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Original Research

Home-made masks with filtration efficiency for nano-aerosols for community mitigation of COVID-19 pandemic

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ARTICLE INFO

Article history:
Received 20 May 2020
Received in revised form
11 August 2020
Accepted 18 August 2020
Available online 2 September 2020

Keywords:
Home-made masks
Filtration efficiency
Nano-aerosols
SARS-CoV-2
COVID-19
Pandemic

ABSTRACT

Objectives: The novel coronavirus disease 2019 (COVID-19) epidemic that emerged in December 2019 has rapidly evolved in recent months to become a worldwide and ongoing pandemic. Shortage of medical masks remains an unresolved problem. This study aims to investigate the filtration efficiency (FE) of home-made masks that could be used as alternatives for community mitigation of COVID-19.

Study design: Experimental observational analytic study.

Methods: The FE of home-made masks and medical masks (as the control) were tested under laminar flow within a scaled air duct system using nebulised NaCl aerosols sized 6–220 nm. The size-resolved NaCl aerosol count was measured using a scanning mobility particle-sizer spectrometer. Home-made masks with an external plastic face shield also underwent a splash test. In addition, the fibre structures of medical masks were studied under an electron microscope after treatment with either 75% alcohol or soap and water at 60 °C.

Results: The FE of the home-made masks at 6–200 nm were non-inferior to that of medical masks (84.54% vs 86.94%, P = 0.102). Both types of masks achieved an FE of 90% at 6–89 nm. A significantly higher FE was achieved when one piece of tissue paper was added adjacent to the inner surface of the medical mask than medical mask alone (6–200 nm: 91.64% vs 86.94%, P < 0.0001; 6–89 nm: 94.27% vs 90.54%, P < 0.0001; 90–200 nm: 82.69% vs 73.81%, P < 0.0001). The plastic face shield prevented the home-made mask from fluid splash. The fibre structures of the external surface of medical masks were damaged after treatment with either 75% alcohol or soap and water at 60 °C.

Conclusions: The home-made masks in this study, which were made of one piece of tissue paper and two pieces of kitchen towels, layered from face to external, had an FE at 6–200 nm non-inferior to that of medical mask materials, which had a certified FE of ≥95% at 3 μm. In the current COVID-19 pandemic with the shortage of medical masks, these home-made masks combined with an external plastic shield could be used as an alternative to medical masks for community mitigation. In addition, one piece of tissue paper could be placed adjacent to the inner surface of a medical mask to prolong effective lifespan of the medical mask. These demand reduction strategies could be used to reserve medical masks for use in healthcare and certain high-risk community settings, such as symptomatic persons, caregivers and attendees to healthcare institutions.

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Introduction

The emerging severe acute respiratory syndrome (SARS) epidemic associated with the novel coronavirus (initially named 2019-nCoV) was first reported in Wuhan, Hubei, the People’s Republic of China on December 30, 2019. Rapid identification and genetic characterisation of 2019-nCoV showed its close relationship to bat SARS-related coronaviruses; thus, the virus could have potentially originated from bats. The epidemic had been going on for more than 3 months (as of writing) globally. The World Health Organisation renamed 2019-nCoV as SARS-CoV-2 and characterised the coronavirus disease 2019 (COVID-19) as a controllable pandemic. This public health emergency has imposed enormous...
physical, mental health and economic burdens on the global population.

The rapid spread of COVID-19 saw a panic-driven desire for medical masks, alcohol-based hand gels, household disinfectants, foods and other items in affected communities. The raw materials for production of personal protective equipment were reported to be running low. Doubt surrounded the effectiveness of medical masks in conferring respiratory protection and respirators that could sufficiently filter aerosols of the size at least comparable to SARS-CoV-2 viral particles with a diameter of 50–200 nm were in high demand; this is much smaller than the 3 μm (measurement conversion 1000 μm = 1 mm) test and certification level of bacterial filtration efficiency (BFE) for medical mask materials. Previous studies have also shown that SARS-CoV and the influenza virus are highly penetrable through medical masks and respirators. Export restrictions on medical masks from certain COVID-19–affected countries for domestic use resulted in further average prices increases; thus, resource inequality in low-resource settings was further aggravated.

