Our results focused on accessible cloth, based on which community house masks can be made—of those fabrics, two-layered nonwoven and jersey 'T-shirt' knit were found to be those with the best performance when considering both filtration capacity and breathability. Nevertheless, their particle retention capacity is still below those of more complex multi-layered textiles and of surgical masks. Therefore, while some 'home-made' masks based on common cloth can be used for daily activities of asymptomatic patients, they are probably inadequate for health professionals or other workers contacting with large numbers of individuals, or for caregivers of Covid-19 patients treated at home. Our results point to the importance of textile properties when devising community masks, to ensure a more effective protection.

Data availability statement: The data that support the findings of this study are openly available at http://simtestcovid.gim.med.up.pt/mask/

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Universal public mask wear during COVID-19 pandemic: Rationale, design and acceptability

To the Editors:

Coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is primarily transmitted by respiratory droplets directly, via fomites indirectly and can be airborne in specific circumstances. Surgical masks and respirators reduce the risk of entry of virus for healthcare workers. However, the benefits of community masking remain a controversial topic.

The rationale of public mask wear is to reduce community transmission from infected individuals, who can be pre-symptomatic or asymptomatic but still be shedding virus and are therefore contagious.[1,2] The World Health Organization (WHO) recommendation of mask wear by symptomatic persons and their contacts only[3] may therefore be inadequate. Countries and cities, such as South Korea and Hong Kong, which adopted universal mask wear have much lower COVID-19 incidence, an indirect evidence of its efficacy.

While surgical masks and respirators are more effective against virus inhalation exposure hazard, due to global shortage, there is consensus that they should be reserved for healthcare workers. Cloth masks, on the other hand, can be made in abundance rapidly, are easier to use, more comfortable, washable and therefore reusable. Advice from the American Control Disease Center and Germany's disease control agency recommends using face coverings even with home-made masks when physical distancing is difficult to maintain at public settings. The Hong Kong SAR government is distributing free reusable CuMask+ (https://www.qmask.gov.hk/about).

Different fabrics have been suggested and tested to address the permeability and breathability of mask design. According to the American Chemical Society, a mask composed of a one layer of a tightly woven cotton sheet (600 threads per inch) combined with two layers of polyester-spandex chiffon has a performance close to that of an N95 mask material.[4] While a normal cotton layer can provide mechanical filtrations against larger particles, finer particles require electrostatic filtration from a second layer made of either synthetic material or natural silk.[4] In Table 1, we list the properties of the ideal cloth mask, and precautions to be taken.

Western society may have difficulty with accepting universal masking for fear of identifying with non-indigenous culture and religious practice. These fears need to be rooted out partly by education and partly by mask design. Public surveillance will need to depend

Table 1 Properties of the ideal cloth mask and precautions for its wear

Properties of the ideal cloth mask
- Impermeable to and absorbs droplets covering all around mouth, nose and chin
- Large and fits well to reduce leak during talking, singing, sneezing and coughing
- Allows for facial anthropometric differences between different age, gender and ethnic groups
- Selected fabrics should have reasonable filtration efficiency against fine aerosols
- Easy to breathe through
- Hypo-allergenic and comfortable with consideration given to points of contact with the face and chin, material for innermost layer
- Degree of vaulting to allow comfort, free movement of mouth and projection of voice
- Some degree of stiffness of structure and fewer layers may give less muffling and better acoustics
- Cost of manufacturer and purchase should be affordable as each person will need to carry at least one spare for changing after coughing, sneezing and build-up of moisture
- Integration of silver ions may reduce odour
- Should be easy to wash, dry (including quick to dry), wear and carry
- Consideration should be given whether mask should be tied, bear Velcro pads, has elasticated straps or be like a balaclava
- Comfortable elasticated bands to the ears may be best but there should be a choice
- Explore multi-layered cloth masks which are transparent to allow lip reading, or consider having a small area of transparent plastic over the mouth area, with steaming up reduced or eliminated with an anti-misting coat
- Designs can be masculine, feminine or gender neutral
- Colours and emblems may be used to denote membership of schools, organizations or clubs and create sense of belonging
- Could also have daytime masks and evening 'cocktail' masks, although costly couture masks from design houses already exist

