Protection Against Airborne Respiratory Viruses

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Background

- Millions have lost their lives to respiratory viruses such as influenza
- Epidemics of varying severity occur worldwide each year.
- Novel Influenza strains are the latest threats
- Current Recommendations for Influenza (CDC, WHO):
  - Droplet/Contact Precautions since Influenza transmission has been thought to primarily occur by large-particle respiratory droplets.
  - Only during aerosol-generating procedures such as bronchoscopies are fit-tested respirators required.
  - New Influenza Strains – airborne plus contact plus eye-protection

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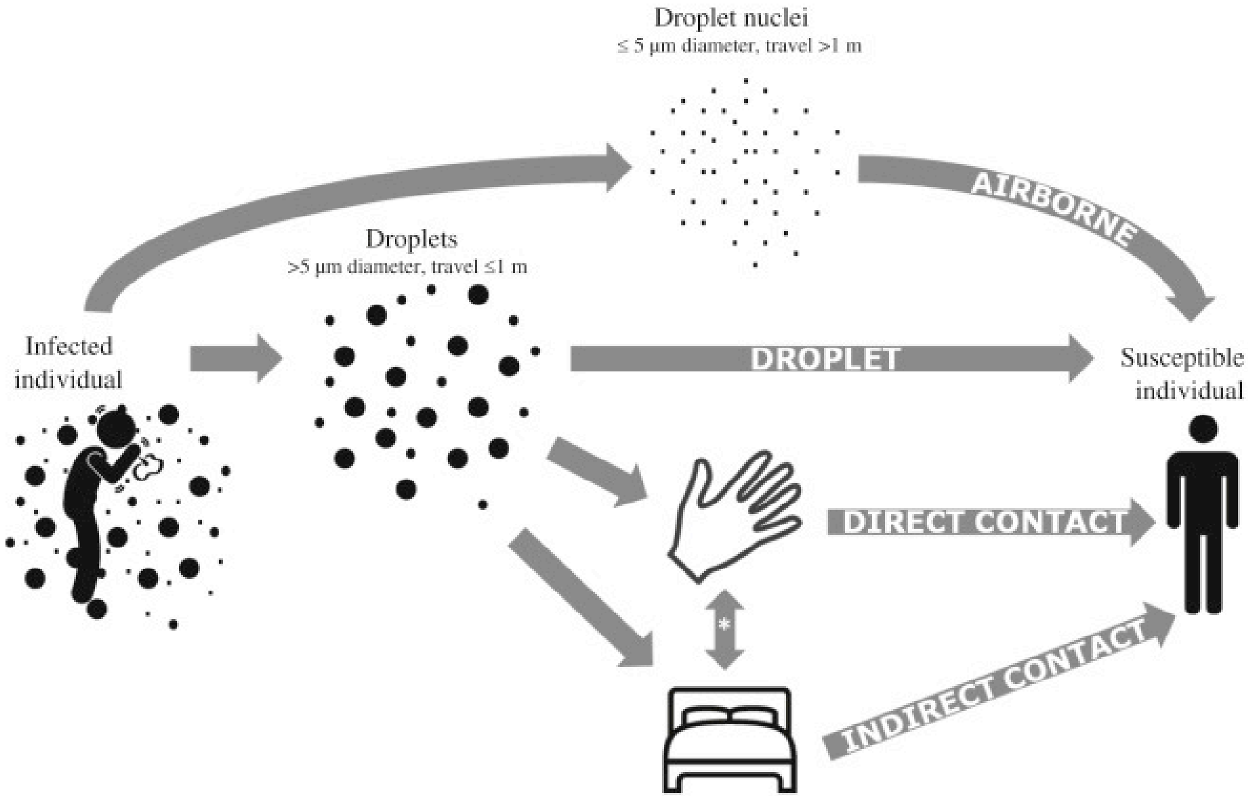
Transmission Routes



* Transmission routes involving a combination of hand & surface = indirect contact.

