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The Utility of Masks as Protection Against Viral Respiratory Illnesses in Healthcare Workers

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Protection Against Viral Respiratory Illnesses

in Healthcare Workers

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"There is no such thing as a self-made man.
You will reach your goals only with the help of others."
~ George Shinn

Abstract

The COVID-19 pandemic is sweeping the globe, increasing the mortality and morbidity rates in areas that are experiencing outbreaks and putting excess pressure on healthcare systems. Healthcare workers (HCWs) have risen to the challenge of caring for those infected during the COVID-19 pandemic, putting themselves in high-risk situations. Current Center for Disease Control and Prevention (CDC) guidelines require HCWs to follow isolation precautions based on transmission routes to protect themselves from becoming infected. For COVID19, the recommendation for HCWs is continuous wearing of a surgical mask during a shift and donning an N95 mask while in direct contact with patients who have an active COVID-19 infection. Unfortunately, despite proper PPE utilization and CDC guidelines, HCWs represent a small portion of the total number of people hospitalized due to COVID-19. The purpose of this literature review is to identify evidence supporting CDC guidelines directed at protecting HCWs from respiratory viral infection and any gaps that may exist which may leave HCWs vulnerable. This literature review took place from September of 2020 to March of 2021, assessed 54 total studies, and identified 16 studies meeting requirements for this review. High level evidence from quasi-experimental studies looking at filtration efficacy of different masks and randomized control trials comparing rates of viral symptoms and viral infections in HCWs wearing different masks were prioritized for this review. While the evidence is inconsistent it still supported current CDC guidelines. The N95 masks showed better filtration efficiency at all particle sizes when compared to all other masks while surgical masks demonstrated better filtration efficiency at all particle sizes when compared to a variety of cloth masks. The N95 masks also reduced rates of viral symptoms and viral infections when compared to surgical masks while surgical masks reduced rates of viral symptoms and viral infections when compared to a variety of cloth masks. Ultimately, N95 and surgical mask use in healthcare settings to provide respiratory

protection to HCWs is supported by current evidence while use of cloth masks of a variety of materials in a healthcare setting is grossly ineffective at providing respiratory protection for HCWs. This review recommends enhancing current CDC transmission-based precaution guidelines by including requirements for patients to don surgical masks while under investigation for respiratory viral infections or with active respiratory viral infections. Including language within the guidelines to require HCWs to don N95 masks during identified aerosol generating procedures is also recommended to maximize protection against small respiratory aerosols. Ongoing HCW education regarding the effectiveness of masks and the current evidence supporting mask use in different situations is also recommended. Lastly, ongoing research into the effectiveness of masks, targeted mask us, and the impact of fit testing N95 masks is highly recommended.

TABLE OF CONTENTS

Introduction

Introduction to Inquiry

The SARS-CoV-2 pandemic that has swept through the global population since the end of 2019 has pressured healthcare systems across the planet, including in the United States. This pressure has drawn the attention of the public to the imperfections that plague the current system more than ever: lack of financial support, poor preparation to properly care for the communities they serve during surges in number of people requiring care, and an inability to provide healthcare workers (HCWs) the resources they need to stay protected from work-related organisms. The spotlight has never shown more brightly on the significance of personal protective equipment (PPE; Cohen & Rodgers, 2020). One of the essential pieces of PPE for protection from respiratory pathogens is the face mask. The topic of face masks has reignited an old controversy that has roots going back to the turn of the 20th century when face coverings were first suggested by Johannes von Mikulicz (Matuschek et al., 2020). During this time period, research into the possibility that germs were being spread by the respiratory system became popular, and von Mikulicz was the first to suggest using a single gauze over the mouth in the operating room. This idea was met with harsh criticism from established surgeons, referencing their years of experience to denounce the use of these gauze masks as unnecessary and uncomfortable. Nurses started wearing masks and gauze face coverings well before surgeons did. In the 1940's, washable and sterilizable face coverings started to gain acceptance internationally (Matuschek et al., 2020). Hospitals began developing their own policies and practices in terms of infection prevention and it was not until 30 years later when the Centers for Disease Control (CDC) and Prevention made official recommendations on the use of face masks for HCWs. The

CDC recommendations helped standardize isolation and infection prevention guidelines across American health care systems to protect HCWs from viral infections.

Background to Inquiry

Viral respiratory tract infections are one of the leading causes of mortality and morbidity worldwide and are responsible for an enormous economic and disease burden (Kutter et al., 2017). Pandemics are large-scale outbreaks of infectious disease, typically with a viral etiology, that has spread over several countries or continents, usually affecting a large number of people (CDC, 2012). Pandemics are responsible for increasing the mortality and morbidity rates in areas that are experiencing outbreaks (Madhav et al., 2017) Due to increased global travel and integration of people between different countries, the risk for viral pandemics is on the rise. Outbreaks and pandemics occur when a host who is infected with a virus spreads the virus to other hosts, unimpeded.

The chain of infection spread includes a source, a susceptible person, and transmission (CDC, 2016). The source of infection is the infectious agent, such as a virus or bacteria. Viruses are unique microorganisms as they are subcellular and thus rely heavily on host cells for survival and replication (Baron et al., 1996). The makeup of the virus is uncomplicated at first glance, consisting of either RNA or DNA strands and a protein coating that provides the virus with protection. This protein membrane also allows the virus to attach to the membrane of a host cell (Baron et al., 1996). Once attached, the virus utilizes the host cells own machinery for energy and replication, allowing the virus to spread and infect other host cells (Baron et al., 1996). Sources may be found in a variety of people within the healthcare setting, including patients, HCWs, or visitors.

For an infection to occur, a source must enter a susceptible individual's body, invade tissues, and begin to multiply, causing a system reaction from the host (CDC, 2016). People who are stressed or acutely ill may become more susceptible to infection. People who are taking medications which compromise the immune system such as steroids and cancer fighting drugs will be more susceptible. Other people who may have increased susceptibility include those who have been admitted into the hospital and require invasive lines such as central venous or foley catheters (CDC, 2016).

Sources of infection cannot independently move themselves, therefore they must rely on other methods to move from one susceptible person to another. The transmission of a virus between hosts occurs via several routes and is impacted by a multitude of external variables to (Kutter et al., 2017). The first route of viral transmission includes contact transmission, which either occurs directly from individual to individual or indirectly from a contaminated object to an individual, also known as a fomite. The second route of viral transmission is through the air, either in droplets or via aerosols. Droplets are typically larger than five micrometers and travel short distances, usually less than one meter. Droplets are dispersed from infected individuals by coughing and sneezing. Viral transmission occurs when these droplets are deposited on the mucous membranes and the upper respiratory tract of non-infected individuals. Aerosols are smaller particles, less than five micrometers, and are dispersed over larger distances, greater than one meter, and also linger in the air for a significant amount of time (Kutter et al., 2017). Viral transmission occurs when these aerosols are inhaled by non-infected individuals and become deposited along the respiratory tract.

Many of the more common viruses seen in the hospital setting are transmitted via multiple routes. Rhinovirus, for example, appears to be infective by inhalation of aerosols and from contact with fomites, but not infective from sneezes or coughs (Kutter et al., 2017). The transmission of influenza A, long thought to be strictly via droplets, has become a hot topic in recent years as more studies have discovered influenza RNA in aerosols more than one meter away from infected individuals. Prior to the onset of the current SARS-COV-2 pandemic, beta coronaviruses such as SARS-COV-1 spread rapidly in hospitals via severely ill patients undergoing aerosol-generating procedures such as intubation, positive pressure ventilation, and nebulizer administration. However, surfaces in infected patient's rooms routinely tested positive for the virus and observation studies found close proximity to infected individuals to be a risk factor for infection, suggesting droplet transmission. The transmission of a virus from individual to individual is complex and infections may occur due to multiple different routes. It is essential to understand the complex nature of viral transmission in order to protect HCWs from viral infections. Findings of previous studies have been conflicting regarding the effectiveness of current guidelines.

Purpose of Inquiry

The CDC released its first manual on infection prevention and isolation recommendations for hospitals in 1970 (Segal, 2016). The recommendations were simple at first, focusing on protective gowns and gloves for HCWs high risk exposure situations and was quickly adopted by 93% of US hospitals. Facemasks were not included in the CDC recommendations until updated guidelines were released in 1985 over the concern of mucous membrane exposure to the blood borne pathogen human immunodeficiency virus (HIV; Segal, 2016). The National Institute of Occupational Health and Safety, NIOSH, is a subgroup within the CDC and was founded in 1970 to help ensure safe and healthful working conditions by providing research, information, education, and training in the field. NIOSH is responsible for conducting research and making recommendations for the prevention of work-related injury and illness and has been integral in the CDC's development of respiratory protection guidelines for HCWs (CDC, 2018a). In 2007, the CDC issued new guidelines regarding isolation precautions in an ongoing effort to prevent the spread of contagious pathogens in healthcare settings (CDC, 2019). These new guidelines focused on transmission-based precautions and created the three primary isolation precautions widely used today: contact, droplet, and airborne isolation; see table 1.

Contact isolation guidelines are designed to protect HCWs from pathogens which are spread through direct person-to-person contact or exchange of body fluids and do not pertain to respiratory protection of HCWs and is therefore not included in this review. Droplet and airborne isolation precautions were created as respiratory protection for HCWs (CDC, 2019).

Droplet isolation guidelines are designed to protect HCWs from pathogens which are spread through close contact with larger respiratory secretions. Patients in droplet precautions are provided with private rooms and require HCWs to wear an isolation gown and wear a surgical mask with a shield for eye protection upon entering the patient's room. The surgical mask provides protection against larger droplets and does not effectively filter smaller particles such as fumes or vapors (CDC, 2018b). Some pathogens which can be spread via droplets include influenza, meningitis, or the mumps (CDC, 2019).

Airborne isolation guidelines are designed to protect HCWs from pathogens which are contained in smaller aerosols and remain suspended in the air for larger distances and longer periods of time. Airborne precautions include placing patients in a private room with special air handling and ventilation, cycling the air at least six times per hour through a HEPA filtration system. Healthcare personnel are also required to be trained and fit-tested for N95 mask or respirator use while caring for patients in airborne precautions. The N95 is a mask designed to protect the HCW from inhaling airborne particles such as vapors, and infectious agents associated with inhaling small and large droplets (CDC, 2018b). Examples of pathogens which can be spread through the airborne route include varicella virus, smallpox, measles, and SARS-COV-1 (CDC, 2019).