Under these circumstances of medical mask shortages, community dwellers attempted unofficial methods to decontaminate and reuse disposable not-for-reuse medical masks and respirators, and made their own masks by referring to unofficial online videos using materials with uncertain filtration efficiency (FE) and no apparent water-resistant functions. Inappropriate reuse of disposable items by the public will increase the risk of cross- and environmental contamination, and infection. Medical masks have been proven to be much more effective in source control or outward protection (i.e. reducing droplet dispersion and environmental contamination from coughing or sneezing) than inward protection (i.e. preventing the wearer from exposure to microorganism-laden droplets); thus, medical masks are normally advised for symptomatic patients. Under the current (as of writing) situation of the COVID–19 pandemic, the majority of the global population are uninfected and susceptible. Significant impacts on healthcare systems are expected before achieving population immunity by natural infection or vaccines (the effectiveness of any immunity also remains uncertain). To date, no effective specific antivirals, chemoprophylaxis or vaccines are available, and asymptomatic- and presymptomatic-infected individuals could shed virus and be responsible for transmission and spreading of COVID–19 in communities. With continued implementation of other infection control measures, medical masks and non-medical face masks (face masks) could serve to prevent transmission by limiting virus-laden droplets being spread from infected individuals in communities. The global need for medical masks in healthcare settings during pandemics is extremely high. Even after boosted global mass production, supply remains an unresolved issue, which is widened further when the demand for community use is taken in to account.

Home-made masks that are made of readily accessible materials with FE at nano-aerosol levels and are affordable and simple to make are urgently needed, especially in low-resource settings as last-resort alternatives to medical masks for community use. The present study examined the FE of home-made masks at 6–220 nm. A splash test was performed on an external plastic shield combined with the home-made mask on a manikin model. The effect of decontamination of medical masks with either 75% alcohol or soap and water was also examined.

**Methods**

**Test materials**

Commercially available pocket-sized 4-ply tissue paper (Neutral Tempo® Petit 4-ply pocket tissue, SCA Hygiene Products GmbH) and kitchen towels (Vinda kitchen towel 9”, Vinda Paper) and medical masks (Bloosoms, BFE ≥95%) were selected for analysis. A transparent stationery plastic folder was used to create a plastic face shield.

**Examination under scanning electron microscopy**

Untreated tissue paper and kitchen towels, and medical masks untreated and treated with 75% alcohol, and soap and water of 60 °C, respectively, were examined under scanning electron microscopy (SEM) for fibre analysis. From the initial findings (Fig. 1), two pieces of kitchen towels were used and overlaid at a 90° rotation to increase the intercalation by overlapping and reduce inter-spaces for testing FE.

**Testing FE**

The test system was built to be similar to that of the American Society for Testing and Materials (ASTM) standard test method for determining particulate filtration efficiency (PFE) in medical masks and has been described previously (Fig. 2 and Supplementary text S1). 220 nm

Combinations of test materials were tested for FE at 6–220 nm (Fig. 3). Two measurements were taken as follows: (i) at point B, the air flow to the external surface to the test material (upstream aerosol count); and (ii) at point C, the air flow and subsequent penetration of aerosols to the inner surface of the test materials (downstream aerosol count) (Fig. 2; Supplementary Tables S1 and S2). FE of different

![Fig. 1. Scanning electron microscopy (SEM) (100×) images of (a) the widest inter-fibre spaces of kitchen towel corresponding to (b) the embossing pattern on the actual kitchen towel.](image-url)
test materials at aerosols of different diameters \(d\) was calculated and shown (Fig. 3). Simulated airflow tested air flowing from the external air, through the masks’ layers, to and behind the inner surface of the mask (i.e. the surface that would be touching the face). The highest FE of the home-made masks was seen with one layer of tissue paper, followed by two layers of kitchen towels; this combination was selected to be tested against medical masks for FE at 3 \(\mu\)m, and with an external plastic face shield for a splash test (Supplementary text S2).