Transmission routes: droplet, airborne, direct contact, and indirect contact.[1]

1. Otter JA et al. Transmission of SARS and MERS coronaviruses and influenza virus in healthcare settings: the possible role of dry surface contamination. Journal of Hospital Infection, Volume 92, Issue 3, 2016, 235–250

Exposure Risk

- Evidence of Influenza Aerosols - Burden:
  - Blachere et al.: up to 16,278 viral RNA copies/m^3 air (Infl. A)[1]
  - Lindsley et al.: 0.7 – 75.4 pg RNA/m^3 air (Infl. A)[2]
  - Tseng et al.: 167.6 – 5,020 viral RNA copies/m^3 air (Infl. A)[3]
  - Leung et al.: 94 – 383 viral RNA copies/m^3 air (Infl. A)[4]
  - Yang et al.: 1.6 + 0.9 x 10^4 viral RNA copies/m^3 air[5]
  - Bischoff et al.: 0.9 - >200 viral RNA copies/m^3 air[6]

Alford et al.: HID_{50} 0.6-3 $TCID_{50}$ = RNA load of 90-1,950 viral copies[7]

1. Blachere et al. CID 2009:48: 438-440; 2. Lindsley et al. CID 2010;50: 693-698; 3. Tseng et al. J Environ Health 2010; 73: 22-28; 4. Leung et al. Plos ONE 11(2): e0128669. doi:10.1371/jounral.pone.0148669; 5. Yang W. et al. J.R. Soc. Interface (2011) 8, 1176-1184; 6. Bischoff WE et al. J Infect Virol 2013;207:1037-46; 7. Alford RH, et al. Proc Soc Exp Biol Med 1966;122:800-4

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Exposure Risk

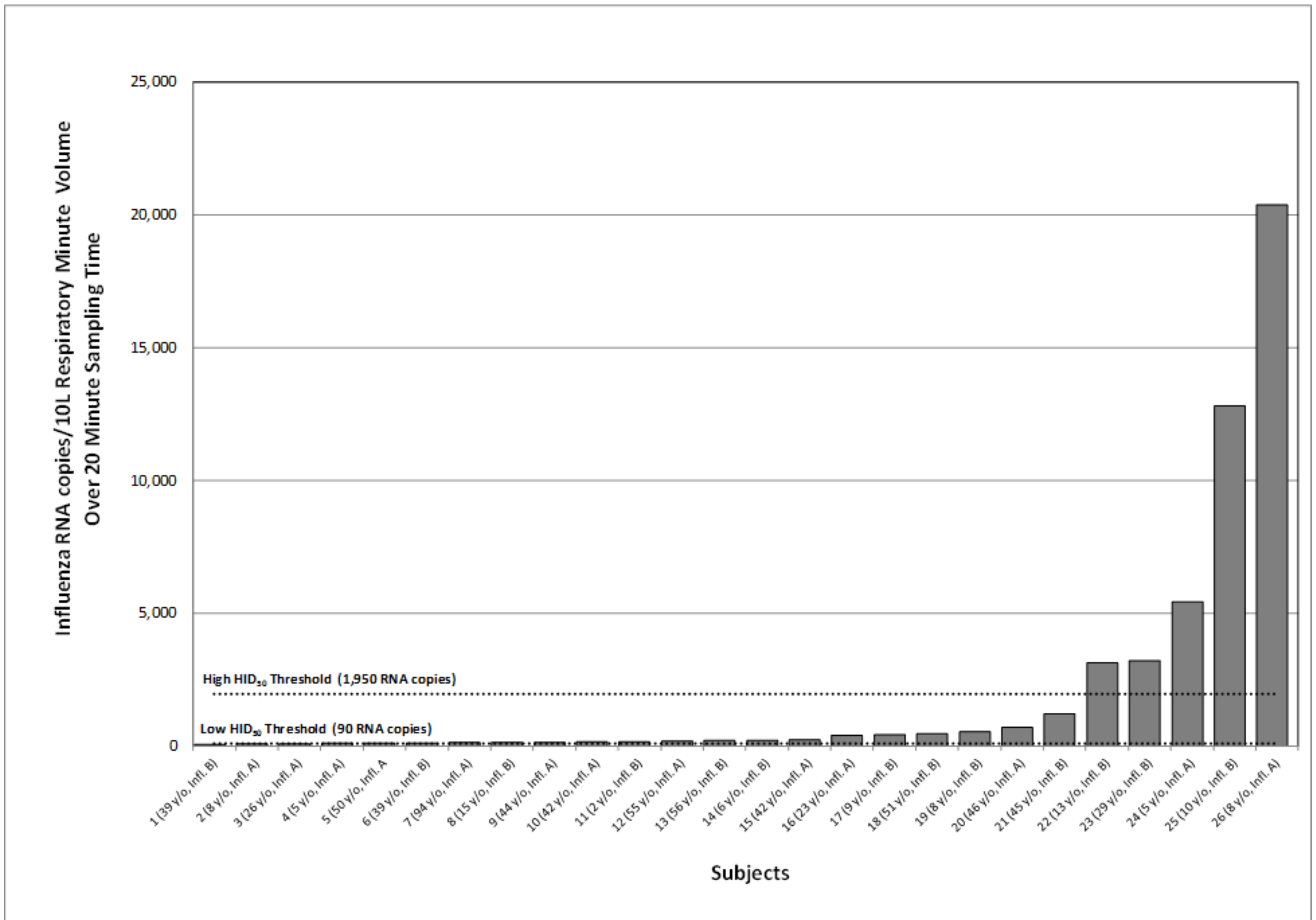
- Evidence of Influenza Aerosols – Particle Size:
  - Blachere et al.: 53% in particles < 4.1 µm (Infl. A)[1]
  - Lindsley et al.: 53% in particles < 4.1 µm (Infl. A)[2]
  - Yang et al.: 64% < 2.5 µm (Infl. A)[3]
  - Bischoff et al.: up to 89% < 4.7 µm (Infl. A and B)[4]

