Emerging Evidence on COVID-19

Evidence Brief on SARS-CoV-2 Virus Dispersion Distance

Introduction

What is the impact of physical distancing of 1 meter, 1.5 meters and 2 meters on SARS-CoV-2 virus transmission risk?

The complex physics and particle dynamics surrounding droplet and aerosol dispersion, as well as the limited evidence on infectious dose and virus viability within expelled particles, make it difficult to confidently quantify SARS-CoV-2 exposure risk based on distance. This evidence brief highlights specific literature on expelled droplet and aerosol particle dispersion distance published up to June 22, 2020.

Key Points

- The body of evidence suggest particle speed, evaporation, air flow, humidity, temperature, all play a role in the distances virus laden respiratory particles can travel after being released by an infectious individual. As such, the protective effects of physical distancing at different distances also depend on the conditions in which they are practiced.
- The available empirical and modeled evidence suggests in some circumstances respiratory droplets and aerosols expelled from infectious individuals may travel distances greater than 2 meters (Table 1), but face coverings are effective at limiting dispersion distances to less than 0.5 meters (Table 2).
- According to mathematical models and fluid dynamic analysis, droplet size, humidity, temperature, air flow, and air turbulence all impact the movement and decay of virus containing airborne particles (Table1).
    - Some models predict small droplets and aerosols can travel distances as far as ten meters when generated by coughs or sneezes, and frequently conclude social distance of two meters is not always sufficient to negate airborne SARS-CoV-2 transmission (Feng, Marchal, Sperry, & Yi, 2020; Guerrero, Brito, & Cornejo, 2020; Zhao, Qi, Luzzatto-Fegiz, Cui, & Zhu, 2020).
    - Low temperature and high humidity are found to facilitate respiratory droplet transmission and dispersion. High temperature and low humidity are found to promote the rapid loss of respiratory droplet mass (from evaporation) thereby reducing droplet travel distance (Feng et al., 2020; Zhao et al., 2020).

    - A multidisciplinary research consortium applied evidence based Monte-Carlo models and 3D simulations to investigate the physics of SARS-CoV-2 aerosol dispersion (Vuorinen et al., 2020). The investigators use computer simulations to demonstrate SARS-CoV-2 aerosols can travel distances up to ten meters, and the inhalation of sufficient concentrations of aerosols (100 virus laden particles was assumed to be infectious) is possible within one second to one hour depending on the surrounding conditions.
    - Results from an agent based model reported a decreasing risk of a transmission event within indoor settings (e.g. supermarket) when the distance between individuals are increase from 30 cm to 2 meters (Hernandez Mejia & Hernandez-Vargas, 2020).
    - Speed of movement also impacts droplet travel distance. Computer fluid dynamic simulations find, although a distance of 1.5 meters may be sufficient when standing still, distances greater than 1.5 meters are necessary when two individuals are running or moving fast as inertia of expelled droplets also impacts droplet spread (Blocken, Malizia, van Druenen, & Marchal, 2020).
- Laboratory simulation studies report human and manikin generated cough droplets can travel distances between one to two meters, and a maximum of four meters in some simulations (Loh et al., 2020; Rodriguez-Palacios, Cominelli, Basson, Pizarro, & Ilic, 2020; Viola et al., 2020).
- Two simulation studies investigated the effects of face covers on expelled particle dispersion distance. Both studies find the inclusion of face covers, such as face shields, filtering face piece respirators, surgical face masks, and homemade masks, reduced the dispersion of expelled droplets to less than 0.5 meter, even when coughing.
- A recent systematic review by Chu et al., quantifies the relative risk of beta-corona virus infection based on distance (Chu et al., 2020). The authors report transmission of viruses to be lower with physical distancing of 1 m or more, compared with a distance of less than 1 m (n=10 736, pooled adjusted odds ratio [aOR] 0·18, 95% CI 0·09 to 0·38; risk difference [RD] −10·2%, 95% CI −11·5 to −7·5; moderate certainty); protection was increased as distance was lengthened (change in relative risk [RR] 2·02 per m; p interaction=0·041; moderate certainty). There appears to be some ambiguity in the measurement of physical distance for some of the evidence included in this review and as such is of low quality. Therefore, it may be premature to quantify the relative risk of SARS-CoV-2 infection based on incremental differences in physical distance, due to the lack of sufficient evidence.
- Presently there are no observational studies that estimate SARS-CoV-2 infection transmission risk based on varied distance from an infectious source.

Overview of the Evidence

Publications appearing in the emerging literature up to June 22, 2020 have informed this evidence brief. The available body of evidence is limited and largely based on simulations under controlled conditions. These studies are of good quality but the generalizability of these results to real world situations is unknown. For this reason additional research on transmission of SARS-CoV-2 under varying situations and distances may change the conclusions of this review.