Question

The guidelines put forth by the CDC are routinely evaluated and updated based on the current available evidence. The current guidelines have been in place since 2007. The COVID-19 pandemic has created a public controversy over masking in the community setting. However, HCW's represent 6% of the total number of people hospitalized due to COVID-19 despite proper PPE utilization (Kambhampati, 2020). This data suggests a critical need to evaluate the effectiveness of the current masking guidelines. In HCWs caring for hospitalized adult patients with upper respiratory viral infections under respiratory precautions, does wearing N95 masks decrease rates of acquired infections in HCWs when compared to surgical masks or cloth face coverings?

Method to Inquiry

An integrative literature review process was utilized to discover evidence necessary to answer the clinical question which is the focus of this project. This method of inquiry requires a comprehensive review of studies and research within the current literature to evaluate the strength of evidence supporting the current guidelines, gaps in the current evidence that are open for further research, and any potential areas with weak evidence that would necessitate updates to the guidelines.

Literature Review

Introduction

The primary search for this literature review took place between September and December of 2020. Several investigative strategies emerged from the primary search, driving a secondary search which took place from January to February of 2021. One of the investigative strategies found throughout multiple studies focused on material analysis; comparing the filtration efficiency between materials commonly used to make commercial or homemade face masks to healthcare quality face masks such as surgical masks and N95s. A second investigative strategy was derived from studies focused on comparing the presence of symptoms or laboratory confirmed viral illness in HCWs after wearing a variety of face masks.

Several themes became apparent while studies were reviewed. The first theme that emerged indicated that cloth masks were significantly less effective at particle filtration than surgical masks and surgical masks were significantly less effective at particle filtration than N95 masks. Another theme present within the literature is that cloth masks may actually become a reservoir for viral transmission, particularly if worn for a longer duration of time. A third theme noted in the studies provided evidence that the smaller the particle, the higher rates of particle penetration throughout all mask types. A final theme identified N95 respirators as being significantly more effective than surgical masks at preventing respiratory illness in HCWs while cloth masks may actually increase the risk of infection.

Search Strategy

An exhaustive review of current literature was completed, utilizing several search engines during the process (Table 2). Search engines included: Cochrane Library, Google Scholar, PubMed, and CINAHL. Guiding the review were several key words including respiratory protection, masks, healthcare workers, and viral transmission. During the secondary search period a higher focus was placed on the key word “filtration” to cue in on studies researching fabric filtration rates. For this search, comparison of common fabrics to medical grade masks was crucial to understand how current medical grade masks compare to homemade masks. The reference list for selected studies were also utilized as a resource to identify similar studies focused on masks and respiratory protection for HCWs. Multiple studies were excluded during the search for not meeting the strict criteria of this literature review. Studies which did not focus on HCWs were excluded. Studies which did not emphasize viral respiratory illness were also excluded.

Selection Criteria

Selection criteria required studies to be within the last 15 years, from 2005 to 2020. The initial search prioritized Randomized Control Trials (RCTs) based on Ackley, Swan, Ladwig, and Tucker's Level of Evidence (Table 3; 2018), categorizing such studies as providing a high level of evidence (level II). The secondary search yielded multiple quasi-experimental studies, which are considered to be level III evidence and were selected based on their focus on smaller respiratory particles and whether or not there were comparisons to medical grade masks within the study. Abstracts were reviewed to determine if studies met criteria for inclusion, including study type and study purpose. The level of evidence associated with the selected studies includes: eight RCTs (level II), seven quasi-experimental (level III).

Appraisal and Themes

Appraisal of the identified literature was completed. Initial focus was on the comparison of filtration efficiency between materials commonly used to make homemade masks and medical grade. Next, the literature appraisal focused on the real-world application of mask filtration efficiency. These studies compared and analyzed rates of symptoms and confirmed viral illness in HCWs who wore different face masks. Appraisal of selected studies included identifying significant statistical power (greater than 80%) and adherence to mask wearing guidelines per study methodology.

Several themes became apparent while studies were reviewed. The first theme that emerged indicated that cloth masks were significantly less effective at particle filtration than surgical masks and surgical masks were significantly less effective at particle filtration than N95 masks. Another theme present within the literature is that cloth masks may actually become a reservoir for viral transmission, particularly if worn for a longer duration of time. A third theme noted in the studies provided evidence that the smaller the particle, the higher rates of particle penetration throughout all mask types. A final theme identified N95 respirators as being significantly more effective than surgical masks at preventing respiratory illness in HCWs while cloth masks may actually increase the risk of infection.

Material Filtration Efficiency

One strategy used to determine the utility of face masks as protection against viral respiratory illnesses in HCWs was to determine the filtration efficiency of the varying types of materials commonly used to make commercial and homemade masks. The first theme identified from the evidence indicated that N95 masks provided better filtration of particles than surgical masks while surgical mask provided better filtration of particles than the materials used for commercial and homemade masks (Asadi et al., 2020; Davies et al., 2013; Lee et al., 2008; Milton et al., 2013; Rengasamy et al., 2010; Zuo et al., 2013). This theme helped to clarify how well different materials filtered out small particles.

Each RCT used a variety of mask materials for their experiment. Davies et al. (2013) and Rengasamy et al. (2010) experimented with various materials ranging from 100% cotton T-shirts to towels and compared filter efficiency with surgical masks (Davies) and N95 masks

(Rengasamay, 2010; Table 5). Asadi et al. focused primarily on masks made from 100% cotton T- shirts and paper towels while comparing their filter efficiency with several models of surgical masks and vented vs. unvented N95 masks (Table 5). The filtration efficiency of common mask material was higher in the Davies et al. study when compared to the penetration rates of common mask material in Rengasamy et al. The Davies et al. and Rengasamy et al. studies indicated a significant difference in particle penetration when common mask materials were compared to N95 masks and surgical masks. This information is visually demonstrated in table 6a which compares particle penetration between mask types and shows that the N95 mask and surgical masks are better at filtration than common mask materials.

Each research study utilized similar methods to obtain their data, utilizing an apparatus which pushes nebulized aerosols through a desired mask material in an environmentally controlled setting. Filter efficiency was determined by testing particle quantity prior to the aerosols hitting the mask and again after the aerosols pass through the mask. Researchers used this information to determine either a filtration efficiency rate (Davies et al.) or a particle penetration rate (Rengasamy et al., 2010; Asadi et al., 2020). While these results have opposing perspectives, they both ultimately provide the same information regarding the effectiveness of the mask at blocking particles. Asadi et al. (2020) used similar methods to test masks. However, filter efficiency was measured by comparing rates as particles per second which penetrated the material rather than a percentage of particles which penetrate the mask. Asadi et al. showed an increase of 384% of particle emission when a single layer mask made from a 100% cotton T-shirt was worn but particle emission rates were significantly reduced when wearing an N95 or surgical mask. Asadi et al. also investigated the impact specific activities had on particle emission and discovered that particle emission rates were still reduced while wearing either an

N95 or surgical mask while talking, coughing, or chewing gum. However, particle emission rates increased while wearing a single layer mask made from a 100% cotton T-shirt and performing tasks such as talking, coughing, or chewing gum. All three studies concluded that masks made from commonly found fabric material are significantly inferior at filtering particles when compared to healthcare quality surgical and N95 masks.

Since CDC guidelines restrict mask use in healthcare settings to either N95 masks or surgical masks for direct patient care, Lee et al. (2008) and Zuo et al. (2013) prioritized comparing the filtration efficiency of masks, see table 5. These two studies used differing methodology to compare the effectiveness of N95 and surgical masks at filtering out particles. Lee et al. utilized an apparatus that size selectively measures the concentration of particles in a preset range. The size range for this study was from 0.04 µm to 1.26 µm, representing the average size of airborne viruses. Zuo et al. used a similar methodology to the Lee et al. study, measuring both small and large particles on the inside and the outside of the masks and determining the rate of particle penetration to determine filtration efficiency. Both of these studies provide evidence which supports N95 masks as providing superior filtration efficiency when compared to surgical masks.

Yet another study sought to investigate surgical mask filtration efficacy by detecting the RNA of influenza that pass through the mask to determine effectiveness as viral source control (Milton et al., 2013). Study data suggests that surgical masks nearly eliminated viral RNA detection overall with a significant 3.4-fold reduction of viral copy number in the exhaled aerosols (Milton et al., 2013). This evidence helps support the use of surgical masks as respiratory protection for HCWs.

The underlying theme that N95 mask material provides better filtration of particle penetration than surgical masks while surgical mask material provides better filtration of particle penetration than masks made from an assortment of common materials is strongly supported by the evidence (Table 5; Asadi et al., 2020; Davies et al., 2013; Lee et al., 2008; Rengasamy et al., 2010; Zuo et al., 2013). However, surgical masks have been shown to provide significant protection against infectious viral copies despite being less efficient than the N95 counterpart (Milton et al., 2013). This strong evidence should be considered while creating guidelines to support respiratory protection for HCWs and encourage an approach leaning heavily towards N95 mask use during high-risk exposure events, surgical masks during standard risk exposure events, and masks made from cloth or other common fabric material as a last approach to protect HCWs.

Cloth Masks as Reservoirs for Viral Transmission

One interesting theme identified in the current literature on filtration efficiency of various mask types was that cotton masks may actually be reservoirs for viral transmission. One focus of the Parlin et al. (2020) study was identifying whether common mask making materials were hydrophilic (“loves water”) or hydrophobic (“dislikes water”). The methodology of this portion of the study included depositing water droplets on the surface of different mask materials and measuring the contact angle. Assuming a hydrophilic state, the material would absorb the droplet thereby reducing the contact angle away from 90 degrees. In contrast, assuming a hydrophobic state, the material would not absorb the droplet, increasing the contract angle of the droplet towards 90 degrees. The Parlin et al. study provides evidence that popular mask material such as cotton and polyester are hydrophilic with rapid changes in droplet contact angle away from 90 degrees indicating near instant absorption. This evidence should be considered in mask selection for HCWs as viral particles are transported via moisture-based aerosols and droplets, indicating that masks made from cotton and polyester fabrics would readily absorb viral containing droplets, becoming reservoirs for viruses. As previously discussed, per NIOSH and the CDC, masks are primarily a source control, preventing ill individuals from transmitting pathogens to others. The evidence provided by Parlin et al. calls into question the ability of masks made from cotton and polyester to perform that task sufficiently.

