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ARTICLE REVIEW

The Roles of Socio-Environmental Factors Influencing the Transmission, Prevention, and Control of COVID-19 and Tuberculosis Disease: A Review

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ABSTRACT

Introduction	Over the past two years, coronavirus disease 2019 (COVID-19) and tuberculosis (TB) have killed over 5.7 million people globally. TB and COVID-19 continue to be significant public health problems worldwide. A growing body of research supports a link between socio-environmental factors and the transmission of COVID-19 and TB disease.
Methods	This review article discussed the socio-environmental factors influencing the transmission, prevention, and control of COVID-19 and Tuberculosis disease..
Results	In this review, we highlight similarities and differences between these two infectious diseases and explore the roles of socio-environmental factors (air pollution exposure and climate change) and socioeconomic factors in disease transmission. A comprehensive, integrated TB-COVID-19 management for prevention and disease control, which includes administrative, engineering, environmental control, effective personal protective equipment, and community-based public health activities were discussed.
Conclusions	Understanding the similarities and differences between these two infectious diseases and the role of socio-environmental factors in disease transmission helps in planning and strengthening an integrated system for disease prevention and control strategies.
Keywords	Tuberculosis; COVID-19; socio-environmental factors

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INTRODUCTION

The leading infectious cause of death is Coronavirus disease 2019 (COVID-19), followed by Tuberculosis (TB), which has held that position since 2014 (when it displaced HIV/AIDS as the primary agent).[1] COVID-19 has been implicated in over 6.8 million fatalities worldwide (as of 23 January 2023).[2] In 2021, the WHO estimated that TB killed over 1.6 million people (including 187000 people with HIV). These infectious diseases cause a double burden for TB-endemic countries. TB-SARS-CoV-2 co-infection presented with lung imaging similarity features, including cavities, infiltrates, ground-glass opacity, nodules, pleural effusion, fibrosis, patchy shadow, consolidation, military lesions, and reticules. Patients with co-infection TB COVID-19 experience more severe symptoms and greater mortality rates than those with only COVID-19 infection.[3,4] The reduced TB detection rate is a significant factor impacting the mortality rate in TB cases. TB case notifications were significantly impacted by COVID-19, falling by 18% from 7.1 million in 2019 to 5.8 million in 2020, a 9-year setback in efforts to End TB. Over the next few years, TB mortality will probably rise significantly due to decreased case-finding.

Although the number of TB-COVID-19 cases is low, the severity and high mortality rate remain a threat. A systematic review and meta-analysis showed that the prevalence of tuberculosis infection was 1.1% in patients with confirmed COVID-19. This co-infection among patients with COVID-19 was 3.6% in Africa, 1.5% in Asia, and 1.1% in America. The outcome showed that 20.83% of evaluated patients died, whereas 65.62% recovered.[5] Another systematic review and meta-analysis evaluate forty-two studies into the analysis, in which nineteen countries reported coinfected patients, including high and low TB prevalence countries. The only study revealing a prevalence rate was 0.04-0.06% from South Africa. The mean overall and in-hospital fatality rates of co-infection were 13.9% and 17.5%, respectively. The mean in-hospital fatality rates for high-income countries (Italy and Argentina) were 6.5%, and for low/middle-income countries (LMICs) (India, Philippines, South Africa) were 22.5%.[6]

Previous viral pandemics have resulted in excessive deaths from TB. These may be due to service interruption, biological interaction between pathogens, and pulmonary destruction from both diseases.[7] The public health response to the COVID-19 pandemic, such as lockdown and social distancing, may have reduced access to health services and the quality of TB care. Reduced TB diagnosis may also have been impacted by a shortage of protective equipment and the prioritisation of laboratory services for COVID-19.[8] A modelling study on the impact of the COVID-19 pandemic suggests that in high-burden settings, disease-related mortality over five years might be increased by up to 10% for HIV, 20% for TB, and 36% for malaria.[1] Synergies between COVID-19 response and conventional public health initiatives should be sought, and the resources and experiences learned in any one of the programmes should be utilised to the benefit of others to reduce the adverse effects of COVID-19 on overall public health services.

The present review aims to describe the available evidence on the interaction between COVID-19 and TB in terms of differences and similarities and the role of socio-environmental factors influencing the transmission of diseases as well as public health implications on prevention and control.

METHODS

A non-systematic search of the English-written scientific literature was carried out using the following keywords: “environmental factors”, “air pollution”, “climate change”, socio-economic factors, “COVID-19”, “tuberculosis” and “prevention”. No time restrictions were applied, and the selected publication types included clinical trials, observational studies, cohort studies, and literature reviews. The information retrieved from the above search was used to compile the present article.

