Assessment of cloth masks ability to limit Covid-19 particles spread: a systematic review

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Abstract
After the spread of Covid 19 worldwide, the use of cloth masks increased significantly due to a shortage of medical masks. Meanwhile, there were different opinions about the effectiveness of these masks and, so far, no study has been done to find the best fabric masks. This study reviews and summarizes all studies related to fabric masks’ effectiveness and various fabrics against coronavirus. This systematic review is based on PRISMA rules. Two researchers separately examined three databases: PubMed, Scopus, and Web of Science. Laboratory and clinical studies were included. After extracting the articles, their quality was assessed with the Joanna Briggs Institute (JBI) tool. In addition to efficacy, other factors, including the penetration of masks, pressure drop, and quality factor, were examined to select the best fabrics. Of the 42 studies selected, 39 were laboratory studies, and 3 were clinical studies. Among the various fabrics examined, cotton quilt 120 thread per inch (TPI), copy paper (bonded), hybrid of cotton with chiffon/silk, and flannel filtration were found to have over 90% effectiveness in the particle size range of Covid-19. The results and comparison of different factors (pressure drop, filtration efficacy, penetration, filtration quality, and fit factor have been evaluated) showed that among different fabrics, hybrid masks, 2-layered cotton quilt, 2-layered 100% cotton, cotton flannel, and hairy tea towel+fleece sweater had the best performance. Clinical studies have not explicitly examined cloth masks’ effectiveness in Covid-19, so the effectiveness of these types of masks for Covid 19 is questionable, and more studies are needed.

Keywords Mask · Covid-19 · Prevention

Introduction
In early December 2019, in Wuhan’s city in Hubei province, China, many people caught pneumonia. After a while, the cause of this cluster of diseases became known, which was a novel virus from the coronavirus’s family. Later, the disease was named Covid-19, caused by the SARS-Cov 2 virus (Chinazzi et al. 2020). This new coronavirus had a 79% sequence similarity to SARS-Cov, which caused a significant outbreak in 2002–2003 (Lake 2020). It did not take long that Covid-19 disease became a pandemic and a global concern that killed more than 1.3 million people up to November 2020, and in most countries, the rate of Covid-19 confirmed cases was rapidly growing, according to World Health Organization (WHO) (Anonymous). Because the SARS-Cov 2 virus is so contagious and due to the lockdown removal, everyone needs to take various preventive measures, including washing their hands regularly, using various protective equipment like gloves, gowns, masks, observing social distance,
conducted a review on their virus-blocking efficacy and summarized such studies. In the present study, we aimed to compare these masks with each other via reviewing all studies related to fabric masks’ effectiveness for Covid-19.

### Methodology

This systematic review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) instructions (Moher et al. 2015). The PECO research strategy (Scells et al. 2017) was used in this study containing the following information: P = droplet and/or aerosol dispersion contamination; E = homemade and/or commercial cloth masks; C = different cloth masks materials.

**Outcome** = cloth masks efficiency in reducing the transmission of contaminated droplets and aerosols through laboratory and clinical tests. We used medical subject heading (MESH) terms and combined the keywords in the title and abstract (cloth mask, fabric mask, textile mask, homemade mask, cotton mask, Covid-19, SARS-Cov-2, n-Cov-19) while searching the main international databases, including PubMed, Scopus, Web of Science. Two researchers searched the databases mentioned above up to 5 January 2021 independently. Examples of PubMed search queries using MeSH Terms and the free-text words were as follows:

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(((homemade mask*[Title/Abstract]) OR (textile mask*[Title/Abstract]) OR (((cloth mask*[Title/Abstract]) cotton mask*[Title/Abstract]) OR (gauze mask*[Title/Abstract])) AND ((Covid-19[Title/Abstract]) OR (COVID-19[Title/Abstract]) OR (cloth mask[MeSH Terms]) OR (fabric mask[MeSH Terms]) OR (textile mask[MeSH Terms]) OR (homemade mask[MeSH Terms]) OR (cotton mask[MeSH Terms]) OR (gauze mask[MeSH Terms]) OR (Covid 19[Title/Abstract]) OR (SARS-CoV-2[Title/Abstract]) OR (SARS-CoV-2[Title/Abstract]) OR (severe acute respiratory syndrome coronavirus 2[Title/Abstract]) OR (ncov[Title/Abstract]) OR (2019-nCoV[Title/Abstract]) OR (COVID 19[Title/Abstract]) OR (COVID-19 Virus[Title/Abstract]) OR (Coronavirus Disease 2019[Title/Abstract]) OR (SARS Coronavirus 2[Title/Abstract]) OR (Coronavirus Disease-19[Title/Abstract]), OR (2019 Novel Coronavirus[Title/Abstract])))
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**Eligibility and selection criteria**

Two authors extracted all experimental and clinical studies that met our search criteria. Additionally, the reference list of the articles included was investigated manually. No restriction was performed on the year and language of our search. After the search was completed, we removed the duplicates and screened the remaining articles. Articles that...
did not meet our inclusion criteria were removed from the list of references during the reading of the title, abstract and full texts. The outcomes of interest were cloth masks, filtration efficiency, penetration, pressure drop, and quality factor. Studies that refer to one or more of the above outcomes are included in our study. The inclusion criteria did not include any editorials, reviews and meta-analyses, reports and conference papers, and articles with insufficient data.

**Data extraction**

Data are summarized in the table (Table 1) based on a pre-defined checklist. The author’s name, date, and place of the study, study type, sample size, identity and size of the particles, air flow rate or velocity, mask type, primary results, and risk of bias were extracted and summarized. All procedures of literature search, study selection, and data extraction were performed separately by two researchers. Any disagreement in the selection of articles has been resolved through discussion and consensus.

**Quality assessment**

The checklist evaluated all laboratory-based quasi-experimental studies (non-randomized experimental studies). For clinical trials, the checklist of randomized control trials (RCTs) from the Joanna Briggs Institute (JBI) was used (Tufanaru et al. 2017). The evaluated criteria were divided into nine areas for experimental studies and thirteen areas for clinical trials, categorized with “yes,” “no,” “unclear,” or “not applicable.” The checklists were analyzed for each study and classified by two authors as low, moderate, or high risk of bias. This final classification was assigned to the study and classified by two authors as low, moderate, or high risk of bias. This final classification was assigned to the experiment, three or four as moderate risk, and five or more as high risk. This final classification was assigned to the study and classified by two authors as low, moderate, or high risk. This final classification was assigned to the study and classified by two authors as low, moderate, or high risk. This final classification was assigned to the study and classified by two authors as low, moderate, or high risk of bias (Santos et al. 2020). In RCTs, one or two domains were included, while three or four were excluded, and five or more needed more information.

**Results**

**Study selection**

A total of 1163 records were primarily identified in the three electronic databases searched: PubMed, Web of Science, and two records from the reference list of other studies (Fig. 1). After the endnote manager removed 381 duplicates, 718 titles and abstracts were examined. Seventy records that satisfied the inclusion/exclusion criteria were retained for full-text assessment. Finally, forty-four articles have been selected and included in the qualitative synthesis of this systematic review. The summaries of the qualitative and quantitative data are shown in Table 1, respectively.