Preparation of home-made masks and plastic face shield

Preparation of the home-made masks

Firstly, hand hygiene was performed.\(^5\,\text{,}^{15}\,\text{,}^{19}\,\text{,}^{20}\) One piece of kitchen towel was put on top of another at 90°. A piece of 4-ply tissue paper (as innermost water absorptive layer of the mask) was placed on top of the kitchen towels; the three-layered stack was folded and cut at its longest edge into two. Four sides of this three-layered material (as 1 mask) were sealed by adhesive tape (2 inch-width). Two holes per side were punched on the left and right sides of the mask by a hole puncher. Plastic-coated wire was attached to the upper edge of the mask by adhesive tape. Alternatively, a pair of glasses could be used to fix the mask on the wearer’s nose bridge if no such wire is available. Rubber bands or strings were threaded through the holes (one for each) on the mask; and their lengths were adjusted accordingly to cover the breathing zone to below the chin.

Preparation of plastic face shield

A transparent stationery plastic folder was cut at its closed edge into half. One piece was attached to the edge of the pair of glasses with binder clips, to serve as a water-proof shield to the face mask. See Supplementary Video S1 to view preparation of the masks and shield.

Statistical analyses

Descriptive statistics were recorded. FE of materials at aerosols sized in diameter \(d\) was calculated as \(\text{FE}(d) = \frac{\text{Upstream aerosol count}(d) - \text{Downstream aerosol count}(d)}{\text{Upstream aerosol count}(d)} \times 100\%\). Student’s paired \(t\)-test was used for comparing means between groups. A \(P\)-value < 0.05 was considered to be statistically significant. IBM® SPSS® Statistics for Windows, version 24.0 (IBM Corp., Armonk, NY) was used for statistics analyses.

Results

The mean, median, geometric standard deviation (GSD) of aerosol sizes and total concentrations of aerosols in the upstream and downstream measurements are shown (Supplementary Tables S1 and S2). The FE of different materials at 25–200 nm showed concave-up curves, all indicating their lowest FE at 100–125 nm, which represents the most penetrating particle size, and highest FE at smaller- (25 nm) and larger- (200 nm) sized aerosols (Fig. 3).

The highest FE of the home-made masks was seen with one layer of tissue paper, followed by two layers of kitchen towels (sample D in Fig. 3), which achieved an FE across 6–200 nm and was non-inferior to that of a medical mask (sample F in Fig. 3) (6–200 nm: 84.54% vs 86.94%, \(P = 0.102\); 90–200 nm: 72.89% vs 73.81%, \(P = 0.109\)) (see Figs. 3 and 4; Table 1). Both the selected home-made mask combination (sample D) and the medical mask (sample F) achieved an FE of >99.9% at 3 \(\mu\)m (Table 1). The FE of using a medical mask in combination with tissue paper (sample E in Fig. 3) was significantly higher than that of the medical mask alone (sample F) (6–200 nm: 91.64% vs 86.94%, \(P < 0.0001\); 6–89 nm: 94.27% vs 90.54%, \(P < 0.001\); 90–200 nm: 82.69% vs 73.81%, \(P < 0.0001\)) (Fig. 4).

The external plastic face shield was shown to prevent splash droplets from contaminating the home-made mask (sample D; Supplementary Fig. S1).

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.puhe.2020.08.018.
Fibre structures on the external surfaces of surgical masks were damaged after treatment with either 75% alcohol or soap and water at 60 °C (Fig. 5). Images of untreated and treated medical masks (Fig. 5) and untreated test materials (Supplementary Fig. S2) under the SEM are shown.