Similarities and Differences Between TB and COVID-19

Several similarities and differences between COVID-19 and TB are summarised in Table 1, most notably transmission of their causative agents, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and Mycobacterium tuberculosis. TB and COVID-19 are airborne transmissible illnesses that mainly target the lungs but can also affect other organs.[9,10] Signs and symptoms are the same, and both can present with cough, fever, and fatigue, potentially challenging differential diagnosis. A complex, slow-growing bacterium causes TB, while COVID-19 is caused by a coronavirus, SARS-CoV-2, which has only recently caused human disease. Evolutionary changes gradually generated resistance, compensatory and fitness mutations resulting in drug-resistant TB. In contrast, the rapid generation of variants due to mutations new SARS-CoV-2 strains has significantly increased their capacity for transmission (alpha, beta, gamma, delta, omicron, lambda, and mu). The incubation period is short (1–14 days) for COVID-19, while TB takes an extended period (2 weeks to several years before active TB develops). Diagnosis can be made by using respiratory samples involving molecular techniques. Nonetheless, point-of-care self-tests for COVID-19 were made accessible quickly, and sputum is not required for diagnosis.

Co-morbidities raise vulnerability for both diseases (including cancer, chronic lung and kidney diseases, diabetes, smoking, alcohol use disorders, depression, HIV, and other immunocompromising diseases).[11] Long-term COVID or post-COVID syndrome may manifest as cognitive, mental health, and respiratory disorders, ageusia, and hypo/anosmia. Commonly, TB sequelae result in lung residual diseases such as bronchiectasis, scars, and cavities with reduced pulmonary function and repeated infections.[12]

While there are curative ways for treating TB, with success rates exceeding 85% in patients who are drug-susceptible (lower for multidrug-resistant patients, in the range of 60%), numerous medications are under evaluation to determine an effective treatment for COVID-19.[11,13] Vaccine availability for both diseases helps prevent severe diseases but does not affect incidence. Moreover, both diseases show tremendous impacts on health and social services and considerable economic repercussions.[11] Therefore, future challenges are required for further evaluation, including their effect on quality of life, the prospective requirement for pulmonary rehabilitation, and long-term socioeconomic support.

Role of Environmental Factor in COVID-19 and TB Disease Transmission

Several factors may influence the emergence of tuberculosis and COVID-19. Specific health determinants, such as genetics, behaviour, social environment, physical environment, and health services, play an essential role in TB and COVID-19 epidemiology. Employing the epidemiological triangle will help control and stop disease transmission by disrupting the connection between the environment, the host, and the agent. Factors such as host susceptibility, the infectiousness of the agent, environment, and exposure determine the likelihood of COVID-19 and TB disease transmissions. Exogenous and endogenous risk factors play a role in the risk of progression from pathogens and exposure to the onset of active illness.

Table 1 Similarities and differences of the main characteristics of TB and COVID-19

Characteristic	COVID-19	TB
Disease transmission	Airborne transmission caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)	Airborne transmission caused by Mycobacterium tuberculosis
Signs and symptoms	Cough, fever, dyspnoea, sore throat, anosmia/hyposmia, ageusia, diarrhoea, myalgia, fatigue; acute onset	Fever and night sweats, persistent productive cough,haemoptysis, loss of appetite, chest pain, fatigue. Insidious onset
Speed of mutation	Rapid generation of variants due to mutations: alpha; beta; gamma; delta; omicron; lambda; mu	Gradual generation of resistance, compensatory, and fitness mutations
Incubation period	Incubation period is short (1–14 days)	Incubation period is long (2 weeks to several years before active TB develops)
Diagnostic tests	RT-PCR, rapid antigen test kits (point-of-care self-testing available) Using naso- and oropharyngeal swabs, saliva (easy-to-obtain specimens)	Sputum microscopy, sputum RT-PCR, and chest X-ray can detect active TB rapidly, culture takes 2–8 weeks Using sputum or extrapulmonary samples
Long term complications	Long-term COVID or post-COVID syndrome may manifest as cognitive, mental health, and respiratory disorders, ageusia, and hypo/anosmia	Lung residual diseases such as bronchiectasis, scars, and cavities with reduced pulmonary function and repeated infections
Treatment modalities	Anti-viral drugs Vaccine	Anti-TB drugs Vaccine