Viral recovery higher in larger particle sizes (93% > 4 µm vs. 7% in 1-4 µm particles)[5]

1. Blachere et al. CID 2009:48: 438-440; 2. Lindsley et al. CID 2010;50: 693-698; 3. Yang W. et al. J.R. Soc. Interface (2011) 8, 1176-1184; 4. Bischoff WE et al. J Infect Virol 2013;207:1037-46; 5. Leung et al. Plos ONE 11(2): e0128669. doi:10.1371/jounral.pone.0148669;

Exposure Risk

- Infectious Heterogeneity (super-emitters)



Bischoff WE, et al. Exposure to influenza virus aerosol during routine patient care. JID 2013;207:1037-1046

Exposure Risk

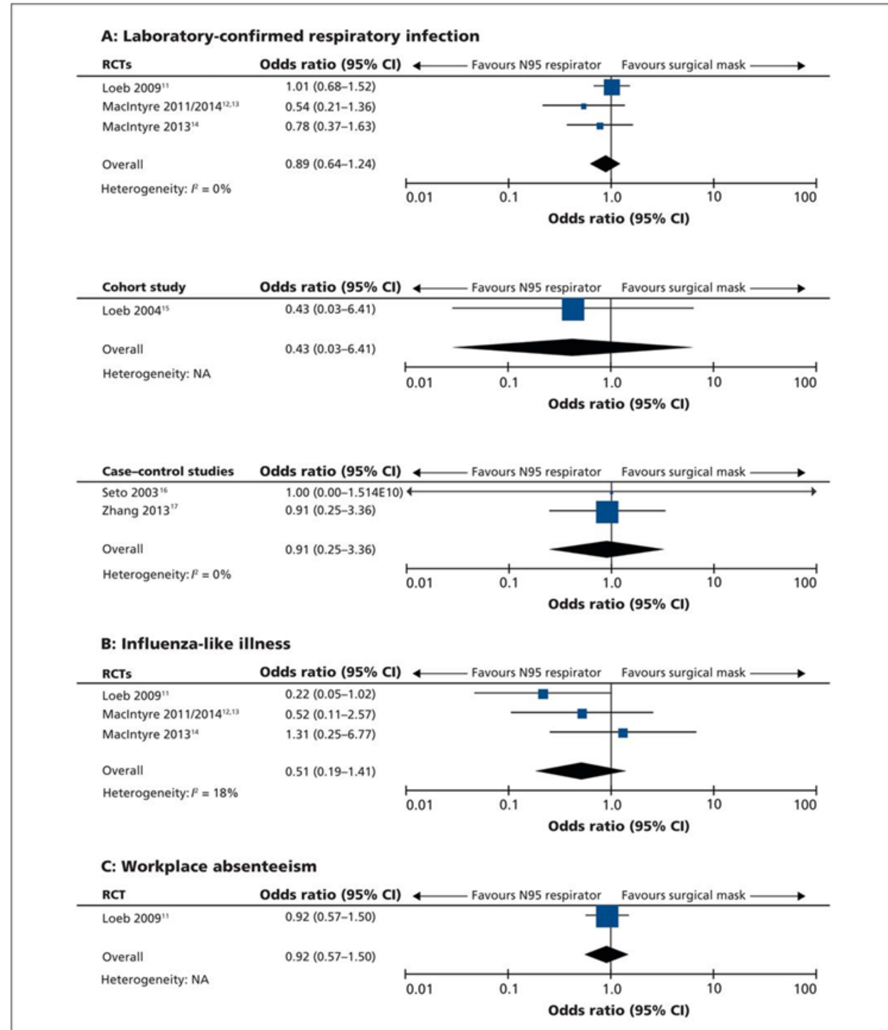
- Entry Routes:
  - Mouth, Nose:
    - Surgical/Medical Masks:
      - Oberg et al. – nine masks tested, none with adequate protection[1]
      - Aiello et al., MacIntyre et al. – no clear protection in community or health care settings[2,3]
      - Bischoff et al. – no protection against LAIV[4]
    - Patients:
      - Johnson et al.[5] – no difference in mask type in preventing aerosol particles emission in patients
      - Diaz et al.[6] – bench model demonstrating successful deflection of exhaled particles

1. Oberg T, Brosseau LM. Surgical mask filter and fit performance. Am J Infect Control. 200836:276-82
2. Aiello AE, et al. Facemasks, hand hygiene, and influenza among young adults: a randomized intervention trial. PLoS One. 2012;7(1):e29744.