**Study characteristics**

The 44 final studies included in this systematic review consisted of three randomized control trials (RCTs) and 41 laboratory studies. The sample size, including different cloth mask models, was between 1 and 48. In three RCTs, the sample size was the number of people who participated in the trial, between 211 and 569. More than half of the studies (n = 21) researched cloth materials, and the other half investigated commercial cloth masks. In these experiments, sodium chloride (NaCl) particles used more than all particles to examine different masks. Seventeen studies used NaCl particles in a size range of 0.009–10 µm, the flow rate was between 0.1–85 L.min⁻¹, and the velocity was in the range of 5.3–1650 cm.s⁻¹ (Bowen 2010; Clapp et al. 2020; Drewnick et al. 2021; Hao et al. 2020; Joshi et al. 2020; Konda et al. 2020a; Liu et al. 2019; Long et al. 2020; Mueller et al. 2020; O’Kelly et al. 2020; Park and Jayaraman 2020; Pei et al. 2020; Rengasamy et al. 2010; Varallyay et al. 2020; Wang et al. 2020; Zangmeister et al. 2020; Zhao et al. 2020; Guha et al. 2021). In addition to sodium chloride, three studies used another particle. One of them used 0.101 µm polystyrene latex (PSL) particles with a velocity of 10 cm.s⁻¹ (Lu et al. 2020). In the other one, paraffin oil aerosols were utilized with the 0.225 µm count median diameter (Jung et al. 2013). The third one used KCL + sodium fluorescein with 0–7 µm particle size range and 28.3 L/min flow rate (Lindley et al. 2021). Nine studies used different particles that ranged in the size of 0.001–10 µm; the flow rate was between 0.9–300 L.min⁻¹ (Aydin et al. 2020; Chen et al. 2013; Cherrie et al. 2018; Lustig et al. 2020; Maher et al. 2020; Neupane et al. 2019; Pacitto et al. 2019; Shakya et al. 2017; Xiao et al. 2020). One study reported a velocity of 44.4 m. s⁻¹ (Xiao et al. 2020), and another study reported the velocity of 17.1 m. s⁻¹ (Aydin et al. 2020). Five studies used virus and bacteria particles to measure the efficiency of masks (Davies et al. 2013; Ma et al. 2020; Rodriguez-Palacios et al. 2020; Ueki et al. 2020; Whiteley et al. 2020). These particle sizes ranged from 0.023–1000 µm. In one study, the flow rate was 30 L.min⁻¹ (Davies et al. 2013). Four other studies did not mention the flow rate or velocity (Ma et al. 2020; Rodriguez-Palacios et al. 2020; Ueki et al. 2020; Whiteley et al. 2020). Three studies designed the experiment with respiratory particles produced by breathing, coughing, and talking that ranged from 0.01 to 20 µm and the flow rate was in the range of 5–80 L.min⁻¹ (Asadi et al. 2020; Li et al. 2020b; van der Sande et al. 2008). Except for three studies that used human subjects (Asadi et al. 2020; Clapp et al. 2020; van der Sande
| Author                | country  | Type of Study | Sample size (n) | Particle(s)                                      | Flow rate (L/min) | Velocity (cm/s) | Type of Mask                                      | Main results (Filtration Efficiency)                                                                 | Risk of bias* |
|-----------------------|----------|---------------|-----------------|--------------------------------------------------|-------------------|-----------------|---------------------------------------------------|---------------------------------------------------------------------------------|----------------|
| (Maher et al. 2020)   | USA      | Experimental  | 12              | 1 µm Di-Ethyl-Hexyl-Sebacat (DEHS)                | 300 L/min         |                 | Masks of one, two, and three layers of cotton shower curtain vacuum bag coffee filter non-woven fabric | Average FE$_{1\mu m}$ was between 74.4–95.2% By increasing the layers, FE increased | Moderate       |
| (Xiao et al. 2020)    | Japan    | Experimental  | 11              | 8.2 µm Starch micro-droplets 0.75 µm Latex microspheres | Velocity 4440 cm/s | 4440 cm/s       | 6 layers cotton gauze masks Cotton T-shirts silk linen tissue paper cotton gauze | Average FE$_{0.75 \mu m}$ was between 53.2–93.8% Average FE$_{8.2 \mu m}$ was between 36.7–90.4% By increasing the layers, FE increased | Low            |
| (O'Kelly et al. 2020) | UK       | Experimental  | 31              | 0.02–0.1 µm NaCl                                  | Velocity 1650 cm/s | 1650 cm/s       | Disposable and Washable HEPA Vacuum Bags Jeans Denim Thick felted wool Windbreaker Cotton, Heavyweight Woven 100% cotton, 100% polyester mix | Average FE$_{0.02–0.1 \mu m}$ was between 10–62% By increasing the layers, FE increased | Moderate       |
| (Lu et al. 2020)      | China    | Experimental  | 4               | 0.101 µm PSL 0.042 µm NaCl                        | Velocity 10 cm/s  |                 | -                                                 | Average FE$_{0.1 \mu m}$ was between 22.9–88.3% By Increasing the filter weight, its efficacy increases Cloth masks washing have little effect on their FE | Low            |
| Author | country | Type of Study | Sample size (n) | Particle(s) | Flow rate (L/min) | Velocity (cm/s) | Type of Mask | Main results (Filtration Efficiency) | Risk of bias* |
|--------|---------|---------------|----------------|-------------|------------------|----------------|-------------|-------------------------------------|--------------|
| (Drewnick et al. 2021) | Germany | Experimental | 48 | 0.03, 0.05, 0.1, 0.25, 0.5, 1, 2.5, 5, and 10 µm NaCl | Velocity | 5.3 cm/s 12.9 cm/s | 100% cotton mixed cotton synthetic cloths PU foams triangle bandage paper towels coffee filter | FE<sub>≤2 microns</sub> was observed for particles between 0.05-0.5 µm. The efficiency was higher for particles above 2.5 µm. With increasing face velocity, the FE decreased for ≤250 nm particles and increased for ≥2.5 µm particles | Low |
| (Konda et al. 2020a) | USA | Experimental | 15 | 0.01–10 µm NaCl | Flow rate | 35 and 90 L/min | Cotton 80 & 600 TPI Chiffon Natural silk hybrids | Average FE<sub>≥0.3 µm</sub> was between 9–97% Average FE<sub>≤0.3 µm</sub> was between 12–99.5% Materials with an electrostatic charge have a better effect on smaller particles By increasing the TPI of the materials FE increase | Moderate |
| Author                  | country     | Type of Study | Sample size (n) | Particle(s)           | Flow rate (L/min) | Velocity (cm/s) | Type of Mask       | Main results (Filtration Efficiency)                                                                                                                                                                                                                                                                                                                                 | Risk of bias* |
|-------------------------|-------------|---------------|-----------------|-----------------------|-------------------|-----------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| (Pei et al. 2020)       | USA-China   | Experimental  | 10              | 0.03–1 µm NaCl         | Velocity 10.5 cm/s |                      | vacuum bag common household materials | Electrically charged fabrics are recommended because they are highly effective and, at the same time, have good breathability. By increasing the layers, FE increased. A coffee filter is not recommended according to its low FE.                                                                                                                                                                                                 | Moderate      |
| (Jung et al. 2013)      | Korea       | Experimental  | 3               | CMD≈ 0.078 µm NaCl CMD≈ 0.225 µm paraffin oil aerosols |                   | handkerchiefs    | handkerchiefs     | have no protection against aerosols                                                                                                                                                                                                                                                                                                                                                   | Low           |
| Author                     | country | Type of Study | Sample size (n) | Particle(s)                          | Flow rate (L/min) | Velocity (cm/s) | Type of Mask | Main results (Filtration Efficiency)                                                                                                                                                                                                 | Risk of bias* |
|---------------------------|---------|---------------|----------------|-------------------------------------|------------------|----------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| (Shakya et al. 2017)      | USA     | Experimental  | 3              | PSL 0.03, 0.1, 0.5, 1, 2.5 µm       | Flow rate 19, 8 L/min | -              | The fabric mask with exhaust valve had the best FE The FE against standard particle sizes of 0.03, 0.1, 0.5, 1, and 2.5 µm was between 39–65% These masks did not provide adequate protection against diesel combustion (poly disperse) particles The FE for diesel combustion particles were between 15–57% for 0.03, 0.1, and 0.5 µm | Moderate     |
| (Hao et al. 2020)         | USA     | Experimental  | 13             | NaCl 0.3-1 µm                       | Velocity 23.2, 15.3, 9.2 cm/s | Scarf Bandana pillowcases with different TPIs | These fabrics with different TPIs did not have good FE and did not have good breathability                                                                                                                     | Moderate     |
| (Zangmeister et al. 2020) | USA     | Experimental  | 41             | NaCl 0.05-0.825 µm                  | Velocity 6.3 cm/s | pieces of cotton wool synthetics synthetic blends synthetic and cotton blends paper fabrics polypropylene-based fiber | Fabrics with the best FE, moderate TPI, and visible raised fibers particle charge have no effect on FE                                                                                                           | Low          |
| Author               | country | Type of Study | Sample size (n) | Particle(s)         | Flow rate (L/min) | Velocity (cm/s) | Type of Mask                  | Main results (Filtration Efficiency)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Risk of bias* |
|---------------------|---------|---------------|-----------------|---------------------|-------------------|-----------------|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
| (Park and Jayaraman 2020) | USA     | Experimental  | 9               | NaCl 0.017-0.982 µm | Velocity 8.7 cm/s | Polyester       | Average FE 0.3 µm was between 9–88% The presence of a filter between the two layers increases the FE A filter with a pile on both sides is more effective than a filter with a one-way pile Increasing layers increases the FE                                                                                                                                                                                                                     | Moderate     |
| (Zhao et al. 2020)  | USA     | Experimental  | 10              | 0.022–0.259 µm NaCl CMD= 0.075 µm | Flow rate 32 L/min | cotton polyester nylon silk | As quality does not change with multilayers, cotton, polyester, and polypropylene multi-layered structures can have an FE equal to or greater than medical masks                                                                                                                                             | Moderate     |
| Author             | Country     | Type of Study | Sample size (n) | Particle(s)                  | Flow rate (L/min) | Velocity (cm/s) | Type of Mask                                                                 | Main results (Filtration Efficiency)                                                                 | Risk of bias* |
|--------------------|-------------|---------------|-----------------|-----------------------------|------------------|----------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|--------------|
| (Teesing et al. 2020) | Netherlands | Experimental  | 10              | 0.3, 0.5, 1.0 and 5.0 µm particles | Flow rate 28.31 L/min |                 | Cleaning cloth between quilt fabric, Two layers of coffee filter between quilt fabric, Felt between quilt fabric, Leather, Microfiber fabric, One layer of Household paper towel between quilt fabric, Two layers of Household paper towel between quilt fabric, Quilt fabric (2,4,6 layers), Static dust cloth between quilt fabric, Tea towel (1,2 layer) | Leather performed the best, and after that, a folded coffee filter or household paper towel between quilt fabric and microfiber fabric. Maximum efficacy is for microfiber material, and minimum efficacy is for tea towel material. The average FE_{0.3 \mu m} was between 5 and 100%. The average FE_{0.5 \mu m} was between 13 and 100%. The average FE_{1 \mu m} was between 14 and 100%. Average FE_{1 \mu m} was between 35 and 99%. The average FE_{3 \mu m} was between 36 and 99%. | Moderate |
| (Long et al. 2020)   | USA         | Experimental  | 9               | Median diameter = NaCl 0.04 µm | Flow rate 25 L/min |                 | Vacuum bag, Cotton, Paper towel                                             | The average FE_{0.04 \mu m} was between 35 and 53%                                                  | Low          |
| Author            | Country | Type of Study | Sample size (n) | Particle(s)                                                                 | Flow rate (L/min) | Velocity (cm/s) | Type of Mask                  | Main results (Filtration Efficiency) | Risk of bias |
|-------------------|---------|---------------|----------------|-----------------------------------------------------------------------------|-------------------|-----------------|-------------------------------|-------------------------------------|--------------|
| (Aydin et al. 2020) | USA     | Experimental  | 14             | 100–1000 µm distilled water with 100 nm-diameter fluorescent nanoparticles (beads) act as covid-19 viruses | Face velocity 1710 cm/s | 100% cotton Knitted and woven 100% polyester Cotton/polyester silk | Breathability increases strongly by fabrics porosity knit fabrics have lower FE than woven fabrics Even one layer of these fabrics has a high FE against high-velocity droplets Increasing the number of layers can increase the effectiveness of these masks | Low | 
| (Mueller et al. 2020) | USA     | Experimental  | 16             | CMD = 0.009 µm CMD = 0.04 µm NaCl | Flow rate 0.1 L/min | Cotton quilt Cotton plain Cotton duck Cotton twill Cotton muslin Pellon Melt blown filter (BFE85) Woven nylon Massage table covering | The average FF 0.04 µm was between 28.2 and 90.7% Nylon overlayer increased the efficacy to 7% more in surgical-type masks and had the least effect on cone-shaped ones | Moderate | 
| (Whiley et al. 2020) | Australia | Experimental | 8              | MS2 aerosols 6 & 2.6 µm | 100% cotton 100% Mulberry Silk | Vacuum cleaner bag | The average FE 6.0 µm was at least 50% | Moderate | 
| (Davies et al. 2013) | UK      | Experimental  | 10             | MS2 0.023 µm Bacillus atrophaeus 0.95–1.25 µm | Flow rate 30 L/min | 100% cotton T-shirt Silk Linen Vacuum cleaner bag | The average FE 0.023 µm was 48.87–89.52% | Moderate |
| Author | country | Type of Study | Sample size (n) | Particle(s) | Flow rate (L/min) | Velocity (cm/s) | Type of Mask | Main results (Filtration Efficiency) | Risk of bias* |
|--------|---------|---------------|----------------|-------------|------------------|----------------|-------------|-------------------------------------|--------------|
| Li et al. 2020b | USA | Experimental | 2 | 0.01–1 µm coughing particles | Flow rate 20.5 L/min | 100% cotton 50% cotton+50% polyester mix | Fabric masks were able to reduce cough particles by up to 77% | Low |
| Pacitto et al. 2019 | Spain | Experimental | 1 | <2.5 µm <0.1 µm air pollution 0.001–0.005 µm black carbon (BC) | Flow rate 32 42 L/min 52 | A Fiber cloth mask | FE increases with breathing rates per PNC FE decreases with the increase of the breathing rate | Moderate |
| Ueki et al. 2020 | Japan–USA | Experimental | 1 | <3 µm 20%; 3 to 5 µm 40% > 5 to 8 µm 40% SARS-CoV-2 Virus suspension particles | - | Cotton masks Comprised a double layer of cotton, with each layer consisting of two layers of 100% cotton gauze, resulting in a total of four layers of gauze, with typical double-strap ties | Cotton masks reduced the respiration of viral particles by 20 to 40% compared to no mask In contrast, a cotton mask reduces the respiration particles of the mask used by up to 50% | Low |
| Chen et al. 2013 | Taiwan | Experimental | 1 | <1 µm particles of welding | Input 2 L/min Output 0.9 L/min | A cotton fabric face-mask | The cotton mask had a more than 99% particle removal efficiency | Low |
| Clapp et al. 2020 | USA | Experimental | 7 | 0.05 µm median count diameter of NaCl particles | - | Woven nylon mask Cotton bandana folded once Multilayer rectangle Woven polyester and Nylon mask Non-woven polypropylene mask Woven gaiter Polyester/spandex Bandana Woven 100% cotton mask | The mean FE of face masks was between 79.0% to 26.5% The 2-layered woven nylon mask showed the highest FE | Moderate |
| Author | country | Type of Study | Sample size (n) | Particle(s) | Flow rate (L/min) | Velocity (cm/s) | Type of Mask | Main results (Filtration Efficiency) | Risk of bias* |
|--------|---------|---------------|----------------|-------------|------------------|----------------|--------------|-------------------------------------|-------------|
| (Li et al. 2020a) | China | Experimental | 4 | 0.006–0.2 µm, 0.3 µm particle (ASTM simulation) | - | - | Tissue paper folded and unfolded Tissue paper + kitchen towel | Single-layer tissue paper had the FE\textsubscript{\text{max}} followed by double-layer kitchen towels (6–200 nm: 84.54%, 90–200 nm: 72.89%, and FE of > 99.9% at 3 µm) | Low |
| (Fischer et al. 2020) | USA | Experimental | 10 | - | - | - | Cotton-polypropylene Cotton mask Maxima AT mask One and two-layer of cotton pleated and olsen style mask Polyester/spandex mask Bandana Polypropylene mask | The bandana merely reduced the droplets The FE of a cotton mask is much stronger | Low |
| (Varallyay et al. 2020) | Portland | Experimental | 18 | 0.04 µm NaCl | - | - | Microfiber woven cloth (4,2,1 layers) 100% woven cotton tea towel (2,1 layers) polyester Knitted (4,2,1 layers) Hospital woven scrubs (2,1 layers) 100% Knitted cotton T-shirt (4,2,1 layers) 100% Knitted polyester thick and thin fleece (2,1 layers) 100% Woven silk (2,1 layers) Vacuum cleaner bag Felt, 1, 1.5, and 2 mm (4,2,1 layers) Paper kitchen towel (2,1 layers) Paper facial tissue (2,1 layers) | The average FE\textsubscript{0.04 µm} for woven fabrics was between 27.64 and 99.66% The average FE\textsubscript{0.04 µm} for non-woven fabrics was between 38.73 and 98.73% Polyester felt demonstrated significantly higher filtration performance On the other hand, noneelastic 100% cotton fabrics performed the worst | Low |
| Author                                      | country | Type of Study | Sample size (n) | Particle(s)                                      | Flow rate (L/min) | Velocity (cm/s) | Type of Mask                  | Main results (Filtration Efficiency)                                                                 | Risk of bias* |
|---------------------------------------------|---------|---------------|-----------------|-------------------------------------------------|-------------------|-----------------|--------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------|
| (Neupane et al. 2019)                       | Nepal   | Experimental  | 4               | <5 5–10 µm >10 Air pollution particles          | -                 | -               | Cloth masks                  | Average FE was between 63 and 84%                                                                               | Low          |
| (Ma et al. 2020)                            | China   | Experimental  | 1               | 3.9 µm CMD of avian influenza virus (AIV) particles | -                 | -               | One layer of polyester cloth + four-layer of kitchen paper | The FE of the homemade mask was 95.15%                                                                          | Low          |
| (van der Sande et al. 2008)                 | Netherland | Experimental | 1               | 0.02–1 µm Particles during breathing or speaking | Flow rate 30, 50, and 80 L/min | -               | Tea cloths homemade mask     | For all types of masks, outward protection was significantly lower than inward protection Homemade masks have very little protection These masks protect children much less than adults Activity had no significant impact on protection | Low          |
| (Joshi et al. 2020)                         | India   | Experimental  | 5               | 0.35, 0.55, 1.25 µm Total (> 0.3 µm) 0.06–0.14, 0.05, 0.02 µm NaCl particles | Flow rate 28.3 L/min | -               | One layer of quilter's cotton fabric | The average FE $_{0.35\mu m}$ was 14.22% The average FE $_{0.55\mu m}$ was 26.49% The average FE $_{1.25\mu m}$ was 39.05% Average FE $_{0.03\mu m}$ was 14.48% The FE$_{min}$ (8.27%) was found to be in the particle size range of 0.06-0.14 µm | Low          |
| Author                  | country   | Type of Study | Sample size (n) | Particle(s)                  | Flow rate (L/min) | Velocity (cm/s) | Type of Mask                                | Main results (Filtration Efficiency)                                                                 |
|------------------------|-----------|---------------|-----------------|------------------------------|-------------------|-----------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------|
| (Wang et al. 2020)     | China     | Experimental  | 17              | 0.075 µm NaCl particles      | Flow rate         |                 | T-shirt, Fleece sweater, Outdoor jacket, Down jacket, Sun-protective clothing, Jeans, Hairy or granular tea towel, Non-woven fabrics, Shopping bag, Vacuum cleaner bag, Diaper, Sanitary pad, Pillowcase air-jet down-proof fabric or jet satin | Average FE\(_{0.075 \mu m}\) Low was between 0-23% The FE of the fleece sweater + hairy tea towel was > 50% |
| (Rengasamy et al. 2010) | USA       | Experimental  | 15              | Poly disperse NaCl aerosols 0.075 µm, Monodisperse NaCl aerosols (0.02, 0.03, 0.04, 0.05, 0.06, 0.08, 0.1, 0.2, 0.3, and 0.4 µm), NaCl larger particles 0.5–1 µm | Velocity 5.5 and 16.5 cm/s | Sweatshirts, T-shirts, Towels, Scarves, Cloth masks | The protection of these masks against polydisperse and monodisperse particles was highly variable With increasing face velocity to 16.5 cm s\(^{-1}\), monodisperse particles' penetration increased, and polydisperse particles did not change Because household masks do not fit well to the face, they provide very little protection against submicron particles | Low                                                                                                                                              |
| Author                     | country | Type of Study | Sample size (n) | Particle(s)                                                                 | Flow rate (L/min) | Velocity (cm/s) | Type of Mask | Main results (Filtration Efficiency)                                                                                                                                                                                                 | Risk of bias* |
|-----------------------------|---------|---------------|-----------------|-----------------------------------------------------------------------------|-------------------|-----------------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| (Rodriguez-Palacios et al. 2020) | USA     | Experimental  | 6               | 20 and 900 µm with peak at 70–100 µm 12-probiotic cultured dairy product bacterial particles | -                 |                 | 100% combed cotton 100% polyester 300 TPI Microfiber 100% loosely woven cotton fabrics (52,48 TPI) 100% polyester in sports jerseys | Increase the material layers to two provides 100% protection against larger particles and 97.2% protection against micro-particles The least-effective textile was one layer of 100%-cotton homespun-115) with FE = 90–99 In the form of two layers showed 99.8% effectiveness | Low             |
| (Asadi et al. 2020)        | USA     | Experimental  | 3               | 0.3 to 20 µm particles during breathing, talking and coughing                | Flow rate 5 L/min |                 | One layer of paper towel mask One layer of 100% cotton T-shirt mask 2 layers of 100% cotton T-shirt mask | 1 layer of paper towel mask did not provide any protection Single and double layers of cotton T-shirt is increased particle penetration significantly Most penetrated particles were <5 µm Cloth masks provide some protection against particles > 0.5 µm | Low             |
Table 1 (continued)

