

REVIEW ARTICLE

Literature review to integrate information to assist workers to select masks even at workplaces without occupational health personnel

Hiroko Kitamura¹  | Shoko Kawanami¹ | Mitsumasa Saito² | Seichi Horie³ 

¹Occupational Health Training Center, University of Occupational and Environmental Health, Japan, Kitakyushu, Japan

²Department of Microbiology, University of Occupational and Environmental Health, Japan, Kitakyushu, Japan

³Department of Health Policy and Management, Institute of Industrial Ecological Sciences, University of Occupational and Environmental Health, Japan, Kitakyushu, Japan

Correspondence

Hiroko Kitamura, 1-1, Iseigaoka, Yahatanishi-ku, Kitakyushu-shi 807-8555, Japan.
Email: h-kita@med.uoeh-u.ac.jp

Funding information

This study was supported by the FY2020 Health and Labour Science Research Grants, Health and Labour Science Special Research Program, Grant Number 20CA2043.

Abstract

Background: With the COVID-19 pandemic, the idea of universal mask wearing to prevent infecting others when one becomes infected has prevailed among people. In general, any workplace is not exempt and workers are required to wear a mask while working at the sites.

Objectives: This study aims to integrate information to assist workers to select effective protectors for the prevention of droplet infection even at workplaces without occupational health personnel.

Methods: A total of 94 studies were included in this study: 91 studies were identified in MEDLINE, which was used for the literature search, and an additional three studies were identified from other information sources. The studies were checked to eliminate duplication and narrowed down to 31 based on the titles and abstracts. The contents of the 31 studies were read through and then 19 studies were extracted for careful reading.

Results and Conclusions: Regarding the protectors used at workplaces, it was suggested that (1) workers continue to use respiratory protectors as needed at sites where respiratory protectors such as an N95 respirator had to be used even before the spread of COVID-19 and (2) wear surgical masks, multi-layer cloth masks, or hybrid fabric masks made of several types of fabrics that are recommended in terms of preventing dissemination of droplets and protecting against inhalation of droplets, selected according to the working conditions, taking account of air permeability, breathability, and durability.

KEYWORDS

aerosol, droplet, literature review, mask, protector

1 | INTRODUCTION

With the COVID-19 pandemic, the purpose of wearing a mask has shifted from a standard precaution at medical

facilities or an idea that a person who has symptoms of coughing or sneezing wears a mask as “coughing etiquette” to “universal masking” to prevent dissemination of infection to people around when a person is infected.

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

© 2021 The Authors. *Journal of Occupational Health* published by John Wiley & Sons Australia, Ltd on behalf of The Japan Society for Occupational Health

Working sites are not exempt and workers are required to wear a mask while working at the sites. There are a variety of masks on the market, with different forms, structures, materials, and performances. Homemade masks made of household fabrics are also used widely and there are various types. We often see faceguards or mouthguards, etc., also used as a substitute to a mask on TV. Even at workplaces without occupational health personnel, it is necessary to select appropriate masks by workers themselves. However, there are few documents that provide information to assist the selection of masks in a simple manner.

1.1 | Objectives

The purpose of this study is to review literature and integrate information to assist workers to select effective protectors for the prevention of droplet infection by themselves.

2 | METHODS

The research questions were set to be: “Does use of a protector improve effect of protection against droplets compared with the situation without a protector?” and “Is there any difference in the effect of protection against droplets among various protectors when a protector is used?” Of P (participants), I (intervention), C (comparison), O (outcome), S (study design), we defined “I” as a use of various types of protectors, “C” as a comparison between wearing no protector and wearing different types of protectors, as well as a comparison between different types of protectors, and “O” as an effect of protection against droplets.

2.1 | Eligible criteria

Assuming that there were few randomized controlled trials on the efficacy of droplet protection with the use of various protectors in patients with respiratory infections, all study designs were included in the literature review, such as observational studies including cohort and case-control studies, case reports, in vivo studies, in vitro studies, and simulation studies without human subjects. According to the PRISMA 2020 statement, “study” eligible for systematic review was described as “an investigation, such as a clinical trial, that includes a defined group of participants and one or more interventions and outcomes”. At this point, this review is not a systematic review.

2.2 | Information sources

We conducted a literature search using the MEDLINE database for studies with the following inclusion criteria: full text available in English language published dates ranging from 2000 to 2021 (including in press). The last search date was October 29, 2020.

2.3 | Search strategy

Database search was conducted with the following search formula.

#1: mask OR masks OR “personal protective equipment” OR PPE OR respirator OR respirators OR N95 OR N97 OR N99 OR “filtering facepiece respirator” OR “filtering facepiece respirators” OR FFR OR “filtering face piece” OR “filtering face pieces” OR FFP OR FFP1 OR FFP2 OR FFP3 OR “face shield” OR “face shields” OR “mouth shield” or “mouth shields” OR “head cover” OR “head covers” OR “neck guard” OR “neck guards”

#2: #1 NOT ventilation NOT artificial

#3: (cough OR sneeze) AND (droplet OR droplets)

#4: (cough AND sneeze) AND (“droplet nuclei” OR “droplet nucleus”)

#5: (cough OR sneeze) AND (aerosol OR aerosols)

#6: #3 OR #4 OR #5

#7: #2 AND #6 AND (precaution OR prevention OR protection OR reduction)

As we did not perform a synthesis method, for example, meta-analysis, data collection process, data items, study risk of bias assessment, synthesis methods, reporting bias assessment, and certainly assessment showed in the PRISMA 2020 Checklist were not presented in this paper.