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SARS-COV-2 DISPERSION DISTANCE

Table 1: Primary literature on droplet aerosol dispersion distance

Publication Title	Key Outcomes	Reference
Experimental Simulation Studies		
The impact of high-flow nasal cannula (HFNC) on coughing distance: implications on its use during the novel coronavirus disease outbreak	A simulation study using healthy volunteers (n=5) found cough-generated droplets spread a mean distance of 2.48 meters (1.03 standard deviation) at baseline, maximum of 3.90 meters. When wearing well-fitting High Flow Nasal Cannula, mean cough generated droplet spread was 2.91 meters (1.09) with a maximum distance of 4.50 meters.	(Loh et al., 2020)
Face Coverings, Aerosol Dispersion and Mitigation of Virus Transmission Risk	Researchers use a background oriented Schlieren technique to visualize airflow and investigate the effectiveness of different face covers in mitigating aerosol dispersion during breathing and coughing. The study reports a thermal plume containing respiratory particles were visible at distances less than 0.5 meters during normal breathing simulated by human subjects and manikins. Thermal plume were visible approximately 1.1 meter away from the source mouth during manikin generated coughing.	(Viola et al., 2020)
Textile Masks and Surface Covers- A Spray Simulation Method and a "Universal Droplet Reduction Model" Against Respiratory Pandemics	Dispersion distances of respiratory droplets when wearing face coverings made of common household materials was measured using a bacterial-suspension spray simulation (mimicking a sneeze). Most bacteria-carrying droplets landed within 1.2 meters of the source with a textile mask compared to droplet travel distances of greater than 1.8 meters when no barriers (meant to mimic no face covering) were in place.	(Rodriguez-Palacios et al., 2020)
Mathematical Models and Simulations		
Publication Title	**Key Outcomes**	**Reference**
Towards aerodynamically equivalent COVID19 1.5 m social distancing for walking and running	Computer Fluid Dynamics study informed by previous data on droplet dispersion around a runner takes into account the potential aerodynamic effects introduced by a person movements (e.g. walking fast, running and cycling) on droplet travel distance. The study investigates whether a leading infectious person standing still and moving nearby a second susceptible person at a distances of 1.5 meters or more can pose any infection transmission risk. Although particle exposure is negligible when two people are standing 1.5 meter apart, if	(Blocken et al., 2020)

	the individuals are running or walking fast even at 1.5 meters apart there is some risk of infectious particle exposure. The study results suggest the greatest exposure to the trailing person occurs if they are directly behind the leading person (positioned in the slipstream). Substantial droplet exposure risk reduction can be achieved by 1) avoiding to walk or run in the slipstream of the leading person, 2) keeping the 1.5 m distance in staggered or side by side arrangement, or 3) by keeping social distances greater than 1.5 meters when moving fast or running.	
When is SARS-CoV-2 in your shopping list?	The spread of COVID-19 in a commercial supermarket and the potential for contagions are estimated using agent based modeling. This method maps all desired characteristics of customers and staff (e.g. number infected vs. susceptible, simultaneous users) and the infectious agent, as well as possible interactions/trajectories in a hypothetical layout. The model analysis finds increasing the distance between individuals in a supermarket setting (tested distances were 30cm, 50cm, 1 meter, 1.5 meters, and 2 meters), as well as limiting the number of individuals within the supermarket improved the percentage of potential transmission events avoided in the simulations.	(Hernandez Mejia & Hernandez-Vargas, 2020)
COVID-19: Effects of weather conditions on the propagation of respiratory droplets	A comprehensive mathematical model is established to explore speech generated droplet evaporation, heat transfer and kinematics under different conditions (e.g. temperature, humidity and ventilation). Low temperature and high humidity facilitate droplet transmission and dispersion, but supresses the formation of aerosols. On the other hand, high temperature and low humidity promotes rapid loss of respiratory droplet mass (from evaporation) and reduce droplet travel distance but these conditions increases transmission risk from aerosol particles. The study concludes current social distancing recommendations may not be sufficient to diminish airborne transmission risks as droplets can travel distances up to 6 meters.	(Zhao et al., 2020)
COVID-19. Transport of respiratory droplets in a microclimatologic urban scenario	Examined the spread of respiratory droplets in outdoor environments by applying a computational model of a sneezing person in an urban scenario under a medium intensity climatological wind. The spread of respiratory droplets is characterized by the dynamics of droplet size: larger droplets (400 – 900μm) are spread between two to five meters during 2.3 seconds while smaller droplets (100 – 200μm) are transported between eight and eleven meters in 14.1 seconds when influenced by turbulent wind.	(Guerrero et al., 2020)
Influence of wind and relative	Air transmission of cough droplets with condensation and evaporation effects are modeled between two virtual humans under different	(Feng et al., 2020)