| Author                  | country | Type of Study | Sample size (n) | Particle(s)                                    | Flow rate (L/min) | Velocity (cm/s) | Type of Mask                                      | Main results (Filtration Efficiency)                                                                 | Risk of bias* |
|-------------------------|---------|---------------|-----------------|------------------------------------------------|-------------------|-----------------|-------------------------------------------------|----------------------------------------------------------------------------------------------------------|---------------|
| (Lustig et al. 2020)    | USA     | Experimental  | 14              | 0.01 and 0.2 μm polydisperse Rhodamine 6G nanoparticles in the PLGA matrix | Flow rate 14 L/min|                 | Double-layer Kona cotton + Double-layer terry cloth | Masks with absorbent layers have been most effective, including terry cloth towels, quilting cotton, and Kona cotton | Low           |
|                         |         |               |                 |                                                |                   |                 | Terry cloth towel (×2,1)                          |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | Kona cotton (×4,3,2)                              |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | White flannel (×2,1)                              |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | Heavy T-shirt 100% cotton (×2,1)                  |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | White denim + double-layer Kona cotton + white denim |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | Double-layer Kona cotton with 1 or 2 layers of white denim between them |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | Double-layer Kona cotton with one layer of white flannel between them |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | Kona cotton + Pellon                              |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | Double-layer Kona cotton with one layer of Pellon between them |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | Double-layer Kona cotton with one layer of Kona 2.2 wt % Scotchgard between them |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | Double-layer white denim with one layer of Pellon between them |                                                                                                           |               |
|                         |         |               |                 |                                                |                   |                 | Double-layer blue denim (4,7,11 oz)              |                                                                                                           |               |
| (Bowen 2010)            | Alabama | Experimental  | 1               | 1.0 to 2.5 μm NaCl                             | Flow rate 8.75 L/min|                 | Bandana                                         | The average FE of the bandana was 11.3%                                                               | Low           |
| (Liu et al. 2019)       | China   | Experimental  | 1               | 0.075 μm NaCl                                  | Flow rate 85 L/min |                 | A reusable cloth mask                            | FE_{0.075μm} was 20%. The airflow resistance was high (200)                                         | Low           |
| Author                  | country | Type of Study | Sample size (n) | Particle(s)      | Flow rate (L/min) | Velocity (cm/s) | Type of Mask                  | Main results (Filtration Efficiency)                                                                                                 | Risk of bias* |
|-------------------------|---------|---------------|-----------------|------------------|-------------------|-----------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| (Cherrie et al. 2018)   | UK      | Experimental  | 3               | <2.5 μm BC       | Flow rate         |                 | Yimeijian, Gucheng Reusable cloth masks | The PN was between 0.2% -20.7%, with the lowest value being for the ‘Yimeijian’ mask and the highest being for the ‘Gucheng mask. By increasing the flow rate, penetration increased. | Low           |
| (Lindsley et al. 2021)  | USA     | Experimental  | 1               | <0.6 μm 14% KCl and 0.4% sodium fluorescein | 28.3 L/min        |                 | 3-ply cotton cloth face mask  | FE<0.6μm was around 30%. The cloth mask FF was 1.3, which means that the ambient aerosol concentration is 1.3 times higher than the concentration inside the mask | Low           |
| Author          | country | Type of Study | Sample size (n) | Particle(s)                  | Flow rate (L/min) | Velocity (cm/s) | Type of Mask | Main results (Filtration Efficiency)                                                                 |
|-----------------|---------|---------------|-----------------|-----------------------------|------------------|-----------------|--------------|---------------------------------------------------------------------------------------------------|
| (Guha et al. 2021) | USA     | Experimental  | 21              | 0.08–0.09 µm NaCl           | 3.0 L/min         |                 |              | 100% cotton<br>100% polyester<br>100% microfiber<br>Polyester<br>Cotton mix<br>100% mulberry silk<br>Polyester + spandex<br>100% cellulose<br>Acrylic + nylon + wool | Loosely knit or woven household fabrics made of cotton are breathable fabrics and low protection fabrics; however, tightly woven cotton fabrics showed breathing resistance and at the same time better FE. Combination of different fabrics revealed better FE. 1000 TPI, 100% cotton tightly woven fabrics FE was above 40% for sub-micron particles |
| (MacIntyre et al. 2015b) | Australia | Clinical trial | 569 people received five cloth masks type | Clinical respiratory illness, influenza-like virus, human metapneumovirus, rhinoviruses, and influenza B | - | Double-layer cotton | The cloth mask did not provide adequate protection so that the disease rate in the control group was lower than the cloth mask group |
| (Yang et al. 2011) | China   | Clinical trial | 239 HCWs received cloth mask | Respiratory infections | - | Cotton-yarn mask | Masks/cotton Yarn masks, which are commonly used in Asia, do not fit well and therefore do not provide good protection |
et al. 2008), all other thirty-seven experimental studies used manikin-based models. Clinical studies measured the mask’s efficiency by health care workers who were infected by different respiratory viruses (Ho et al. 2020; MacIntyre et al. 2015b; Yang et al. 2011).