3 | RESULTS

We identified 91 literature through database research. The studies were checked to eliminate duplication and narrowed down to 30 studies by screening the titles and abstracts. We completed the full-text reading of potentially eligible 30 studies and included 14 studies. Among excluded 61 studies, there was one review article. We conducted a reference list screening of the review article, extracted five studies, and added them to the list of included articles. In total, 19 studies were included in this literature review.

The research questions were set to be: “Does use of a protector improve the effect of protection against droplets compared to without a protector?” and “Is there any difference in the effect of protection against droplets among

various protectors when a protector is used?" By thorough reading of the studies, it was known that the prevention of dispersal of droplets and/or protection against inhalation of droplets was effective for protection against droplets. The 19 studies were therefore categorized into those evaluating the effect of preventing dispersal of droplets and those evaluating the effect of protecting against inhalation of droplets and investigated the association of the structure and fabric of masks, as well as the wearing state of protectors, to the effect of protection against droplets.

3.1 | Effect of preventing dispersal of droplets

Fischer et al.¹ investigated the rate of droplet transmission through a protector when droplets were released by a person speaking while wearing a protector. If the droplet count of the speaker without a protector was 1, the relative droplet count with a fit-tested N95 respirator was less than 0.001, N95 respirator with an exhalation valve was 0.15, three-layer surgical mask was 0.01, two-layer polypropylene mask and cotton-polypropylene-cotton mask was 0.05, two-layer cotton mask was 0.1–0.3, one-layer cotton mask was 0.2, neck gaiter was 1.1, and bandana was 0.5.

Aydin et al.² investigated the rate of droplets transmitted through the sample mask fabric using a reused metered-dose inhaler to spray particles of 100 nm-diameter fluorescent beads suspended in distilled water, which mimic SARS-CoV-2 virus, at a distance of 25 mm from a sample mask fabric. If the droplet count released without a sample mask fabric was 1, the relative droplet count with a surgical mask (non-woven) was 0.02, one-layer 100% cotton mask (knitted) was 0.03–0.20, one-layer 100% cotton mask (woven) was 0.28, one-layer 75% cotton/25% polyester (knitted) was 0.28, one-layer 70% cotton/30% polyester (woven) was 0.06, one-layer 60% cotton/40% polyester (knitted) was 0.17, one-layer 35% cotton/65% polyester (woven) was 0.18, one-layer 100% polyester (woven) was 0.05, one-layer 80% polyester/20% polyamide (napped) was 0.02, one-layer silk (woven) was 0.01–0.07, two-layer 100% cotton (knitted) was 0.06, three-layer 100% cotton (knitted) was 0.01, two-layer 60% cotton/40% polyester (knitted) was 0.02, and three-layer 60% cotton/40% polyester (knitted) was less than 0.02.

Xiao et al.³ investigated the rate of droplet transmission through a sample mask fabric when blocking micro-droplet-sized starch particles (average diameter of 8.2 μm) and aerosol-sized latex particles (average diameter of 0.75 μm) using centrifugation to simulate the velocity of a sneeze. Regarding micro-droplet sized starch particles, if the droplet count without a sample mask fabric was 1, the relative droplet count with a surgical mask was 0.22, a

gauze mask with non-woven fabric filter and polypropylene filter was 0.10, one-layer cotton was 0.16, two-layer cotton was 0.11–0.13, four-layer silk was 0.11, two-layer linen was 0.20, four-layer linen was 0.13, and eight-layer gauze was 0.63. In case of aerosol-sized latex particle, if the droplet count without a sample mask fabric was 1, the relative droplet count with a surgical mask was 0.35, a gauze mask with non-woven fabric filter and polypropylene filter was 0.22, two-layer cotton was 0.25, two-layer linen was 0.47, four-layer linen was 0.34, and four-layer silk was 0.06.

Asadi et al.⁴ investigated the amount of particles emitted per second when talking and coughing while wearing various types of protectors. As for talking, if the droplet count without a protector was 1, the relative droplet count with an N95 respirator with an exhalation valve was 0.03–0.06, KN95 respirator was 0.13, a surgical mask was 0.06, one-layer 100% cotton t-shirt mask was 6.27, two-layer 100% cotton t-shirt mask was 1.08. As for coughing, if the droplet count without a protector was 1, the relative droplet count with an N95 respirator with an exhalation valve was 0.29–0.35, KN95 respirator was 0.61, a surgical mask was 0.24, one-layer 100% cotton t-shirt mask was 4.87, and two-layer 100% cotton t-shirt mask was 3.57.

Figure 1 showed the relationship between various protectors and various fabrics for homemade masks and relative droplet counts.

Using an airborne transmission simulator consisting of a spreader and a receiver, Ueki et al.⁵ studied how the virus particles of 5.5 μm in mass median diameter, which were sprayed at a velocity of 2 m/s from the spreader, emitted through a protector, and were received by the receiver at a distance of 50 cm from the spreader. If the RNA copies of virus sprayed from the spreader with no protector and received by the receiver were 1, the relative virus RNA copies of a fitted N95 respirator, non-fitted N95 respirator, surgical mask, and cotton mask were 0.003, 0.04, 0.42, and 0.43, respectively.

Rodriguez-Palacios et al.⁶ placed germ-free Swiss Webster mice into cages covered with 100% combed cotton with low surface density (Gram per Square Meter: GSM120) and 100% combed cotton with high surface density (GSM200) and sprayed a bacterial suspension of probiotics to test the effectiveness of household textiles as a barrier to block virus-containing micro-droplets by the spray-simulation method (mimicking a sneeze). Both 100% combed cotton (GSM120) and 100% combed cotton (GSM200) completely blocked the droplets.

