

Effectiveness Of Various Types Of Face Mask In Preventing Air Borne Diseases

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Abstract

Masks have long been regarded to be an efficient tool for combating with external factors. They are utilized to protect the respiratory system from harmful respiratory droplets and fumes such as viruses and contamination particles. Droplets can be pollutants in the air or infectious aerosolized viruses spread by sick people's coughing and sneezing. Because of the varying sizes, patterns, and characteristics of the droplets, the filtering efficacy of numerous masks against such pollutants tends to vary. As a consequence, the goal is to develop more effective filtration masks to reduce permeability ratios in the most extreme situations. To fully understand this concept, one must first understand the mechanics of airborne particle permeation through masks under various effective environmental factors. The related techniques of aerosol

permeation through masks are described in this paper. The effect of the surroundings on infiltration and construction effectiveness is investigated

Introduction

Due to the impact of the COVID-19 pandemic, there has been an unprecedented surge in global demand for masks. Facemasks currently in use include N95 respirators, surgical masks, medical masks, and non-medical masks (e.g., cloth or cotton masks) (Kim et al., 2022). The items are distinguished by their construction and purpose of use. Medical masks and fabric masks (hereafter "facemasks") were developed to prevent disease transmission from individual to individual, but they are also

frequently used to protect users from potentially infectious fluid spills or sprays. Facemasks are loosely regulated, will not form a barrier over the face, and are available in a variety of styles and materials. A respirator is a face-fitting tool that is characterized and strictly controlled by its filtration capabilities to prevent users from respiratory infections (MacIntyre & Chughtai, 2015).

Face masks are especially effective at both blocking and minimizing the intake of airborne droplets expelled by individuals during ventilatory events; however, effectiveness varies according to the type of mask used. Hui et al. investigated the impact of face masks on the distance covered by airborne particle suspensions during human coughing. Coughing without a mask causes turbulence that carries particles an average of 70 cm from their original location; wearing a surgical mask or an N95 mask reduces this range considerably. Even though the N95 respirator effectively prevented cough bursts from being transferred forward, there was still considerable leaking to the side. Fabric masks were found to be nearly as reliable as medical face masks, while alternatives such as neck gaiters or bandanas offer only marginal protection. Dbouk and Drikakis determined that some vapours travel to greater distances even when a face mask is worn, and that mask effectiveness gradually decreases over successive cough cycles. Verma et al. examined the effectiveness of various brands of face masks in impeding ventilatory jets using a laser sheet to visualize aerosols; wearing a mask significantly reduced the average distance travelled by the jets, though some aerosol leaked from the mask's edges. Kähler and Hain (2020) proposed employing particulate filtration devices in masks to improve their efficacy (0.1 to 2 μm).

According to published studies, N95 masks are successful in minimizing the propagation of suspensions during individual coughs, but their limited supply and high prices during the ongoing pandemic compelled decision makers to turn to other options, such as single- or multilayer surgical masks or handmade alternatives. As the number of layers on a mask increases, breathability decreases. Surgical mask pressure-drop values remain within the ASTM F2100-11 recommended breathability limits. Previous research on surgical face masks has primarily focused on the scattering length of coughing droplets and their leakage from the mask's edges, addressing mainly the smaller vapours (0.1 to 100 μm) that transfer through the mask's porous structure; these studies do not fully address the advancement of particle impedance within the mask itself. In this paper, it is demonstrated that secondary atomization occurs when large droplets collide with single- or double-layer masks, producing much smaller particles that can become aerosolized (Sharma, Pinto, Saha, Chaudhuri, & Basu, 2021).

TYPES OF FACE MASK

We will look at the many types of disposable face masks and determine which are suitable for which situations in this review article.

Fabric Masks

Fabric masks must meet certain standards in order to be a feasible alternative for transmission prevention. Fabric face masks should: (1) have no gaps and fit properly over the nose, mouth, and chin; and (2) be formed of an intricately woven fabric that does not permit light through when held up to the sun, and should have a wire that sits over the bridge of the nose. Because of these requirements, not all masks found in stores are guaranteed to provide full protection — a mask must be made of a fabric that conforms to the contours of the face and has more than one layer to create an adequately thick barrier.

