Indoor Environment and Viral Infections

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The global pandemic of severe acute respiratory coronavirus 2 (SARS-CoV-2) (ie, the cause of COVID-19) has brought the importance of the environment for health to the forefront. As people spend the majority of their time indoors, the quality of the indoor environment has a major impact on overall health. It affects risk of disease through multiple factors,including indoor air pollutants; surface contamination with toxins and microbes; and contact among persons at home, at work, in transportation, and other indoor public and private places.[1-4] Counter measures, which are conceptually amenable to focused interventions guided by science, differ markedly according to the pathogen of interest.

For viral transmission, the role of temperature and humidity has received particular attention. These relationships are critically important for predicting infection growth rates and to counsel people on possible home interventions that could be deployed to mitigate viral transmission.

The purpose of this perspective is to discuss concisely the association between virus transmission and the indoor environment. We will focus on data pertaining to temperature and humidity and comment on implications for current practice and future research.

ENVIRONMENTAL FACTORS AND VIRAL TRANSMISSION

Environmental factors—such as temperature, humidity, and ventilation—play a role in the persistence, infectivity, and dispersal and removal of viruses and can alter human defense mechanisms that protect against respiratory pathogens.[5]

Animal experiments have demonstrated a link between temperature and relative humidity and viral transmission, with a greater persistence and infectivity of influenza A virus at cold temperatures and low relative humidity.[6] Although the relationship between environmental factors and transmission of virus are multifaceted, several factors—likely operating in combination—have been evoked including reduction of mucociliary clearance by desiccation of upper airways, increased stability of viruses with a lipid envelope in dry air, and impact of relative humidity on droplet dynamics.

Cold temperature and low relative humidity are also believed to increase the transmission of other respiratory viruses, including respiratory syncytial virus (RSV), human rhinovirus, and avian influenza virus.[7]

A recent systematic analysis of 37,335 studies reported on seasonal patterns among 4 viruses: influenza virus, RSV, parainfluenza virus (PIV), and human metapneumovirus (hMPV).[8]

Influenza virus exhibited distinct seasonality in winter months in temperate climates, but the timing of epidemics was less seasonal at locations closer to the equator. Epidemics of RSV were seasonal in all regions, starting in late summer in the tropics, and showing increased prominence during the winter in temperate sites. Parainfluenza virus epidemics occurred primarily in spring and early summer. Metapneumovirus epidemics happened in late winter and spring in most temperate sites.

Importantly in this extensive analysis, the association between seasonality and temperature and relative humidity was different for influenza virus and RSV. Lower temperature was associated with higher activity of both viruses; however, higher relative humidity was associated with increased influenza virus activity if temperature was above average. In contrast, RSV activity was higher when the temperature was lower than

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average. This important work illustrates the complexity of the mechanisms of viral persistence and transmission and the importance of considering the impact of environmental factors on a virus-by-virus basis.[7]

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the virus that causes COVID-19. SARS-CoV-2 most often spreads via droplets when infected persons exhale, cough, sneeze, or talk. Although a less prominent mechanism of transmission, airborne transmission of SARS-CoV-2 is currently a topic of growing interest.[9,10] The virus may remain infectious in aerosols for hours and on surfaces up to days. This emerging observation opens the door to mitigating interventions focused on ventilation and air filtration.

The link between humidity and temperature and the transmission of SARS-CoV-2 has been evoked but remains to be established. A recent study used weather data and global reports of infection to model COVID-19 growth rate before any intervention. This study indicated that higher temperature increased COVID-19 growth rate, relative humidity was associated with a nonsignificant decrease in growth rate, and ultraviolet light had the strongest effect in decreasing COVID-19 growth rate. Most importantly, a majority (64%) of the variation in COVID-19 growth rate remained unexplained by meteorological data. Examples of putative yet unmeasured factors include movements of persons inside and outside buildings and variations in immune response, possibly mediated in part by exposure to vitamin D.

Although it should be emphasized that the evolution of the current pandemic will provide more data points and inform future modeling, the available information urges caution with regard to the assumption of a substantial seasonal reprieve of the infection rates.

PRACTICAL RECOMMENDATIONS

Interventions on environmental factors to mitigate viral transmission must be grounded in science. Indoor humidity and temperature levels are the product of a dynamic interaction between the outdoor and indoor environments and other factors such as building materials and configuration (eg, window tightness), air-conditioning systems, and the number of occupants. Options to control indoor humidity include in-duct humidifiers in central air systems or portable humidifiers, which are attractive because of ease of installation.

Because indoor humidity is not uniform, particularly in larger spaces or in residences with multiple rooms, its accurate assessment requires measurements at multiple locations, especially areas close to doors, windows, supply air diffusers, and return-air grilles. For most commonly available humidity sensors, the measurement error is less than 5% and therefore adequate for typical residential use. The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) recommends maintaining indoor relative humidity (RH) within the range of 40% to 60 % RH, and the United States Environmental Protection Agency recommends maintaining 30% to 50% RH, ranges that optimize thermal comfort, air quality, and reduce growth of mold. Indoor temperatures should be maintained within comfortable ranges.[11]

With regard to future research, emerging evidence on possible airborne transmission of SARS-CoV-2 underscores the importance of studies focused on ventilation and air-filtration optimization to reduce transmission of viruses.

CONCLUSION

This perspective underscores the critical importance of multidisciplinary research to advance science and practice on this topic. Virologists focus on events within the host cells, whereas public health scientists focus on exposures in populations and on the circulation of pathogens in communities. Building scientists focus on the optimization of our residential and working environments and how it can promote overall health. Research questions are often analogous across these scientific domains, which constitute a singular opportunity for transdisciplinary work. The worldwide threat of

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COVID-19 constitutes the most powerful call to action to deploy this needed team science approach.

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