**Systematic review**

**Filtration efficacy (FE)**

By measuring the pre and post mask viral aerosols concentration, the FE will be calculated by this formula: $\text{Efficiency} (\%) = (1 - \frac{B}{A}) \times 100\%$. A: refers to the concentration of viral aerosol challenging the mask, and B is the concentration of viral aerosol after mask filtration (Wen et al. 2010). The FE in forty-one experimental studies was reported in the range of 0–100%. Four studies found FE increases by increasing the layer of clothes (Maher et al. 2020; O’Kelly et al. 2020; Xiao et al. 2020; Guha et al., 2021). One study added a nylon layer to different cloth masks and obtained the FE of surgical type masks increased but it had no effect on cone-shaped masks (Muel ler et al. 2020). Guha et al. study also revealed that a combination of woven and loosely knitted fabrics can increase the FE against sub-micron particles (Guha et al. 2021). Two different studies concluded that by increasing the weight of filter material (Lu et al. 2020) and the thread per inch (TPI) (Konda et al. 2020a), FE increased. Additionally, FE depends on different parameters, including particle size, and flow rate through the filter material (Cherrie et al. 2018). Studies showed that by increasing the flow rate and/or face velocity, FE decreases (Shakya et al. 2017; O’Kelly et al. 2020). However, Lu et al. asserted that velocity increasing (from 4 to 16 cm s$^{-1}$) has no effect on FE (Lu et al. 2020). We have to keep this point in mind that in different studies flow rate is not constant. To be sure about the comparisons, new studies with the same situation should be done. Twelve studies calculated the filtration efficiency of different materials in the particle size range of the Covid-19, which (60–100 nm) was between 0–97% (Joshi et al. 2020; Konda et al. 2020a; Li et al. 2020a, b; O’Kelly et al. 2020; Pei et al. 2020; Shakya et al. 2017; Wang et al. 2020; Zangmeister et al. 2020; Zhao et al. 2020; Lindsley et al. 2021; Guha et al., 2021) (Table 2). According to Konda et al. study, the most effective cloth mask was a hybrid of cotton/chiffon ( ). They compared different fabric materials with a separate TPI and a different number of layers (Konda et al. 2020a). Then they selected some material that had a better performance to combine. Finally, between different tested materials, cotton quilt (120 TPI) (FE = 96%), and among different hybrid masks, hybrid of cotton/chiffon (FE = 97%), hybrid of cotton/silk (no gap) (FE = 94%), hybrid of cotton/flannel (FE = 95%) had the best filtration efficiency. Albeit, we have
to mention some defects of this study. Carr et al. published a letter and criticized this study methods. According to Carr et al. study the pressure drop values were significantly lower compared to similar articles (Carr et al. 2020). Furthermore, FE of N95 reported 45–70%, which was controversial. In response, Konda et al. corrected that the N95 and cloth masks capturing efficacy measured in a significantly lower pressure drop (2.5 – 13 Pa) than similar studies (Konda et al. 2020b). The Pillowcase 80 s × 60 s Jet satin had no efficacy (Wang et al. 2020). Zangmeister et al. examined different cloth materials with a different number of layers. The best-performing materials were 100% cotton fabrics, including down-proof ticking, woven hand towel, light-weight flannel, and a 4-layer 100% cotton light-weight flannel (poplin) with a FE of 48% (Zangmeister et al. 2020). By evaluating different cloth materials, Zhao et al. found that cellulose copy paper (bonded) had the best 99.85% FE (Zhao et al. 2020). Pei et al. evaluated five layers of different materials; a 5-layer shop towel with 69% FE had better performance (Pei et al. 2020). In a study by Li et al. several cloth materials have been examined and then reported a mixture of tissue paper and kitchen towels with 71.5% FE that performed the best (Li et al. 2020a). The Joshi et al. study tested just a single-layered quilter’s cotton fabric (TPI = 85–100) that had an inadequate FE against particles in size range of 60–140 nm (FE = 8.27%) (Joshi et al. 2020). Wang et al. compared different materials; the results showed that all of the materials had low FE, but hairy tea towel 80% polyester/20% nylon with 23% FE was the best (Wang et al. 2020). O’Kelly et al. reported that disposable HEPA Vacuum Bags filtered more than 60% of 20–1000 nm particles (O’Kelly et al. 2020). In another study by Li et al., 2-ply 100% cotton masks showed 77% FE for 10–1000 nm particles (Li et al. 2020b). Shakya et al. compared 3 different cloth masks. One of them had an exhalation valve and, the others did not have it. In this study, the cloth mask with exhalation valve showed ≈ 90% FE for 100 nm particles (Shakya et al. 2017). Lindsley et al. study, revealed the ≈ 28% FE of 3-ply cotton face masks for particles ranged between 0–600 nm (Lindsley et al. 2021). And the Guha et al. reported the One Thousand TPI Bedsheet—1 (1000 TCBS1) with 48.9% FE was the best performing one-layered fabric which showed ≈ 5% FE increase after adding up another layer (Guha et al. 2021).

