

Incidence and Case-Fatality Ratio of COVID-19 Infection in Relation to Tobacco Smoking, Population Density and Age Demographics in the USA: could Particulate Matter derived from Tobacco Smoking act as a Vector for COVID-19 Transmission?

Yves Muscat Baron

Department of Obstetrics and Gynaecology, Mater Dei Hospital, University of Malta Medical School, Malta

Correspondence should be addressed to Yves Muscat Baron, yambaron2018@gmail.com

Received: October 23, 2020; Accepted: November 10, 2020; Published: November 17, 2020

ABSTRACT

BACKGROUND

Tobacco smoking is known to increase the risk for bacterial and viral respiratory infections and this also applies to second-hand smoking. Smoking has been shown to increase the severity of COVID-19 infection and the consequent risk for intra-tracheal ventilation in smokers. Tobacco smoking exposes the user and nearby individuals to very high concentrations of particulate matter in a short period of time. Genes appertaining to COVID-19 have been found adherent to particulate matter which has been shown to travel beyond the social distance of 2 metres up to 10 metres. COVID-19 related mortality has been linked to elevated atmospheric levels of the particulate matter, PM2.5. The aim of the study was to observe the incidence of infection rate and case fatality ratios in the USA, comparing states with partial bans on tobacco smoking, to States with more restrictive smoking regulation, exploring a possible link between smoke-related particulate matter and COVID-19 transmission.

METHODOLOGY

Two groups of USA states, differentiated by the degree of smoking legislative restrictions, had a number of variables compared. The incidence of COVID-19 infection, case-fatality ratio and testing frequency were obtained from the John Hopkins Coronavirus Resource Centre. The degree of smoking bans in the USA states was obtained from the websites of the Nonsmokers Rights Foundation. The percentage of the state population which smokes was collected from the Centres of Disease Control database. Population density, Body mass index and population percentages of individuals 65+ years/75+ years were obtained from databases concerning USA demographics.

RESULTS

With the available data there was no significant difference in COVID-19 testing prevalence between the partial smoking ban group and the more restrictive regulated group. The incidence of COVID-19 infection in the states with limited bans on tobacco smoking

Citation: Yves Muscat Baron, Incidence and Case-Fatality Ratio of COVID-19 Infection in Relation to Tobacco Smoking, Population Density and Age Demographics in the USA: could Particulate Matter derived from Tobacco Smoking act as a Vector for COVID-19 Transmission?. J Clin Cases Rep 4(S6): 16-24.

2582-0435/© 2021 The Authors. Published by TRIDHA Scholars.

was 2046/100,000 (sd \pm 827) while the infection incidence in states with more restrictive rulings on tobacco smoking was 1660/100,000 (sd \pm 686) ($p < 0.038$). The population percentage of smokers in states with minor limitations to smoking was 18.3% (sd \pm 3.28), while states with greater smoking restrictions had a smoking population percentage of 15.2% (sd \pm 2.68) ($p < 0.0006$).

The two populations of both groups did not differ numerically ($p < 0.24$) and numbered 157,820,000 in the partial smoking ban group and 161,439,356 in the more restrictive group. Population density correlated significantly with the case-fatality ratio ($R = 0.66$ $p < 0.0001$), as did the 75+ years age group ($R = 0.29$ $p < 0.04$). Reflecting the possibility of trans-border transmission, the smoking status of adjacent partial smoking ban States may influence the COVID-19 incidence of bordering States (e.g. Utah) even if the smoking regulations of the latter were stricter than the former.

Other factors that could impact the COVID-19 pandemic in the USA such as the state case-fatality ratio, population density, population percentage with elevated body mass index and the percentage of the state population aged 65-years or above did not show any significant difference between both groups of states.

CONCLUSION

States in the USA with high levels of tobacco smoking and limited regulation had significantly higher rates of COVID-19 infection incidences than states with greater smoking restrictions. Population density and the age group of 75+ years, showed a positive significant correlation with the case-fatality ratio. Besides the adverse effects of tobacco smoking on pulmonary defences, it would be interesting to explore the possibility of infection transmission via coronavirus-laden particulate matter from exhaled fumes derived from tobacco smoking.