Rodriguez-Palacios et al.⁷ measured the distance over which the airflow mimicking a human sneeze reached passing through a protector. If the distance over which the airflow reached without a protector was 1, the relative distance over which the airflow reached with the use of a

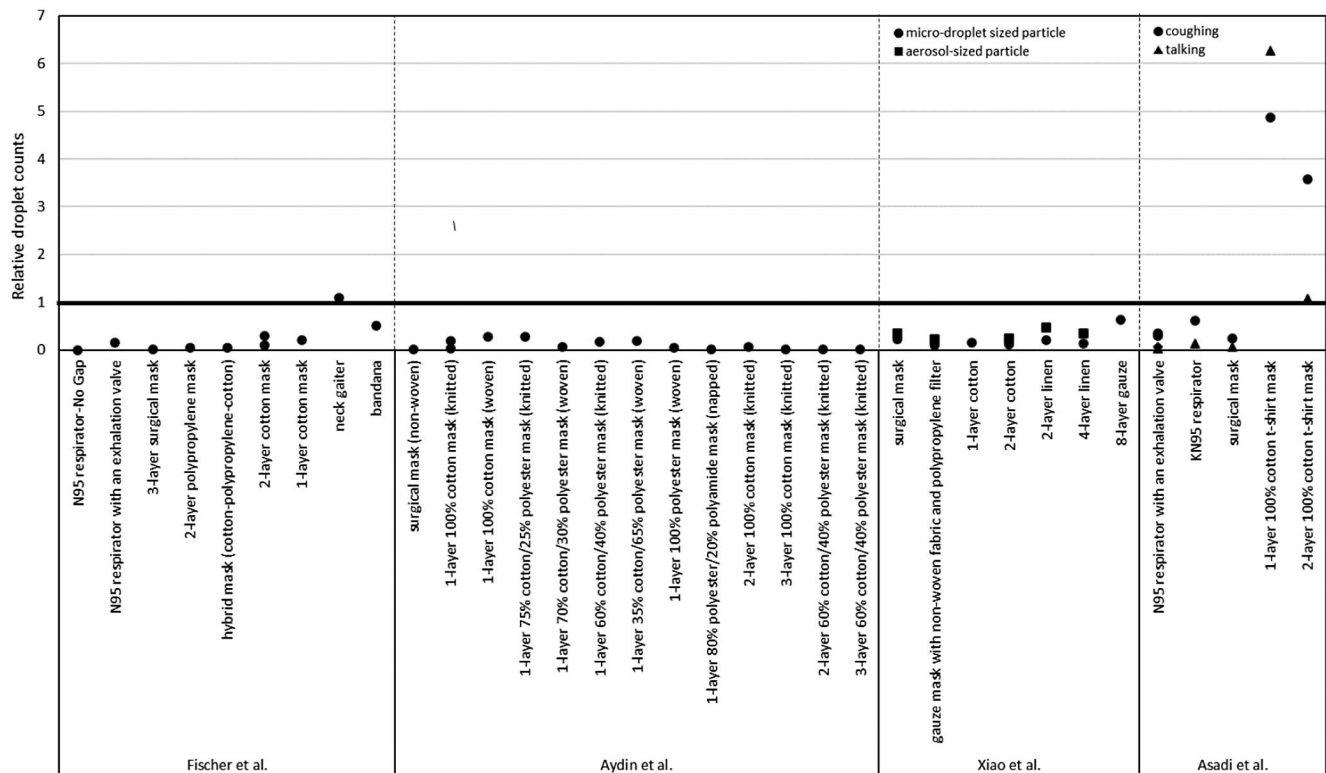


FIGURE 1 For each reference, if the droplet count without a protector was set to 1, the relative droplet count with various types of protectors was shown. Xiao et al. carried out the experiment under two conditions using micro-droplet-sized particles and aerosol-sized particles. Results for micro-droplet-sized particles were shown as black circles: ● and results for aerosol-sized particles were shown as black squares: ■. Asadi et al. conducted the experiment with two situations: coughing and talking. Results for coughing were shown as black circles: ● and results for aerosol-sized particles were shown as black triangles: ▲

protector made of 100% polyester (GSM100), 100% polyester sports jersey (GSM120), 100% cotton t-shirt (GSM140), 100% combed cotton t-shirt (GSM140), and 100% cotton (GSM115) were all 0.19 when each fabric was one-layered and 0.06 when two-layered.

Verma et al.⁸ measured the distance over which the airflow mimicking a human expiration reaches passing through a protector. If the distance over which the expired air reached without a protector was 1, the relative distance over which the expired air reached with the use of a one-layer bandana was 0.45, two-layer quilt cotton was 0.03, and eight-layer cotton was 0.13.

Kähler et al.⁹ investigated the flow field generated by speaking and coughing with or without a surgical mask. In the experiments, the airflow reached over a distance of about 1 m from the mouth when speaking, and a single cough set the air over a distance of 1 m or more, and exhaled air traveled much farther when speaking without a surgical mask than coughing with a surgical mask.