Moreover, Table 3 shows different surrogates tested which NaCl was the most used one. Among those tested NaCl particles, copy paper (bonded) indicated the highest FE. All these results can be seen in Fig. 2.

Two clinical trials reported that cloth masks’ efficacy was low, and the rate of respiratory infections in the cloth mask wearers was high (MacIntyre et al. 2015b; Yang et al. 2011). The previous clinical study found no difference between the cotton mask and a medical mask (Ho et al. 2020).
Table 2  Summary of studies that evaluated cloth materials in the Covid-19 particle size range

| Mask type                                         | Filter efficiency (%) | $\Delta P$ (Pa) | QF (kPa$^{-1}$) | Particle size         |
|--------------------------------------------------|-----------------------|-----------------|-----------------|-----------------------|
| 100% cotton hand towel (block), 2-layers         | 32                    | 61.8            | 6.25            | 50–825 nm             |
| 100% cotton light weight flannel (poplin), 2-layers | 24.3                  | 106             | 2.62            | NaCl method (Zangmeister et al. 2020) |
| 100% cotton light weight flannel (poplin), 4-layers | 48                    | 216             | <2.62          |                       |
| 100% cotton pillowcase (satin), 2-layers         | 20.3                  | 128.5           | 1.77            |                       |
| Polyester apparel fabric (poplin), 2-layers      | 21.4                  | 104             | 2.32            |                       |
| Polyester apparel fabric (soft spun), 2-layers   | 20.2                  | 177.6           | 1.27            |                       |
| Coffee filter                                    | 34.4                  | -               | -               |                       |
| polypropylene 4 (PP-4)                           | 6.1                   | 1.6             | 16.9            | 22–259 nm NaCl NIOSH method (Zhao et al. 2020) |
| Cotton pillow cover (woven)                      | 5.04                  | 4.5             | 5.4             |                       |
| Cotton T-shirt (knit)                            | 21.62                 | 14.5            | 7.4             |                       |
| Cotton sweater (knit)                            | 25.88                 | 17.0            | 7.6             |                       |
| Polyester toddler wrap (knit)                    | 17.50                 | 12.3            | 6.8             |                       |
| Silk napkin (woven)                              | 4.77                  | 7.3             | 2.8             |                       |
| Nylon exercise pants (woven)                     | 23.33                 | 244.0           | 0.4             |                       |
| Paper towel (bonded)                             | 10.41                 | 11.0            | 4.3             |                       |
| Tissue paper (bonded)                            | 20.2                  | 19.0            | 5.1             |                       |
| Copy paper (bonded)                              | 99.85                 | 1883.6          | 1.5             |                       |
| Coffee filter, 2 layers                          | 14                    | 153.4           | -               | 100 nm                |
| Kitchen towel, 5 layers                          | 40                    | 158.9           |                 | NaCl NIOSH method (Pei et al. 2020) |
| Bed sheet, 5 layers                              | 54                    | 433.9           |                 |                       |
| T-shirt, 5 layers                                | 64                    | 231.1           |                 |                       |
| Shop towel, 5 layers                             | 69                    | 185.8           |                 |                       |
| 4-ply tissue paper                               | 30.4                  | -               | -               | 100 nm                |
| 4-ply tissue paper folded once                   | 41.2                  |                 |                 | ASTM method (Li et al. 2020a) |
| Tissue paper + kitchen towel                     | 71.5                  |                 |                 |                       |
| Disposable HEPA Vacuum Bags                      | 60.86                 | 2               | -               | 20–1000 nm            |
| Windbreaker 100% Polyester                       | 47.12                 | 3               |                 | NaCl method (O’Kelly et al. 2020) |
| Jeans Denim 100% Cotton                          | 45.94                 | 3               |                 |                       |
| Washable Vacuum Bag HEPA                         | 43.64                 | 2               |                 |                       |
| Thick felted wool 100%                           | 35.87                 | 0               |                 |                       |
| Cotton, Heavyweight Woven 100%                   | 35.77                 | 2               |                 |                       |
| Folded Sock Cotton                               | 35.36                 | 2               |                 |                       |
| Quilting Cotton 100%                             | 34.54                 | 1               |                 |                       |
| Two-Sided Minky Fabric                           | 34.17                 | 1               |                 |                       |
| Shirting Cotton 100%                             | 33.59                 | 1               |                 |                       |
| Cotton, Lightweight Woven 100%                   | 30.2                  | 0               |                 |                       |
| Cotton Quilt Batting 100%                        | 29.81                 | 0               |                 |                       |
| Cotton Flannel 100%                              | 28.5                  | 1               |                 |                       |
| Craft Felt Miss crafts Rayon, Acrylic, Polyester  | 27.72                 | 0               |                 |                       |
| 100% Nylon Woven                                 | 27.61                 | 3               |                 |                       |
| T-shirt, Heavyweight 100% Cotton                 | 25.21                 | 1               |                 |                       |
| Cotton Jersey Knit 100% Cotton                   | 24.56                 | 0               |                 |                       |
| Lycra 82% Nylon, 18% Spandex                     | 21.6                  | 0               |                 |                       |
| Fusible Interfacing HTC                          | 15                    | 0               |                 |                       |
| T-Shirt (50% Polyester + 50% Cotton)             | 10.5                  | 0               |                 |                       |
| Quilter’s cotton fabric (TPI = 85–100), 1 layer  | 8.27                  | -               | -               | 60–140 nm             |
|                                                   |                       |                 |                 | NaCl method (Joshi et al. 2020) |
| Mask type                          | Filter efficiency (%) | ΔP (Pa) | QF (kPa−1) | Particle size     |
|-----------------------------------|-----------------------|---------|------------|------------------|
| T-shirt 100% cotton               | 12%                   | 15.8    | -          | 75 nm NaCl method (Wang et al. 2020) |
| Fleece sweater 100% cotton        | 6%                    | 5.86    | -          |                  |
| Hairy tea towel 80% polyester/20% nylon | 23%           | 13.72   | -          |                  |
| Hairy tea towel + Fleece sweater  | 56%                   | 22.84   | -          |                  |
| Fleece sweater + T-shirt          | 12%                   | 20.32   | -          |                  |
| Fleece sweater, 2 layers          | 11%                   | 12.4    | -          |                  |
| Granular tea towel 80% polyester/20% nylon | 12%           | 5.72    | -          |                  |
| Fleece sweater + Granular tea towel | 11%              | 14.08   | -          |                  |
| Non-woven shopping bag 100% polypropylene | 14%            | 7.06    | -          |                  |
| Non-woven shopping bag + T-shirt  | 30%                   | 25.26   | -          |                  |
| Non-woven shopping bag + Hairy tea towel | 46%         | 23.64   | -          |                  |
| Non-woven shopping bag + Granular tea towel | 47%        | 14.44   | -          |                  |
| Non-woven shopping bag + Fleece sweater | 35%        | 14.4    | -          |                  |
| Non-woven shopping bag, 2 layers  | 18%                   | 13.72   | -          |                  |
| Pillowcase 80 s x 60 s Jet satin  | 0%                    | 26.86   | -          |                  |
| 1000 TPI Bedsheet, 1 layer (1000 TCBS1) | 48.95       | 272     | -          | 80–90 nm NaCl method (Guha et al. 2021) |
| 1000 TPI Bedsheet, 2 layers (1000 TCBS1) | 53.34       | 314     | -          |                  |
| 1000 TPI Pillowcase (1000 TCPC)   | 41.62                 | 231     | -          |                  |
| Blue Jeans                        | 40.52                 | 197     | -          |                  |
| Microfiber pillowcase, layer (Microfiber PC1) | 30.82   | 196     | -          |                  |
| Canvas dropcloth                  | 18.89                 | 58      | -          |                  |
| Silk Pillowcase                   | 12.90                 | 11      | -          |                  |
| 200 TPI Pillowcase                | 9.94                  | 11      | -          |                  |
| 600 TPI Bedsheet 100              | 8.70                  | 19      | -          |                  |
| Wash cloth                        | 7.89                  | 5       | -          |                  |
| Flannel Bedsheets                 | 7.32                  | 11      | -          |                  |
| Microfiber Pillowcase, 2 layers   | 7.12                  | 21      | -          |                  |
| Neck tube                         | 7.10                  | 14      | -          |                  |
| Face tissue paper                 | 4.57                  | 20      | -          |                  |
| Scarf                             | 3.79                  | 5       | -          |                  |
| T-shirt                           | 3.68                  | 6       | -          |                  |
| Paper towel                       | 3.34                  | 12      | -          |                  |
| Cooling scarf                     | 2.94                  | 2       | -          |                  |
| Bandana                           | 1.52                  | 2       | -          |                  |
| 2-ply, 100% cotton mask           | 77%                   | -       | -          | 10–1000 nm volunteer method (Li et al. 2020b) |
| 3-ply, cotton cloth face mask     | ≈ 28%                 | -       | -          | <600 nm modified Greene and Vesley method (Lindsley et al. 2021), with the cough aerosol simulator |
| Cloth mask 1 (exhalation valve)   | ≈ 90%                 | -       | -          | 100 nm PSL method (Shakya et al. 2017) |
| Cloth mask 2                      | ≈ 65%                 | -       | -          |                  |
| Cloth mask 3                      | ≈ 60%                 | -       | -          |                  |
## Table 3: Comparison of different study conditions