KEYWORDS

Tobacco smoking; Second-hand smoking; COVID-19; Incidence: Case-fatality ratio; Population density; 75+ age group

INTRODUCTION

Tobacco smoking is responsible for a significant proportion of global mortality. Of the global burden of 8 million deaths per year, more than 85% of these deaths occur in smokers themselves. Nonsmokers are also at risk, resulting in approximately one million deaths per annum due to second-hand smoking. Second hand smoking exposes bystanders to more than 7,000 chemicals, including about 70 known and probable carcinogens, including toxic and irritant agents. Second-hand smoking exposes these individuals to particulate matter and potentially to respiratory disease through smoke-induced infection transmission [1,2].

In an effort to curb smoking and reduce the deleterious effects of second-hand smoking, several countries have introduced restrictive measures. In the USA there appears to be a divide, with some States applying restrictive

smoking regulation while in others there exist partial smoking bans.

Smoking is associated with significantly elevated human exposure to particulate matter. Long-term exposure to particulate matter PM_{2.5} in the USA has been linked to COVID-19 related mortality [3]. Particulate matter has been noted to have genes appertaining COVID-17 adherent to it [4]. The possibility of a dual effect of reducing pulmonary defences and the carriage of COVID-19 by particulate matter has been explored by Comunian et al. 2020 [5].

This paper assesses whether smoking in USA varies across its member States some of which have less restrictive regulation on tobacco smoking than others. Concomitantly the incidence of COVID-19 across the USA was assessed in relation to the USA's States reviewed in an effort to find an incidence pattern and

case-fatality ratio coinciding with COVID-19 infection. As a corollary the population density body mass index and age demographics were also assessed between both groups of States.

METHODOLOGY

This study compared two groups of States in the USA, differentiated by the gradation of legislative restrictions on tobacco smoking. The variables assessed include COVID-19 incidence, case-fatality ratios, state population density and population percentages of individuals 65 years/75 years and older. The incidence of COVID-19 infection, prevalence of testing and case-fatality ratios were attained from the John Hopkins Resource Centre database [6]. The degree of smoking restrictions in the States assessed was obtained from the websites of the Nonsmokers’ Rights Foundation [7,8]. The legislative measures included in the study governed smoking related legal restrictions up to October 2018. The percentage of the state smoking was retrieved from the US Centres of Disease Control database [9]. Population density, body mass index and population percentages of individuals 65 years/75 years and older were obtained from websites concerning USA demographics in 2018 and 2019 [10].

STATISTICS

The data was analysed for normality by the Smirnov-Kolmogroff test. The percentage of smokers in the state population, incidences of COVID-19 infection, age demographics and body mass index all showed a normal distribution while all the other data assessed were nonparametric. The independent T-test was applied to the population percentage of smokers and incidences of COVID-19 infection. The Mann Whitney U-test was applied for comparing nonparametric variables of both groups of States. Pearson correlation was applied for parametric variables and Spearman rank was implemented for nonparametric findings [11].

RESULTS

COVID-19 infection incidences were significantly higher in the states with partial bans on tobacco smoking compared with highly regulated states ($p < 0.038$). The incidence of COVID-19 infection in the states with partial bans on tobacco smoking was 2046/100,000 (sd \pm 827), while the infection incidence in states with restrictive regulation on tobacco smoking was 1660/100,000 (sd \pm 686) (Table 1 and Table 2).