Leung et al.¹⁰ investigated virus shedding, which means viral copies per sample, in respiratory droplet ($>5 \mu\text{m}$) and aerosol ($\leq 5 \mu\text{m}$) samples collected for 30 min not wearing or wearing a surgical mask from patients with acute respiratory symptoms who were positive for human (seasonal)

coronavirus, influenza virus and rhinovirus as determined by RT-PCR in any of nasal swab, throat swab, respiratory droplets, and aerosols. If the detection rate of each virus in droplets and aerosols without a surgical mask was 1, using a surgical mask, the relative detection rate of human (seasonal) coronavirus in droplets and aerosols were both 0, influenza virus was 0.14 in droplets and 0.64 in aerosols, rhinovirus was 0.79 in droplets and 0.67 in aerosols.

Ho et al.¹¹ investigated the number concentration of particles with a size range of 20–1000 nm: $NC_{0.02-1}$ passed through a protector in patients with confirmed influenza or suspected COVID-19, when the patient did not hold their breathing, coughing, and sneezing. Measurements were conducted twice (wearing surgical mask and three-layer cotton mask) in an indoor bedroom and in a car on the street, with different background particle concentrations. If $NC_{0.02-1}$ of a patient without a protector was 1, the relative droplet count with a surgical mask was 0.06 and three-layer cotton mask was 0.12 in the bedroom, while the relative droplet count with a surgical mask was 0.03 and three-layer cotton mask was 0.04 in the car.

Milton et al.¹² investigated exhaled influenza viral particle copy number using quantitative RT-PCR in two size fractions, coarse fraction ($>5 \mu\text{m}$) and fine fraction

($\leq 5 \mu\text{m}$), among patients with seasonal influenza with or without wearing surgical mask. If the RNA copies of the virus without a protector were 1, the relative virus RNA copy number with the surgical mask was 0.04 for the coarse fraction, 0.36 for the fine fraction, and 0.29 overall.

Davies et al.¹³ investigated the number of colonies of microorganisms formed from droplets expelled by coughs, passing through a mask worn by healthy volunteers. If the number of colonies of microorganisms formed without a mask was 1, the relative colony forming unit of a surgical mask was 0.56 and that of a 100% cotton homemade mask was 0.33 in case of particles with diameter over $7 \mu\text{m}$; the relative colony forming unit of a surgical mask and 100% cotton homemade mask was 0.39 for both with particles of diameter $4.8\text{--}7 \mu\text{m}$; the relative colony forming unit of a surgical mask and 100% cotton homemade mask was 0.8 for both with particles of diameter $3.3\text{--}4.7 \mu\text{m}$; the relative colony forming unit of a surgical mask was 0.11 and that of 100% cotton homemade mask was 0.15 with particles of diameter $2.1\text{--}3.3 \mu\text{m}$; the relative colony forming unit of a surgical mask was 0.06 and that of 100% cotton homemade mask was 0.16 with particles of diameter of $1.1\text{--}2.1 \mu\text{m}$; the relative colony forming unit of a surgical mask was 0.14 and that of 100% cotton homemade mask was 0.29 for particles of diameter $0.65\text{--}1.1 \mu\text{m}$; and the relative colony forming unit of a surgical mask was 0.15 and that of 100% cotton homemade mask was 0.22 overall.

3.2 | Effect of preventing inhalation of droplets

Rengasamy et al.¹⁴ investigated the penetration levels for 100 cm^2 samples of polydisperse NaCl aerosol particles (count median diameter of 75 nm), used for NIOSH particulate respirator certification, when passing through sample mask fabrics at face velocities of 5.5 cm/s (corresponding flow rate of 33 L/min) and 16.5 cm/s (corresponding flow rate of 99 L/min). The standard face velocity used for testing various filter media is 5.3 cm/s . To verify the filtration potential of the mask fabric materials, a face velocity of 5.5 cm/s , which is close to the standard procedure, and a relatively high face velocity (16.5 cm/s) were employed. The penetration level for an N95 respirator was 0.12% at 5.5 cm/s face velocity and less than 5% at 16.5 cm/s face velocity. The penetration level for three different cloth masks was $74\%\text{--}90\%$ at 5.5 cm/s face velocity, and the penetration level at a face velocity 16.5 cm/s was almost the same. The penetration level for three different sweatshirt masks was $40\%\text{--}82\%$ at 5.5 cm/s face velocity, and the penetration level at a face velocity 16.5 cm/s was $57\%\text{--}82\%$. The penetration level for all three different T-shirt masks was about 86% at both 5.5 and

16.5 cm/s face velocity. The penetration level for three different towel and scarf masks was $60\%\text{--}66\%$ and $73\%\text{--}89\%$ at 5.5 cm/s face velocity, respectively, and the penetration levels for both masks were almost the same at a face velocity of 16.5 cm/s .

