure to sunlight. Thorax. 2007;62:1003–7.
41. Martineau AR, Nhamoyebonde S, Oni T, et al. Reciprocal seasonal variation in vitamin D status and tuberculosis notifications in Cape Town, South Africa. Proc Natl Acad Sci U S A. 2011;108:19013–7.
42. Nnoaham KE, Clarke A. Low serum vitamin D levels and tuberculosis: a systematic review and meta-analysis. Int J Epidemiol. 2008;37:113–9.
43. Akhtar S, Mohammad HG. Seasonality in pulmonary tuberculosis among migrant workers entering Kuwait. BMC Infect Dis. 2008;8:3. PMID: 18179720.
44. Onozuka D, Hagihara A. The association of extreme temperatures and the incidence of tuberculosis in Japan. Int J Biometeorol. 2015;59:1107–14.
45. Smith GS, Schoenbach VJ, Richardson DB, Gammon MD. Particulate air pollution and susceptibility to the development of pulmonary tuberculosis disease in North Carolina: an ecological study. Int J Environ Health Res. 2014;24:103–12.

46. Lai TC, Chiang CY, Wu CF, et al. Ambient air pollution and risk of tuberculosis: a cohort study. Occup Environ Med. 2016;73:56–61.
47. Hwang SS, Kang S, Lee JY, et al. The impact of outdoor air pollution on the incidence of tuberculosis in Seoul metropolitan area, South Korea. Korean J Intern Med. 2014;29:183–90.
48. Kim J. Is ambient air pollution another risk factor of tuberculosis? Korean J Intern Med. 2014;29:170–2.
49. Lee SH, Hwang ED, Lim JE, et al. The risk factors and characteristics of COPD among nonsmokers in Korea: an analysis of KNHANES IV and V. Lung. 2016;194:353–61.