States	Percentage Population of Smokers	Incidence of COVID-19 Infection/100,000	Population Density Individuals per Km ²	COVID-19 Incidence /Population Density	Percentage Case-Fatality Ratio
Minnesota	15.1	1596	26	61.38	2.22
Wisconsin	16.4	1670	41	40.73	1.2
Michigan	18.9	1282	67	19.13	5.38
Nebraska	16	2124	9	236	1.09
Iowa	16.6	2544	21	121.14	1.58
Illinois	15.5	2181	89	24.51	3.12
Kansas	17.2	1808	14	129.14	1.12
Colorado	14.5	1125	20	56.25	3.09
Utah	9	1989	14	142.07	0.68
New York	12.8	2312	162	14.27	7.44
Maryland	12.5	1987	238	8.34	3.22
Vermont	13.7	274	26	10.53	3.37
Maine	17.8	377	16	6.61	2.72
Massachusetts	13.4	1850	336	5.505	7.38
Rhode Island	14.6	2229	394	5.657	4.57
New Jersey	13.1	2249	470	4.78	8.01
Delaware	16.5	2009	187	10.74	3.18
New Mexico	15.2	1315	6	219.166	3.07
Arizona	14	2925	23	127.17	2.56
California	11.2	1989	97	48.51	1.91
Oregon	15.6	719	16	44.937	1.71
Washington	12	1084	41	26.439	2.48
Montana	19.5	963	2	481.5	1.52
South Dakota	19	2113	4	528.25	1.05
North Dakota	19	2356	4	589	1.06
Alaska	19.1	933	1	933	0.65
Hawaii	13.4	805	86	9.36	1.05

Table 1: Variables assessed of States with strict smoking bans and lower smoking population rates.

The percentage of the smoking population in the states with minimum regulation in 2018 was significantly higher than that of States with more severe prohibitions on tobacco smoking ($p < 0.0006$). The percentage of smokers in states with minimal restrictions to smoking was 18.3% (sd \pm 3.28) while states with greater smoking restrictions had a smoking population percentage of 15.2% (sd \pm 2.68). Other factors that could affect the COVID-19 USA pandemic such as the state case-fatality ratio, population density, body mass index and the percentage of the state population aged 65-years or above did not show any significant difference between both groups of states (Table 1 and Table 2).

States	Percentage Population Age >65 Years	Percentage Population Age >75 Years Native Born	Percentage Population Age >75 Years Foreign Born	Total Percentage Population Age >75 Years	Percentage of Population Overweight or Obese
Minnesota	16.3	6.38	0.35	6.73	67.3
Wisconsin	17.5	6.82	0.32	7.14	68.4
Michigan	17.6	6.62	0.49	7.11	68.2
Nebraska	16.1	6.58	0.22	6.8	73.7
Iowa	17.5	7.4	0.16	7.56	72
Illinois	16.1	5.73	0.92	6.65	65.8
Kansas	16.3	6.58	0.23	6.81	70.5
Colorado	15.6	4.91	0.45	5.36	61.9
Utah	11	4.12	0.28	4.4	65.2
New York	16.9	5.25	1.92	7.17	57.2
Maryland	15.9	5.53	0.84	6.37	66.5
Vermont	20	7.12	0.56	7.68	66.9
Maine	21.2	8	0.38	8.38	66.4
Massachusetts	16.8	5.77	1.2	6.97	62.1
Rhode Island	17.7	6.56	0.94	7.5	64.4
New Jersey	16.6	5.48	1.55	7.03	65.9
Delaware	19.4	7.03	0.5	7.53	65.9
New Mexico	18	6.44	0.59	7.03	62.8
Arizona	18	6.54	0.86	7.4	66.3
California	14.8	3.93	2.1	6.03	58.5
Oregon	18	6.35	0.61	6.96	64.6
Washington	15.9	5.16	0.86	6.02	63.7
Montana	19.3	7.21	0.24	7.45	60.1
South Dakota	17.1	6.88	0.07	6.95	72.4
North Dakota	15.8	6.81	0.09	6.9	76.9
Alaska	12	3.38	0.47	3.85	72.9
Hawaii	18.9	5.98	1.91	7.89	72.9

Table 2: More variables assessed of States with strict smoking regulation and lower smoking population rates.

A number of significant correlations were obtained when comparing variables of all the USA states together and when the two groups of states were assessed separately. The states' population density correlated significantly ($R = 0.66$ $p < 0.0001$) with the case-fatality ratio. The correlation of the population density/case fatality ratio still applied when the two groups of states were assessed separately (partial ban $R = 0.58$ $p < 0.003$ and restrictive regulation $R = 0.74$ $p < 0.0001$) (Table 1 and Table 2).