Fabric masks serve as a protective barrier to droplets released into the air, but their efficacy is defined by the structure, texture, and fabric components used, as illustrated in Figure 1. Human emulators are used to estimate the distance droplets travel when

speaking and coughing while wearing and without wearing different kinds of masks. All types of masks have been reported to reduce the potentially contaminated range of environmental aerosols surrounding a source. According to observational data, a multilayer mask has higher filtering effectiveness when used with a good fit (Krishan et al., 2021).

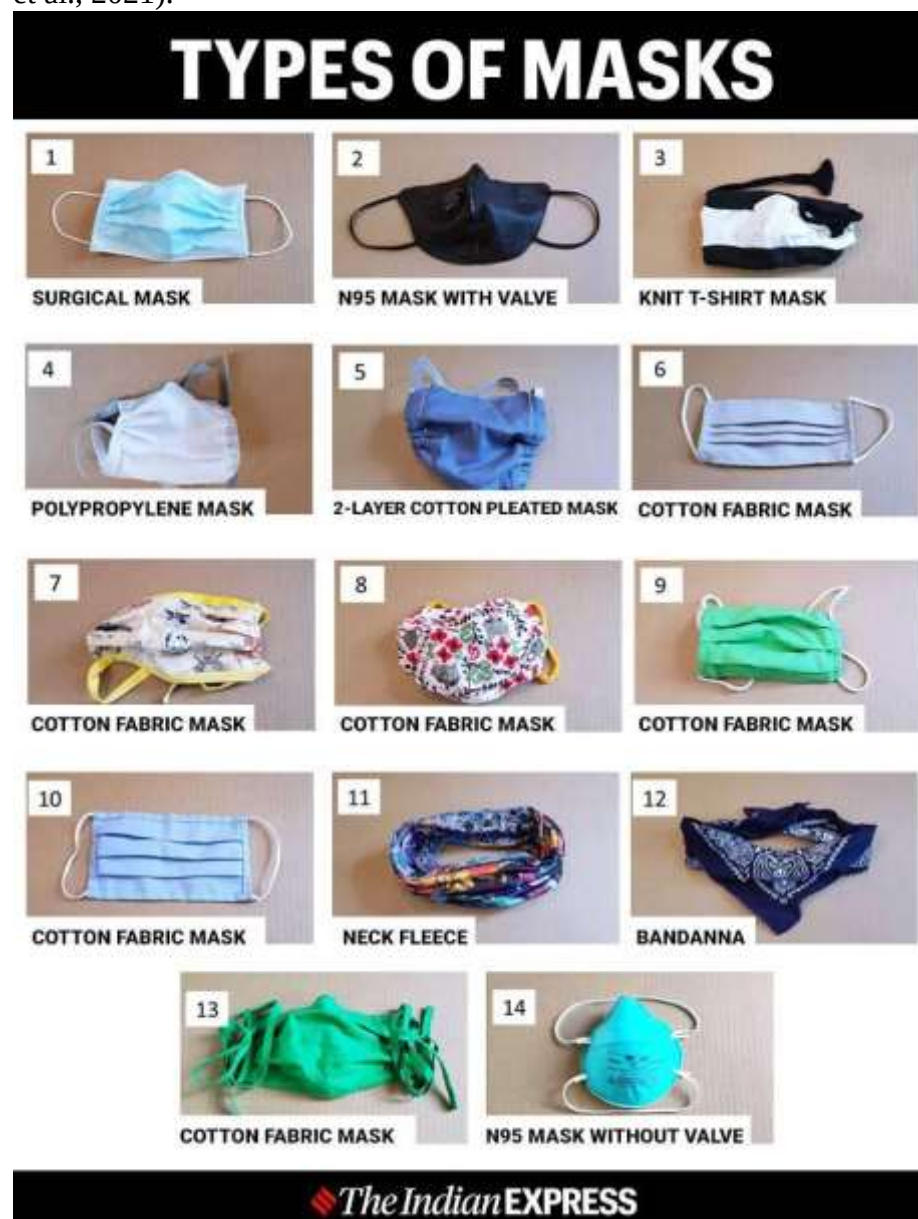


Figure 1. Different types of fabric mask (source: The Indian Express)

Viral Filtration Efficiency

According to the research, cloth masks have a viral filtration efficiency (VFE) of more than 50% against aerosol particles with a mean range of 6.0 μm , rising to 63% against aerosol particles with a mean range of 2.6 μm — representing the bulk of aerosol particles capable of reaching the lower respiratory system. A cloth fabric mask with a pocket for the insertion of a portion of vacuum-cleaner bag or a dry baby wipe performed much better than plain fabric masks, achieving VFE values above 97%. Masks made of two layers of replaceable shopping bag (nonwoven polypropylene) and one layer of cotton, or of a 100% cotton outer layer with a poly-membrane centre layer and an organic-cloth inner lining, were also highly effective, per Victorian DHHS guidelines.