3. MacIntyre CR et al. Face mask use and control of respiratory virus transmission in households. Emerg Infect Dis. 2009;15:233-41
4. Bischoff WE et al. Transocular entry of seasonal influenza-attenuated virus aerosols and the efficacy of n95 respirators, surgical masks, and eye protection in humans. J Infect Dis. 2011;204:193-9.
5. Johnson DF, et al. A quantitative assessment of the efficacy of surgical and N95 masks to filter influenza virus in patients with acute influenza infection. Clin Infect Dis. 2009;49:275-7.
6. Diaz KT, Smaldone GC. Quantifying exposure risk: surgical masks and respirators. Am J Infect Control. 2010;38:501-8.

Exposure Risk

- Entry Routes – Mouth, Nose

Results of meta-analysis to determine effectiveness of N95 respirators versus surgical masks in protecting health care workers against acute respiratory infection.



Smith JD et al. CMAJ 2016;188:567-574

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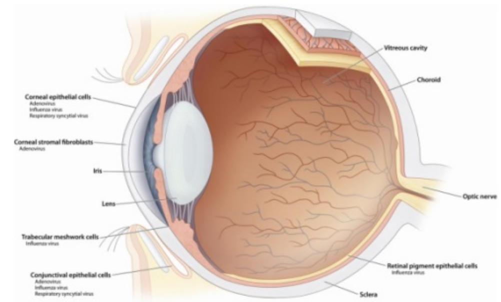
Exposure Risk



- Entry Route:
  - Eyes:
    - Replication of influenza, adenovirus, RSV within ocular tissue[1]
    - Influenza – successful ocular-only aerosol inoculation in ferrets[2],
    - Influenza – trans-ocular entry of seasonal influenza virus in volunteers detected[3]
- Should ocular protection be considered besides respiratory protection?