Air Pollution Exposures

The elements of air pollution are a complex mixture of gaseous and particle materials that vary spatially and temporally. It is also important to note that both PM_{10} and $PM_{2.5}$ in this context represent ultrafine particles (diameter <0.1 µm). Carbonaceous PM from coal, fuel, or wood combustion is the most hazardous and is responsible for many chronic diseases, including cardiopulmonary and metabolic diseases, cancer, and low birth weight. Air pollution, particularly exposure to particulate matter (PM), increases protein expression, which is vital to SARSCoV-2 entry into host cells.[14] Long-term exposure to PM, NO_2, and ozone may also cause immunological damage before COVID-19 infection, raising the chance of COVID-19 infection and its severity. There is evidence from numerous ecological studies conducted in the Netherlands, China, Italy, the United States, and other countries showing places with poorer air quality are more likely to have higher COVID-19 incidence and fatality rates.[15] Air pollution, especially PM, can reduce UV penetration, as demonstrated by several studies reported that air pollutants such as PM significantly reduce the amount of UVB received by the body and, thus, lead to reduced vitamin D synthesis. Vitamin D has antioxidant activity, which protects against respiratory infections and oxidative stress due to air pollution.[16–18] Moreover, air pollution exposure significantly impacted people with low socioeconomic status in both the outdoor and indoor environment.[19], contributing to discrepancies in the incidence and fatality rates of COVID-19. Additionally, Bowe et al. found that the impact of air pollution on COVID-19 results is modified by racial and geographic factors, with a higher risk for Black people and residents of low-socioeconomic-status neighbourhoods.[20]

Previous research has shown that air pollutants impact the incidence of TB, possibly by impacting the dissemination of Mycobacterium tuberculosis (M.tb) and raising population vulnerability. A meta-analysis in 2013 confirmed that indoor air pollution was related to the increased risk of TB.[21] A previous systematic review reported a significant association between exposure to $PM_{2.5}$, PM_{10}, and SO_2 and the incidence of pulmonary tuberculosis.[22] The study explored that increased exposure to $PM_{2.5}$ impairs the immunity of the respiratory system by causing oxidative stress and raises the host's susceptibility to tuberculosis.[23] Moreover, it has been shown that A549 cells exposed to $PM_{2.5}$ and PM_{10} produced less human b-defensin 2 (HBD-2) and HBD-3, which are crucial for preventing Mycobacterium tuberculosis infection.[24] In addition, indoor air pollution from burning biomass fuels increases the risk of TB.[25] Biomass is a significant energy source for baking, cooking, and heating for more than half of the world's population. Frequently, this happens when biomass is burned indoors in rural parts of less developed nations. Additionally, dwellings do not have enough ventilation, and this inefficient fuel source exposes more women and their young children to smoke for extended periods. More research is needed to explore the mechanisms of other air pollutants involved in the pathogenesis of TB.

Climate Change

Climate conditions implicated as possible drivers of SARS-CoV-2 infection risk and COVID-19 susceptibility and severity—temperature, humidity, UV radiation, and extreme weather events—by which these elements may also influence viral persistence in the environment, immune system performance, population movement, and human behaviours. A growing body of epidemiologic evidence suggests that SARS-CoV-2 transmission risk is higher at lower ambient temperatures and humidity. Temperature and relative humidity can modulate the decay rate of viruses within aerosols as well as droplet size through evaporation.[26] In the absence of UV radiation, the sensitivity of the viral to temperature is the highest.[27] A systematic review found consistent evidence that SARS-CoV-2 transmission was associated with low temperatures and humidity.[28] Shifting temperatures and precipitation patterns could significantly affect the future seasonality and spatial transmission of SARS-CoV-2 and other viruses either directly or through effects on reservoir species. The severity of COVID-19 could also be correlated with hypovitaminosis D.

Changes in climatic conditions impact the pattern and burden of tuberculosis, a global public health issue impacting low and middle-income nations. Climate change affects tuberculosis through diverse pathways: changes in climatic factors like temperature, humidity, and precipitation influence host response through alterations in vitamin D distribution, ultraviolet radiation, malnutrition, and other risk factors. Less humidity leads to the evaporation of droplets, reduces their size, and escalates their ability to travel further, which increases the possibility of transmission.[29] Extreme climate events also induce population displacement, associated with increased TB transmission. Moreover, climate change is expected to influence the trend and distribution of TB burden.

Role of Socioeconomic Factor in COVID-19 and TB Disease Transmission

The socioeconomic determinants of TB and COVID-19 emphasise the significance of prioritising health, and allocating sufficient human and financial resources, while meeting the needs of disadvantaged communities. Many social determinants of health, including poverty, smoke exposure, and racial discrimination, can affect COVID-19 and TB outcomes.