In addition to the evidence showing that masks made from cotton and polyester are reservoirs for viruses, Asadi et al., (2020) investigated the impact specific activities had on particle emission. The Asadi et al. study found that activities such as talking, coughing, and chewing gum increased the shedding of micron-scale particles (0.3 µm to 20 µm) from cotton and paper towel masks, but no increase in N95 or surgical masks was identified. The researchers then compared these findings to the quantity of particle emission after manually rubbing the mask material together. They discovered a similar increase in particle emission of the same size range in the cotton and paper towel masks but not the N95 or surgical mask (Asadi et al, 2020). These findings indicate that frictional forces play an integral role in particle emission in masks made from cotton or paper towel.

The studies by Parlin et al., 2020 and Asadi et al., 2020 were independently completed and investigated two different properties of masks. Combined, their results provide worrisome evidence concerning the efficacy of non-medical grade N95 or surgical masks. Parlin et al. 2020 demonstrated that cloth masks made from polyester or cotton were hydrophilic and rapidly absorbed moisture into the material. Asadi et al. 2020 demonstrated that this moisture is significantly more likely to shed in non-medical grade N95 or surgical masks due to frictional forces from activities such as rubbing the mask, talking, coughing for chewing gum. There is strong evidence to support the conclusion that masks made from cotton are reservoirs for viral transmission. For HCWs who regularly perform these basic activities, this evidence supports avoiding cloth masks as a means of high-quality respiratory protection.

Smaller particles Reduce Filtration Efficiency

Several studies were identified as differentiating filtration efficiency of mask material between large and small particulates (Davies et al., 2013; Lee et al., 2008; Milton et al., 2013; Zuo et al., 2013). Lee et al. and Zuo et al. compared N95 masks with surgical masks and their ability to filter particles within a range of sizes. Lee et al. utilized an electrical low-pressure impactor to measure particle concentration in a size-selective fashion. Particle size for this study ranged from 0.04 µm to 1.26 µm. Zuo et al. used a scanning mobility particle sizer to compare the number of particles upstream from the mask to downstream from the mask using nebulized adenovirus and swine flu virus from a range of sizes from 14 nm to 470 nm. Both of these studies provide evidence which indicates both N95 and surgical masks provide improved protection from larger particles with more particle penetration from smaller particles (Lee et al., 2008; Zuo et al., 2013). Davies et al. (2013) utilized bacteria to simulate viral penetration through masks and analyzed the filtration efficiency. *Bacillus atrophaeus* was used to simulate larger particles and had a size range from 0.95 µm to 1.25 µm while bacteriophage MS2 was used to simulate smaller particles and was 23 nm in size. The study results showed that all mask types, including surgical masks, saw a drop in filtration efficiency with the smaller particle size, suggesting that different viruses may penetrate masks at different rates based on their size (Davies et al., 2013). These three studies provide evidence showing smaller particles penetrate in all mask types at higher rates, lowering mask effectiveness against the smaller range of particles (Table 6b).

Milton et al. (2013) took a different approach on analyzing droplet size and investigated how many infectious viral copies could be found on large versus small aerosols after passing through surgical masks. Utilizing volunteers who had tested positive for influenza, the study analyzed the number of influenza RNA strands there were detectable in droplets larger than 5 μm and aerosols smaller than 5 μm. The results showed that there were 8.8 times as many viral copies in the small particle groups compared to the large particle group (Milton et al., 2013). The evidence suggests that surgical masks nearly eliminated viral RNA detection in large particles with a 25-fold reduction in the number of viral copies. Viral copies detected in the fine aerosol fraction saw a 2.8-fold reduction (Milton et al., 2013). This study provides supportive evidence that viruses are present at higher rates in smaller aerosol particles. While surgical masks provided significant protection against droplets of all sizes, there is a significant drop in filtration efficiency as droplet particles get smaller.

When analyzing these studies together, we see strong evidence that masks in general are less efficient at filtering small particles (Davies et al., 2013; Lee et al., 2008; Milton et al., 2013; Zuo et al., 2013) and strong evidence that viral copies are present at higher rates in these smaller particles (Milton et al., 2013). To provide optimal respiratory protection to HCWs, prioritizing masks that maximize filtration efficiency of particle size for each specific organism's size range will be crucial.

Rates of Symptoms and/or Infections

Another method used to determine the utility of face masks as protection against viral respiratory illnesses in HCWs is to compare and contrast the rates of viral respiratory infections in HCWs who wear different types of masks. Eight relevant randomized control trials were identified as comparing mask type and their ability to reduce a variety of viral respiratory illnesses in HCWs. (Jacobs et al., 2009; Loeb et al., 2009; MacIntyre et al., 2011; MacIntyre et al., 2013; MacIntyre et al., 2014; MacIntyre et al., 2015; MacIntyre et al., 2017; Radonovich et al., 2019). These studies generally used similarly defined parameters as primary outcomes. Clinical Respiratory Illness (CRI) was defined as experiencing two respiratory symptoms or one respiratory symptom and one systemic symptom. Influenza like illness (ILI) was defined as fever greater than 38^{o}C plus experiencing at least one respiratory symptom. The last two outcomes investigated within these studies were laboratory confirmed viral (LCV) illness. These studies would randomly assign HCWs to wear a specific mask type during their work shift and have the HCWs document specified symptoms and receive regular viral testing.

According to CDC guidelines (CDC, 2019), mask use in healthcare settings is primarily limited to N95 and surgical mask. Thus, a majority of the RCT studies meeting selection criteria for this review focused on comparing these two types of masks (Loeb et al., 2009; MacIntyre et al., 2011; MacIntyre et al., 2013; MacIntyre et al., 2014; MacIntyre et al., 2017; Radonovich et al., 2019). Even though N95 masks were generally better at reducing outcome parameters compared to surgical masks, significant evidence was inconsistent throughout the studies. Most studies only identified one of the four outcome parameters as having a significant reduction in symptom rates or lab confirmed infection fates. Each study identified a different parameter as being significantly reduced. One study saw a significant decrease in ILI with N95 masks compared to surgical masks, but no other parameters saw a significant change (Loeb et al., 2009). Two studies found a significant decrease in LCV infections with N95 masks compared to surgical masks, but no other parameters showed any significant decrease (MacIntyre et al., 2011; MacIntyre et al., 2014). Another study completed by MacIntyre et al., 2013, showed only N95 masks demonstrated a significant difference in CRI rates. Only one study obtained data that showed a significant change in more than one of the primary outcome parameters, demonstrating that the N95 mask helped to significantly reduce the rate of laboratory confirmed viral infections, including influenza A and B (MacIntyre et al. 2017). Table 7 helps visualize the results of these studies and clearly presents the variable findings between each study. The underlying theme between these studies, however, is clearly seen in this table, showing that N95 masks consistently outperform all other masks as protection against respiratory symptoms or respiratory infection rates in HCWs.

Two studies, also included in table 7, met selection criteria for this literature review were unable to find a significant difference between N95 and surgical masks at preventing respiratory symptoms or lab confirmed viral infection (Loeb et al., 2009; Radonovich et al., 2019). These RCT's focused primarily on laboratory confirmed influenza as a primary outcome and utilized two different influenza testing methods. In the Radonovich trial (2019) four separate trials were completed, and each trial was 12 weeks long. None of the trials, either independently or combined, provided significant evidence of the reduction of laboratory confirmed influenza when comparing N95 masks to surgical masks (Table 7; Radonovich et al., 2019). The Loeb et al. trial (2009) strictly compared rates of laboratory confirmed cases of respiratory viral infections between HCWs who wore N95s for their entire shift and HCWs who wore surgical masks for their entire shift. They found that surgical masks were non-inferior to N95 masks at preventing laboratory confirmed respiratory viral infection (RVI) in HCWs (Loeb et al., 2009).

There were three studies which compared medical grade masks to a variety of homemade cloth masks (Jacobs et al., 2009; MacIntyre et al., 2015; MacIntyre et al., 2017). All three trials concluded decisively that cloth masks and homemade masks were significantly inferior as respiratory protection compared to the medical grade masks. Cloth masks were found to significantly increase the rates of respiratory infection in HCWs (MacIntyre et al., 2015). The common theme throughout each of these studies found that use of N95 masks showed an overall trend of protection against respiratory illness but did not definitively provide consistently significant reduction in respiratory illness rates in HCWs. (Jacobs et al., 2009; Loeb et al., 2009; MacIntyre et al., 2011; MacIntyre et al., 2013; MacIntyre et al., 2014; MacIntyre et al., 2015; MacIntyre et al., 2017; Radonovich et al., 2019) See table 7.

Two of the previously mentioned studies simultaneously compared masking to a control arm of participants who either wore no masks (MacIntyre et al., 2011) or followed routine care (MacIntyre et al., 2015). Both studies provide strong evidence that wearing a medical grade N95 or surgical mask throughout a shift helped to provide significant protection against self-reported clinical respiratory illness in HCWs.

Summary of Evidence

The findings of each of the selected studies were inconsistent. Some found a significant reduction in respiratory symptoms but not in laboratory confirmed viral infection, while others found a significant reduction in laboratory confirmed RVI but not a significant reduction in respiratory symptoms (Jacobs et al., 2009; Loeb et al., 2009; MacIntyre et al., 2011; MacIntyre et al., 2013; MacIntyre et al., 2014; MacIntyre et al., 2015; MacIntyre et al., 2017; Radonovich et al., 2019). The trend amongst results showed potential for protection, though significance was limited. Only half of the studies that compared N95 to surgical masks found a significant difference in laboratory confirmed viral infection with only one of those studies showing a significant reduction in rates of laboratory confirmed influenza infection. One common limitation amongst all reviewed studies was the use of self-reporting as a tool to diagnose respiratory illness. Individuals may be asymptomatic carriers of a virus and may minimize symptoms they are experiencing and fail to report. Ultimately, the studies reviewed provided some evidence suggesting the use of an N95 mask over surgical mask throughout the work shift and could help reduce the rates of respiratory illness. Evidence also strongly suggests that wearing a surgical mask or N95 mask throughout the work shift correlated with significant protection against CRI and ILI over cloth masks or not wearing a mask at all.