The N95 and surgical masks had comparably high bacterial filtering effectiveness (around 99%). Cotton masks may be a suitable replacement for medical masks for

persons with respiratory illnesses living in air-conditioned environments, and because they are washable and reusable, healthy individuals in the community may wear them regularly. During a pandemic, when disposable medical masks may be scarce, conventional fabric materials can be a viable alternative for healthy individuals (Ho, Lin, Weng, & Chuang, 2020).

The mask filtration testing described in the source material followed the ASTM F2101-14 Standardized Test Procedure for assessing Bacterial Filtration Efficiency (BFE), modified to use bacteriophage MS2 (27 nm diameter) instead of *Staphylococcus aureus*, since MS2 is roughly 2–3 times the size of the SARS-CoV-2 virion and offers a more cautious model organism. Masks were exposed to a defined concentration of MS2 viral particles at a fluid velocity within the normal range of human breathing, with the challenge suspension administered at 35 kPa for one minute. Viral droplets that passed through the mask were captured on a six-stage cascade impactor and cultured overnight; positive-hole-adjusted plaque counts were compared to positive and negative controls to calculate VFE at both a coughing-aerosol mean size (6.0 μm) and a lower-respiratory-relevant size (2.6 μm) (Whiley, Keerthirathne, Nisar, White, & Ross, 2020).