The case fatality ratio correlated with increasing age in the 75-years and over age group ($R = 0.29$ $p < 0.04$). No significant correlation between the 65-years and over age group and the case fatality ratio. In the 75-years and over age group the proportion of foreign born population (0.7% $sd \pm 0.57$) was significantly higher in the states with restrictive smoking regulations compared to the population of states with limited smoking restrictions (0.45% $sd \pm 0.45$). There was no difference when comparing the proportion of native born to the foreign born cohorts when the both groups of states were combined in both the 75+ year age group. The correlation between the percentage smoking population and case-

fatality ratio just missed statistical significance ($R = 0.27$ $p < 0.056$). There was no significant correlation between the incidence of COVID-19 and case-fatality ratio (Table 3 and Table 4).

States	Percentage Population of Smokers	Incidence of COVID-19 Infection/100,000	Population Density Individuals per Km ²	COVID-19 Incidence /Population Density
Indiana	21.1	1656	71	23.32
Missouri	19.4	1860	34	54.7
Oklahoma	19.7	1941	22	88.22
Arkansas	22.7	2509	22	114.04
Tennessee	20.7	2687	61	44.04
Kentucky	23.4	1377	43	32.02
Ohio	20.5	1234	109	11.32
Pennsylvania	17	1210	110	11
New Hampshire	15.6	584	57	10.24
Connecticut	12.3	1557	286	5.44
Virginia	14.9	1644	81	20.29
North Carolina	17.4	1845	79	23.35
South Carolina	18	2687	62	43.338
Georgia	16.1	2883	68	42.397
Florida	14.5	3183	145	21.95
Alabama	19.2	2956	37	79.89
Mississippi	20.5	3137	24	130.708
Louisiana	20.5	3467	41	84.56
Texas	14.4	2458	40	61.45
Nevada	15.7	2461	10	246.1
Idaho	14.7	2097	7	299.57
Wyoming	18	841	2	420.5
West Virginia	25.2	785	29	481.5

Table 3: Variables assessed of States with partial smoking bans and higher smoking population rates.

States	Percentage Population Age >65 Years	Percentage Population Age >75 Years Native Born	Percentage Population Age >75 Years Foreign Born	Total Percentage Population Age >75 Years	Percentage of Population Overweight or Obese
Indiana	16.1	6.32	0.22	6.54	68.4
Missouri	17.3	6.97	0.19	7.16	68.5
Oklahoma	16.1	6.31	0.23	6.54	71.9
Arkansas	17.4	6.88	0.12	7	71.2
Tennessee	16.7	6.4	0.19	6.59	69.7
Kentucky	16.8	6.48	0.14	6.62	69.8
Ohio	17.5	6.85	0.37	7.22	69.2
Pennsylvania	18.7	7.5	0.48	7.98	67.7
New Hampshire	18.6	6.67	0.6	7.27	66.5
Connecticut	17.7	6.53	1.03	7.56	61.5
Virginia	20.5	5.7	0.62	6.32	66.2
North Carolina	16.7	6.2	0.3	6.5	68.2
South Carolina	18.2	6.5	0.32	6.82	66.7
Georgia	14.3	4.88	0.44	5.32	66.4
Florida	20.9	7.12	2.06	9.18	65.7
Alabama	17.3	6.7	0.18	6.88	68.6
Mississippi	16.4	6.25	0.12	6.37	65.8
Louisiana	15.9	5.93	0.21	6.14	69.3
Texas	12.9	4.19	0.77	4.96	67.2
Nevada	16.1	4.8	1.2	6	66.4
Idaho	16.2	6.05	0.28	6.33	67.8
Wyoming	17.1	6.3	0.12	6.42	61.5
West Virginia	19.7	7.95	0.135	8.085	70

Table 4: More variables assessed of states with partial smoking bans and higher smoking population rates.