Conceptual Framework

A problem-solving approach was utilized when constructing the framework for this literary review investigating the utility of a variety of mask material as respiratory protection for HCWs. The Johns Hopkins Nursing Evidence-Based Practice Model **(**JHNEBP) is a powerful implementation tool designed to meet the needs of HCWs using a straightforward three-step process known as PET: practice question, evidence, and translation (Vera, 2020).

The process begins by asking a practice question. In this initial step, a problem is identified, and an inquiry is defined. For this literature review, the problem identified was that HCWs were still becoming ill during the COVID-19 pandemic despite current droplet and airborne isolation guidelines being practiced. Therefore, an inquiry into the effectiveness of different mask types at providing respiratory protection for HCWs was initiated.

The next step involves researching evidence related to the best practice for the problem in question by performing a literature review, appraising the discovered evidence, and synthesizing data into recommendations. This literature review was able to synthesize the best available evidence into four themes: N95 masks generally provided better protection than surgical masks while both provide significantly better respiratory protection than cloth face coverings or no mask at all, that cloth masks may actually be reservoirs for viral transmission, all masks were less protective against smaller particles, and that cloth masks were not significantly more effective at reducing viral symptoms or laboratory confirmed infections compared to surgical masks or N95 masks. These four themes provide support for current CDC guidelines requiring HCWs to wear N95 masks for protection in patients under airborne isolation and surgical masks with an eye shield for patients in droplet isolation.

Finally, the recommendations are then translated into an action plan. The current CDC guidelines for isolation based on transmission should continue to be followed based on the current available data. An action plan which could be implemented by hospitals to improve the protection of HCWs would be to require patients suspected of being infected or who are confirmed to have a viral infection to wear a hospital-provided surgical mask throughout their hospitalization.

Conclusions, Recommendations, and Implications for Nursing

Introduction

The purpose of this extensive literature review was to critically evaluate the protective capabilities of several types of masks and establish evidentiary support for current CDC respiratory isolation guidelines. This section will conclude the review, discuss practice implications, and provide recommended adjustments to current CDC respiratory isolation guidelines and suggest areas where evidence is lacking, and identify where further research is needed.

Conclusions

Working in healthcare comes with a risk of exposure to a variety of chemicals and pathogens. It is the ethical responsibility of employers to protect HCWs and institute policies according to current CDC guidelines. The frequency of healthcare worker infections related to the current COVID-19 pandemic calls into question the effectiveness of current guidelines to optimally protect HCWs from respiratory illness. Ultimately, the literature provides supportive evidence for current CDC respiratory isolation guidelines. In high-risk situations often found in healthcare settings, cloth masks simply will not provide enough protection to HCWs. Cloth masks do not provide consistently significant filtration and could possibly absorb viral laden droplets and aerosolize them due to friction created by jaw movements or simply touching the mask. Both surgical and N95 masks were shown to provide significant protection when compared to cloth masks and wearing no mask at all, supporting their use by HCWs as respiratory protection. The literature also demonstrates a decreasing filtration capacity of masks for smaller particles, supporting the use of the higher filtration of the N95 mask for pathogens spread by smaller, airborne aerosols.

Nursing Implications

Nurses are at the forefront of healthcare, are involved directly with the patient, and likely at high risk for exposure to pathogens. During the current COVID-19 pandemic, nurses make up the largest demographic of HCW's requiring hospitalization due to COVID-19 infection at 36% (Kambhampati, 2020). In order for our healthcare system to function effectively and meet the needs of the community, we need healthy and protected HCWs. Ongoing surveillance of evidence regarding the effectiveness of PPE such as masks at protecting HCWs is required to maintain the high standards of CDC guidelines. Maintaining hospital policy based on these guidelines and providing yearly and up to date education on isolation practice recommendations will help ensure adherence by HCWs.

Recommendations

Based on the integrative literature review, an evidence-based project focused on developing policy to protect HCWs from respiratory infection is recommended utilizing the

JHNEBP model. First, it is recommended that organizations should prioritize infection prevention policy regarding protecting HCWs on current CDC transmission-based isolation guidelines. This mean requiring HCWs to don an N95 mask for patients under airborne isolation and a surgical mask for patients under droplet precautions (CDC, 2019). The evidence also supports creating a policy requiring patients under investigation for RVI to wear a surgical mask. Requiring patients who have tested positive for a viral illness or are experiencing symptoms to wear a mask is not a current CDC recommendation. In order to adequately protect HCWs, source control is vital and requiring patients to wear a mask will improve respiratory protection and reduce HCW infection rates. Another addition to policy focused on protecting HCWs from respiratory protection should require all HCWs participating in an aerosol generating procedure to don an N95 mask. Aerosol generating procedures (AGPs) are procedures which produce smaller airborne particles, creating a high-risk environment for HCWs. The evidence shows that N95 masks provide better protection against these smaller particles when compared to surgical masks or no mask. Therefore, the recommendation is that N95 masks should be the standard PPE to optimize respiratory protection during all AGPs such as bronchoscopy procedures and intubations. Also, cloth masks should not be an acceptable form of respiratory protection in healthcare settings as they could be a reservoir for viral transmission, particularly if worn for long periods of time such as the duration of a HCW shift.

With the current scrutiny over masks and their capabilities to provide protection, ongoing research is recommended to build the body of evidence used to support CDC guidelines. Despite current evidence supporting N95 masks as providing superior protection to surgical masks and cloth masks, some of that data was not statistically significant. (MacIntyre et al., 2017; Radonovich et al., 2019). More studies are needed to clarify these trends and provide statistically significant data is warranted. Lastly, both MacIntyre et al. (2011) and MacIntyre et al. (2014) compared non-fit-tested N95 mask use to fit-tested N95 mask use in HCWs and found no significant difference in RVI rates. While this topic is outside the scope of this review, further research into the impact of fit-testing on the effectiveness of N95's at reducing RVI in HCWs is recommended based on the evidence discovered in this review.

Summary

Personal protective equipment is vital for the health and safety of HCWs. Guidelines designed to recommend which PPE to use for which situations should be based on current evidence. Current evidence supports the CDC's use of transmission-based isolation as the basis for their guidelines requiring N95 masks for airborne precautions and surgical masks for droplet precautions. However, there does appear to be gaps within the CDC guidelines and addressing those gaps could lead to improved protection for HCWs. Given the decreasing filtration efficiency of masks relative to the decreasing size of virus containing particles, higher level of protection should be required during all aerosol generating procedures such as intubation or bronchoscopies. In addition, masks have been shown to be a better source control. Therefore, patients who are suspected of having a viral infection or who have been confirmed to have a viral infection should be expected to wear a surgical mask when HCWs are present in their hospital room to provide optimal protection for all HCWs. Current CDC guidelines are well established and provide evidence-based recommendations for respiratory protection of HCWs. Ultimately, in HCWs caring for hospitalized adult patients with upper RVIs under respiratory precautions, current evidence provides inconsistent evidence that wearing an N95 mask decreases rates of acquired infections in HCWs when compared to surgical masks. However, both N95 and surgical masks show a significant decrease in rates of acquired infections in HCWs when compared to cloth masks and no mask at all. In summary, the available evidence supports current CDC guidelines on infection prevention, but incorporating policies requiring virally infected patients to wear surgical masks and requiring all HCWs involved in all AGPs to wear N95 mask could go a long way to reduce viral infection rates in HCWs.

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APPENDIX A

Table 1

CDC Guidelines: Transmission Based Isolation Precautions.

Droplet Precautions	Airborne Precautions

• Droplet Precautions are recommended for patients known or suspected to be infected with pathogens transmitted by respiratory droplets that are generated by a patient who is coughing, sneezing or talking
• In acute care hospitals, place patients who require Droplet Precautions in a single-patient room when available
• Don a mask upon entry into the patient room or cubicle
• No recommendation for routinely wearing eye protection (e.g., goggle or face shield), in addition to a mask, for close contact with patients who require Droplet Precautions
• Utilize when the following diseases are suspected or confirmed:
  ◦ *B. pertussis*,
  ◦ Influenza virus
  ◦ Adenovirus
  ◦ Rhinovirus
  ◦ *N. meningitides*
  ◦ group A streptococcus
	• In acute care hospitals, place patients who require Airborne Precautions in an AIIR that has been constructed in accordance with current guidelines
	• Provide at least six (existing facility) or 12 (new construction/renovation) air changes per hour.
	• Wear a fit-tested NIOSH-approved N95 or higher-level respirator for respiratory protection when entering the room of a patient
	• Utilize when the following diseases are suspected or confirmed:
	  ◦ Infectious pulmonary or laryngeal tuberculosis
	  ◦ Smallpox
	  ◦ Measles
	  ◦ Chickenpox
	  ◦ Disseminated zoster

(CDC, 2019)

APPENDIX B

Table 2

Databases Searched and Data Abstraction

Date of Search	Keyword Used	Database	Number of Hits		
			Listed	Reviewed	Used
9/20	Masks, Healthcare Worker	Cochrane Library	7	0	0
9/20	Masks, Healthcare Worker	PubMed	1885	8	3
10/30	Mask, Respiratory Illness	CINAHL	173	12	4
10/30	Masks, Respiratory Illness	Academic Search Premier	360	3	1
11/6	Viral Transmission, Protection	CINAHL	1411	10	0
11/6	Respiratory, Medical Mask	CINAHL	412	3	2
12/14	Respiratory Protection, Healthcare Worker	Google Scholar	138000	6	2
12/14	Respiratory Protection, Healthcare Worker	CINAHL	205	2	1
2/22	Masks, filtration	PubMed	542	10	2

APPENDIX C

Table 3

Levels of Evidence

Level I	Evidence from a systematic review or meta-analysis of all relevant RCTs (randomized controlled trial) or evidence-based clinical practice guidelines based on systematic reviews of RCTs or three or more RCTs of good quality that have similar results.
Level II	Evidence obtained from at least one well-designed RCT
Level III	Evidence obtained from well-designed controlled trials without randomization (i.e. quasi-experimental).
Level IV	Evidence from well-designed case-control or cohort studies.
Level V	Evidence from systematic reviews of descriptive and qualitative studies (meta-synthesis).
Level VI	Evidence from a single descriptive or qualitative study.
Level VII	Evidence from the opinion of authorities and/or reports of expert committees.