Discussion

To the best of the authors’ knowledge, this is the first study of FE of home-made masks at 6–200 nm-sized aerosols during the initial phase of the COVID-19 pandemic. Crisis/alternate strategies for safe extended use and limited reuse of respirators in healthcare settings has been implemented both during this time of medical mask shortage in the COVID-19 pandemic and previously.15,19,24 Based on available data (as of writing) on transmissibility and clinical severity of COVID-19, the use of face masks in community settings for high-risk groups is recommended.13,15,16,18,19 Moreover, there are asymptomatic- and presymptomatic-infected individuals who carry and shed SARS-CoV-2 from their upper respiratory tract, with viral loads at almost peak levels just before they become symptomatic.16–18 The risk of spreading COVID-19 in communities is further increased in those with prolonged asymptomatic phases and those with very high viral loads.16,17

When the majority of the global population was susceptible to SARS-CoV-2 infection, during the initial 100 days of COVID-19 pandemic, the incidence of COVID-19 in Hong Kong (HK) where early and community-wide (>95% population) face mask use was implemented was significantly less (129.0 per million population) than that of other comparative countries where face mask usage was not adopted in the community (e.g. Spain 2983.2, Italy 2250.8, Germany 1241.5, France 1151.6, US 1102.8, UK 831.5, Singapore 259.8 and South Korea 200.5 per million population); other multifaceted control and administrative interventions had been achieved when there is no active community transmission. With variable and fluctuated levels of transmission activities in different localities over time, and before effective specific antivirals, such inward protection (i.e. self-protection from being infected) remained significant, even after accounting for the differential respirator use between healthcare and community settings. Inward protection was also shown when use of face masks (including reusable gauze or multilayered cotton masks) was compared to wearing no masks. These findings support face mask use, irrespective of settings during the COVID-19 pandemic. Face shield use could confer additional benefits that might result in a further large reduction in viral infection.25

An animal experiment showed that medical masks were effective for inward protection in reducing infection risk of uninfected hamsters from SARS-CoV-2-infected hamsters via non-contact modes, and even more effective for source control (i.e. limiting the spread of infection).26 Moreover, another recent study has shown that home-made masks (made of 4-layers of kitchen towels and 1-layer of polyester cloth) had a comparable efficiency (95.15%) to N95 respirators (99.98%) and medical masks (97.14%) in preventing nebulised live low-pathogenic avian influenza virus–laden aerosols (median d 3.9 μm; 65% < 5.0 μm), as surrogates of coronaviruses, from penetrating the masks under an experimental system simulating human breathing. It was suggested that such home-made masks might be efficacious to slow the spread of SARS-CoV-2 in communities.27

The global success in combating the pandemic can only be achieved when there is no active community transmission. With variable and fluctuated levels of transmission activities in different localities over time, and before effective specific antivirals,

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**Fig. 3.** Mean filtration efficiency (%) of different combinations of test materials at respective aerosol sizes. The key is written in layering order as if simulating wearing a mask from face to external area (number of pieces used are given in parentheses). Materials were tested with aerosols as follows: (i) at point B, the air flow to the external surface of the test material (upstream aerosol count); and (ii) at point C, the air flow and subsequent penetration of aerosols to the inner surface of the test materials (downstream aerosol count) (Fig. 2). FE of different test materials at aerosols of different diameters (d) was calculated and shown.
Materials were tested with aerosols as follows: (i) at point B, the air flow to the external surface of the test material (upstream aerosol count); and (ii) at point C, the air flow and subsequent penetration of aerosols to the inner surface of the test materials (downstream aerosol count) (Fig. 2). FE of different test materials at aerosols of different diameters \(d\) was calculated, compared and shown.