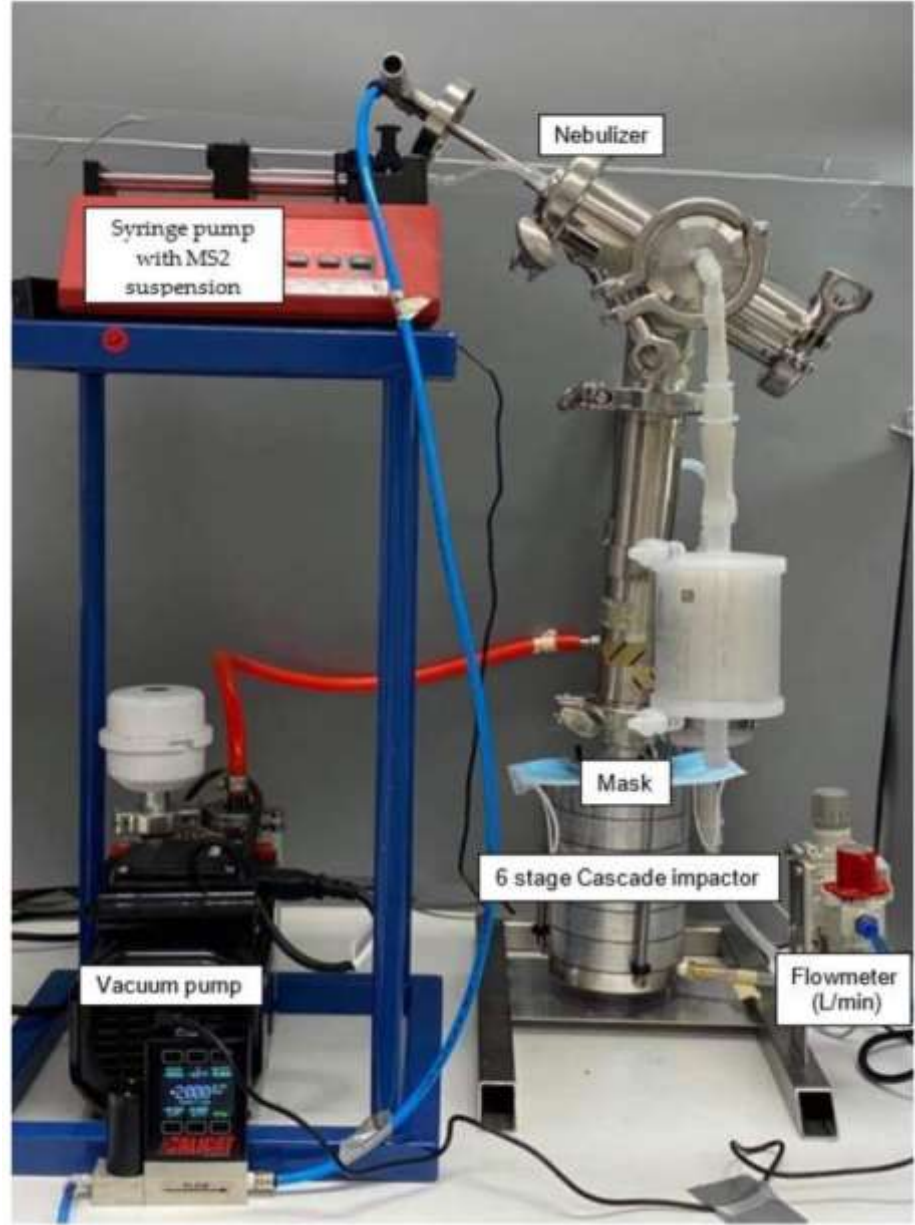


Figure 2. Mask testing rig, set up according to ASTM F2101-14

The table below summarizes the composition, estimated porosity, thread diameter, and thread pitch of several common household fabrics evaluated for mask-making.

Pitch and thread width typically change with weave direction, resulting in observed variance (Konda et al., 2020).

Fabric Name	Composition	Porosity (%)	Thread Diameter (μm)	Thread Pitch (μm)
Cotton Quilt	Two layers of 120 TPI cotton. Filling: ~0.5cm (90% Cotton, 5% polyester, 5% other fibers)	20.1	227	300-400
Quilters Cotton #80	100% cotton	14	270	460-500
Cotton #600	100% cotton	<1	55-75	70-75
Flannel	65% cotton, 35% polyester	15	300-440	500-650
Chiffon	90% polyester, 10% spandex	3	200-250	220-320
Natural Silk	100% silk	1.5	180-260	270-500
Synthetic Silk	100% polyester	3	190-230	440-570
Satin	97% polyester, 3% spandex	11	210	165-520
Spandex	52% nylon, 39% polyester, 9% spandex	6	160-170	200-480
Polyester	100% woven polyester	23	180-200	300-500

Table 1. Composition and structural properties of common mask fabrics (Konda et al., 2020)

Fabric Breathability

Fabric breathability is defined as the ratio of the change in air-flow rate per unit area of fabric to the change in pressure difference across the sample required to induce that flow. Measurements were taken with a plug-flow tube: the sample cloth closed the aperture of the tube, pressurized air was applied, and gauge pressure drove air through the fabric. Because the cross-sectional area of the tube closely matched the sample, the change in flow rate per unit area was equivalent to the change in average flow speed within the tubing, giving breathability as the slope of velocity versus pressure. The relationship between pressure and velocity was found to be highly linear across all samples tested (following Darcy's Law), so breathability was determined from the slope of a least-squares fit line. Porosity had a considerable impact on breathability in domestic textiles (correlation coefficient $r = 0.929$ for woven fabrics, $r = 0.894$ for knit fabrics). Knit materials with the same porosity were found to be more permeable than woven ones, likely because knit fabrics stretch more under air pressure. Droplet-blocking efficiency was found to be anti-correlated with breathability ($r = 0.820$): a single layer of T-shirt fabric had good permeability but low filtering efficacy (median 83.1%), while a second layer substantially improved filtering efficacy (median 98.1%) at the cost of lower permeability. Droplet filtering efficacy was likewise anti-correlated with porosity ($r = 0.796$ for woven, $r = 0.822$ for knit fabrics).

Aerosol Filtering Mechanisms of Household Fabric

Most single-layer household textiles can successfully block both lower- and higher-impact droplets, with filtering efficacy comparable to two- or three-layer medical masks while retaining or enhancing breathability. Medical masks are typically made of three layers of hydrophobic fabric (non-woven polypropylene), which do not absorb water, whereas most household textiles are hydrophilic and do absorb water. High-speed video of aerosols passing through a surgical mask and one or two layers of T-shirt fabric showed that large droplets strike and press against the fabric at an average speed of about 17.1 m/s, stretching the material; some droplets squeeze through small pores and break into smaller particles as surface tension is overcome and kinetic energy is dissipated by the fabric's deformation.