(Ackley et al., 2008)

APPENDIX D

Table 4

Literature Tables: Effectiveness of Masks at Preventing Respiratory Illness in Healthcare Workers

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/ Setting	Study Design/Methods/ Major Variables/ Instruments and Measures	Results/Main Findings	Implications/ Critique	Themes/ Comments
Asadi, S., Cappa, C., Barreda, S., Wexler, A., Bouvier, N., & Ristenpart, W. (2020, September 24). *Efficacy of masks and face coverings in controlling outward aerosol particle emission from expiratory activities*. Nature. https://www.nature.com/scientificreports	Level III	Assess the efficacy of several different types of masks at reducing the aerosol particle emission rates in healthy individuals.	Population included 10 individuals ranging in age from 18-45 who were non-smokers and currently healthy. The mask samples included surgical, unvented KN95, vented N95, a single layer paper towel, a single layer cotton t-shirt and a double layer cotton t-shirt.	Quasi-Experimental Design An aerodynamic particle sizer was set up to measure the size and number of particles emitted over 1 minute from study participants while wearing a pre-selected variety of mask types and materials. Participants performed different tasks such as breathing, talking, coughing, and chewing gum. These tasks were performed within an enclosed hood to minimize ambient particle detection. Data collected were compared between the masks and a non-masked control group.	Unvented KN95 masks reduced the outward flow of aerosolized particles by 90% during talking and coughing tasks. Surgical masks reduced the outward flow of aerosolized particles by 76% during talking and coughing tasks. Single- and double-layer cotton masks saw an increase in particle emission rates of up to 492% (single layer t-shirt). A portion of the particles emitted from these mask types were shown to be from the masks themselves as washing the masks appeared to reduce the number of particles emitted from these masks.	One of the major implications of this study is demonstrating the importance of cleaning reusable masks to reduce the number of particles on the surface. N95 and Surgical masks significantly help reduce the outward emission rates of particles. For all activities, wearing a double layered cloth mask showed no difference in particle emission rate compared to being maskless. Wearing a single layer cotton mask increased the rate of particle emission when compared to being maskless by near 5 times.	The study did not look at viral emissions specifically. Interesting that the authors concluded masking could help mitigate pandemics caused by respiratory disease, yet majority of people wear cloth masks and this study clearly demonstrated a major increase in particle emission while wearing cloth masks.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications/ Critique	Themes/ Comments
Davies, A., Thompson, K. A., Giri, K., Kafatos, G., Walker, J., & Bennett, A. (2013, August 1). *Testing the Efficacy of Homemade Masks: Would They Protect in an Influenza Pandemic?* PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7108646/	Level III	To analyze whether improvised masks could provide any protection to others from those who are infected	Study sample included several materials which could be used to make masks: 100% cotton Scarf Towel Pillowcase Cotton mix Linen Silk Vacuum bag	Quasi-Experimental Design Surgical masks were used as the control. Volunteers coughed using a homemade mask, a surgical mask, and no mask. A Henderson apparatus was used to deliver a test aerosol across each material selected for this experiment. Downstream air was tested prior to passing through the filter. Air that had passed through the filter material was tested for microorganisms. Filtration Efficiency was calculated be comparing colony forming unites before and after passing through the material. Bacillus atrophaeus (larger) and Bacteriophage MS2 (smaller) were used to simulate viral particles as they cover the range of size of typical influenza particles. Pearson x2 test was used to compare the proportion of particles greater than 4.7mm in diameter with particles less than 4.7mm in diameter.	The filtration efficiency for bacteriophage MS2 was 10% lower than for Bacillus atrophaeus. The surgical mask showed higher filtration efficiency compared to all other materials for both Bacillus atrophaeus and bacteriophage MS2. homemade masks did not significantly reduce the number of particles emitted (P = 106). surgical masks did significantly reduce the number of particles emitted (P < 0.001)	Data can be used for any organism within the size range, not just influenza. Regularly training and fit testing for masks should be emphasized to maximize filtration efficiency. Masks made from a variety of materials do not significantly reduce the number of particles emitted.	Surgical masks clearly provide better filtration efficiency than a variety of other materials. The smaller the particle, the worse the filtration efficiency for all mask types.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/ Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications /Critique	Themes/ Comments
Jacobs, J., Odhe, S., Takahashi, O., Tokuda, Y., Omata, F., & Fukui, T. (2009). Use of surgical face masks to reduce the incidence of the common cold among health care workers in Japan: A randomized controlled trial. *American Journal of Infection Control*, *37*(5), 417–419. https://doi.org/10.1016/j.ajic.2008.11.002	Level II	To investigate the superiority of face mask over no mask use in preventing upper respiratory illness.	33 Volunteers were selected from a population of healthcare workers in Toyko, Japan Volunteers were separated into their job class (Nurse, doctors, complimentary staff) and randomized them into either the mask group or the non-mask group.	Randomized Control Trial The mask group (17) were required to wear a mask while in the hospital, the non-mask group (15) did not wear a mask unless required to per policy. Masks were standard surgical masks per hospital guidelines. Volunteers completed a daily record of any symptoms and their severity on a 4-point scale. Symptoms monitored include: Headache, cough, sneeze, stuffy nose, runny nose, sore throat, earache, or just generally feel bad with 4 points being the worse symptom URI was considered if a score of 14 was obtained for 2 consecutive days. Fisher's exact test was used to compare URI rates between the masked and the non-masked group. P value < 0.05 was considered significant. Volunteers were monitored for 77 days.	There was no significant difference in prevalence of URI symptoms between the two groups except 1. Headaches were significantly less reported in the non-mask wearing group. P = 0.01 While not meeting "significance" standards (P = 0.06) there were more days when those wearing masks reported "feeling bad" (5.6 days) when compared to those who were not wearing masks (2.6 days). Mask use compliance rate was monitored and recorded at 84.6%	The findings did not provide evidence that generalized masking practices helped reduce the prevalence of URI in healthcare workers. Those who did not wear masks had fewer days with reported headaches. Behavior outside the hospital was not monitor, cannot guarantee any symptoms were contracted while at work.	Very low sample size, not sure if it meets power needed. This focuses on the common cold rather than more infective type virus' such as influenzae or corona viruses.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications /Critique	Themes/ Comments
Loeb, M., Dafoe, N., Mahoney, J., John, M., Sarabia, A., Glavin, V., Webby, R., Smieja, M., Earn, D., Chong, S., Webb, A., & Walter, S. (2009, November 4). *Surgical Mask vs N95 Respirator for Preventing Influenza Among Health Care Workers: A Randomized Trial*. Geriatrics | JAMA | JAMA Network. https://jamanetwork.com/journals/jama/fullarticle/184819	Level II	To compare the surgical mask with the N95 respirator in health care workers. Hypothesize that the surgical mask offers similar protection to the N95 respirator among health care workers at highest risk for exposure to influenza.	446 nurses from emergency departments, medical units, and pediatric units. 8 different hospitals in and around the Toronto area. Full time nurses who worked specified units during the 2008 to 2009 flu season who passed fit-testing certification to wear N95 respirator masks. Average age of participants was 36 years old and 94% were female.	Randomized Control Trial Nurses were distributed into either the surgical mask group (n=225) or the N95 mask group (n=221), wearing their masks while caring for patients with febrile respiratory illness. Participants and their family members (monitoring for household exposures) were assessed for signs and symptoms of influenza twice weekly using online questionaries. Symptoms triggering a nasal swab sample included fever > 38ºC, cough, nasal congestion, sore throat, headache, muscle aches, fatigue, chills, earache, or ear infection. <u>*Primary endpoint*</u> was laboratory confirmed presence of viral RNA via PCR compared between the N95 group and the SM group by 2-sided 95%confidence interval and Fischer's exact test to identify significance. <u>*Secondary endpoint*</u> was non-influenza respiratory viral infections. Physician visits and workplace absenteeism were also monitored. To obtain a power > 90%, 191 participants were required for each group, 420 for the whole study.	Lab confirmed influenza by PCR was23.6% in the SM group and 22.9% in the N95 group, a non-significant difference, P=0.86. No significant difference was noted between the SM group and the N95 group for those having an infection with a respiratory virus other than influenza (52 total participants). Fever was the only significant symptomatic difference between the SM group and the N95 group, 12 to 2, P = 0.007. No significant differences were found between the groups for physician visits (p = 0.39) or workplace absenteeism (P = 0.59).	Efficacy of surgical masks was within 1% of N95 when comparing incidence rates of PCR confirmed influenza. Hand hygiene and use of gloves were not monitored. Adherence to masking protocols was excellent based on an audit of mask use techniques.	N95 masks are no better at protecting healthcare workers from influenza than surgical masks. Small droplets were not the dominant form of transmission. Household exposure was evenly distributed between the 2 groups, minimizing the chance that community exposure impacted the results.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications /Critique	Themes/ Comments
Lee SA, Grinshpun SA, & Reponen T. (2008). Respiratory performance offered by N95 respirators and surgical masks: human subject evaluation with NaCl aerosol representing bacterial and viral particle size range. *Annals of Occupational Hygiene*, *52*(3), 177–185. https://doi-org.wsuproxy.mnpals.net/10.1093/annhyg/men005	Level III	1 - to estimate how much protection can be provided by N95 filtering facepiece respirators and surgical masks against bacteria and viruses 2 - to investigate whether exhalation valves affect the protection levels provided by N95 filtering facepiece respirators	12 students and faculty from the University of Cincinnati were volunteers for the testing. 2 N95 masks, one with high protection, one with medium protection. 2 N95 masks, one with an exhalation valve and one without. 3 surgical masks, one high protection, one medium protection, one low protection based on fit testing results.	Quasi-Experimental The volunteers were fit tested to the masks using standard fit testing guidelines. A challenge aerosol spray of sodium chloride was used and an ELPI was used to size-selectively measure the number concentration of particles in an aerodynamic size, ranging from d_a = 0.029 to 10.18 µm. The particle concentration inside the mask were averaged during all exercises. The particle concentration outside the mask was measured throughout the test and were averaged. Theses concentrations were divided to give the mask's protection factor (PF). Data was analyzed with ANOVA with P < 0.05 being considered significant. T-test was used to compare the N95s with and without an exhalation valve. Tukey's studentized range tests were used to compare the PF between surgical masks and particle size.	Lowest protection by an N95 masks occurred with particle sizes 0.08 and 0.2 micrometers. No significant difference was found between the N95 masks with and without exhalation valves (P >0.05). Lowest protection by any surgical masks occurred with particle sizes between d_a = 0.04 and 0.32 µm.	Size of coronavirus and influenza virus fall within the size range of the most penetration particles, meaning these masks are the least protective against these viruses.	The average PF offered by N95 filtering facepiece respirators against particles in the tested size range was about 8–12 times greater than that provided by surgical masks.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications /Critique	Themes/ Comments
MacIntyre, R. C., Wang, Q., Cauchemez, S., Seale, H., Dwyer, D. E., Yang, P., Shi, W., Gao, Z., Pang, X., Zhang, Y., Wang, X., Duan, W., Rahman, B., & Ferguson, N. (2011). A cluster randomized clinical trial comparing fit-tested and non-fit-tested N95 respirators to medical masks to prevent respiratory virus infection in health care workers. *Influenza & Other Respiratory Viruses*, *5*(3), 170–179. https://doi-org.wsuproxy.mnpals.net/10.1111/j.1750-2659.2011.00198.x	Level II	To determine the efficacy of medical masks compared to fit-tested and non-fit-tested N95 respirators in HCWs in the prevention of disease because of influenza and other respiratory viruses.	481 nurses and doctors in nine hospitals were the control group who wore no masks. 1441 nurses and doctors from 15 hospitals were the experimental group and were asked to wear masks during their entire shift for 4 weeks. Study required 500 participants to obtain a power level of greater than 80%. Symptomatic participants were tested with PCR swabs x 2.	Randomized Control Trial 492 nurses and doctors were chosen to wear surgical masks. 461 nurses and doctors were chosen to wear fit tested N95 masks 488 nurses and doctors were chosen to wear non-fit tests N95 masks. Mask wearing compliance was measured as wearing the face mask for at least 80% of the individual's shift. Fit testing failure rates for N95 masks were monitored. Different in proportions between experimental arms was calculated by Pearson's Chi-square. Multivariable analysis was used to adjust for confounding variables. Clinical Respiratory illness was defined as 2 respiratory symptoms or 1 respiratory symptom and a system symptom. Influenza like Illness defined as fever > 38OC plus 1 respiratory symptom Lab confirmed respiratory viral infection Lab confirmed influenza A or B	Non-fit tested N95s had lower rates of infection than fit tested N95s. For all N95/surgical mask infection rates (%): CRI – 3.9/6.7 ILI – 0.3/0.6 Lab confirmed virus- 1.4/2.6 Lab confirmed influenza - 0.3/1 None of these differences were found to be significance. Mask wearing compliance was high > 74% for all experimental arms. Surgical mask group did not have significantly lower rates of infection compared to the no mask group. N95 masks had significantly lower rates of infection compared to the no mask group.	Influenza vaccinated individuals could have impacted the results of influenza testing. Hospitals were specifically selected where mask wearing was not common practice.	Interesting to note that fit testing did not impact the effectiveness of N95 masks. HCW's who performed high risk procedures had higher rates of CRI but not lab confirmed cases. Behavioral factors impacted mask compliance more than issues with discomfort.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications/ Critique	Themes/ Comments
MacIntyre, R. C., Wang, Q., Seale, H., Yang, P., Shi, W., Gao, Z., Rahman, B., Zhang, Y., Wang, X., Newall, A. T., Heywood, A., & Dwyer, D. E. (2013). A Randomized Clinical Trial of Three Options for N95 Respirators and Medical Masks in Health Workers. *American Journal of Respiratory and Critical Care Medicine, 187*(9), 960-6. http://wsuproxy.mnpals.net/login?url=https://www-proquest-com.wsuproxy.mnpals.net/scholarly-journals/randomized-clinical-trial-three-options-n95/docview/1439802777/se-2?accountid=15069	Level II	To determine the efficacy of three different options for the use of masks and respirators in HCWs working in high-risk hospital wards, in the prevention of respiratory infections.	68 emergency departments of respiratory units at 19 hospitals in Beijing, China. 1669 nurses and doctors who were 18 years old or older and works in the emergency department or respiratory ward were recruited for the study.	Randomized Control Trial 560 participants per arm were needed to obtain a power of more than 80% *Arm 1* consisted of 572 participants who wore surgical or medical masks for their entire shift. *Arm 2* consisted of 581 participants who wore N95's for their entire shift. *Arm 3* consisted of 516 participants who wore N95 masks during aerosol generating procedures only and did not wear masks during the rest of their shift. Monitored events include: **CRI** – Two respiratory symptoms. **Bacteria + CRI** **ILI** – fever > 38OC and at least one respiratory symptom Lab confirmed respiratory viral infection Lab confirmed influenza A or B Event rates were compared across the study arms using cluster adjusted Chi-square tests. The effect of each arms interventions was analyzed using a HR with the multivariable Cox proportional hazards model.	Fit test failure for the N95 arms was insignificant at 2.6%. CRI rates were significantly different: SM – 17% tN95 – 11.8% N95 - 7.2% $P < 0.05$ Lab confirmed respiratory viral infection rates were insignificant between arms. Rates of bacterial coinfection w/ CRI were significantly different: SM - 14.7% tN95 - 10.1% N95 - 6.2% $P = 0.02$ N95 was significantly more protective against CRI compared to tN95 HR of 0.56, 95% CI 0.32-0.98. Compliance rates were significantly different: SM – 66% tN95 – 82% N95 – 57% $P < 0.001$	No difference between targeted N95 use and surgical masks. Implications on policy if ineffective options are recommended Surgical masks showed no significant protection against CRI.	Compliance with masking become more difficult with the increase in discomfort reported of the mask. Only 12% of lab confirmed viral infections also had a fever.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/ Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications /Critique	Themes/ Comments
McIntyre, R. C., Wang, Q., Rahman, B., Seale, H., Ridda, I., Gao, Z., Yang, P., Shi, W., Pang, X., Zhang, Y., Moa, A., & Dwyer, D. (2014). Efficacy of face masks and respirators in preventing upper respiratory tract bacterial colonization and co-infection in hospital healthcare worker. *Preventative Medicine*, *62*, 1–7. https://doi.org/10.1016/j.ypmed.2014.01.015	Level II	Compared the efficacy of medical masks (MM) and N95 respirators (N95) in preventing bacterial colonization/infection in healthcare workers (HCWs)	Healthcare workers who worked full time in the emergency department or the respiratory ward from 15 hospitals. 481 healthcare workers from the same hospitals were selected as a control group and did not routinely wear masks during the study period. 1441 nurses and doctors were recruited for the experimental arms. 949 HCWs were split into the N95 group, 461 were fit tested, 488 non-fit tested. There were 492 HCWs placed into the medical mask group.	Randomized Control Trial Participants randomized into 3 arms: Medical Mask, Non-fit tested N95 mask, and fit tested N95 mask plus a non-masking control arm. Each person worse their designated mask for their entire shift for 4 weeks. Primary endpoint was lab confirmed bacterial colonization of the upper respiratory tract. Multiplex PCR was used to test specifically *for S. pneumoniae, legionella spp, B. pertusis, Chlamydia, M. pneumoniae*, and *H. influenzae* type B. Looked for co-infection with respiratory virus' such as adenovirus, HPV, coronavirus, parainfluenza, influenza A and B, and rhinovirus. Participants contacted daily for 5 weeks, including 1 week post study cessation, to follow up regarding respiratory symptoms (cough, sneeze, fever, runny nose, shortness of breath). Any subject reporting respiratory symptoms were tested with both a nasal and oral swab. Intent to treat analysis was performed on the primary end point. Risk Ratio was analyzed to compare the N95 and the medical mask arms to the control group. Fischer's exact test was used to calculate P values to ensure significance with comparisons.	Only 5 of 461 fit tested N95 wearers failed their fit test. Rates of bacterial infection were lower in N95 (2.8%) when compares to the MM (5.3%) P = 0.02. N95s were more effective when compared to MM at preventing bacterial infection P = 0.02, and co-infection P = 0.004. N95s were significantly more effective than MM in all studied parameters. MM was not significantly more effective at preventing bacterial infection, P = 0.16, viral infection P = 0.657, or co-infection P = 0.336. HCW's working on a respiratory ward were at significantly higher risk compared to other wards (7.3% to 3.5 %, P < 0.001). Nurses were at significantly higher risk compared to doctors (3.2% to 1.4% P = 0.02)	No difference in demographics between the groups. No significant difference between fit tested and non-fit tested groups. Results support a synergistic relationship between bacterial and viral respiratory infections. N95 mask provided better protection against bacterial and coinfection for HCW that MM	No significant difference between the fit tested and non-fit tested groups, so they were combined for further analysis. Is Fit testing necessary?