1. Belser JA, et al. Ocular tropism of respiratory viruses. Microbiol Mol Biol Rev. 2013 Mar;77(1):144-56
2. Belser JA, et al. Influenza Virus Infectivity and Virulence following Ocular-Only Aerosol Inoculation of Ferrets. J Virol. 2014 Sep 1;88(17):9647-54
3. Bischoff WE, et al. Transocular entry of seasonal influenza-attenuated virus aerosols and the efficacy of n95 respirators, surgical masks, and eye protection in humans. J Infect Dis. 2011;204:193-9.

Efficacy of N95 Respirators Against Aerosolized Influenza Virus

[redacted]

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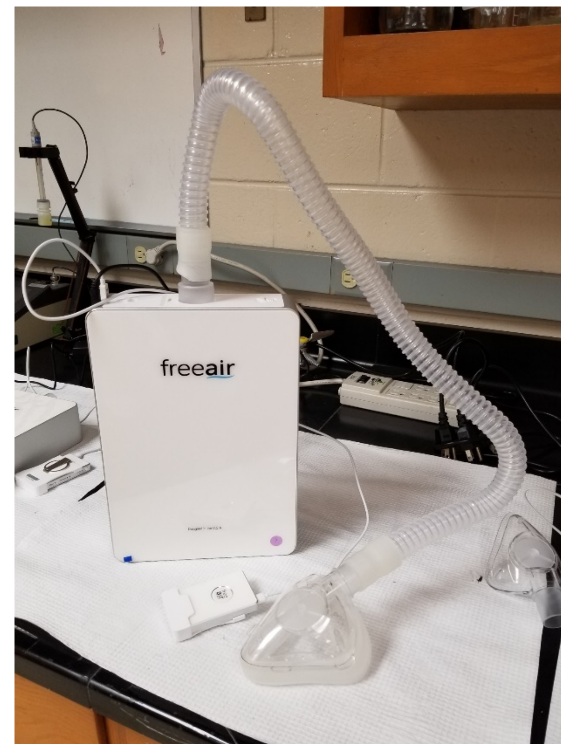
Objective

- To assess the efficacy of a commercially available N95 Respirator mask against a novel half-mask Powered Air Purifying Respirator (PAPR) in a human exposure model.

Methods

- Healthy volunteers randomized to:
  - N95 (Kimberly-Clark N95 particulate filter respirator and surgical mask, Irving, TX)
  - PAPR (Pioneer 300, Celios, Tampa, FL) exposure group
- Qualitative fit-testing (3M, FT-10)
- Negative control by nasal swabs before exposure
- Exposure Agent: Seasonal, cold-adapted, live attenuated Influenza vaccine as exposure agent (LAIV; 2015/16 FluMistTM Quadrivalent, Gaithersburg, MD)
- Participants fitted with disposable gowns, gloves, cap, shoe covers, and air-tight goggles



