




COVID-19

Scientific Brief: SARS-CoV-2 Transmission

Updated May 7, 2021

[Print](#)

Summary of recent changes

Updates as of May 7, 2021 

- This science brief has been updated to reflect current knowledge about SARS-CoV-2 transmission and reformatted to be more concise.
- Modes of SARS-CoV-2 transmission are now categorized as inhalation of virus, deposition of virus on exposed mucous membranes, and touching mucous membranes with soiled hands contaminated with virus.
- Although how we understand transmission occurs has shifted, the ways to prevent infection with this virus have not. All prevention measures that CDC recommends remain effective for these forms of transmission.

SARS-CoV-2 is transmitted by exposure to infectious respiratory fluids

The principal mode by which people are infected with SARS-CoV-2 (the virus that causes COVID-19) is through exposure to respiratory fluids carrying infectious virus. Exposure occurs in three principal ways: (1) inhalation of very fine respiratory droplets and aerosol particles, (2) deposition of respiratory droplets and particles on exposed mucous membranes in the mouth, nose, or eye by direct splashes and sprays, and (3) touching mucous membranes with hands that have been soiled either directly by virus-containing respiratory fluids or indirectly by touching surfaces with virus on them.

People release respiratory fluids during exhalation (e.g., quiet breathing, speaking, singing, exercise, coughing, sneezing) in the form of droplets across a spectrum of sizes.¹⁻

⁹ These droplets carry virus and transmit infection.

- The largest droplets settle out of the air rapidly, within seconds to minutes.
- The smallest very fine droplets, and aerosol particles formed when these fine droplets rapidly dry, are small enough that they can remain suspended in the air for minutes to hours.

Infectious exposures to respiratory fluids carrying SARS-CoV-2 occur in three principal ways (not mutually exclusive):

1. **Inhalation** of air carrying very small fine droplets and aerosol particles that contain infectious virus. Risk of transmission is greatest within three to six feet of an infectious source where the concentration of these very fine droplets and particles is greatest.
2. **Deposition** of virus carried in exhaled droplets and particles onto exposed mucous membranes (i.e., “splashes and sprays”, such as being coughed on). Risk of transmission is likewise greatest close to an infectious source where the concentration of these exhaled droplets and particles is greatest.
3. **Touching** mucous membranes with hands soiled by exhaled respiratory fluids containing virus or from touching inanimate surfaces contaminated with virus.

The risk of SARS-CoV-2 infection varies according to the amount of virus to which a person is exposed

Once infectious droplets and particles are exhaled, they move outward from the source. The risk for infection decreases with increasing distance from the source and increasing time after exhalation. Two principal processes determine the amount of virus to which a person is exposed in the air or by touching a surface contaminated by virus:

1. **Decreasing concentration of virus in the air** as larger and heavier respiratory droplets containing virus fall to the ground or other surfaces under the force of gravity and the very fine droplets and aerosol particles that remain in the airstream progressively mix with, and become diluted within, the growing volume and streams of air they encounter. This mixing is not necessarily uniform and can be influenced by thermal layering and initial jetting of exhalations.
2. **Progressive loss of viral viability and infectiousness** over time influenced by environmental factors such as temperature, humidity, and ultraviolet radiation (e.g., sunlight).

Transmission of SARS-CoV-2 from inhalation of virus in the air farther than six feet from an infectious source can occur

With increasing distance from the source, the role of inhalation likewise increases. Although infections through inhalation at distances greater than six feet from an infectious source are less likely than at closer distances, the phenomenon has been repeatedly documented under certain preventable circumstances.¹⁰⁻²¹ These transmission events have involved the presence of an infectious person exhaling virus indoors for an extended time (more than 15 minutes and in some cases hours) leading to virus concentrations in the air space sufficient to transmit infections to people more than 6 feet away, and in some cases to people who have passed through that space soon after the infectious person left. Per published reports, factors that increase the risk of SARS-CoV-2 infection under these circumstances include:

- **Enclosed spaces with inadequate ventilation or air handling** within which the concentration of exhaled respiratory fluids, especially very fine droplets and aerosol particles, can build-up in the air space.
- **Increased exhalation** of respiratory fluids if the infectious person is engaged in physical exertion or raises their voice (e.g., exercising, shouting, singing).
- **Prolonged exposure** to these conditions, typically more than 15 minutes.