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications /Critique	Themes/ Comments
MacIntyre, R. C., Seale, H., Dung, T., Hien, N., Nga, P., Chughtai, A., Rahman, B., Dwyer, D., & Wang, Q. (2015, April 1). *A cluster randomised trial of cloth masks compared with medical masks in healthcare workers*. BMJ Open. https://bmjopen.bmj.com/content/5/4/e006577	Level II	To compare the efficacy between cloth masks and medical or surgical masks in hospital healthcare workers. Null hypothesis that there is no difference between cloth and medical masks worn in the hospital by healthcare workers.	Setting in 14 hospitals in Vietnam including 74 different hospital wards. Population consisted of 1607 healthcare workers, all of whom were older than 18 years of age. Participants had to consent, work full time hours, had no facial hair, and had no chronic or acute respiratory illnesses or allergies. Participants included nurses and doctors.	Randomized Control Trial Participating healthcare workers were randomized into three groups. - 580 wore medical masks - 569 wore cloth masks - 458 were the control Control group was asked to follow their usual practice which may or may not have included mask wearing. Participants were asked to wear their mask for their whole shift during a 4-week period. Each group wore identical cloth or surgical masks. 3 outcomes were measured - Clinical Respiratory illness - Influenza-like illness - Laboratory confirmed respiratory viral infection Tonsillar and pharyngeal swabs were performed by lab, blind to which group test subjects were part of. PCR testing was performed. Filtration performance of each mask was also tested.	Healthcare workers who wore cloth masks had the highest lab confirmed infection rates: RR of 13.25 compared to surgical masks. RR of 3.49 compared to the control arm. Of the laboratory confirmed cases, 85% were infected with rhinovirus. Participants in the cloth arm group washed their masks on average 23/25 days worked during the study period.	Difficult to differentiate between more efficient surgical mask or if cloth masks were simply detrimental. The lack of a consistent control in this study is a limitation, as the control group primarily wore both surgical and cloth masks throughout the study period. An insignificant number of individuals did not wear masks or wore N95 masks. Showed hand hygiene was helpful in preventing the spread of viral transmission, however, mask type was an independent indicator for infection.	In the healthcare setting, cloth masks clearly do not protect healthcare working at the same level as medical masks. Cloth masks should not be recommended for healthcare workers. Washing masks in this study did not seem to impact infection rates. cloth masks cause an increase in infection risk in HCWs

