Respiratory Protection and Influenza-laden Cough Aerosols in a Simulated Medical Examination Room

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The Problem: Pandemic Influenza and Healthcare Workers

- During an influenza pandemic, the demands on healthcare workers will be extremely high.
- Healthcare workers will face much greater exposure to influenza than will the general public.
- How should these workers be protected from influenza infection during a pandemic?
- Is influenza spread by inhaling small airborne droplets produced during coughing, sneezing, speaking and breathing? Or is it only spread by direct contact and by large visible drops?
- Do healthcare workers need to wear respiratory protection during a pandemic?
- If so, what kind? When does it need to be worn?

Our Approach: A simulated medical examination room

- NIOSH has constructed a test chamber to simulate a coughing patient in an examination room with a healthcare worker.
- The room includes a coughing simulator, a breathing simulator, airborne particle (aerosol) counters and aerosol samplers to collect particles for analysis.
- The coughing simulator can cough aerosols containing influenza virus into the room.
- The breathing simulator can be outfitted with different types of personal protective equipment (PPE) such as surgical masks, filtering-facepiece respirators, powered air-purifying respirators (PAPRs) and face shields.
- The breathing simulator can be moved to different locations in the room.
- The room temperature, humidity and ventilation rate can be controlled.
- The room has an HEPA filtration system to clear particles from the air and a germicidal UV light to disinfect the air.

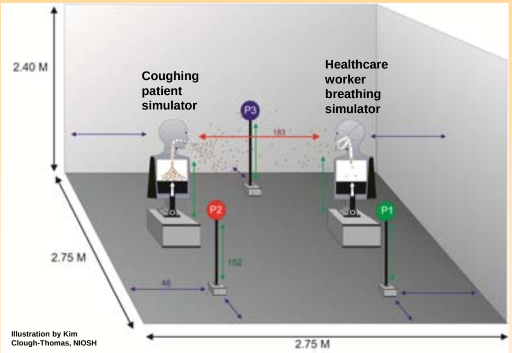
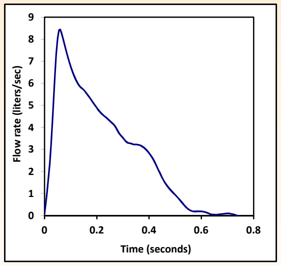


Illustration by Kim Clough-Thomas, NIOSH

Respiratory protective device	Abbreviation	N95?	Surgical mask?
Kimberly-Clark Technol 47080	KCS470	no	yes
Kimberly-Clark Technol 47625	KCS476	no	yes
Prohibit Surgical Mask	PRS	no	yes
3M Model 8210	3MN8210	yes	no
Moldex Model 2201	MON2201	yes	no
Gerson Model 1730	GRN1730	yes	no
3M Model 1860S	3MN1860S	yes	yes
3M Model 1870	3MN1870	yes	yes
Kimberly-Clark Technol 46827	KCN468	yes	yes

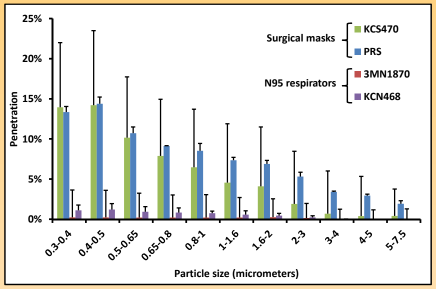
- This table shows the surgical masks, N95 respirators and combination N95 respirator/surgical masks that have been tested thus far.
- For most experiments, each mask and respirator was sealed to the head form with adhesive to simulate the best possible fit.
- Sealing the mask or respirator also compensates for the fact that the surface of the head form is rigid, not pliable like human skin, and it is thus more difficult to form a seal.



- This plot shows the flow rate over time of an experimental cough.
- This flow profile is based on measurements of coughs from 17 healthy adult subjects in a previous study at NIOSH (WT Goldsmith et al. A system for analyzing aerosols produced by humans during respiratory maneuvers. *Ann Biomed Eng* 29 Sup 1: S141, 2001).
- The experimental cough has a 2.1 liter volume with a peak flow of 8.45 liters/sec and a mean flow of 2.64 liters/sec.
- The breathing simulator has a sinusoidal flow rate of 32 liters/min for most experiments; 85 liters/min is used for some experiments to study the effect of breathing rate.