Droplets passing through a single layer of T-shirt fabric exited at a much lower mean speed (9.6 m/s) than their initial speed, meaning any droplets reaching a second layer arrive with significantly less energy — explaining why a two-layer T-shirt sample allowed relatively few droplets to escape (median blocking efficacy 98.1%, minimum 94.0%). This velocity reduction by the first layer, combined with trapping of lower-momentum particles by the second layer, appears to be a key mechanism behind the strong particle-filtering efficacy of multi-layered household fabrics.

Permittivity Analysis at Home

As specialized laboratory equipment for testing breathability and droplet filtration is not accessible to the general public, a simple water-permeability test was developed for comparing fabric options at home. Premoistened fabric samples (excluding surgical masks, which cannot be wetted) were secured over the mouth of a water-filled container with a small pressure-equalizing hole, and the time taken for the water to drain, T-drain, was recorded; $1/T$ -drain provides an indication of moisture absorption. A strong association was found between $1/T$ -drain and breathability ($r = 0.943$) and, consistent with the inverse relationship between permeability and droplet-blocking efficiency, between $1/T$ -drain and aerosol filtering effectiveness ($r = 0.828$). This simple test — using only a water bottle, a rubber band, and a timer — allows consumers to compare relative filtration performance across household fabric options, though it should be used only for relative comparisons rather than to determine absolute breathability or efficacy values (Aydin et al., 2020).

Surgical Facemask

Public and professional interest in infectious-disease propagation has spurred efforts to safeguard both patients and clinicians against cross-contamination. Face masks have been recommended by both the ADA and the CDC to minimize the prevalence of respiratory problems and to avoid particle inhalation. Aerosol particles produced during procedures such as dental work comprise soluble and insoluble particles smaller than $50\text{ }\mu\text{m}$, along with potentially hazardous microbes and biological fluids. Particles larger than $50\text{ }\mu\text{m}$ are normally ballistic and are not absorbed into airborne aerosols; particles in the $20\text{--}50\text{ }\mu\text{m}$ range may be absorbed into aerosols and are typically screened by the nostrils on inhalation, while particles in the $5\text{--}20\text{ }\mu\text{m}$ range tend to accumulate in the bronchi and bronchioles due to inertial impaction.



Figure 3. Surgical mask

The mucociliary escalator and macrophage phagocytosis eliminate insoluble particles accumulated in the upper airway, while smaller particles can reach the non-ciliated alveolar and terminal bronchial regions and remain airborne for several hours, making them available for inhalation. In vitro experiments on masks made of woven synthetic fibres show that a fabric layer of about $5\text{ }\mu\text{m}$ thickness is particularly effective at blocking particle and germ infiltration. It has also been established that droplets tend to follow the path of least resistance during exhalation, leading to peripheral leakage around the mask's border rather than passage through the mask membrane itself —

meaning the mask can act more as a diverter of exhaled air than as a complete filter if the peripheral seal is imperfect.

Face Masks' Effectiveness in Preventing Airborne Contaminant Inhalation

Droplets produced during dental operations have been linked to upper respiratory tract infections, tuberculosis transmission, microbial transfer, and pneumoconiosis development. A high-speed vacuum system is the first line of defense in minimizing aerosol spread into the dental setting. Medical face masks are a significant technique for preventing cross-contamination from airborne pollutants; in vitro experiments have demonstrated that improved mask fabrics composed of synthesized interwoven fibres are effective at inhibiting fine-particle penetration, though several investigations have found that masks may exhibit marginal leakage that allows contaminated air to bypass the filtering material, and that peripheral seal quality varies with individual facial structure.

Studies comparing masked and unmasked conditions have found that conventional masks permitted a similar number of recovered spores as the unmasked comparison group in some settings, suggesting that traditional face masks are not always effective and that the mask's imperfect fit to facial contours, along with the mask fabric itself impeding airflow, may explain the marginal leakage observed. Design features such as manual nose knots and flexible metal nose bands help improve facial adaptation and reduce peripheral leakage (Pippin, Verderame, & Weber, 1987).

Surgical Face Masks and Reduction of Bacterial Contamination

Using a face mask has been shown to dramatically decrease microbiological load on surfaces near the upper airway. In one study simulating conditions typical of subarachnoid block procedures, microbial spores were recovered on more than half of the agar plates exposed when the operator was not wearing a medical mask, whereas a new face mask nearly eliminated contamination, with only a slight and statistically negligible rise after fifteen minutes of wear. Bacterial meningitis following a subarachnoid block is uncommon but has been reported on occasion, sometimes involving organisms of minimal pathogenicity such as alpha-hemolytic streptococcus associated with dental flora, underscoring that ordinarily innocuous organisms can cause CSF infection when normal protective barriers are breached.