The correlation of the integer dividing the incidence of COVID-19 by the state population density compared to

the case-fatality ratio was also carried out. The incidence of COVID-19 infection when factored with state population density as a denominator, significantly correlated ($R = 0.67$, $p < 0.0001$) with the case-fatality ratio. This latter correlation also applied for both the states with partial smoking bans ($R = 0.57$ $p < 0.003$) and more strict regulation ($R = 0.75$ $p < 0.0001$) of tobacco smoking (Table 3 and Table 4).

DISCUSSION

The incidence of respiratory infection increases with tobacco smoking. Moreover tobacco smoking exacerbates the severity of pulmonary infections. The risk for mortality from tuberculosis has been shown to increase nine-fold in tobacco smokers [12]. Legionella infection is known to increase up to 121% increased risk of legionella pneumonia with every packet of cigarettes smoked [13]. Similarly mycoplasma and viral infections such as the influenza are more common in tobacco smokers [14]. Smokers have also been noted to have had higher mortality in the 2012 MERS-CoV outbreak. In a similar fashion COVID-19 is a highly infectious viral disease that affects the respiratory system leading to a myriad of presentations and complications.

Smoking impairs pulmonary defences against lung infection [15], and may be implicated in the transmission of COVID-19. The immune system is adversely affected by the components of tobacco smoking including particulate matter element. Tobacco smokers through their smoking habits are exposed to very high concentrations of particulate matter [16]. The exposure to polluted air in London is equivalent to smoking 150 cigarettes per year.

The impact of particulate matter PM_{2.5} on the immune response influences macrophage function and the modulation of the cytokine response. PM_{2.5}-induced inflammation may result in an increase in the number of pulmonary neutrophils, eosinophils, T cells and

mastocytes [17,18]. This cellular reaction can result in inflammatory cytokine production and the resultant cytokine storm has been responsible for a significant number of COVID-19 related deaths [19].

Most of the early studies linking smoking to COVID-19 infection were carried out in mainland China. Zhou et al. [20] assessed 191 patients infected with COVID-19, 54 of whom succumbed to the infection, while the other 137 survived resulting in a case- fatality ratio of 28.3%. The high case-fatality ratio suggests that this cohort (191) were seriously ill with COVID-19. A nonsignificant proportion (9%) of those who succumbed to the infection were currently smoking as opposed to 4% smokers among those who survived. Similar nonsignificant results were obtained by Zhang et al 2020 [21]. Out of 140 patients with COVID-19, 58 had severe infection. Of the patients with severe infection 3.4% were current smokers and 6.9% were smokers in the past, while in the less severe group none were presently smoking and only 3.7% were previous smokers. The largest study performed in China recruited 1,099 patients with COVID-19 infection [22]. The proportion of patients with severe symptoms comprised 15.7%. Of the patients presenting with severe symptomatology, 16.9% were recent smokers and 5.2% were ex-smokers, while in the group with minimal COVID-19 symptoms 11.8% were currently smoking and 1.3% smoked in the past.

Meta-analysis of several studies from various centres were carried out in the months following the outbreak in China. One meta-analysis analysing 11,590 hospitalized patients, indicated that which 2,133 (18.4%) developed severe disease. Disease severity occurred in 29.8% of patients who smoked currently or in the past compared with 17.6% of non smokers (OR = 1.91; 95% CI: 1.42-2.59) [23]. Another meta-analysis by Simons et al., [24] assessed 102 studies investigating the connection between disease progression and smoking status. Patients who were currently smoking were more likely to

experience disease progression as opposed to non smokers (RR = 1.39; 95% CI: 1.09-1.77).

This study indicated that states in the USA with high levels of tobacco smoking and partial regulation had significantly higher rates of COVID-19 infection incidences than states with more severe smoking bans. As described earlier this could be attributed to the reduced respiratory immunity due to the toxicity of tobacco smoking including particulate matter. Alternatively besides impaired pulmonary defences, transmission of COVID-19 infection through viral carriage by surface particulate matter has been alluded to by Comunian et al., [5] Tobacco smoking has the attribute of exposing both smokers and bystanders to very high concentrations of particulate matter in a short period of time. This has been noted not only indoors with adequate ventilation, but also in the open air.