| Mask type                                      | Filter efficiency (%) | Flow rate   | Testing surrogates used | Particle size      | Type of aerosols/droplets | Electrostatic charge of the particles |
|------------------------------------------------|-----------------------|-------------|-------------------------|-------------------|---------------------------|---------------------------------------|
| 100% cotton hand towel (block), 2-layers       | 32                    | 2.2 L/min   | NaCl                    | 50–825 nm         | Solid                     | No                                   |
| 100% cotton light weight flannel (poplin), 2-layers | 24.3                  |             |                         |                   |                           |                                       |
| 100% cotton light weight flannel (poplin), 4-layers | 48                    |             |                         |                   |                           |                                       |
| 100% cotton pillowcase (satin), 2-layers       | 20.3                  |             |                         |                   |                           |                                       |
| Polyester apparel fabric (Poplin), 2-layers   | 21.4                  |             |                         |                   |                           |                                       |
| Polyester apparel fabric (soft spun), 2-layers | 20.2                  |             |                         |                   |                           |                                       |
| Coffee filter polypropylene 4 (PP-4)           | 34.4                  | 32 L/min    | NaCl NIOSH method       | 22–259 nm         | Solid                     | No                                   |
| Cotton pillow cover (woven)                    | 5.04                  |             |                         |                   |                           |                                       |
| Cotton T-shirt (knit)                          | 21.62                 |             |                         |                   |                           |                                       |
| Cotton sweater (knit)                          | 25.88                 |             |                         |                   |                           |                                       |
| Polyester toddler wrap (knit)                  | 17.50                 |             |                         |                   |                           |                                       |
| Silk napkin (woven)                            | 4.77                  |             |                         |                   |                           |                                       |
| Nylon exercise pants (woven)                   | 23.33                 |             |                         |                   |                           |                                       |
| Paper towel (bonded)                           | 10.41                 |             |                         |                   |                           |                                       |
| Tissue paper (bonded)                          | 20.2                  |             |                         |                   |                           |                                       |
| Copy paper (bonded)                            | 99.85                 |             |                         |                   |                           |                                       |
| Coffee filter, 2 layers                        | 14                    | 85 L/min    | NaCl NIOSH method       | 100 nm            | Solid                     | No                                   |
| Kitchen towel, 5 layers                        | 40                    |             |                         |                   |                           |                                       |
| Bed sheet, 5 layers                            | 54                    |             |                         |                   |                           |                                       |
| T-shirt, 5 layers                              | 64                    |             |                         |                   |                           |                                       |
| Shop towel, 5 layers                           | 69                    |             |                         |                   |                           |                                       |
| 4-ply tissue paper                             | 30.4                  |             | Laminar airflow         | 100 nm            | Solid                     | No                                   |
| 4-ply tissue paper folded once                 | 41.2                  |             | NaCl ASTM method        | 100 nm            | Solid                     | No                                   |
| Tissue paper + kitchen towel                   | 71.5                  |             |                         |                   |                           |                                       |
Table 3 (continued)

| Mask type                                | Filter efficiency (%) | Flow rate | Testing surrogates used | Particle size | Type of aerosols/droplets | Electrostatic charge of the particles |
|------------------------------------------|-----------------------|-----------|-------------------------|---------------|---------------------------|--------------------------------------|
| Disposable HEPA Vacuum Bags              | 60.86                 | -16.5 m/s velocity | NaCl                    | 20–1000 nm    | Solid                     | (O’Kelly et al. 2020)                 |
| Windbreaker 100% Polyester               | 47.12                 |           |                         |               |                           |                                      |
| Jeans Denim 100% Cotton                  | 45.94                 |           |                         |               |                           |                                      |
| Washable Vacuum Bag HEPA                 | 43.64                 |           |                         |               |                           |                                      |
| Thick felted wool 100%                   | 35.87                 |           |                         |               |                           |                                      |
| Cotton, Heavyweight Woven 100%           | 35.77                 |           |                         |               |                           |                                      |
| Folded Sock Cotton                       | 35.36                 |           |                         |               |                           |                                      |
| Quilting Cotton 100%                     | 34.54                 |           |                         |               |                           |                                      |
| Two-Sided Minky Fabric                   | 34.17                 |           |                         |               |                           |                                      |
| Shirting Cotton 100%                     | 33.59                 |           |                         |               |                           |                                      |
| Cotton, Lightweight Woven 100%           | 30.2                  |           |                         |               |                           |                                      |
| Cotton Quilt Batting 100%                | 29.81                 |           |                         |               |                           |                                      |
| Cotton Flannel 100%                      | 28.5                  |           |                         |               |                           |                                      |
| Craft Felt Miss crafts Rayon, Acrylic, Polyester | 27.72                  |           |                         |               |                           |                                      |
| 100% Nylon Woven                         | 27.61                 |           |                         |               |                           |                                      |
| T-shirt, Heavyweight 100% Cotton         | 25.21                 |           |                         |               |                           |                                      |
| Cotton Jersey Knit 100% Cotton           | 24.56                 |           |                         |               |                           |                                      |
| Lycra 82% Nylon, 18% Spandex             | 21.6                  |           |                         |               |                           |                                      |
| Fusible Interfacing HTC                  | 15                    |           |                         |               |                           |                                      |
| T-Shirt (50% Polyester+50% Cotton)       | 10.5                  |           |                         |               |                           |                                      |
| Quilter’s cotton fabric (TPI=85–100), 1 layer | 8.27                 | 28.3 L/min | NaCl                    | 60–140 nm    | Solid                     | (Joshi et al. 2020)                  |
|                                         |                       |           |                         |               |                           |                                      |
Table 3  (continued)

| Mask type                              | Filter efficiency (%) | Flow rate | Testing surrogates used | Particle size | Type of aerosols/droplets | Electrostatic charge of the particles |
|----------------------------------------|-----------------------|-----------|-------------------------|---------------|---------------------------|---------------------------------------|
| T-shirt 100% cotton                    | 12%                   | 30 L/min  | NaCl                    | 75 nm         | Semi-solid                | (Wang et al. 2020)                     |
| Fleece sweater 100% cotton              | 6%                    |           |                         |               |                           |                                       |
| Hairy tea towel 80% polyester/20% nylon | 23%                   |           |                         |               |                           |                                       |
| Hairy tea towel + Fleece sweater        | 56%                   |           |                         |               |                           |                                       |
| Fleece sweater + T-shirt                | 12%                   |           |                         |               |                           |                                       |
| Fleece sweater, 2 layers                | 11%                   |           |                         |               |                           |                                       |
| Granular tea towel 80% polyester/20% nylon | 12%               |           |                         |               |                           |                                       |
| Fleece sweater + Granular tea towel     | 11%                   |           |                         |               |                           |                                       |
| Non-woven shopping bag 100% polypropylene | 14%                  |           |                         |               |                           |                                       |
| Non-woven shopping bag + T-shirt       | 30%                   |           |                         |               |                           |                                       |
| Non-woven shopping bag + Hairy tea towel | 46%                  |           |                         |               |                           |                                       |
| Non-woven shopping bag + Granular tea towel | 47%              |           |                         |               |                           |                                       |
| Non-woven shopping bag + Fleece sweater | 35%                   |           |                         |               |                           |                                       |
| Non-woven shopping bag, 2 layers       | 18%                   |           |                         |               |                           |                                       |
| Pillowcase 80 s × 60 s Jet satin        | 0%                    |           |                         |               |                           |                                       |
Penetration (PN)

The percent aerosol penetration (P) is defined as the ratio of the viral aerosols after filtration by maks (B) to the challenge aerosol concentration (A). Therefore, it will be calculated by this formula: \( P = \frac{B}{A} \times 100 \) (Tcharkhtchi et al. 2021). Four studies investigated the PN of particles from fabrics (Cherrie et al. 2018; Jung et al. 2013; Rengasamy et al. 2010; Shakya et al. 2017). Three of them used the hot plate method to fix the masks (Cherrie et al. 2018; Jung et al. 2013; Rengasamy et al. 2010), but one of them used maniquine based method.