Konda et al.¹⁵ investigated the penetration levels of polydisperse NaCl aerosol particles in the range of few tens of nanometers to approximately $10 \mu\text{m}$ when passing through sample mask fabrics. Penetration tests were carried out at two different airflows: 1.2 and 3.2 cubic feet per minute: CFM, representative of respiration rates at rest (flow rate of 35 L/min) and during moderate exertion (flow rate of 90 L/min), respectively. At a flow rate of 1.2 CFM and the particle diameter of less than 300 nm , the penetration level for an N95 respirator-No Gap was 15% , that of an N95 respirator-Gap was 66% , surgical mask-No Gap was 24% , surgical mask-Gap was 50% , two-layer cotton quilt filling up to 0.5 cm with 90% cotton, one-layer quilter's cotton (80 turns per inch (TPI), 100% cotton) was 91% , two-layer quilter cotton (80 TPI, 100% cotton) was 62% , one-layer 100% cotton (600 TPI) was 21% , two-layer 100% cotton (600 TPI) was 18% , flannel was 43% , one-layer chiffon was 33% , two-layer chiffon was 17% , one-layer natural silk was 46% , two-layer natural silk was 35% , four-layer natural silk was 14% , cotton/chiffon was 3% , cotton/silk was 6% , and cotton/flannel was 5% . At the same flow rate and the particle diameter of 300 nm or more, the penetration level of an N95 respirator-No Gap was 0.1% , that of N95 respirator-Gap was 88% , surgical mask-No Gap was 0.4% , surgical mask-Gap was 56% , two-layer cotton quilt was 3.9% , one-layer quilter's cotton (80 TPI, 100% cotton) was 86% , two-layer quilter's cotton (80 TPI, 100% cotton) was 51% , flannel was 56% , one-layer 100% cotton (600 TPI) was 1.6% , two-layer 100% cotton (600 TPI) was 0.5% , flannel was 46% , one-layer chiffon was 27% , two-layer chiffon was 10% , one-layer natural silk was 44% , two-layer natural silk was 35% , four-layer natural silk was 12% , cotton/chiffon was 0.8% , cotton/silk was 1.5% , and cotton/flannel was 4% . At a flow rate of 3.2 CFM and the particle diameter of less than 300 nm and 300 nm and more, the penetration level for an N95 respirator (fitted) was 6% and 0.1% , respectively, that of an N95 respirator (not fitted) was 42% and 36% , respectively, surgical mask (fitted) was 39% and 19% , respectively, surgical mask (not fitted) was 85% and 90% , respectively, two-layer cotton quilt was 36% and 18% , respectively, one-layer quilter's cotton (80 TPI, 100% cotton) was 86% and 61% , respectively, flannel was 78% and 46% , respectively, and one-layer chiffon was 75% and 41% , respectively.

Davies et al.¹³ investigated the penetration levels of air containing microorganism aerosols when passing across sample mask fabrics at 30 L/min . The penetration level of a surgical mask against *Bacillus atrophaeus* was 3.6% ,

that of 100% cotton T-shirt was 30.6%, scarf was 37.7%, tea towel was 16.8%, pillowcase was 38.7%, anti-bacterial pillowcase was 34.4%, vacuum cleaner bag was 5.6%, cotton mix was 25.4%, linen was 40.0%, and silk was 42.0%. The penetration level of a surgical mask against Bacteriophage MS2 was 10.5%, that of 100% cotton T-shirt was 49.1%, scarf was 51.1%, tea towel was 27.5%, pillowcase was 42.9%, anti-bacterial pillowcase was 31.1%, vacuum cleaner bag was 14.0%, cotton mix was 29.8%, linen was 38.3%, and silk was 45.7%.

Noti et al.¹⁶ investigated the penetration levels of air containing influenza virus aerosols when passing across masks. The penetration levels for a tightly fitted N95 respirator were 0.2% of all viruses and 0.4% of infectious virus. The penetration levels for a poorly fitted N95 respirator were 35.5% of total virus and 33.5% of infectious virus. The penetration levels for a tightly fitted surgical mask were 5.5% of all viruses and 5.2% of infectious virus. The penetration levels for a poorly fitted surgical mask were 31.5% of total virus and 43.4% of infectious virus.

Balazy et al.¹⁷ investigated the penetration levels of MS2 viral aerosols (particle diameter distribution peak: 30 nm) at a flow rate of 30 and 85 L/min. The maximum

penetration was observed at approximately 50 nm for an N95 respirator, and the penetration level was 5% or less at a flow rate of 30 L/min and 6% or less at a flow rate of 85 L/min. The penetration levels of surgical masks varied widely among the different two types, but both surgical masks showed the consistent tendency of larger particles having higher penetration rates of 20%–80% and 2%–12% at 30 L/min and 30%–85% and 6%–20% at 85 L/min.

Figure 2 shows the relationship between various protectors and various fabrics for homemade masks and penetration levels.

Ueki et al.⁵ used an airborne transmission simulator consisting of a spreader and a receiver and studied the virus particles of 5.5 μm in mass median diameter sprayed at a flow speed of 2 m/s from the spreader through a protector and captured on the receiver at a distance of 50 cm from the spreader. They studied the virus RNA copies of the droplets captured on the receiver. Compared with the RNA copies of droplets from the spreader without a protector, the relative virus RNA copies of a fitted N95 respirator were 10%, those of a non-fitted N95 respirator was 14%, those of a surgical mask was 50%, and those of a cotton mask was 63%.