### Table 1

Mean filtration efficiency (%) ± standard deviation (SD) of different test materials at respective aerosol sizes.

| Test materials | \(25\) nm | \(50\) nm | \(75\) nm | \(100\) nm | \(125\) nm | \(150\) nm | \(175\) nm | \(200\) nm | \(3\) \(\mu\)m (3000 nm) |
|----------------|---------|---------|---------|----------|----------|----------|----------|----------|------------------|
| A. Tissue paper (1) | 52.56 ± 1.36 | 35.62 ± 0.53 | 31.61 ± 1.14 | 30.45 ± 0.50 | 30.47 ± 1.54 | 33.49 ± 1.33 | 34.20 ± 0.61 | 36.99 ± 1.15 | Not done |
| B. Tissue paper (1 & folded) | 65.81 ± 0.47 | 48.40 ± 0.21 | 42.39 ± 0.46 | 41.21 ± 0.47 | 41.15 ± 1.31 | 42.41 ± 1.26 | 44.31 ± 2.21 | 44.64 ± 0.76 | Not done |
| C. Kitchen towel (2) + tissue paper (1) | 78.16 ± 0.30 | 60.67 ± 0.51 | 53.85 ± 0.55 | 50.63 ± 0.06 | 50.04 ± 0.41 | 50.99 ± 0.48 | 50.89 ± 0.27 | 49.86 ± 0.37 | Not done |
| D. Tissue paper (1) + kitchen towel (2) | 91.20 ± 0.26 | 78.82 ± 0.30 | 73.46 ± 0.58 | 71.53 ± 0.53 | 71.79 ± 0.37 | 73.24 ± 0.34 | 74.93 ± 1.17 | 76.54 ± 0.94 | 99.99 ± 0.01 |
| E. Tissue paper (1) + medical mask (1) | 95.28 ± 0.11 | 89.00 ± 0.20 | 85.21 ± 0.60 | 83.22 ± 0.53 | 82.21 ± 0.32 | 82.88 ± 0.26 | 83.23 ± 0.96 | 82.87 ± 0.80 | Not done |
| F. Medical mask (1) | 91.54 ± 0.23 | 82.63 ± 0.24 | 77.59 ± 0.11 | 74.78 ± 1.21 | 73.33 ± 0.25 | 73.31 ± 0.21 | 74.21 ± 0.44 | 73.85 ± 1.27 | 99.87 ± 0.16 |

* In layering order as if simulating wearing a mask from face to external (number of pieces used are given in parentheses). Materials were tested with aerosols as follows: (i) at point B, the air flow to the external surface of the test material (upstream aerosol count); and (ii) at point C, the air flow and subsequent penetration of aerosols to the inner surface of the test materials (downstream aerosol count) (Fig. 2). FE of different test materials at aerosols of different diameters \(d\) was calculated and shown.

Although medical mask shortage in healthcare settings remains unresolved, home-made masks with FE at the nano-aerosol level could be used as alternatives for certain lower-risk community settings, thus enabling to reallocation and prioritisation of medical masks for healthcare settings and high-risk community settings, such as for caregivers, attendees to healthcare and institutional facilities.

An external plastic face shield could also be used as personal protective equipment from droplets when social distancing is not possible and/or masks are not feasible (e.g. for toddlers or when eating/drinking). Such practices might also limit the spread of future droplet-transmitted epidemics and help prevent overwhelming the already stretched healthcare systems and associated excess mortality. Moreover, unprotected healthcare workers in the community could acquire infection that could then result in nosocomial outbreaks. Subsequent quarantine and isolation of healthcare workers would further overwhelm the already stretched healthcare system.
FE certification of home-made mask materials is not available locally, and there is insufficient time to wait for overseas-certified FE results. Unlike mass production of commercially available medical masks using the same FE-certified materials, there could be slight, but minimal, heterogeneity in the materials used for the home-made masks in this study when prepared by individuals from different communities. Nevertheless, the tissue paper and kitchen towels complied with international standards for tissue paper and tissue products, and food safety management systems involving different mechanisms, including impaction, interception, diffusion and electrostatic attraction necessary for total bacterial counts in testing BFE.9,11,22,23 The flow rate and exposure time, which simulated cough velocity and coughing time, respectively, also fulfilled those required in standard tests.9,22,23,24