Prevention of COVID-19 transmission

The infectious dose of SARS-CoV-2 needed to transmit infection has not been established. Current evidence strongly suggests [transmission from contaminated surfaces](#) does not contribute substantially to new infections. Although animal studies²²⁻²⁴ and epidemiologic investigations²⁵ (in addition to those described above) indicate that inhalation of virus can cause infection, the relative contributions of inhalation of virus and deposition of virus on mucous membranes remain unquantified and will be difficult to establish. Despite these knowledge gaps, the available evidence continues to demonstrate that existing recommendations to prevent SARS-CoV-2 transmission remain effective. These include physical distancing, community use of well-fitting masks (e.g., barrier face coverings, procedure/surgical masks), adequate ventilation, and avoidance of crowded indoor spaces. These methods will reduce transmission both from inhalation of virus and deposition of virus on exposed mucous membranes. [Transmission through soiled hands and surfaces](#) can be prevented by practicing good [hand hygiene](#) and by [environmental cleaning](#).

References

1. Stadnytskyi V, Bax CE, Bax A, Anfinrud P. The airborne lifetime of small speech droplets and their potential importance in SARS-CoV-2 transmission. *Proc Natl Acad Sci U S A*. Jun 2 2020;117(22):11875-11877. doi:10.1073/pnas.2006874117

2. Alsved M, Matamis A, Bohlin R, et al. Exhaled respiratory particles during singing and talking. *Aerosol Science and Technology*. 2020;54(11):1245-1248. doi:10.1080/02786826.2020.1812502
3. Echternach M, Gantner S, Peters G, et al. Impulse Dispersion of Aerosols during Singing and Speaking: A Potential COVID-19 Transmission Pathway. *Am J Respir Crit Care Med*. Dec 1 2020;202(11):1584-1587. doi:10.1164/rccm.202009-3438LE
4. Asadi S, Wexler AS, Cappa CD, Barreda S, Bouvier NM, Ristenpart WD. Aerosol emission and superemission during human speech increase with voice loudness. *Sci Rep*. Feb 20 2019;9(1):2348. doi:10.1038/s41598-019-38808-z
5. Asadi S, Wexler AS, Cappa CD, Barreda S, Bouvier NM, Ristenpart WD. Effect of voicing and articulation manner on aerosol particle emission during human speech. *PLoS One*. 2020;15(1):e0227699. doi:10.1371/journal.pone.0227699
6. Morawska L., Johnson GR, Ristovski ZD, et al. Size distribution and sites of origin of droplets expelled from the human respiratory tract during expiratory activities. *Aerosol Sci*. 2009;40(3):256-269.
7. Buonanno G, Stabile L, Morawska L. Estimation of airborne viral emission: Quanta emission rate of SARS-CoV-2 for infection risk assessment. *Environment international*. May 11 2020;141:105794. doi:<https://dx.doi.org/10.1016/j.envint.2020.105794> 
8. Papineni RS, Rosenthal FS. The size distribution of droplets in the exhaled breath of healthy human subjects. *J Aerosol Med*. Summer 1997;10(2):105-16. doi:10.1089/jam.1997.10.105
9. Edwards DA, Ausiello D, Salzman J, et al. Exhaled aerosol increases with COVID-19 infection, age, and obesity. *Proc Natl Acad Sci U S A*. Feb 23 2021;118(8)doi:10.1073/pnas.2021830118
10. Bae S, Kim H, Jung TY, et al. Epidemiological Characteristics of COVID-19 Outbreak at Fitness Centers in Cheonan, Korea. *J Korean Med Sci*. Aug 10 2020;35(31):e288. doi:10.3346/jkms.2020.35.e288
11. Brlek A, Vidovic S, Vuzem S, Turk K, Simonovic Z. Possible indirect transmission of COVID-19 at a squash court, Slovenia, March 2020: case report. *Epidemiol Infect*. Jun 19 2020;148:e120. doi:10.1017/S0950268820001326
12. Cai J, Sun W, Huang J, Gamber M, Wu J, He G. Indirect Virus Transmission in Cluster of COVID-19 Cases, Wenzhou, China, 2020. *Emerging infectious diseases*. Mar 12 2020;26(6):12. doi:<https://dx.doi.org/10.3201/eid2606.200412> 
13. Shen Y, Li C, Dong H, et al. Community Outbreak Investigation of SARS-CoV-2 Transmission Among Bus Riders in Eastern China. *JAMA Intern Med*. Dec 1 2020;180(12):1665-1671. doi:10.1001/jamainternmed.2020.5225
14. Groves LM, Usagawa L, Elm J, et al. Community Transmission of SARS-CoV-2 at Three Fitness Facilities — Hawaii, June–July 2020. *MMWR Morb Mortal Wkly Rep*. Feb 24 2021;70(Early Release)
15. Hamner L, Dubbel P, Capron I, et al. High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice – Skagit County, Washington, March 2020. *MMWR Morb Mortal Wkly Rep*. May 15 2020;69(19):606-610. doi:10.15585/mmwr.mm6919e6