Smoking was linked to a higher risk of severe COVID-19, including death or mechanical ventilation, in many patients admitted for COVID-19, regardless of sociodemographic factors and medical history.[30] When people smoke, nicotine induces overexpression of the angiotensin-converting -enzyme II (ACE2) receptor in pulmonary epithelial cells through nicotinic acetylcholine receptors (nAChRs).[31,32] The ACE2 receptor is essential for the entry point of the SARS-CoV-2 virus into host cells because the S1 domain of the SARS-CoV-2 virus membrane spike protein has a high affinity with the ACE2 receptor on lung epithelial cells.[33] ACE2 expression plays a crucial role in susceptibility to COVID-19 and is involved in innate and adaptive immune responses, affecting the immune regulation of B cells and cytokine secretion, which could exacerbate the illness.[34] Similarly, smoking also increases the risk of Mycobacterium tuberculosis infection, the risk of disease progression following infection, and the risk of death in TB patients. The risk of TB infection is higher among current or ex-smokers than non-smokers.[35] A higher incidence of TB transmission to children has been associated with exposure to environmental tobacco smoke, particularly second hand smoke.[36]

Occupation environmental factor is also an essential factor that should be considered. An occupational hazard in hospitals for the spread of TB and COVID-19 has been identified as inadequate air change rates, negative airflow, and air recirculation. Studies in hospitals and healthcare facilities have shown that poor ventilation design or construction has contributed to the transmission of infection. Certain occupations, such as mining, are also at an increased risk of TB.[37]

TB has been referred to as a disease of poverty partly because the impoverished tend to include high population density, crowded living spaces, and inadequate ventilation. Poor access to healthcare, a higher prevalence of HIV, inadequate nutrition and immunity, and multi-generational family structures frequently make these conditions more complicated to treat. Several studies have shown that crowding communities with a higher average housing density have an increased risk for infection. A few factors, such as the outside temperature, noise, comfort, energy expenses, the condition of the windows or doors, and cultural and individual habits, may prevent a house from having more ventilation.

Ventilation and occupancy issues have become growing concerns in the battle to slow the spread of COVID-19. Crowding can raise SARS-CoV-2 transmission risk by increasing interpersonal contact frequency and duration. Racial and socioeconomic segregation can increase the chance of the COVID-19 virus spreading by putting up obstacles that prevent communities from accessing resources they need, increasing exposure to the SARS-CoV-2 virus, and concentrating the virus in segregated areas.

Malnutrition primarily affects infants, children, adolescents, and the elderly, increasing their vulnerability to infections, the leading cause of global immunodeficiency. Malnutrition profoundly affects cell-mediated immunity (CMI), and CMI is the principal host defence against TB. This secondary immunodeficiency increases the host's susceptibility to infection and increases the risk of developing TB. Additionally, population-level malnutrition appears to be a driver of an increased risk for fatal COVID-19 in areas with a marked burden of undernutrition.[38]

Integration Prevention and Control Programme

The emergence of the SARS-CoV-2 pandemic is a public health threat, but reports of M. tb/SARS-CoV-2 co-infection resulted in a double burden. Due to the potentially worse outcome of co-infection, a comprehensive investigation is required from all sectors. Understanding all potential outcomes and estimating the impact of TB-COVID-19 are essential to foresee the cascading effect of both diseases in all sectors and other communicable diseases. Recognizing the significance of solving problems inspires various strategic efforts to develop integrated management systems in the health systems in the future, elevating the importance of many elements, including multicenter cooperation. Since TB is a complicated infectious disease, there is an urgent need for remedies in several situations, including antibiotic resistance and latent TB infection (LTBI). The COVID-19 pandemic will impact TB management when the focus of attention is shifted to response and dealing with the prolonged spread of infection. COVID-19 and TB share commonalities in transmission and public health response: case finding, contact identification, and evaluation. Therefore, integrated TB-COVID-19 management is needed to minimize the effect of the pandemic on the TB program. It is necessary to strengthen monitoring and evaluation of the implementation of TB control programs integrated with other communicable diseases.

The COVID-19 control programme is based on the same strategy as the TB control programme, i.e., early detection of an infectious case, infection prevention, and contact tracing. These measures include administrative control (which targeted to reduce contamination of shared air by infectious subjects—e.g., cough triage, early diagnosis, and treatment), engineering and environmental control (which aims to minimise exposure to Mycobacterium tuberculosis or SARS-CoV-2 virus through disinfection or removal of contaminated air), personal protective measures (which aim to minimise inhalation of contaminated air using personal protective equipment —e.g., N95 respirators) and community-based public health activities, even without robust scientific evidence. Implementing infection prevention and control measures quickly and effectively is essential to prevent the spread of SARS-CoV-2 and TB due to the severity and the degree of infectiousness.