It was found that simple paper or fabric masks were less effective, while large, soft, pleated masks made of any suitable material performed best; the better masks remained efficient bacterial filters for up to eight hours, though a small increase in agar contamination was observed after fifteen minutes of wear. It may therefore be prudent to use a new surgical mask for every procedure (Philips, Fergusson, Armstrong, Anderson, & Wildsmith, 1992).

Surgical Masks to Protect Health Care Workers

Surgical masks have long been used to protect health-care personnel — physicians, nurses, and paramedics — from ordinary influenza and other illnesses. These masks have not been shown to be totally effective, however, since filtering performance has varied widely, with aerosol infiltration ranging from about 4% to 90%, and because the mask's exposed edges allow leakage following a sneeze or forceful cough (Gupta, 2011).

To reduce the risk of pathogenic microbial spread via contaminated protective equipment, an antibacterial nanoscale coating using titanium-dioxide and silver-nitrate nanoparticles has been developed. Silver and its compounds are known for broad-spectrum antibacterial properties and are widely used as coatings on medical devices, though bacterial resistance has emerged from extensive, unregulated use; combining silver with titanium dioxide, which emits microbiocidal hydroxyl radicals under UV exposure, aims to limit the growth of silver-resistant microbes while

enhancing the antibacterial protection of nanoparticle-coated masks (Li, Leung, Yao, Song, & Newton, 2006).

Permeation of Aerosols via Medical Masks

Medical masks protect patients from illness caused by germs or viruses expelled by medical personnel through sneezing, coughing, speaking, or ordinary breathing, which can lead to post-operative infections. Concerns about respiratory protection for both patients and operating-room staff have grown with the use of newer laser surgical procedures and the emergence of new infections, since procedures such as CO₂ laser surgery and electrocautery can generate aerosols and “laser plume” particles well below one micrometre in size — smaller than typical droplets produced by the human body — prompting reassessment of surgical mask filtering efficiency across a wide range of particle sizes.

A widely used bacterial filtration efficiency (BFE) test, first devised by Green and Vesley in 1962 and still used in modified form today, measures mask retention of an aerosolized *Staphylococcus aureus* challenge. However, sub-micrometre filtration performance does not necessarily predict performance against larger particles, and vice versa, meaning BFE testing with large droplets may not accurately reflect a mask's ability to block microscopic bacterial or viral particles (Chen & Willeke, 1992). The overall protection afforded by a surgical mask depends both on the quantity of aerosol passing through the filter media and on the degree of peripheral leakage around the mask's edges; because most medical masks in current use are made of less-effective filtration material and available test methods cannot distinguish perimeter leakage from filter penetration, this remains a key limitation of surgical mask protection.

N95 Respirator

An N95 respirator is a type of respiratory protection gear designed to give a very tight face fit while efficiently filtering airborne particles, with edges meant to form a seal around the mouth and nose. Surgical N95 respirators are a form of N95 Filtering Facepiece Respirator (FFR) commonly used in hospital settings.



Figure 4. N95 mask



Figure 5. Special type of N95 mask

KN95 masks come in a variety of styles and, unlike N95 FFRs, are typically certified to a Chinese standard rather than the NIOSH N95 FFR certification criteria, though they have comparable filtering efficacy with a maximum inward-leakage restriction of 8% (durtha & Naqvi, 2021).

The Efficiency of N95 Respirators Against Influenza

A meta-analysis found no significant difference between N95 respirators and medical masks in preventing laboratory-confirmed influenza, laboratory-proven respiratory viral infections, or influenza-like illness, although N95 respirators showed antimicrobial colonization resistance in laboratory testing. Results were broadly consistent across community and hospital settings for confirmed influenza and respiratory virus infections, though sensitivity analysis showed some inconsistency for laboratory-proven respiratory illness more broadly. Study limitations noted included potential bias from difficulty blinding participants to mask type, a limited number of community-focused studies, reliance on RCTs drawn from existing systematic reviews, and the possibility of publication bias (Chandini Raina MacIntyre et al., 2017).