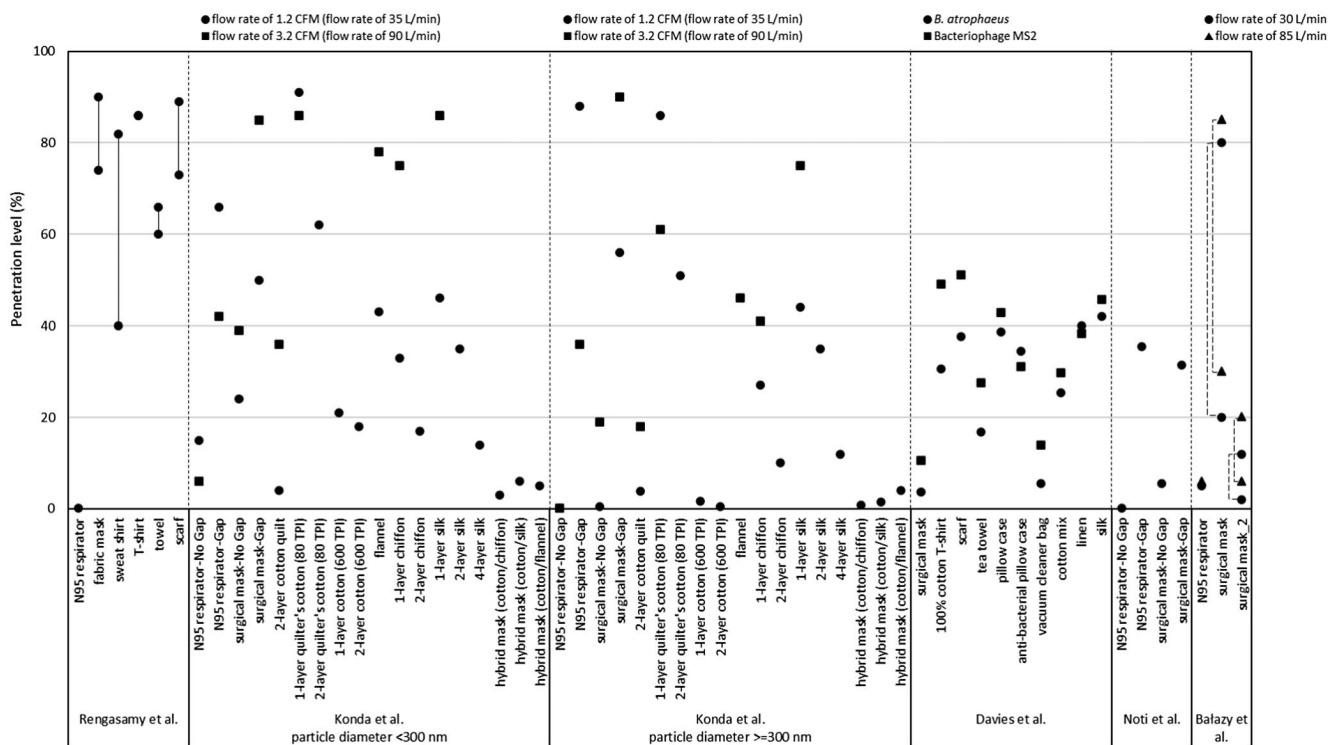


FIGURE 2 Konda et al. carried out the experiments with two size of particles whose diameter was less than 300 and 300 nm or more, each with two conditions. Results for flow rate of 1.2 CFM (flow rate of 35 L/min) were shown as black circles: ● and results for flow rate of 3.2 CFM (flow rate of 90 L/min) were shown as black squares: ■. Davies et al. conducted experiments using *B. atrophaeus* and Bacteriophage MS2. Results for *B. atrophaeus* were shown as black circles: ● and results for Bacteriophage MS2 were shown as black squares: ■. Balazy et al. carried out the experiments with two conditions. Results for flow rate of 30 L/min were shown as black circles: ● and results for flow rate of 85 L/min were shown as black squares: ■

Li et al.¹⁸ conducted a study in which healthy adult subjects exercised while wearing each of an N95 respirator, an N95 respirator with a nano-coated outer layer, a surgical mask, and a surgical mask with a nano-coated outer layer. While the subjects were exercising, KCl-containing solution mimicking virus aerosol was sprayed onto the protectors to study the penetration levels. The surgical masks were three-layered and penetration levels of KCl into the masks were 80%–82%, 13%–16%, and 3%–4.5% from the outer layer, while N95 respirators were four-layered and the penetration levels of KCl into the protectors were 85%–90%, 3.5%–7%, 2%–3%, and 3%–4% from the outer layer.

Lindsley et al.¹⁹ investigated the effect of face shields for reduction of inhalation of aerosol with a volume median diameter of 8.5 and 3.4 μm , respectively. During 1–30 min after a cough, the aerosol particles with both large diameter and small diameter that the respiration simulator inhaled were reduced by the use of face shields.

4 | DISCUSSION

In this literature review, both studies on patients with respiratory infections and studies on healthy volunteers were included. In addition to studies that observed droplets emitted by actual human breathing and coughing, the literature review also included simulation studies that observed the protective effects of protectors against artificially generated aerosols that mimic breathing, coughing, and speaking, and simulation studies that evaluated the potential performance of protector materials in airflow faster than human breathing. There were evaluations of protectors actually worn by people, as well as evaluations of mechanical performance of various fabrics used to make protectors. With the limited information available on the evaluation of protectors worn by people, we

considered the information from simulation studies to be important in integrating information to assist to select protectors.

Since the particles sizes and airflow rates were different in the studies reviewed in this literature search, the relative droplet counts and penetration levels delivered to each mask fabric cannot be compared directly. However, at least we found that the effect of preventing dispersal of droplets and effect of protecting against inhaling droplets of homemade masks are associated with forms, multi-layer structure, fitness to the face (involving the structure of the masks and wearing methods), materials, and fibers constituting the fabrics, method of manufacturing the fabrics (weaving/knitting), surface density (GSM), weaving density (thread counts), and combination of fabrics. Multi-layered structures tended to have a greater effect of preventing the dispersal of droplets; however, such effect cannot be expected in fabrics with low density such as gauze even if it was multi-layered. Therefore, the surface density was considered to have higher priority than multi-layer structure in terms of effect of preventing dispersal of droplets. Except for respirators such as N95 respirators, surgical masks were shown to be expected to be effective in preventing dissemination of droplets and protecting the inhalation of droplets among so-called masks. However, some investigations demonstrated that two-layer cotton masks, two-layer polypropylene masks, four-layer silk, a combination of cotton/chiffon or cotton/polypropylene/cotton were equal or superior to surgical masks in the effects. The results suggested that effects of preventing dissemination of droplets and protecting inhalation of droplets of masks are associated with random spacing between threads through which droplets pass through, are attributable to multi-layered, thin-threaded, highly dense woven fabrics, as well as the course of fibers and multi-layered structure.