humidity on the social distancing effectiveness to prevent COVID-19 airborne transmission: A numerical study	environments and wind velocities. Micro-droplets follow airflow streamlines and can be deposited on virtual human bodies (including head regions) at greater than 3.05 meter (10 feet) distances. High relative humidity (99.5%) also leads to larger droplet sizes and greater deposition of cough droplets on surfaces (due to hygroscopic growth effects). Suspended microdroplets could be transmitted between the two virtual humans in less than 5 seconds. The study concludes due to environmental wind, convection effects, and relative humidity on respiratory particles emitted by humans, the frequently recommended 1.83 meters (six feet) of social distancing may not be sufficient to prevent inter-person aerosol transmission.	
Modelling aerosol transport and virus exposure with numerical simulations in relation to SARS-CoV-2 transmission by inhalation indoors	Available evidence on aerosol transport in air is combined with 0D-3D simulations in physics-based models and theoretical calculations. Monte Carlo simulations indicate droplets produced by speech and cough (diameter < 20 µm) can become airborne and linger in air from 20 minutes up to one hr, and be inhaled by others. The exposure time to inhale 100 aerosols (assumed to be an adequate infectious dose) is variable based on the situation and can range from one second, to one minute, to one hour. 3D computational fluid dynamic (CFD) simulations suggest aerosols (dp <20 µm) can be transported over 10 meter distances in generic environments, dependent on relative humidity and airflow. Finally the rapid drying of expelled mucus droplets would yield droplet nuclei and aerosols which could potentially carry airborne virus particles. Such droplets (initial particle diameter of 50µm to 100µm) could remain airborne for approximately 20 seconds to three minutes.	(Vuorinen et al., 2020)
Field Studies		
Publication Title	**Key Outcomes**	**Reference**
Aerosol and Surface Transmission Potential of SARS-CoV-2	Air and surface samples from isolation spaces housing individuals with COVID-19, in the United States, were collected and tested for SARS-CoV-2 viral RNA. High volume air samples, and low volume personal air samples were tested for SARS-CoV-2 presence by RT-PCR. 63.2% of air samples from patient isolation areas were positive for viral RNA, and 58.3% of air samples from hallways outside of patient isolation areas were also positive for the virus. The findings suggest viral aerosol particles can be produced by infected individuals even during the absence of cough, and travel distances greater than 6 feet (1.8 meters).	(Santarpia et al., 2020)

SARS-COV-2 DISPERSION DISTANCE AND FACE COVERING

Table 2: Primary literature on effectiveness of face covering and distance

Publication Title	Key Outcomes	Reference
Textile Masks and Surface Covers—A Spray Simulation Method and a "Universal Droplet Reduction Model" Against Respiratory Pandemics	Dispersion distances of respiratory droplets when wearing face coverings made of common household materials was measured using a bacterial-suspension spray simulation (mimicking a sneeze). Most bacteria-carrying droplets landed within 1.2 meters of the source, but some droplets did travel distances greater than 1.8 meters when no barriers (meant to mimic no face covering) were in place. All tested textiles reduced the number of droplets reaching surfaces, restricting their dispersion to <30 cm, when used as single layers. When used as double-layers, textiles were as effective as medical mask/surgical-cloth materials, reducing droplet dispersion to <10 cm, and the area of circumferential contamination to ~0.3%.	(Rodriguez-Palacios et al., 2020)
Face Coverings, Aerosol Dispersion and Mitigation of Virus Transmission Risk	Researchers use a background oriented Schlieren technique to visualize airflow and investigate the effectiveness of different face covers in mitigating aerosol dispersion during breathing and coughing. The study reports a thermal plume containing respiratory particles were visible at distances less than 0.5 meters during normal breathing generated by human subjects and manikins. Thermal plume were visible approximately 1.1 meter away from the source mouth during manikin generated coughing. All tested face covers (including surgical mask, homemade mask, filtering face piece respirators, and face shields) were found to reduce front flow of respiratory jets by more than 90%, and thermal plumes were visible at less than 0.5 meters for coughing. Several backward and downward leakage jets were also detected at distances less than 0.2 from the source for coughing.	(Viola et al., 2020)

Methods:

A daily scan of the literature (published and pre-published) is conducted by the Emerging Sciences Group, PHAC. The scan has compiled COVID-19 literature since the beginning of the outbreak and is updated daily. Searches to retrieve relevant COVID-19 literature are conducted in Pubmed, Scopus, BioRxiv, MedRxiv, ArXiv, SSRN, Research Square and cross-referenced with the literature on the WHO COVID literature list, and COVID-19 information centers run by Lancet, BMJ, Elsevier and Wiley. The daily summary and full scan results are maintained in a RefWorks database and an Excel list that can be searched. Targeted keyword searching is conducted within these databases to identify relevant citations on COVID-19 and SARS-CoV-2. Search terms used included: distance.

Each potentially relevant reference was examined to confirm it had relevant data and relevant data is extracted into the review. This review contains research published up to June 22, 2020.

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