Studies have shown that average levels of PM_{2.5} in open-air smoking venues exceed the WHO recommendation of 25 µg/m³. These levels varied from 8.32 µg/m³ to 124 µg/m³ at open-air settings where tobacco smoke was present. Extremely elevated levels of 1,000µg/m³ have been noted in some smoking venues. These elevated levels of PM_{2.5} are more likely in densely packed areas with poor ventilation, in the presence of smokers. Confirming the risks of PM_{2.5} exposure due to passive smoking, even smoke-free venues close to open-air smoking settings also had potentially high PM_{2.5} concentrations, with levels ranging from 4 µg/m³ to 120.51 µg/m³ [25].

Setti et al. [26] have shown increased COVID-19 transmission has been noted was noted to coincide with elevated peaks of particulate matter. The same authors have suggested that the recommended social distance of 2 metres is only effective if masks are worn because particulate matter can travel up to distances of 10 metres and more [26]. The importance of face protection with

masks cannot be understated, as Zhang et al. [27] have shown that the use of masks was crucial in determining the disease spread in Wuhan, Italy and New York. Wearing of masks has been estimated to have reduced the number of COVID-19 infections by more than 78,000 in Italy and over 66,000 in New York City during the months of April and May 2020 (Zhang et al 2020) [27].

In a paper linking subway particulate matter and COVID-19, it was hypothesized that the haematite-rich particulate matter may be a superior vector to surface particulate matter as it creates a microenvironment suitable for COVID-19 persistence [28]. Whereas surface carbon-rich particulate matter has adsorbing properties on adherent substances, subway haematite-rich particulate matter may easily release any adherent COVID-19. Moreover, COVID-19 has been noted to have persisted on steel objects for up to 72 hours.

Ambient salinity and the sodium chloride component in PM_{2.5} have been touted as protective factor against COVID-19 [29,30]. The particulate matter sodium chloride component has the propensity to attract water which may deter the hydrophobic C-terminal protein in the COVID-19 spike protein [30]. This protective effect did not apply to the pandemic in the salinity-rich East Coast of USA. Although the states of New Jersey, Connecticut and Massachusetts have high levels of ambient salinity [31], the incidence and case-fatality ratio was still elevated. The role of subway commuter congestion, interconnectivity and elevated subway PM_{2.5} levels may have eclipsed any saline related protective factors, causing high death rate in New York State [32] and the adjacent states of Connecticut, New Jersey and Massachusetts. Similarly, the exhaled tobacco derived particulate matter is devoid of any exposure to ambient salinity. In a similar manner, the protective effect of sodium chloride may not be available to particulate matter originating from exhaled tobacco fumes.

This study also indicated that population density and age beyond 75-years and over was a significant factor in the case-fatality ratio. It has been shown that the case-fatality ratio varies according to the population demographics - the older the population the greater the case fatality ratio. The population in Northern Italy aged 65-years and over constituted 25% of the Lombardy population. Consequently the case-fatality ratio in Italy was 9.3%. Similarly the Netherlands had a case-fatality ratio of 7.4% with a background 65+ years population of 20% [33]. It is therefore biologically plausible that tobacco smoking in densely packed areas with elderly and vulnerable persons in the vicinity put these individuals at greater risk.

It is interesting to note that at the time of the study, Utah, the only state with a single digit percentage USA smoking population had a relatively elevated COVID-19 incidence. The percentage population who smoke in Utah is 9% and its incidence was 1989/100,000 which is high for a state with a restrictive smoking regulation. The presence of neighbouring partial ban States such as Nevada, Idaho and Wyoming may explain Utah's COVID-19 incidence. However Utah's case-fatality ratio was the lowest in the USA, possibly due to the combined factors of low smoking prevalence, low population density and low percentage cohorts in both the 65+ (11%) and 75+ (4.4%) age groups.