TABLE 1 Effects of preventing dissemination of droplets and effects of protecting against inhalation of droplets of protectors used at construction sites

		Effect of preventing dissemination of droplets	Effect of protecting against inhalation of droplets
Ready-made protectors	N95 respirator	High	High (moderate-high)
	N95 respirator with an exhalation valve	Moderate (moderate-high)	No data
	Surgical mask	Moderate (low-high)	High (low-high)
	Neck gaiter	Low	No data
	Face shield	Low	Low
Home-made masks	Fabric mask (1-layer cotton)	Low (low-high)	Low (low-high)
	Fabric mask (multi-layer cotton)	Moderate (low-high)	Low (low-high)
	Hybrid mask (various types of fabrics, multi-layer)	Moderate	High (moderate-high)

For using homemade masks, it will be useful to have information on fabrics and combinations of those fabrics that have sufficient effects of preventing dissemination of droplets and protecting against inhaling droplets, while being readily available, more comfortable, and less hot and stuffy. Such proposal of fabrics and combinations of fabrics will be a future issue.

The effect of protecting against inhaling droplets of fitted N95 respirators is outstanding and it was suggested that it is difficult to substitute N95 respirators with other protectors. At the working sites where the use of appropriate respiratory protectors is required as a device for occupational health protection even before the outbreak of COVID-19, the workers should continue to use appropriate respiratory protectors. However, N95 respirators with an exhalation valve may have a risk of increasing dissemination of droplets to the surrounding area by strong outward air current, and therefore, the use of this type of respirators is best avoided by anyone who is not feeling well.

Table 1 showed the effects of preventing dissemination of droplets and effects of protecting against inhalation of droplets of protectors. There is a national certification standard for particulate respirators that requires safety and international consistency. Particulate respirators are classified into three categories according to their particulate filtration efficiency (PFE): category 3 shows PEF over 99.9%, category 2 shows PEF over 95%, and category 1 shows PEF over 80%. In reference to the classification of particulate respirators, for the effect of preventing dissemination droplets, relative droplet counts of less than 0.05 were classified as “high,” less than 0.2 as “moderate,” and more than 0.2 as “low.” For the effects of protecting against inhalation of droplets, penetration level of less than 5% were classified as “high,” less than 20% as “moderate,” more than 20% as “low.” As for the face shield, we used the published simulation results using the super-computer “Fugaku.”

Points that should be noted when selecting a protector are shown in Table 2. For about the five ready-made protectors and homemade masks listed in Table 1, we categorized them as high, moderate, and low for affordance, durability, breathability, comfortable and reusable, based on the review by Tcharkhtchi et al.²⁰ and taking into account the empirical rules from previous occupational health activities.

5 | CONCLUSION

We conducted a literature search to integrate information to assist workers to select effective protectors for the prevention of droplet infection even at workplaces without

TABLE 2 Points to be noted when selecting a protector

		Affordable	Durability	Breathability	Comfortable	Reusable
Ready-made protectors	N95 respirator	Moderate-high	Low	Low	Moderate	No
	N95 respirator with an exhalation valve	Moderate-high	Low	Low-moderate	Moderate	No
	Surgical mask	High	Low	Moderate	High	No
	Neck gaiter	High	Moderate	Moderate	High	Yes
	Face shield	High	Moderate	High	Moderate	Yes
Home-made masks	Fabric mask (1-layer cotton)	High	Moderate	Moderate	High	Yes
	Fabric mask (multi-layer cotton)					
	Hybrid mask (various types of fabrics, multi-layer)					

occupational health personnel. Regarding the protectors, it was suggested that (1) workers continue to use respiratory protectors as needed at sites where respiratory protectors such as an N95 respirator had been required even before the spread of COVID-19, and (2) surgical masks, multi-layer cloth masks, and hybrid fabric masks made of several types of fabrics are recommended for prevention of dissemination of droplets and protection against inhalation of droplets. However, it is necessary to choose masks in terms of air permeability, breathability, and durability according to the working conditions. For the use of homemade masks, it will be useful to have information on fabrics and combinations of those fabrics that are sufficiently effective in preventing dissemination of droplets and protecting against inhaling droplets while being readily available, more comfortable, and less hot and stuffy. Such proposal of fabrics and combinations of fabrics will be a future issue.

DISCLOSURE

Approval of the research protocol: N/A. *Informed consent:* N/A. *Registry and registration no. of the study/trial:* N/A. *Animal studies:* N/A. *Conflict of interest:* The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Hiroko Kitamura led the writing, Shoko Kawanami, Mitsumasa Saito and Seichi Horie provided feedback for each area of expertise.

DATA AVAILABILITY STATEMENT

Data sharing not applicable – no new data generated.