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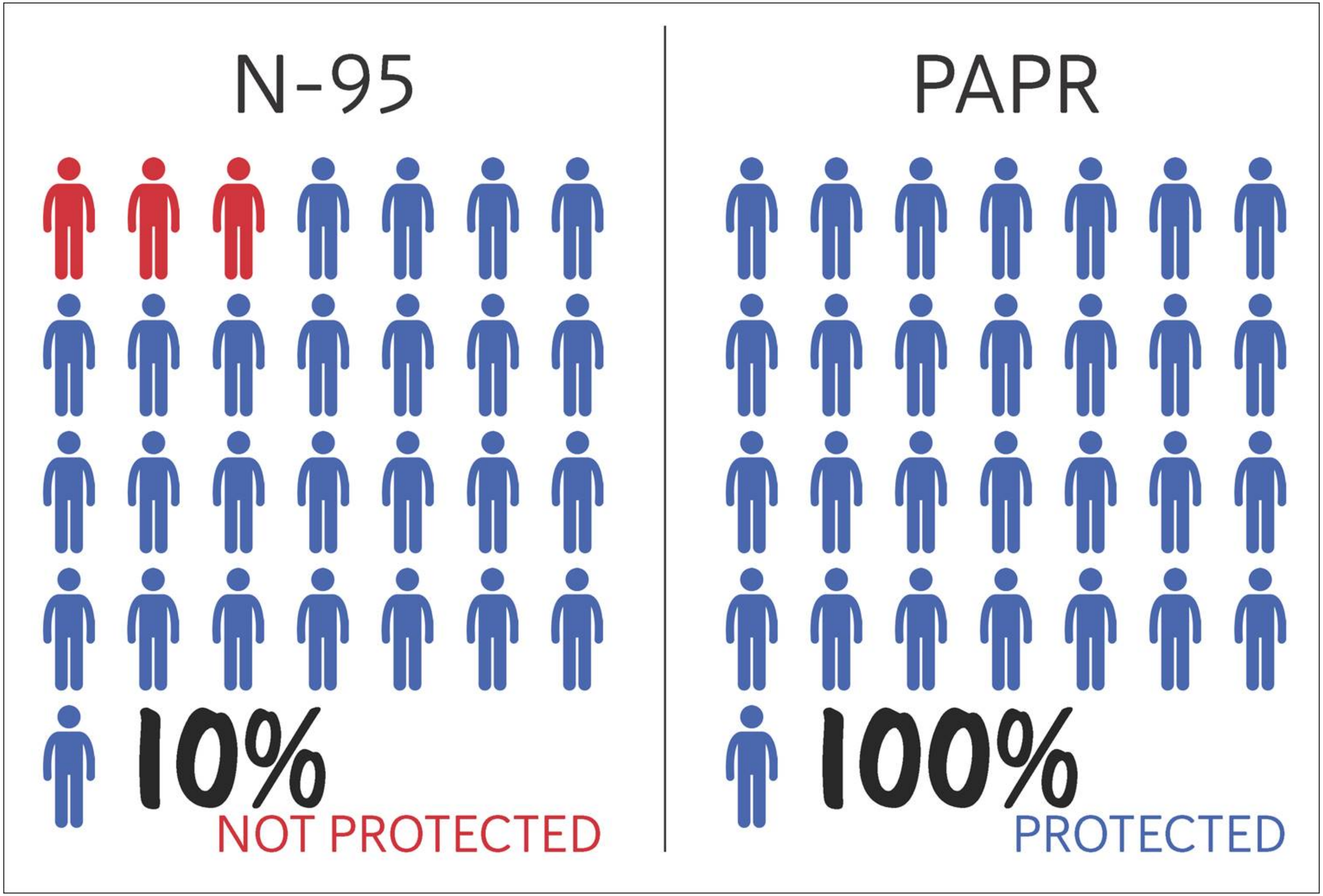
Methods

- Placement in HEPA air filtration exposure chamber
- LAIV aerosolized with nebulizer MQ5800 Airial, Medquip, Bluffon, SC)
- During exposure participants performed a standardized set of movements and reading exercises to mimic normal daily usage
- 20 minute exposure run followed by five minute evacuation run
- Nasal swabs post evacuation run
- qRT-PCR targeting Influenza A strains in LAIV

Results



Results

- For PAPR users no Influenza virus was detected (0%; exact 95% CI, 0-0.12)
- For N95 respirators Influenza virus was detected in 3 out 29 participants (10%; exact 95% CI, 0.02-0.27)
- The three subjects with virus detection included two Caucasian males (ages 31 and 40) and one African American female (age: 23)
- Total RNA copies recovered from the three subjects were 4,745, 5,471, and 65,206 copies (mean: 25,141 copies)
- No adverse events were noted during the trial.

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Conclusion

- Participants wearing the N95 respirator encountered breakthrough events to LAIV in 3 out of 29 cases (10% failure)
- RNA copies recovered all above known HID_{50} for Influenza
- The PAPR completely blocked the transmission of LAIV (100% protection)
- NIOSH assigned protection factor (APF):
  - N95 respirators: APF 10 – match
  - PAPR: APF 50
- Is a 10% failure rate for N95 respirators acceptable?