Nano-sized aerosols were used because technology advancement has made submicron measurements feasible for droplets ranging from <100 nm to 5–10 μm, which have previously not been able to be detected in cough clouds.32,33 The most prevalent aerosols were sized <100 nm and 100–300 nm, each quantified at least 10^6, among the expelled particles (ranging from <100 nm to 10,000 nm) generated from coughing patients with a respiratory infection.33 The majority of exhaled particles (70%) from influenza-infected coughing patients ranged from 300 to <500 nm, followed by 500 nm to 1 μm (17%).34 The least protection that medical masks conferred was found to be in the 40–320 nm range.11 Under certain conditions, appropriately sized aerosols with viable viral droplet nuclei could theoretically be suspended in the air for extended durations and recirculated for long travel distances; although, clinically, this remains controversial.11,34 Influenza viral RNA load was found to be highest in aerosols sized <4 μm (42% in <1 μm; 23% in 1–4 μm) in coughs from influenza A–infected patients; and 18% (2 of 11) of these patients had viable virus detected in cough aerosols.34 The FE of medical masks at nano-sizes has not been certified previously. Our study provides FE of home-made masks and medical masks for nano-aerosols. This might reduce doubts on using home-made masks in certain community settings as a last-resort for community mitigations in the current pandemic.

The concave-up FE curves (Fig. 3) can be explained by the classical fibrous filtration theory that smaller particles are transported predominantly by diffusion (Brownian motion), larger particles mainly by inertial impaction and interception, and intermediate-sized particles are transported by both mechanisms without any predominance.22,23 Medical masks and the home-made mask materials used in this study worked as a fibrous filter, comprising of abundant randomly oriented fibres forming a dense mat to capture and retain particles throughout its depth or thickness.22,34 Aerosol transport and filtration through fibrous filters involves different mechanisms, including impaction, interception, diffusion and electrostatic attraction necessary for total bacterial counts in testing BFE.9,22,23 The flow rate and exposure time, which simulated cough velocity and coughing time, respectively, also fulfilled those required in standard tests.9,22,23,24

FE of test materials for larger-sized aerosols was not tested in the present study because the plastic shield was designed to serve as an external physical barrier preventing conjunctiva mucosa, mask–face interface (face-seal leak) at different edges of the home-
made mask, and the breathing zone, from direct exposure to larger-sized aerosols and fluid splash at low to moderate amounts, to counter-balance the limitations of the home-made masks.

At 25 nm, FE was 91.20% for the home-made masks (sample D, Fig. 3), which is better than a vacuum cleaner bag (86%), tea towel (72.5%), cotton mix (70%), antimicrobial pillow case (68.9%) and 100% cotton T-shirt (50.9%) at 23 nm. The FE of medical masks (sample F, Fig. 3) at 25 nm (91.54%) concurred the previously reported 89.5% at 23 nm; but no comparison should be made with its certificated BFE, which was tested at 3 μm.

The higher FE in sample D than sample C (see Fig. 3) could be explained by the different layering order. The overlapped kitchen towels facing externally might reduce the inter-fibre spaces, increasing obstruction and aerosol travelling time during the initial path of aerosol penetrating of the home-made mask. The fluffy alternate raised flat areas of kitchen towels might also increase the surface areas to trap incoming particles. The higher FE in sample E (tissue paper plus medical mask) than sample F (medical mask alone) is likely to be related to increased aerosol travel distance.

There are limitations to the present study. The set-up was similar to that in ASTM methods for PFE, and the testing parameters were stringent and referenced to standard protocols using nano-aerosols. The FE of medical masks (99.87% at 3 μm) illustrated that the current test method was able to test and achieve a comparable FE as certified by ASTM method. At 75 nm, FE was 77.6%, which concurred with previous findings of medical masks FE 54.74–88.4%. The area of the test materials was smaller than required in BFE/PFE tests; however, the materials adequately covered the highest (and the usually constant) area of mouth opening during coughing and the usual cough-cloud width. The overall effectiveness of home-made masks for protection was not tested, which was out of the study’s scope. Nevertheless, the in-use plastic face shield would cover any face-seal leak, preventing larger droplet dispersion from sources or exposure to receivers. Virus-laden droplets, if any, in incoming airflow from the front and sides, would have highly likely been impacted to the external surface of the face shield and the droplet speed would then be largely retarded before they could penetrate the face shield (if possible) and contact the breathing zone. Airflows heading up from below the chin and entering the shield-mask (external surface) interspaces might be prevented by the properly worn home-made mask, which covered the breathing zone to below the chin.