Precautionary measures on mask wear
- Pre-existing respiratory and cardiovascular diseases may pose elevated health risk for wearers so patients should consult their family doctors for advice and clearance
- Mask wearers must be properly educated on the use and maintenance of their selected masks through instruction leaflet, and traditional and social media
- Both inhalation and exhalation protection are reduced by facial hair interfering with seal
- To ensuring continued efficacy, wearers must inspect for mask damage each time prior to use
- Wearers must also be familiar with proper donning, adjustment and doffing of mask (see next point)
- As used masks must be considered contaminated, it is important that wearers are trained on proper doffing techniques to prevent accidental cross contamination between the mask surface and the body
- To prevent accidental virus transmission, wearers must store masks in clean sealed and labelled bags and never share the mask with another person
- Wearers must never be complacent with mask use and ignore other equally important exposure control measures such as maintaining physical distancing, or removing mask intermittently during the middle of use in high-risk public areas for whatever purpose (e.g. conversation)
- Wearers must establish proper preventive maintenance programme for mask use including following daily mask washing procedure and set up a regular mask replacement schedule

more on iris, upper face, voice and gait recognition as a result of mask wear. To ensure safety and efficacy, mask designs must be tested and certified by an official authority such as the European Committee for Standardization (CEN) or the American National Institute for Occupational Safety and Health (NIOSH).

Universal mask wear by the public is an important policy to reduce transmission of COVID-19, especially when countries come out of lockdown and in packed enclosed spaces. We need to encourage acceptance by governments and people. We need to reduce talking, and those with symptoms of cough and sneezing should self-isolate. This new normal will need to continue until there are safe and effective pharmacological treatments and vaccines against COVID-19. Face covering provides better protection when combined with the other protective measures including frequent hand washing with soap and running water, not touching face, respiratory etiquette, social solidarity and physical distancing.

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Reply

From the Authors:

We thank Drs Sousa-Pinto *et al.*[1] for their research efforts addressing the limited evidence currently available on the differing effectiveness of homemade cloth mask materials. We agree with the authors' statement that the materials used are critical determinants of mask effectiveness as shown in the several studies we have also included. We also applaud their focus on affordable materials that can be readily accessed in low-income settings.

The results of their study show better filtration properties for non-woven and two-layered jersey for larger size particles (3 and 5 μm) and cotton plain weave for smaller sized ones (0.5, 0.7 and 1 μm), supporting the results of a recent laboratory study by Konda *et al.*[2] However, the results showing that polyester was ineffective in filtering smaller sized particles seem to contradict the results of the same author which showed an effectiveness 67–83%.[2] We would also like to bring attention to the importance of fit in the evaluation of these materials as poor fit can have substantial impacts on the material's performance in practice.[3]

We appreciate the comments by Drs Liu *et al.*[4] on the potential properties of an ideal cloth mask and precautions for wearers which support the need for further research on mask materials, design and wear. This may differ between countries based on the availability of materials, facial structure and level of health literacy. Thus, we also support the authors' proposal that national authorities for occupational health could develop standards to be met to ensure safety and efficacy by locally manufactured cloth masks, and agree that the support of health authorities for mask wear in public will be important as lockdown restrictions are relaxed.

While laboratory studies such as the one reported by Drs Sousa-Pinto *et al.* make an invaluable contribution to our understanding of the factors contributing to mask effectiveness, we urgently need studies evaluating mask effectiveness in real-world settings such as the current pandemic. We believe that the behavioural aspects of mask wearing by the public and the public health recommendations to support it are essential components of success when added to the use of effective materials with known filtration capacity. We urgently need this research to inform public policy to reduce the spread of respiratory viruses such as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Only then can the current controversy on recommending face masking in public be resolved.

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