The author's home country Malta sustained two waves of the coronavirus infection. During the first wave the incidence was low (135/100,000) and so was the case-fatality ratio (0.29%). This cannot be said for the second wave whereby both the incidence (726/100,000) and case fatality ratios (1.2%) are significantly higher. It is interesting to note that during the first wave the ban on smoking was more severe whereby smoking in public places was only allowed 10 metres away from non-smoking patrons. This ban was not applied during the second wave. Another interesting factor is that the

incidence of COVID-19 infection during the second wave appeared to peter off from 106 cases/day (16th September) to 21 cases/day (27th September), 13 days after the first heavy rainfall (14th September). This may suggest that coronavirus-laden atmospheric particulate matter could have been cleared off during the rainfall. Once the clement weather returned, the incidence of COVID-19 increased again.

There a number of limitations to the observations noted in this paper. There is some asynchrony in a number variables assessed. The population percentage of smokers was derived from 2018 data from the Centre of Disease Centre and Prevention. This also applies to the States' population, population density and percentage of individuals deemed overweight or obese. The data regarding incidence of COVID-19 infection, case-fatality ratio and testing frequency were collected over the period between the 18th September and 25th September so as to reduce the bias for the constantly evolving fluctuations. Testing frequency was not available for all states, however there did not appear a significant difference of the testing frequency between both groups of states in the data available. Not all the required data from the district of Columbia, Puerto Rico, American Samoa and North Mariana Islands was available for assessment, so these territories were excluded from this study. These four regions constitute 1.37% of the whole USA population. The paper did not review the inter-state differences in infrastructure, healthcare provision, lifestyle differences and the poverty index, all of which may directly or indirectly impact on infection transmission and case-fatality ratios. Moreover the state bans considered were those imposed in 2018 and since then smoking regulations may have been altered. This study presupposes the unlikely assumption that adherence to smoking bans is enacted across the USA uniformly and admittedly this is unlikely to occur as has been shown in other countries such as Israel [34].

CONCLUSION

This paper suggests that states in the USA with elevated levels of tobacco smoking and limited smoking bans had significantly higher rates of COVID-19 infection incidences than States with more severe smoking restrictions. As shown in other papers, population density and individuals aged 75-year and over demonstrated a significant correlation with the case-fatality ratio.

Adjacent state smoking ban status could affect neighbouring State COVID-19 incidence. Besides the adverse effects of tobacco smoking on pulmonary defences, it would be interesting to explore the possibility of infection transmission via COVID-19 laden particulate matter from exhaled fumes derived from tobacco smoking. Second-hand smoking may be implicated in COVID-19 transmission.

REFERENCES

1. Lubick N (2011) Smoking and secondhand smoke: Global estimate of SHS burden. *Environmental Health Perspectives* 119(2): A66-A67.
2. USA department of health and human services (2014) The health consequences of smoking - 50 years of progress: A report of the surgeon general Atlanta: US department of health and human services, centers for disease control and prevention, national center for chronic disease prevention and health promotion, office on smoking and health.
3. Wu X, Nethery RC, Sabath BM, et al. (2020) Exposure to air pollution and COVID-19 mortality in the United States. medRxiv.
4. Setti L, Passarini F, De Gennaro G, et al. (2020) The potential role of particulate matter in the spreading of COVID-19 in Northern Italy: First evidence-based research hypotheses. medRxiv.
5. Comunian S, Dongo D, Milani C, et al. (2020) Air pollution and Covid-19: The role of particulate matter in the spread and increase of Covid-19's morbidity and mortality. *International Journal of Environmental Research and Public Health* 17(12): 4487.
6. John hopkins resource centre.
7. (2014) Overview list - How many smokefree laws?, Americans for nonsmokers' rights.
8. (2014) Summary of 100% smokefree state laws and population protected by 100% US smokefree laws, Americans for nonsmokers' rights.
9. Centres of disease control database.
10. Data USA.
11. Withings health observatory.
12. Wen CP, Chan TC, Chan HT, et al. (2010) The reduction of tuberculosis risks by smoking cessation. *BMC Infectious Diseases* 10(1): 156.
13. Almirall J, Blanquer J, Bello S (2014) Community-acquired pneumonia among smokers. *Archivos de Bronconeumología* 50(6): 250-254.
14. Doolittle LM, Davis IC (2018) Influenza in smokers: More than just a cause of symptom exacerbations? *American Journal of Respiratory Cell and Molecular Biology* 59(6): 670-671.
15. Thimmulappa RK, Gang X, Kim JH, et al. (2012) Oxidized phospholipids impair pulmonary antibacterial defenses: Evidence in mice exposed to cigarette smoke. *Biochemical and Biophysical Research Communications* 426(2): 253-259.
16. Loffredo CA, Tang Y, Momen M, et al. (2016) PM_{2.5} as a marker of exposure to tobacco smoke and other sources of particulate matter in Cairo, Egypt. *The International Journal of Tuberculosis and Lung Disease* 20(3): 417-422.
17. Sigaud S, Goldsmith CAW, Zhou H, et al. (2007) Air pollution particles diminish bacterial clearance in the primed lungs of mice. *Toxicology and Applied Pharmacology* 223(1): 1-9.