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications/ Critique	Themes/ Comments
MacIntyre, C. R., Chughtai, A., Rahman, B., Peng, Y., Zhang, Y., Seale, H., Wang, X., & Wang, Q. (2017, November 1). *The efficacy of medical masks and respirators against respiratory infection in healthcare workers*. Wiley Online Library. https://onlinelibrary.wiley.com/doi/full/10.1111/irv.12474	Level II	Examine the efficacy of medical masks and respirators in protecting against respiratory infections using pooled data from two randomized control clinical trials (RCTs)	Population consisted of healthcare workers in China. Setting was multiple Hospitals in Beijing, China. Population and settings were chosen specifically for their regularly low-level use of masks.	Randomized Control Trial Population was randomized into several groups. Continuous N95 group (n=1530) Targeted N95 group (n=516) - wore N95 during specified procedures. Continuous Surgical Mask group (n=1064) Control group (n=481)– follow typical mask wearing routine. Lab Confirmed Viral infection (LCV) Lab Confirmed Influenza infection (LCI) Relative Risk was used to analyze and compare mask types	Relative Risk for LCV and LCI for lowest in the continuous N95 group (.33 and .46, P < 0.001) and was the only significant finding. Continuous N95 vs control arm showed 77% efficacy of continuous N95 use with a relative risk of 0.23 Medical mask did reduce risk (RR – 0.81) but it was not statistically significant	Study demonstrated superior clinical efficacy of continuous use of N95 against infections presumed to be spread by the droplet mode. Targeted use of N95 respirators is associated with reduced risk for HCWs, but continuous N95 use provides significantly superior protection.	Transmission of viral particles much more complex Trends for medical masks were not significant but did indicate some mild degree of protection.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/ Major Variables/Instruments and Measures	Results/Main Findings	Implications / Critique	Themes/ Comments
Milton, D. K., Fabian, M. P., Cowling, B. J., Grantham, M. L., & McDevitt, J. J. (2013). Influenza Virus Aerosols in Human Exhaled Breath: Particle Size, Culturability, and Effect of Surgical Masks. *PLoS Pathogens*, *9*(3), e1003205. https://doi.org/10.1371/journal.ppat.1003205	Level III	To describe the number of copies of viral RNA in two aerosol size fractions, report the capturability of virus in the fine-particle fraction, and the effect of surgical masks.	38 volunteers who had tested positive for influenza A or influenza B were selected from Massachusetts.	Quasi-Experimental Volunteers sat with their face in a cone-shaped collector which directed breaths into a human breath air sampler. They would spend 30 minutes in this position and were asked to cough 10 times every 10 minutes. This process was repeated twice for each volunteer, once while wearing a mask, then once while not wearing a mask. The "impact surface" of the air sampler was collected after each session and swabbed. Viral presence was double confirmed by plate cultures and Flu Detect PCR test strips. Relative risk and the mean of viral particle counts were used to analyze mask effectiveness. McNemar's test was also used to analyze mask effect.	Viral particles greater than 5 micrometers were detected from 11% of volunteers while wearing a mask and from 43% while not wearing a mask. Relative risk was 0.25 while wearing a mask ($p = 0.003$). Facemasks produced a 25-fold reduction in copies of larger influenza virus particles ($p = 0.002$). Viral particles less than 5 micrometers were detected in 78% of volunteers while wearing a mask and 92% of samples when they were not wearing masks. Relative risk was 0.96 and not significant ($p = 0.06$). Facemasks produced a 2.8-fold reduction in copies of smaller influenza virus particles. ($p = 0.01$).	Small study of only 38 individuals. Most participants were male. Masks nearly eliminated large viral particles., but not as effective at eliminating small particles. May not be good at preventing someone from getting infected, but better at controlling the source of infected individuals.	

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/ Setting	Study Design/Methods/ Major Variables/Instruments and Measures	Results/Main Findings	Implications /Critique	Themes/ Comments
Parlin, A. F., Stratton, S. M., Culley, T. M., & Guerra, P. A. (2020). A laboratory-based study examining the properties of silk fabric to evaluate its potential as a protective barrier for personal protective equipment and as a functional material for face coverings during the COVID-19 pandemic. *PLoS ONE*, *15*(9), 1–19. https://doi-org.wsuproxy.mnpals.net/10.1371/journal.pone.0239531	Level III	To examine commonly available materials, i.e., cotton, polyester, and silk, for their suitability as a protective layer for respirators	Study Fabrics included: *Silk* – 100% silk scarves and 100% mulberry silk pillowcases *100% cotton* – piece of fabric, Egyptian cotton pillowcase, and a handkerchief *Polyester* – 88% polyester and 12% nylon pillowcase, a 100% polyester pillowcase, and 100% polyester bag *Surgical Masks* P*ositive controls* – white paper towels, brown paper towels, and a Kiwipe	Quasi-Experimenta**l** **Contact angle trial** – measures the hydrophobicity of a material with greater hydrophobicity at contact angles greater than 90°. Starting and ending contact angles were compared using one-way ANCOVA. **Saturation propensity trial** – test the permeability of test material by placing a droplet of water and measuring area of spread after 1 minute. Comparisons were made with one-way ANCOVA. **Gas exchange trial –** gas exchange was measured in terms of the amount of water vapor allowed to pass through the material placed in an airtight apparatus. **Aerosolized droplet spray test –** analyzed the penetration of aerosol particles through each mask material via an experimental apparatus. Testing was done both before and after sterilization process in a dry-heat oven at 70°C. Comparisons were made with one-way ANOVA.	Cotton, polyester, and paper towel groups were found to be hydrophilic as they had the fastest change in contact angle such as the droplet was almost immediately absorbed. $P < 0.001$. 100% cotton and paper towels had the smallest contact angle. $P < 0.001$ Cotton and paper towel had significantly larger droplet spread area than the other materials $P < 0.001$. Increasing the cotton or paper towels thickness did not prevent saturation but increasing polyester thickness did minimize penetration. Gas exchange was significantly different between groups with cotton having the has exchange rates $P < 0.001$ There was a significant decrease in aerosolized droplets between no mask control and single ($P < 0.05$) and double ($P < 0.05$) layer masks of any material. No significant difference in ability to stop aerosolized droplet penetration was noted between material groups, $P > 0.05$. Filtration efficiency of silk improved with additional layers, likely related to the electrostatic effect on aerosols.	Silk appears to be hydrophobic and act similarly to surgical masks but has the benefit of being able to be sterilized. Due to the hydrophilic nature of cotton, cotton masks readily absorb and become saturated with droplets and may quickly become reservoirs and act as conduits for viral transmission. Silk may be used to cover N95 respirators to help keep them clean and extend their life. Silk is a better material for face coverings in the general public.	Limitation of all respiratory protection is that breathing may be hampered while being worn. Prolonged use increases local humidity, creating a potential pathway for viral travel. Cotton and polyester masks are satisfactory for brief, one-time uses. Double layered silk masks prevent droplet penetration and has efficient filtration ability.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/ Setting	Study Design/Methods/ Major Variables/ Instruments and Measures	Results/Main Findings	Implications/ Critique	Themes/ Comments
Radonovich, L. J., Jr, Simberkoff, M. S., Bessesen, M. T., Brown, A. C., Cummings, D., Gaydos, C. A., Los, J. G., Krosche, A. E., Gibert, C. L., Gorse, G. J., Nyquist, A. C., Reich, N. G., Rodriguez-Barradas, M. C., Price, C. S., Perl, T. M., & ResPECT investigators (2019). N95 Respirators vs Medical Masks for Preventing Influenza Among Health Care Personnel: A Randomized Clinical Trial. *JAMA*, *322*(9), 824–833. https://doi.org/10.1001/jama.2019.11645	Level II	To compare the effect of N95 respirators vs medical masks for prevention of influenza and other viral respiratory infections among HCP.	conducted at 137 outpatient study sites at 7 US medical centers between September 2011 and May 2015, with final follow-up in June 2016. Each year for 4 years, during the 12-week period of peak viral respiratory illness, pairs of outpatient sites (clusters) within each center were matched and randomly assigned to the N95 respirator or medical mask groups. 1446 participants were involved in 1 year of the trial. 723 participants were involved in 2 years of the trial. 693 participants were involved in 3 or 4 years of the trial.	Randomized Control Trial 1993 participants in 189 clusters were randomly assigned to wear N95 respirators (2512 HCP-seasons of observation) and 2058 in 191 clusters were randomly assigned to wear medical masks (2668 HCP-seasons) when near patients with respiratory illness. Primary outcome was incidence of laboratory-confirmed influenza. Secondary outcomes included incidence of acute respiratory illness, laboratory-detected respiratory infections, laboratory-confirmed respiratory illness, and influenza like illness. Adherence to interventions was assessed.	N95 group was exposed to workplace respiratory illness 22.5% of the time and to household respiratory illness 3.6% of the time. Surgical Mask group was exposed to respiratory illness 21.6% of the time and to household respiratory illness 3.4% of the time. Laboratory confirmed influenza events occurred 8.2% in N95 and 7.2% in Surgical mask group. 1% different was insignificant (P = 0.18). Acute Respiratory illness events occurred 1556 times in the N95 group and 1711 in the medical mask group, difference was insignificant (P = 0.10) The difference in Lab confirmed respiratory illness events occurred 371 times in N95 group and 417 times in the medical mask group was insignificant (P = 0.39). Individual adherence to masking guidelines for each individual group: 89.4% in the N95 group and 90.2% in the medical mask group.	N95 respirators vs medical masks as worn by participants in this trial resulted in no significant difference in the incidence of laboratory-confirmed influenza and other respiratory illnesses.	While not statistically significant, it was pretty clear that those who were in the medical mask group tended to have higher rates of respiratory illnesses and symptoms.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications/ Critique	Themes/ Comments
Rengasamy, S., Eimer, B., & Shaffer, R. (2010, October 1). Simple Respiratory Protection Evaluation of the Filtration Performance of Cloth Masks and Common Fabric Materials Against 20–1000 nm Size Particles. PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7314261/	Level III	Household fabric materials and cloth masks were challenged with polydisperse as well as monodisperse particles in the 20–1000 nm size range, which include the size of many viruses and initial penetration levels measured and compared with those values obtained for N95 respirator filter media	5 major fabric types were tested: Sweatshirts T-shirts Towels Scarves Cloth Masks N95 masks were used as control media for comparison	Quasi-Experimental TSI 8130 Automated Filter Tester, used for respirator certification was used in this study. Mask materials were tested for NaCl aerosol penetration at a face velocity of 5.5 cm/s and 16.5 cm/s Monodisperse and polydisperse testing was done to look at standard filtration rates and filtration rates of smaller, aerosol particles Analysis was done using average penetration values with 95% confident intervals	Cloth masks had penetration levels between 74 and 90% while N95 had a penetration level of 0.12% Sweatshirts showed a 40-82% penetration. All t-shirts showed penetration leves of > 86%. Towels had a 60-66% penetration level. Scarves had a 73-89% penetration level.	Fabric masks may only provide minimal levels of respiratory protection. Limited selection of fabric types. All fabrics were new and unwashed, these practices could impact penetration levels,	Large variability in filtration rate of all fabric types. Materials are not designed for filtration. Some fabrics had similar range of particle penetration as surgical masks from previous studies. Fabric masks do not provide enough respiratory protection for healthcare workers in high exposure settings.