16. Jang S, Han SH, Rhee JY. Cluster of Coronavirus Disease Associated with Fitness Dance Classes, South Korea. *Emerg Infect Dis*. Aug 2020;26(8):1917-1920. doi:10.3201/eid2608.200633
17. Lendacki FR, Teran RA, Gretsch S, Fricchione MJ, Kerins JL. COVID-19 Outbreak Among Attendees of an Exercise Facility — Chicago, Illinois, August–September 2020. *MMWR Morb Mortal Wkly Rep*. Feb 24 2021;70(Early Release)
18. Li Y, Qian H, Hang J, et al. Probable airborne transmission of SARS-CoV-2 in a poorly ventilated restaurant. *Build Environ*. Jun 2021;196:107788. doi:10.1016/j.buildenv.2021.107788
19. Lu J, Gu J, Li K, et al. COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020. *Emerging infectious diseases*. Apr 2020;26(7)doi:10.3201/eid2607.200764
20. Katelaris AL, Wells J, Clark P, et al. Epidemiologic Evidence for Airborne Transmission of SARS-CoV-2 during Church Singing, Australia, 2020. *Emerg Infect Dis*. Apr 5 2021;27(6)doi:10.3201/eid2706.210465
21. Charlotte N. High Rate of SARS-CoV-2 Transmission Due to Choir Practice in France at the Beginning of the COVID-19 Pandemic. *J Voice*. Dec 23 2020;doi:10.1016/j.jvoice.2020.11.029
22. Shi J, Wen Z, Zhong G, et al. Susceptibility of ferrets, cats, dogs, and other domesticated animals to SARS–coronavirus 2. *Science*. 2020:eabb7015. doi:10.1126/science.abb7015
23. Kim YI, Kim SG, Kim SM, et al. Infection and Rapid Transmission of SARS-CoV-2 in Ferrets. *Cell host & microbe*. Apr 5 2020;doi:10.1016/j.chom.2020.03.023
24. Kutter JS, de Meulder D, Bestebroer TM, et al. SARS-CoV and SARS-CoV-2 are transmitted through the air between ferrets over more than one meter distance. *Nat Commun*. Mar 12 2021;12(1):1653. doi:10.1038/s41467-021-21918-6
25. Klompas M, Baker MA, Rhee C, et al. A SARS-CoV-2 Cluster in an Acute Care Hospital. *Ann Intern Med*. Feb 9 2021;doi:10.7326/M20-7567

Last Updated May 7, 2021

Content source: [National Center for Immunization and Respiratory Diseases \(NCIRD\), Division of Viral Diseases](#)