Modeling the risk of airborne transmission of respiratory viruses in microgravity

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Rationale and objectives: Airborne transmission is one of the most efficient ways respiratory viruses such as SARS-CoV-2 spread. Aboard the International Space Station (ISS), this route is especially worrying: in microgravity, the tiny virus-laden particles people exhale do not settle to the floor as they do on Earth but instead linger in the air for very long periods, raising the chance that others breathe them in. The danger is compounded by the limited medical facilities on a spacecraft and by evidence that spaceflight weakens astronauts' immune systems—dormant viruses such as herpesviruses are known to reactivate in space. Yet how respiratory viruses actually spread under these unusual conditions has remained largely unstudied. This work set out to quantify the airborne transmission risk of respiratory viruses in microgravity, using SARS-CoV-2 as a case study, and to test how well countermeasures such as facemasks and air filtration would perform.

Summary: The researchers adapted a validated terrestrial tool, the COVID Airborne Risk Assessment (CARA), to represent a spacecraft cabin by changing how gravity affects the settling and suspension of exhaled particles. The model follows the whole transmission chain—from an infected crew member emitting virus-laden particles, through their dispersal in the cabin air, to inhalation by a susceptible crew member—and estimates the resulting probability of infection. Using conditions matching an ISS module, the team compared Earth's gravity with microgravity and tested several countermeasures: facemasks worn by the emitter, the recipient, or both, and continuous HEPA air filtration. To probe how a spaceflight-weakened immune system might change the picture, they also modeled scenarios with 4-, 8-, and 16-fold higher viral shedding, drawing on documented herpesvirus reactivation in astronauts, alongside scenarios of boosted host immunity.

Outcome: In microgravity, exhaled particles stayed aloft dramatically longer—a 3-micrometer droplet that settles within about 1.5 hours on Earth could in principle remain airborne for over 17 years—driving airborne virus concentration up roughly 286-fold and pushing the one-week infection probability to about 78%, nearly double the value on Earth. Countermeasures helped substantially: having the infectious person wear a mask was the most effective masking strategy, and continuous HEPA filtration (at five air changes per hour) cut airborne virus concentration by 99.79%, lowering infection probability to 25%, below the Earth baseline. However, when a weakened immune system was modeled as higher viral shedding, risk rose sharply—an 8-fold increase pushed infection probability to 87%—and the countermeasures became less effective on their own. The strongest protection came from combining strategies: boosting host immunity together with HEPA filtration lowered infection probability by up to about 14%, underscoring that a layered defense—clean air, masks, and strong immunity—is key to protecting crew on long missions.

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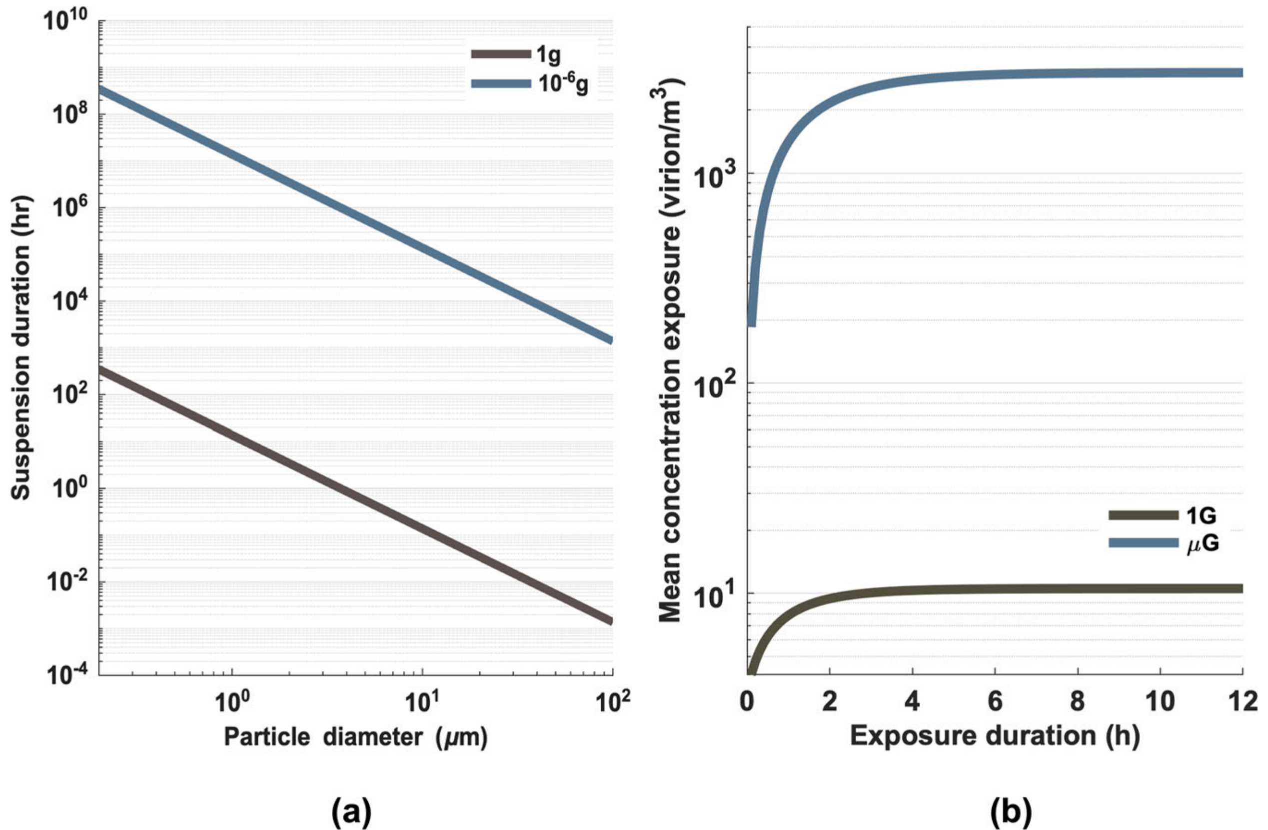
Related SDGs goal: 3. Good health and well-being.



Graphical summary: Impact of microgravity on respiratory droplet behavior and airborne viral concentration. **(a)** Suspension time of exhaled respiratory droplets under Earth's gravity (g = 9.8 m/s^2) versus microgravity (g = 9.8 × 10^{-6} m/s^2), as a function of particle diameter, showing how dramatically longer particles stay airborne when gravity is reduced. **(b)** Build-up of SARS-CoV-2 concentration over time in an enclosed cabin holding one infected person, comparing Earth's gravity (1G) with microgravity (μG).

Related publication:

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