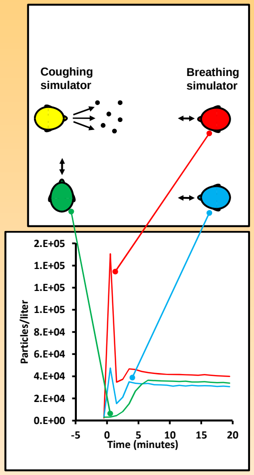
For more information, contact Dr. William G. Lindsley, wlindsley@cdc.gov.

Results: Masks & N95 respirators vs. particle size

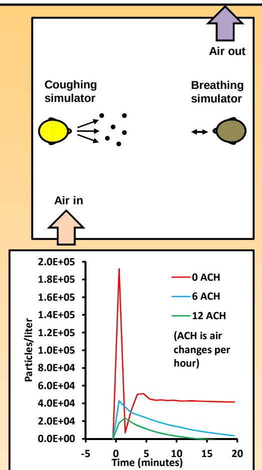


- This plot shows the percentage of particles of different sizes that reach the mouth while the simulated worker is wearing typical surgical masks (KCS 470 and PRS), and typical medical N95 respirators (3MN1870 and KCN468).
- For these experiments, the masks and respirators were sealed to the breathing simulator head form.
- Masks and respirators block large particles most effectively, and their filtration efficiency decreases as particle size decreases down to 0.3 µm.
- Even when it is sealed to the face, a surgical mask still allows about 14% of the smallest airborne particles to be inhaled.
- In practice, face seal leaks around the edge of a surgical mask lead to much worse filtration performance.
- On the other hand, an N95 respirator provides excellent protection if it forms an adequate seal with the face.

Results: How cough aerosol particles spread in a medical examination room

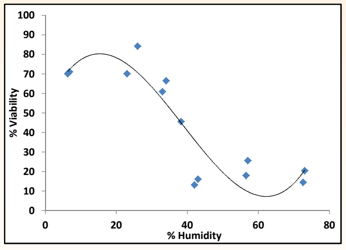


- This plot shows the concentration of airborne particles from a single cough at different locations in the exam room over time.
- In the first few minutes after a cough, the cough particles travel across the room in a concentrated plume, causing a sharp spike in exposure for anyone directly across from the patient.
- However, within about 5 minutes, the cough particles spread throughout the room, and everyone inside is exposed to them regardless of their location.

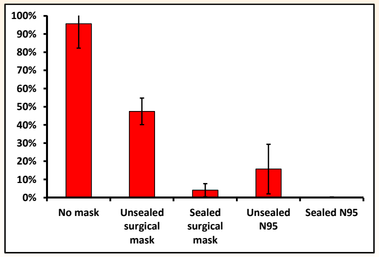


- Room ventilation can reduce, but not entirely eliminate, exposure to airborne particles.
- This plot shows the effect of different amounts of ventilation on exposure to cough particles.
- The air inlet was located in the ceiling while the outlet was near the floor.
- The ventilation reduced the initial cough aerosol peak by sweeping the particles sideways away from the breathing simulator.
- Ventilation also gradually reduced the particle concentration in the room.

Results: Protection from Airborne Influenza Virus



- Air humidity has been shown previously to have a substantial impact on the viability of airborne influenza virus.
- In our experiments, influenza virus was coughed into the simulated exam room and collected for 1 hour.
- The influenza virus in the airborne particles survived much better at low humidities than it did at higher humidities.
- This may explain in part why influenza seasons occurs in the winter in the US, since indoor humidities tend to be much lower.



- This plot shows the amount of live influenza virus collected inside the mask or respirator compared to the outside.
- An unsealed surgical mask (as normally worn by healthcare workers) allowed almost half of the airborne virus to be inhaled.
- A sealed surgical mask blocked much of the virus, showing that most of the influenza virus admitted by the unsealed mask entered through face seal leaks rather than through the mask itself.
- An N95 respirator with face seal leaks also admitted a substantial amount of virus, demonstrating the importance of proper fit when using a respirator.
- An N95 respirator with a good seal around its edges blocked almost all of the influenza virus from being inhaled.

Our Publications

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