Effective epidemic surveillance systems can enable knowledge of infection among asymptomatic individuals by expanding the capacity of mass testing to self-isolate infected patients or implementing effective contact tracing through Bluetooth and /or GPS tracking. Individuals should practise good hygiene, stay at home when sick, keep a safe physical distance from others to reduce the risk of spreading disease and use a face-covering or mask in public or community settings when physical distancing cannot be maintained. Health system preparedness and capacity need to be addressed, including upgrading hospital infrastructure or building new hospitals, increasing intensive care unit bed numbers, deploying human resources, and enhancing laboratory capacity.

The COVID-19 response has shown that the international community can mobilise resources, accelerate scientific advancement, and deploy innovative public health tools to combat a pandemic with political will, priority, and investments. Similarly, these strategies can be employed for the TB program. However, the COVID-19 response, particularly the strict lockdowns and mobility restrictions, has also significantly harmed social and economic conditions and highlighted the need to carefully balance immediate improvements in public health with unintended adverse effects on social and physical conditions. Previous studies concluded that the evidence strongly supports the role of ventilation as an environmental control in minimizing the risk of airborne transmission of Mycobacterium tuberculosis and SARS-CoV-2.[39] In order to reduce the concentrations of indoor air pollutants or contaminants, including any viruses or bacteria in the air, it is vital to improve ventilation or the amount of outdoor air that enters the building. In general, increasing ventilation and filtration is usually appropriate; however, due to the complexity and diversity of building types, sizes, construction styles, heating, ventilation, and air-conditioning (HVAC) system components, and other building features, a professional should interpret guidelines for their specific building and circumstances.[40] Ventilation also is crucial while cleaning and disinfecting for COVID-19. If disinfecting, follow the label instructions using registered cleaning and disinfecting products to ensure that any hazards of indoor air pollution are reduced while still preserving the effectiveness of the disinfecting product. Ventilation should be used with other preventative measures such as physical distancing, avoiding crowded areas, wearing a mask, frequently washing hands, staying home if ill, coughing or sneezing into a bent elbow, and vaccination. More efficient filters exist as high-efficiency particulate air (HEPA) is used in isolation rooms and intensive care units designed to meet specific requirements for managing infectious diseases.

Another role of the environment is that climate change interferes with the growth and disease transmission through effects on the host's immune and detrimental effects in the social and environmental determinants, all in a complex interaction. Identifying the risk of climate change and the effect of population displacement and migration will alert the health system emergencies to increase awareness, further identification, and screening. The associations between climatic conditions and infectious disease incidence may be observed at spatial and temporal scales. Forecasting future infectious diseases under climate change risks requires jointly modelling both changes to future climate and the climate–disease relationship, accounting for uncertainties in both.

Malnutrition and indoor air pollution are recognized risk factors that are confounded with the socioeconomic status of a setting. Many high-burden countries have developed policies addressing TB and nutrition. A helpful illustration of multisectoral programming and strategic planning can be found in Timor-Leste, a country with a high prevalence of TB and malnutrition. The plan encourages coordination between the national TB programme and the reproductive, maternity, new-born, and child health (RMNCH) services to enhance community TB detection and maximise contact opportunities and human resources. Health facilities and outreach workers will routinely test undernourished people, and those with TB will be referred immediately. All MDR-TB patients will also get nutritional assistance packages for the duration of their therapy to help them adhere to their regimens better.[41] The experiences of Southeast Asia in implementing social protection strategies like cash transfers, microcredit, and training to enhance the prevention and mitigation of undernutrition and TB should also help inform the design, implementation, and monitoring of actions in the larger global context.

In addition, interventions against COVID-19 and TB should include public awareness campaigns followed by policy actions to reduce the risk of infection from smoking, hazardous lifestyles, and living conditions. Interventions should be done to promote smoking cessation or eliminate indoor smoking and consequently reduce latent TB infection (LTBI) or disease transmission in children who are exposed to tobacco smoke and COVID-19 severity and fatality. Prevention strategy also should include enforcing environmental law, not simply towards achieving the ambient air pollution standard only, but also towards the global issue of climate change. Lastly, future scientific collaboration and consistent, ongoing study will add to our knowledge and understanding to design an efficient integrated management system for serious communicable diseases that can be implemented globally.

CONCLUSION

COVID-19 and TB have become serious health issues worldwide, particularly in highly prevalent countries. Understanding the similarities and differences between these two infectious diseases and the role of socio-environmental factors in disease transmission helps in planning and strengthening an integrated system for disease prevention and control strategies.

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