The meta-analysis concluded that using N95 respirators instead of medical masks was not associated with a lower incidence of laboratory-confirmed influenza, and recommended against routine N95 use for the general public and non-high-risk health workers without direct contact with influenza patients (Long et al., 2020). Guidelines on respiratory protective equipment for severe respiratory illness remain inconsistent across organizations (Smith et al., 2016), though other research indicates that N95 respirators can more effectively reduce aerosol transmission than medical masks under laboratory conditions (Radonovich, Simberkoff, & Perl, 2020).

N95 and KN95 Face Mask Structural Elements

The N95 respirator is a filtering facepiece respirator (FFR) with at least 95% filtration effectiveness that meets NIOSH certification, typically built from three key layers: an outer layer, a filter layer, and an inner layer. The filter layer is about three times thicker than the inner or outer layers and accounts for more than half of the total layer thickness; its smaller fibre diameter provides superior mechanical filtration through smaller pore sizes, and its much higher dipole charge density provides substantial additional electrostatic filtration.

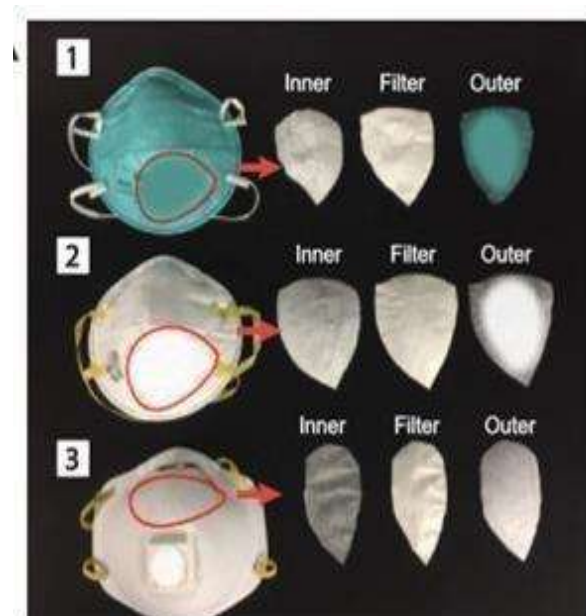


Figure 6. Structural components of an N95 facemask

KN95 respirators, which adhere to Chinese regulations rather than NIOSH certification, include four layers — outer, filter, cotton, and inner — with a filter layer that is markedly thinner than that of an N95 respirator and a supplemental “cotton layer” between the inner and filter layers making up around 70% of the respirator's thickness. Testing with and without the filtration layer showed that filtering effectiveness dropped by more than 90 percentage points when the filter layer was removed in both N95 and KN95 masks, confirming that the outer and inner layers mainly protect the filtration layer and remove larger contaminants, while the filter layer itself provides the great majority of filtering effectiveness. Despite their thinner and less-charged filtration layers, EUA-approved KN95 respirators demonstrated comparable filtration efficiency to N95 respirators, potentially because of a narrower average hole size (Yim et al., 2020).

SUMMARY

Three kinds of facemasks — N95 respirators, non-woven material similar to medical masks, and home-made dual-layered cotton textiles — were evaluated for particle filtration and filtration power loss at different flow rates, before and after sterilization, using both ambient and laboratory-produced aerosols. Differential pressure increased with flow rate, confirming that breathing through a facemask becomes more difficult at higher respiratory flow, though pressure drops remained within permissible inhalation and exhalation resistance limits. The filtration efficiency of medical masks was found to be comparable to that of certain double-layer cloth masks, while filtration efficiency for both fabric and medical masks improved as particle size increased above the most-penetrating particle size, though efficiency was generally lower at higher flow rates.

Sterilization method affected filtration performance differently across mask types: gamma sterilization reduced the filtration efficiency of N95 masks at the most-penetrating particle size, while autoclaving improved the efficiency of cloth masks but could degrade elastic bands and fibres with extended steam exposure. N95 filtration efficiency was largely preserved after hydrogen peroxide vapour sterilization and after dry-heat sterilization for shorter durations, making these preferable options for reprocessing where reuse is necessary. Overall, while surgical masks are somewhat more efficient than double-layer fabric masks, the gap can be narrowed with three-layer cotton masks of high thread count, supporting cloth masks as a reasonable option for the general public when combined with proper hand hygiene, correct fit, and regular disinfection (Kumar, Bhattacharjee, Sangeetha, Subramanian, & Venkatraman, 2020).

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