Table 3 (continued)

| Mask type                          | Filter efficiency (%) | Flow rate | Testing surrogates used | Particle size   | Type of aerosols/droplets | Electrostatic charge of the particles |
|------------------------------------|-----------------------|-----------|-------------------------|-----------------|---------------------------|--------------------------------------|
| 1000 TPI Bedsheet, 1 layer (1000 TCBS1) | 48.95%                | 3.0 L/min | NaCl                    | 80–90 nm        | Solid                     | No                                   |
| 1000 TPI Bedsheet, 2 layers (1000 TCBS1) | 53.34%                |           |                         |                 |                           |                                      |
| 1000 TPI Pillowcase (1000 TCPC)     | 41.62%                |           |                         |                 |                           |                                      |
| Blue Jeans                         |                       |           |                         |                 |                           |                                      |
| Microfiber pillowcase, layer (Microfiber PC1) | 30.82%                |           |                         |                 |                           |                                      |
| Canvas dropcloth                   | 18.89%                |           |                         |                 |                           |                                      |
| Silk Pillowcase                    | 12.90%                |           |                         |                 |                           |                                      |
| 200 TPI Pillowcase                 | 9.94%                 |           |                         |                 |                           |                                      |
| 600 TPI Bedsheet 100               | 8.70%                 |           |                         |                 |                           |                                      |
| Wash cloth                         | 7.89%                 |           |                         |                 |                           |                                      |
| Flannel Bedsheets                  | 7.32%                 |           |                         |                 |                           |                                      |
| Microfiber Pillowcase, 2 layers    | 7.12%                 |           |                         |                 |                           |                                      |
| Neck tube                          | 7.10%                 |           |                         |                 |                           |                                      |
| Face tissue paper                  | 4.57%                 |           |                         |                 |                           |                                      |
| Scarf                              | 3.79%                 |           |                         |                 |                           |                                      |
| T-shirt                            | 3.68%                 |           |                         |                 |                           |                                      |
| Paper towel                        |                       |           |                         |                 |                           |                                      |
| Cooling scarf                      | 2.94%                 |           |                         |                 |                           |                                      |
| Bandana                            | 1.52%                 |           |                         |                 |                           |                                      |
| 2-ply, 100% cotton mask           | 77                    | -         | Cough particles         | 10–1000 nm      | Liquid                    | NG                                   |
| 3-ply, cotton face mask            | ≈ 28%                 | 28.3 L/min| KCL + sodium fluorescein| <600 nm         | Solid                     | NO                                   |
| Cloth mask 1 (exhalation valve)    | ≈ 90%                 | 8 L/min   | NIOSH modified method   | 100 nm          | Solid                     | NG                                   |
| Cloth mask 2                       | ≈ 65%                 |           |                         |                 |                           |                                      |
| Cloth mask 3                       | ≈ 60%                 |           |                         |                 |                           |                                      |
| Cloth mask 1 (exhalation valve)    | ≈ 90%                 |           |                         |                 |                           |                                      |
| Cloth mask 2                       | ≈ 32%                 |           |                         |                 |                           |                                      |
| Cloth mask 3                       | ≈ 28%                 |           |                         |                 |                           |                                      |

NG not given
and for mask sealing used parafilm (Shakya et al. 2017). One study tested the PN of cotton and gauze handkerchiefs with the NIOSH and KFDA methods. First, they found there was no significant difference between these two methods; second, they reported that handkerchiefs, regardless of material, had no protection against 0.075 µm NaCl and paraffin oil particles (PN > 98%) (Jung et al. 2013). Another study compared the PN of three commercial cloth masks. The one with an exhaust valve and a cone or tetrahedral shape that can fit well to the face had the least PN in both flow rates (8 & 19 L.min⁻¹) (Shakya et al. 2017). The improved performance with well-fitting masks suggests that leakage may be an issue in studies that utilize mannequins to test for filter penetration. Rengasamy et al. showed variable PN rates in cloth masks and fabric materials. The cloth masks PN was between 50 and 90% for polydisperse and 70–80% for 100 nm monodisperse aerosols at 33 L.min⁻¹. The PN of fabric materials for polydisperse aerosols was between 40–89%, and for monodisperse ones was among 9–95% at 33 L.min⁻¹ indicating that all of them had marginal efficacy (Rengasamy et al. 2010). The last study found that by increasing the flow rate, PN increased. In this study, PN was between 0.2 and 20.7%. The lowest value reported was for the “Yimeijian” mask, and the highest was for the “Gucheng” mask (Cherrie et al. 2018).

**Pressure drop (breathability)**

Seventeen studies evaluated pressure drop (ΔP) (Aydin et al. 2020; Davies et al. 2013; Drewnick et al. 2021; Hao et al. 2020; Joshi et al. 2020; Jung et al. 2013; Konda et al. 2020a; Long et al. 2020; Maher et al. 2020; Park and Jayaraman 2020; Pei et al. 2020; Teesing et al. 2020; Varallyay et al. 2020; Wang et al. 2020; Zangmeister et al. 2020; Zhao et al. 2020; Guha et al. 2021), which indicated breathability or comfort when you are breathing and face fitness of the mask or presence any leakage. ΔP has a reverse relation with breathability, which means by increasing the ΔP, breathability decreases. Also, in some studies, ΔP significantly improved by increasing the layers (Aydin et al. 2020; Davies et al. 2013; Jung et al. 2013; Wang et al. 2020). In one study, however, with increasing the layers of tightly woven fabrics, ΔP significantly declined (Guha et al. 2021). Additionally, breathability depends strongly on porosity and TPI, which means increasing the porosity increases breathability, but increased TPI has the opposite effect. (Aydin et al. 2020; Zhao et al. 2020).

Among different materials: cotton (Long et al. 2020; Maher et al. 2020), cotton-quilt (Konda et al. 2020a; Teesing et al. 2020), cotton bandana (Hao et al. 2020), cotton block hand towel (Zangmeister et al. 2020), pillowcase 100% woven cotton (Davies et al. 2013; Varallyay et al. 2020; Zhao et al. 2020), 100% cotton T-shirt (Davies et al. 2013; Varallyay et al. 2020), gauze and cotton handkerchiefs (Jung et al. 2013), fleece sweater (Wang et al. 2020), woven 100% silk scarf and thick fleece-Knitted 100% polyester (Varallyay et al. 2020), 100% polyester (Cooling scarf) and 100% microfiber polyester (bandana mask) (Guha et al. 2021), and muslin (Drewnick et al. 2021) were most breathable fabrics. The materials with the least breathability were vacuum cleaner bag and tea towel because of their thickness and stiffness (Davies et al. 2013; Long et al. 2020; Maher et al. 2020), non-woven shopping bag + T-shirt (Wang et al. 2020), microfiber cloth—80% polyester—20% polyamide (TPI: 38) (Varallyay et al. 2020), leather (Teesing et al. 2020), cellulose copy paper and nylon (Zhao et al. 2020), coffee filter (Hao et al. 2020), plain polyester (Zangmeister et al. 2020), 5-layer bedsheet (Pei et al. 2020), poplin (Drewnick et al. 2020).
One study measured breathability ($\beta$), which is related to both the pressure drop ($\Delta P$) and the changes in the flow rate, then reported that, for the same porosity, knit fabrics had higher breathability than woven fabrics (Aydin et al. 2020). Loosely knit or woven fabrics in another study considered highly breathable compared to tightly woven fabrics, which were less breathable (Guha et al. 2021). Furthermore, used knitted undershirt (75% cotton—25% polyester) showed the most breathability but, used knitted shirt (100% cotton) and used woven shirt (70% C—30% PE) were the least breathable fabrics. It has been shown that using cotton fabrics that have been washed experience shrinkage that results in pore size decrease and less breathability. Also, if various cleaning products (e.g., starch) are used for washing cloth fabrics, they can alter breathability (Aydin et al. 2020). Albeit, we have to keep in mind that cloth masks reuse will increase the risk of infection unless washing properly (Szarpak et al. 2020).

Additionally, one study tested all the fabrics after one cycle of washing with a home laundry machine. In this study, dampness has been tested. Some fabrics FE like quilting cotton, cotton flannel after dampness has not been changed. However, some of them like denim FE substantially decreased (O’Kelly et al. 2020). Therefore, we can conclude that washing can affect some fabrics FE but not all. Another study reported no significant pressure drop indicated between different fabrics (Park and Jayaraman 2020).

Filter quality (Q)

Four studies evaluated the filter quality of different fabrics (Drewnick et al. 2021; Hao et al. 2020; Zangmeister et al. 2020; Zhao et al. 2020). Filter quality is a factor for indicating filter performance. It is related to two factors: FE and pressure drop; by increasing the FE and decreasing the pressure drop, the filter’s quality increases. It will also not be affected by the number of layers of a single-layer fabric (Zangmeister et al. 2020; Zhao et al. 2020). Furthermore, a study found no correlation between filter quality and TPI (Drewnick et al. 2021). In one study, cotton sweaters and T-shirts had better filter quality, but cellulose copy paper had the worst quality (Zhao et al. 2020). The second study reported better filter quality for vacuum bags (Drewnick et al. 2021; Hao et al. 2020), and the coffee filter had the lowest quality (Hao et al. 2020). In the third study, cotton hand towels had better filter quality, and plain polyester had a low filter quality (Zangmeister et al. 2020). In the fourth study, silk had the least quality (Drewnick et al. 2021).

Fit factor (FF)

FF describes the penetration around the mask and towards the breathing zone and expresses how good the fit of a mask is on the face. FF is the ratio of time-averaged particle concentration outside and inside mask (van der Sande et al. 2008). The FE of a mask is dependent on the FF, while the FF itself could be influenced by some factors such as the type of user's activity and facial characteristics (Pacitto et al. 2019). One study done by Clapp et al. measured the fitted filtration efficiency (FFE) ranged from 26.5 to 79% by OSHA regulations. All the samples were fitted on a man face with no beard in different ways (Clapp et al. 2020).