ORCID

Hiroko Kitamura  <https://orcid.org/0000-0001-5106-7094>

[org/0000-0001-5106-7094](https://orcid.org/0000-0001-5106-7094)

Seichi Horie  <https://orcid.org/0000-0002-8347-2630>

REFERENCES

- Fischer EP, Fischer MC, Grass D, Henrion I, Warren WS, Westman E. Low-cost measurement of face mask efficacy for filtering expelled droplets during speech. *Sci Adv.* 2020;6(36). doi:10.1126/sciadv.abd3083
- Aydin O, Emon B, Cheng S, Hong L, Chamorro LP, Saif MTA. Performance of fabrics for home-made masks against the spread of COVID-19 through droplets: a quantitative mechanistic study. *Extreme Mechanics Letters.* 2020;40:100924. doi:10.1016/j.eml.2020.100924
- Xiao LI, Sakagami H, Miwa N. A new method for testing filtration efficiency of mask materials under sneeze-like pressure. *In Vivo.* 2020;34(3 Suppl):1637-1644. doi:10.21873/invivo.11955
- Asadi S, Cappa CD, Barreda S, Wexler AS, Bouvier NM, Ristenpart WD. Efficacy of masks and face coverings in controlling outward aerosol particle emission from expiratory activities. *Sci Rep.* 2020;10(1):15665. doi:10.1038/s41598-020-72798-7
- Ueki H, Furusawa Y, Iwatsuki-Horimoto K, et al. Effectiveness of face masks in preventing airborne transmission of SARS-CoV-2. *mSphere.* 2020;5(5). doi:10.1128/mSphere.00637-20
- Rodriguez-Palacios A, Conger M, Cominelli F. Germ-free mice under two-layer textiles are fully protected from bacteria in sprayed microdroplets: a functional in vivo test method of face-mask/filtration materials. *Front Med.* 2020;7:504. doi:10.3389/fmed.2020.00504
- Rodriguez-Palacios A, Cominelli F, Basson AR, Pizarro TT, Ilic S. Textile masks and surface covers—a spray simulation method and a “universal droplet reduction model” against respiratory pandemics. *Front Med.* 2020;7:260. doi:10.3389/fmed.2020.00260
- Verma S, Dhanak M, Frankenfield J. Visualizing the effectiveness of face masks in obstructing respiratory jets. *Phys Fluids.* 2020;32(6):061708. doi:10.1063/5.0016018
- Kähler CJ, Hain R. Fundamental protective mechanisms of face masks against droplet infections. *J Aerosol Sci.* 2020;148:105617. doi:10.1016/j.jaerosci.2020.105617
- Leung NHL, Chu DKW, Shiu EYC, et al. Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nat Med.* 2020;26(5):676-680. doi:10.1038/s41591-020-0843-2
- Ho KF, Lin LY, Weng SP, Chuang KJ. Medical mask versus cotton mask for preventing respiratory droplet transmission in micro environments. *Sci Total Environ.* 2020;735:139510. doi:10.1016/j.scitotenv.2020.139510
- Milton DK, Fabian MP, Cowling BJ, Grantham ML, McDevitt JJ. Influenza virus aerosols in human exhaled breath: particle size, culturability, and effect of surgical masks. *PLoS Pathog.* 2013;9(3):e1003205. doi:10.1371/journal.ppat.1003205
- Davies A, Thompson KA, Giri K, Kafatos G, Walker J, Bennett A. Testing the efficacy of homemade masks: would they protect in an influenza pandemic? *Disaster Med Public Health Prep.* 2013;7(4):413-418. doi:10.1017/dmp.2013.43
- Rengasamy S, Eimer B, Shaffer RE. Simple respiratory protection—evaluation of the filtration performance of cloth masks and common fabric materials against 20–1000 nm size particles. *Ann Occup Hyg.* 2010;54(7):789-798. doi:10.1093/annhyg/meq044
- Konda A, Prakash A, Moss GA, Schmoltdt M, Grant GD, Guha S. Aerosol filtration efficiency of common fabrics used in respiratory cloth masks. *ACS Nano.* 2020;14(5):6339-6347. doi:10.1021/acsnano.0c03252
- Noti JD, Lindsley WG, Blachere FM, et al. Detection of infectious influenza virus in cough aerosols generated in a simulated patient examination room. *Clinical Infect Dis.* 2012;54(11):1569-1577. doi:10.1093/cid/cis237
- Balazy A, Toivola M, Adhikari A, Sivasubramani SK, Reponen T, Grinshpun SA. Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks? *Am J Infect Control.* 2006;34(2):51-57. doi:10.1016/j.ajic.2005.08.018
- Li Y, Wong T, Chung J, et al. In vivo protective performance of N95 respirator and surgical facemask. *Am J Ind Med.* 2006;49(12):1056-1065. doi:10.1002/ajim.20395

19. Lindsley WG, Noti JD, Blachere FM, Szalajda JV, Beezhold DH. Efficacy of face shields against cough aerosol droplets from a cough simulator. *J Occup Environ Hyg*. 2014;11(8):509-518. doi:10.1080/15459624.2013.877591
20. Tcharkhtchi A, Abbasnezhad N, Zarbini Seydani M, Zirak N, Farzaneh S, Shirinbayan M. An overview of filtration efficiency through the masks: mechanisms of the aerosols penetration. *Bioact Mater*. 2021;6(1):106-122. doi:10.1016/j.bioactmat.2020.08.002

How to cite this article: Kitamura H, Kawanami S, Saito M, Horie S. Literature review to integrate information to assist workers to select masks even at workplaces without occupational health personnel. *J Occup Health*. 2021;63:e12309. doi:[10.1002/1348-9585.12309](https://doi.org/10.1002/1348-9585.12309)