The home-made masks in this study need to be changed once wet as this impacts the absorbency of the materials. Disposable masks have lower risks of cross-contamination than reused items. The acceptance of home-made masks regarding comfortability and breathability (assessed by pressure drop across materials) were not assessed. Nevertheless, the authors of the study and associated members of the working group who tried and used the home-made masks in community settings, perceived the masks to be acceptable for general use as suggested. The home-made masks in this study had fewer layers (3 layers; 2 were kitchen towels) and might be more breathable than the other home-made masks (e.g. 5 layers; 4 were kitchen towels) whose breathability was also perceived as acceptable and more breathable than N95 respirators by their authors. A meta-analysis, which included studies in non-healthcare settings during COVID-19 and other previous epidemics, found that use of face masks and face shields were acceptable, feasible and reassuring.

At times when limited medical masks are available, the home-made masks in this study provide a suitable alternative with a non-inferior FE to medical masks. However, other home-made masks with variable or unknown FE, and the reuse of disposable not-for-reuse face masks may provide false protection, although inward (self-) protection has been shown, even with home-made masks, which is better than no protection. Hence, if people cannot get hold of medical masks, they may consider home-made masks to protect their breathing-zone in the current COVID-19 pandemic.

Conclusions

Home-made masks with FE in the nano-sized range are urgently needed for community mitigation of COVID-19 and as alternatives to medical masks because of their current shortage. In this study, the FE of medical masks at 3 μm was comparable to the certificated BFE at 3 μm. The FE of home-made masks using one layer of tissue paper and two layers of kitchen towels (sample D) was non-inferior to that of medical masks for 6–200 nm aerosols, and the FE of medical masks with tissue paper (sample E) was higher than for medical masks alone (sample F). In times of medical mask shortage, one piece of tissue paper might be put adjacent to the inner surface of the medical mask to reduce contamination and prolong the effective lifespan of the medical mask. The current home-made masks, combined with plastic face shields (Supplementary Video S1), could be used as alternatives to medical masks for low-risk community settings to reserve medical masks for healthcare use and certain community settings, to mitigate the spread of COVID-19 until chemoprophylaxis and/or vaccines are available. Decontamination of medical masks damaged their fibre structures and is not recommended; reuse of such masks would give a false sense of protection. Commercially available hats/visors with plastic face shields could be alternatives to the plastic face shield in the current study (Fig. 6).

Nanotechnology incorporation in masks/fabrics, with or without copper-impregnated for antimicrobial effects, are available. Further research is needed to develop effective materials, reusability and decontamination methods, if feasible, of medical masks for respiratory protection, and for better quality and

Fig. 6. Home-made mask combined with hat/visor with plastic face-shield. (Biophysical measurements of the human model: body height 160 cm; hairline to tip of the chin 20 cm; left ear lobe to tip of the nose 13 cm; tip of the nose to right ear lobe 13 cm)
effectiveness improvement of home-made masks should be investigated as an alternative. Collaboration from interdisciplinary and cross-specialty expertise were used in this study to achieve evidence-based applications for timely and constructive responses to mitigate damage control during the COVID-19 pandemic.

Author statements

Competing interests

None declared.

Author contributions

All authors contributed equally. I.W.-s. Li, J.K.-m. Fan, A.C.-k. Lai et al. in the study. MH, J.R., and L.C.-L. contributed to the study design, data analysis, and interpretation. All authors contributed equally. IWSL and ACKL: study methods; administrative support with manuscript writing; critical revision of the manuscript for important intellectual content. JKMF and CML: concept and design; administrative support; CML: supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpubhe.2020.08.018.

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