Additionally, Teesing et al. considered a FF of 100 or higher as a good fit. In their study, none of the cotton masks report a well fit (Teesing et al. 2020). Protection factors (PF) is a similar concept to FF that is related to Portacount devices, but FF is used by OSHA (van der Sande et al. 2008). Mueller et al. found that surgical-type cloth masks had less FE because of their poor fit. Therefore, adding up a nylon layer to the cloth masks decreased gaps and increased FE (Mueller et al. 2020). Davis et al. revealed that stretchy fabrics like 100% cotton T-shirts are more fittable and preferable than non-stretch fabrics with the same FE (Davies et al. 2013). Lindsley et al. analyzed the FF of 3-ply cotton face mask which was 1.3 and showed the 50.9% FE (Lindsley et al. 2021).

Discussion

Currently, many studies have been evaluated on fabric masks, but none of them have compared the protected efficacy of fabric masks. This issue has become even more complex when one compares different types of fabrics, different layers of fabrics. In this systematic review, we attempt to compare fabric masks based on filtration efficiency, pressure drop, QF, penetration, and fit factor. Different fabric masks’ performance to find the best potential choice to limit the spread of respiratory particles. In two studies, single-layered cotton quilt (TPI≈80) showed FE≈9% (Joshi et al. 2020; Konda et al. 2020a). After adding another layer of the cotton quilt, its efficiency increased five times (FE = 50%). Also quilting cotton was one of the best fabrics as it showed an acceptable FE for both damp and dry particles and good breathability (O’Kelly et al. 2020). Moreover, by increasing the cotton quilt’s TPI to 120, its efficiency increased by more than ten times (FE = 96%) (Joshi et al. 2020). Despite increasing the number of layers or increasing the TPI of the fabric, all samples were breathable, and that was a good point. The tighter a fabric’s weave, the smaller the pores and the increase in FE as 1000 TPI 100% cotton bed sheets showed modest FE (48.9%) but high $\Delta P$, which exceeded...
the limit (Guha et al. 2021). In contrast, a higher yarn count and a looser weave resulted in a lower FE (Zangmeister et al. 2020). Cotton with a higher yarn count and a looser weave showed a lower FE. Perhaps the higher yarn count causes more penetration and less FE. It should be mentioned that the best performing cloth materials have moderate yarn counts (Zangmeister et al. 2020). In addition to the cotton quilt, other 100% cotton fabrics like cotton flannel revealed well FE and tolerable ΔP (O’Kelly et al. 2020). Additionally, in the Zangmeister et al. study, 2-layers 100% cotton fabrics (TPI = 100 = 150) had 24% ≤ FE ≤ 32%. In this study, 4-layer 100% cotton light-weight flannel (poplin) had elevated FE to 48% compared with two layers (FE = 24.3%). After increasing the layers, ΔP increased, and filter quality decreased (Zangmeister et al. 2020). Hence, 100% cotton fabric like cotton flannel with one to two layers can be a good option. Also, in the Li et al. study, a 2-ply 100% cotton fabric’s FE was 77% but, they reported that all tested cloth masks had less FE for particles < 1000 nm (Li et al. 2020b). We note that the efficacy of these two is different, perhaps because of the difference in the particle size range, which was greater in the Li et al. study (50–825 nm vs 10–1000 nm). To enable a better comparison, 2-layered 100% cotton should be tested in the same situation. Given this study and the previous one, it can be concluded this fabric can be a good choice. A 3-ply cotton face mask showed about 28% FE for particles < 600 nm (Lindsay et al. 2021). In Zhao et al. ‘s study, the copy paper, while showing high FE, also had a very high ΔP that made it of low quality. Despite having good filtration, copy paper is not a good choice for a mask (Zhao et al. 2020). O’Kelly et al., after evaluating different fabrics, stated that vacuum cleaner bags had the best efficacy. Also, Windbreaker 100% Polyester and Jeans Denim 100% Cotton had good FE, but they were not as breathable as vacuum cleaner bags (O’Kelly et al. 2020). Therefore, a vacuum cleaner HEPA bag seems a good choice as a filter layer in a cloth mask but, three studies reported it as an unbreathable fabric (Davies et al. 2013; Long et al. 2020; Maher et al. 2020). This discrepancy refers to the other materials tested in O’Kelly’s study. As we mentioned, the vacuum cleaner bag is more breathable than jeans and a windbreakerFabrics like silk have enhanced FE because of their electrostatic properties that attract and hold particles. This is an important point that is being considered in mask design (Zhao et al. 2020). In another study, hairy tea towels alone had 23% efficacy. After it was combined with the fleece sweater, its efficacy converted to the best among other materials and became more than 50%. Its ΔP was under 49 Pa, which shows it is a breathable fabric. Fleece sweater is one of the most breathable fabrics that its FE is reported 6% (Wang et al. 2020). Therefore, it is a good choice for combining with other fabrics to make a breathable and more effective mask. Pei et al. evaluated different fabrics against particles in the 30–1000 nm size range. For 100 nm particles, a 5-layer shop towel had the best efficacy, but the study did not report its explicit material. Furthermore, the figure of merit related to FE and ΔP did not compare the shop towel with the other materials (Pei et al. 2020). So, we cannot decide if it is a reasonable choice. In the Li et al. study, one layer of 4-ply tissue paper followed by two layers of kitchen towel showed the best efficacy (FE = 71.5% for 100 nm particles). They also reported that the most particle penetrating size was between 100 and 125 nm (Li et al. 2020a). Although the mask has the least efficacy at 100 nm, it is suitable for preparing fabric masks. However, it should be noted the mask breathability and quality factor were not reported and require further study. Considering these results, hybrid fabrics can work well as a mask. In the second step, we are going to discuss cloth mask studies. Shakya et al. compared three different cloth masks but they did not mention the cloth mask fabric materials. They recently reported the cloth mask with an exhalation valve had better filtration effectiveness and less particle penetration (Shakya et al. 2017). Thus, we are unable to fully evaluate their findings. In addition to the FE, some studies compared different cloth masks by using penetration rates. Three did not mention the details about cloth mask materials (Cherrie et al. 2018; Rengasamy et al. 2010; Shakya et al. 2017). In addition to the cloth masks, Rengasamy et al. had also examined several different fabrics: three brands of Sweatshirt, T-shirt, towel, and scarf in different materials. Penetration for mono and polydisperse aerosols was variable, and it showed marginal efficacy for these materials, especially for particles < 1000 nm (Rengasamy et al. 2010). Jung et al. investigated the penetration of cotton and gauze handkerchiefs with two KFDA and NIOSH methods. This evaluation showed that both cotton and gauze handkerchiefs had more than 98% penetration, and after folding, penetration decreased to 87%, which is still high. These results show us that handkerchiefs are not able to filter 75 nm particles well (Jung et al. 2013). Fabrics tested in penetration studies could not filter particles well. Between two RCTs tested on health care workers (HCWs), the first RCT reported that cotton yarn masks were not recommended for HCWs. The cloth mask layer count was not mentioned in this study (Yang et al. 2011). The second one used a 2-layered cotton cloth mask, but the highest rate of respiratory infections was in HCWs who wore cloth masks (Machntyre et al. 2015b). In both studies, only one type of cloth mask was used, not different types. We recommend more clinical trials to compare cloth masks but not for HCWs, as two RCTs reported them insufficient. Another clinical study reported that a 3-layered 100% cotton mask had no significant difference from a surgical mask but did not report its exact FE (Ho et al. 2020). So, we are not able to report it as a good choice. Although our study aimed to compare just cloth masks FE. Masks of category 1 which
filters > 95% of particles > 3 μm (respirators), and medical masks are more effective than cloth masks (Chughtai et al. 2020) as some countries like France banned the use of cloth masks with the outbreak of new covid-19 variants (Mahase 2021).

Limitations

Our results and conclusion are based on all the studies that are done up to the present time, which are mostly experimental. Thus, there is a great need for clinical trials. In these studies, instead of using the Covid-19 particles, different surrogates (sodium chloride, cough particles, KCL + sodium fluorescein, PSL) have been used. All the studies that analyzed the FE of masks against particles in the Covid-19 particle size range with the use of different surrogates did not evaluate the FF. Because of that, we could not compare masks in this field. At the end of this study, we bring some tables that compare studies in different aspects. But because of the different situations of these studies, we could not bring a complete comparison, and some factors like the type of the surrogates and flow rate that have critical effects of FE are not mentioned.

Conclusion

Cloth masks and fabrics have provided some protection, with some variability noted. The use of cloth masks by the general population can protect them to some degree. The purpose of this study is to find the best fabrics, especially against Covid-19. We compare different materials for their filtration, efficacy, penetration, pressure drop, and filter quality. The best performing fabrics are: cotton quilt (1–2 layers), cotton flannel, 2-layered 100% cotton, hybrid of cotton + flannel, and hairy tea towel + fleece sweater. Multi-layered fabrics showed better filtration efficiency, and breathability. One RCT reported a 3-layered 100 cotton cloth mask had equal efficacy with a surgical mask. According to two RCTs, cloth mask use is not recommended for HCWs. At the end, we have to mention that limited clinical trials showed the cloth masks or fabrics effectiveness in Covid-19; these findings are our suggestion after reviewing all articles in this area. So the use of these types of masks may not be appropriate for Covid 19.

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Author contribution

MA, FMS, SN, MA, and OM contributed to conception, design, and preparation of the manuscript. MA, SN conducted literature search and contributed in article selection, MA and SN made data extraction. MA, SN, and OM contributed to acquisition, and interpretation. MA, FMS, SN, MA, and OM made substantial contributions in drafting the manuscript and revising it critically for important intellectual content. All authors have read and approved the final version of manuscript.

Data availability

The datasets are available from the corresponding author on formal and logic request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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