Citation	Level of Evidence	Purpose/ Objective	Study Population/ Sample/Setting	Study Design/Methods/Major Variables/Instruments and Measures	Results/Main Findings	Implications / Critique	Themes/ Comments
Zuo, Z., Kuehn, T. H., & Pui, D. Y. H. (2013). Performance evaluation of filtering facepiece respirators using virus aerosols. *American Journal of Infection Control*, *41*(1), 80–82. https://doi.org/10.1016/j.ajic.2012.01.010	Level III	To compare the physical penetration and virus infectivity penetration through respirators. Identify whether the physical penetration depended on the type of challenge virus aerosol used.	Adenovirus and Swine Flu (H3N2) were obtained, and an aerosol spray was created for the experiment. N95s respirators, including 2 models which were certified by the National Institute for Occupational Safety and Health. 1 model which was not an N95 was compared to the N95 models.	Quasi-Experimental The generated viral aerosol was passed through a sealed chamber enclosed with specified mask. Physical aerosol penetration was measured by comparing the upstream to downstream concentrations. Viral load was measured upstream vs. Downstream by a particle sizer to evaluate viral penetration. 3 samples of each mask were tested 3 times for each viral aerosol. Tests were analyzed via analysis of variance.	Viral aerosols exhibited higher rates of penetration in the non-N95 model when challenged. Swine Influenza Virus showed a greater propensity for penetration than the adenovirus, this difference in penetration ability was significantly different for model C, but not for model A. No infectious adenovirus was recovered during the infectivity challenge once respirators were put in place.	Quick decay of adenovirus particles in aerosols may contribute to reduce infectivity rates. Low levels of virus in the aerosol spray could have impacted the levels of penetration and infectivity. the particle size that gives the highest penetration of 40-60 nm	The model of the N95 mask may play a contributing role in viral penetration. Different types of virus' may be able to penetrate masks better than others.

APPENDIX E

Table 5

Filtration Efficiency (%) of Varying Mask Materials

Study	N95 Mask	Surgical Mask		Common Fabric Masks										
				Cloth		Scarf		Sweat shirt	Towel		T-Shirt		Silk	
Asadi et al., 2020[+]	0.07 p/s	0.06 p/s									0.61 p/s			
Davies et al., 2013*		S	L	S	L	S	L		S	L	S	L	S	L
		89.5	96.4	70.2	74.6	48.9	62.3		72.5	83.2	50.9	69.4	54	58
Rengasamy et al., 2010	0.12	-		74-90		73-89		70-82	60-66		> 86			
Zuo et al., 2013	1.9-3.6	4.7-5.2												

+ Measured in particles per second (p/s). No Mask control rate was 0.31 p/s
* Examined both (S)mall (23 nm) and (L)arge (1.25 µm) sized particles

Table 6a

Comparison of Particle Penetration between Mask Type

Study	N95	Surgical Masks	Cloth Masks
Davies et al., 2013	-	↑	↑↑
Lee et al., 2008	↑	↑↑	-
Rengasamy et al., 2010	↑	-	↑↑
Zuo et al., 2013	↑	↑↑	-

↑ = Lower particle penetration
↑↑ = Higher particle penetration
\- = Mask type not studied

Table 6b

Comparing Small v. Large Particle Penetration

Study	N95		Surgical Mask		Cloth Masks	
	Small	Large	Small	Large	Small	Large
Davies et al., 2013	-	-	↑↑	↑	↑↑	↑
Lee et al., 2008	↑↑	↑	↑↑	↑	-	-
Zuo et al., 2013	↑↑	↑	↑↑	↑	-	-

↑ = Lower particle penetration
↑↑ = Higher particle penetration
\- = Mask type not studied

Table 7

Comparison of Rates of Illness Reduction between Mask Type

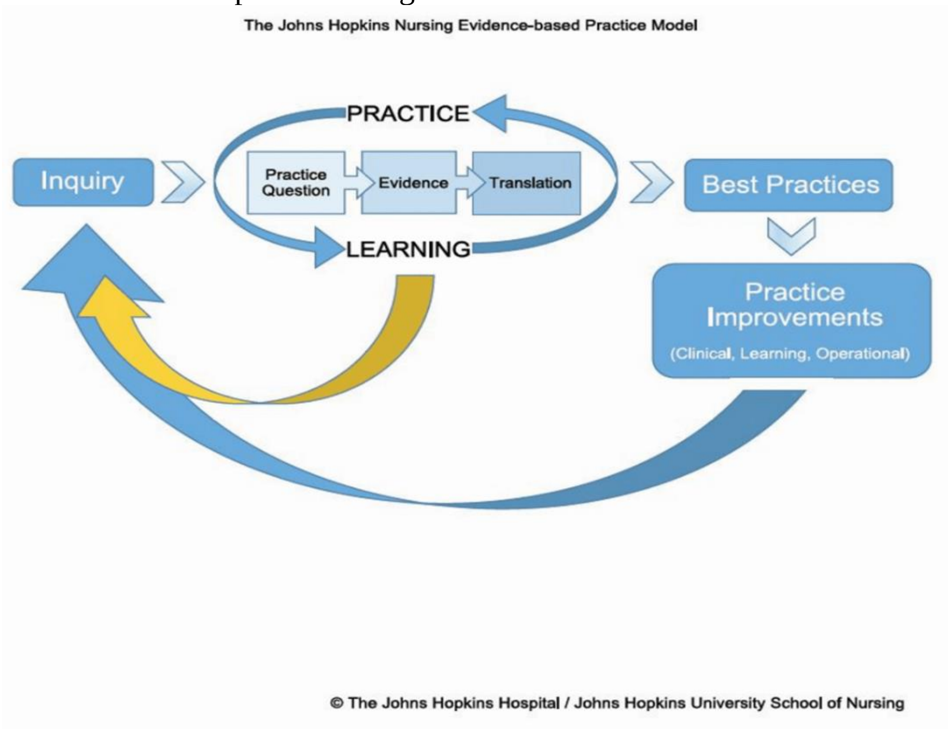
Study	N95 Mask				Surgical Mask				Common Fabric Masks**			
	CRI*	ILI+	LCV#	LCI@	CRI*	ILI+	LCV#	LCI@	CRI*	ILI+	LCV#	LCI@
Jacobs et al., 2009	–	–	–	–								
Loeb et al., 2009		X							–	–	–	–
MacIntyre et al., 2011			X						–	–	–	–
MacIntyre et al., 2013	X								–	–	–	–
MacIntyre et al., 2014			X						–	–	–	–
MacIntyre et al., 2015	–	–	–	–		X	X					
MacIntyre et al., 2017			X	X								
Radonovich et al., 2019									–	–	–	–

** Face Coverings include materials such as Silk, cotton, paper towel
*CRI – Clinical Respiratory Illness = 2 respiratory symptoms or 1 respiratory symptom & 1 systemic symptom
+ILI – Influenza like illness, defined as fever > 38°C plus 1 respiratory symptom
#LCV – Lab confirmed viral illness
@LCI – Lab confirmed Influenza
X = Indicates significant reduction compared to other mask types

- = Study did not include this mask type

APPENDIX F

Johns Hopkins Nursing Evidence-Based Practice Model



Practice Question
Step 1: Recruit interprofessional team
Step 2: Define the problem
Step 3: Develop and refine the EBP question
Step 4: Identify stakeholders
Step 5: Determine responsibility for project Leaders
Step 6: Schedule team meetings

Evidence
Step 7: Conduct internal and external search for evidence
Step 8: Appraise the level and quality of each piece of evidence
Step 9: Summarize the individual evidence
Step 10: Synthesize overall strength and quality of evidence
Step 11: Develop recommendations for change based on evidence synthesis

Translation:
Step 12: Determine fit, feasibility and appropriateness of recommendations
Step 13: Create action plan
Step 14: Secure support and resources to implement action plan
Step 15: Implement action plan
Step 16: Evaluate outcomes
Step 17: Report outcomes to stakeholders
Step 18: Identify next steps
Step 19: Disseminate findings