18. Gripenbäck S, Lundgren L, Eklund A, et al. (2005) Accumulation of eosinophils and T-lymphocytes in the lungs after exposure to pinewood dust. *European Respiratory Journal* 25(1): 118-124.
19. Nile SH, Nile A, Qiu J, et al. (2020) COVID-19: Pathogenesis, cytokine storm and therapeutic potential of interferons. *Cytokine & Growth Factor Reviews*.
20. Zhou F, Yu T, Du R, et al. (2020) Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: A retrospective cohort study. *The Lancet* 395(10229): 1054-1062.
21. Zhang JJ, Dong X, Cao YY, et al. (2020) Clinical characteristics of 140 patients infected with SARS-CoV-2 in Wuhan, China. *Allergy* 75(7): 1730-1741.
22. Guan WJ, Ni ZY, Hu Y, et al. (2020) Clinical characteristics of coronavirus disease 2019 in China. *New England Journal of Medicine* 382(18): 1708-1720.
23. Patanavanich R, Glantz SA (2020) Smoking is associated with COVID-19 progression: A meta-analysis. *Nicotine & Tobacco Research* 22(9): 1653-1656.
24. Simons D, Shahab L, Brown J, et al. (2020) The association of smoking status with SARS-CoV-2 infection, hospitalisation and mortality from COVID-19: A living rapid evidence review. *Qeios*.
25. Potera C (2013) Outdoor smoking areas: Does the science support a ban?. *International Journal of Environmental Research and Public Health* 17(8): 2932.
26. Setti L, Passarini F, De Gennaro G, et al. (2020) Airborne transmission route of COVID-19: Why 2 meters/6 feet of interpersonal distance could not be enough. *International Journal of Environmental Research and Public Health* 17(8): 2932.
27. Zhang R, Li Y, Zhang AL, et al. (2020) Identifying airborne transmission as the dominant route for the spread of COVID-19. *Proceedings of the National Academy of Sciences* 117(26): 14857-14863.
28. Baron YM (2020a) Elevated levels of PM2.5 in crowded subways of cities with high COVID-19 related mortality. *medRxiv*.
29. Baron YM (2020b) Covid-19 pandemic in relation to levels of pollution with PM2.5 and ambient salinity. *An Environmental Wake-up Call*. *medRxiv*.
30. Baron YM (2020c) COVID-19 and PM2.5 sodium chloride content. *Research Square*.
31. Poma J (2018) Salt Air: How far inland does salty air affect metals? *Galvanizers Association*.
32. Harris JE (2020) The subways seeded the massive coronavirus epidemic in New York city. *NBER Working Paper* (w27021).
33. Sudharsanan N, Didzun O, Bärnighausen T, et al. (2020) The contribution of the age distribution of cases to COVID-19 case fatality across countries: A 9-country demographic study. *Annals of Internal Medicine*: M20-2973.
34. Baron-Epel O, Satran C, Cohen V, et al. (2012) Challenges for the smoking ban in Israeli pubs and bars: Analysis guided by the behavioral ecological model. *Israel Journal of Health Policy Research* 1(1): 1-10.