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ORIGINAL ARTICLE

Use of cloth masks in the practice of infection control - evidence and policy gaps

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Abstract

Cloth masks are commonly used in low and middle income countries. It is generally believed that the primary purpose of cloth masks is to prevent spread of infections from the wearer. However, historical evidence shows that they have previously been used to protect health care workers (HCWs) from respiratory infections. Currently there is a lack of evidence on the efficacy of cloth masks. In this paper, we examined the evidence around the efficacy of cloth masks and discuss the use of cloth masks as a mode of protection from infections in HCWs. We also reviewed the various approaches implemented to try and improve the effectiveness of cloth masks; for example; type of fabric, masks design and face fit.

Our results highlight that there is currently no published research on the efficacy of cloth masks. The few available studies on cloth masks are either descriptive or in-vitro. Studies show that some fabrics may provide better protection than others, and that in-vitro filtration capacity improves with increasing fineness of fabric and number of layers. The presence of moisture, distance traveled by the droplets and the design of mask were identified as other important factors related to the in-vitro filtration efficacy. Cloth masks may provide some protection and reduce exposure to respiratory aerosols, but this is unproven in the absence of a RCT. Given that cloth masks are widely used around the world and are not adequately addressed in infection control guidelines, research is required to test the clinical efficacy of cloth masks. Other future research questions should include filtration efficacy, length of use, methods of decontamination and fit testing. The use of cloth masks should be addressed in policy documents to inform best practice in low and middle income countries.

Keywords: Masks; Infection Control

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Background

The use of personal protective equipment (PPE) is recommended for the prevention of infections in the health care setting.[1-5] Masks and respirators are the most common products referred to in guidelines to prevent the spread of pathogens through the respiratory droplet and aerosol routes.[6-22] The main difference between the two products is their intended use. The described purpose of face masks are to prevent the spread of infections from the wearer and to protect the user from body fluids splashed or sprayed, whereas respirators are used to protect the wearer from others with confirmed or possible respiratory infections.[1,11,23-25] However, in low resource settings, the provision of single-use surgical masks and respirators may not be feasible. Instead, various types of cloth masks (i.e. cotton/ woven or gauze) are also widely utilized in various healthcare settings in resource-poor countries. In countries such as China and Vietnam, where the historical risk from emerging infections is high,[26, 27] use of cloth masks by health workers (HCWs) is widespread.[28-30] Currently, there is a lack of sufficient data to either support or refute the effectiveness of cloth masks, in preventing transmission of infections.[25] In this article, we examine the historical and present role of cloth masks in the healthcare setting and the evidence regarding the effectiveness of the product. In this setting, we refer to cloth masks as 'reusable masks made of cloth or any other fabric, including cotton, gauze, silk or muslin'.

Use of cloth masks in the hospital setting

The first evidence of mask use can be traced to the late 19th century, when gauze masks were used by patients to protect the spread of infection.[31, 32] In 1905, Hamilton proved the presence of Streptococcus in sputum droplets and suggested that HCWs use masks to prevent spread of streptococcus infection in operating theaters.[33] It is generally believed that masks were primarily designed to prevent spread of infections from the wearer, i.e. from both patients and HCWs, referred to as "source control".[34] However, the literature shows that masks had also been used to protect HCWs from acquiring respiratory infections in early 20th century.

The Institute for Infectious Diseases in Chicago was the first to recommend that masks be used to protect HCWs from respiratory infection. HCWs in Durand Hospital, Chicago used double layered gauze masks from 1913 to 1916,[35] which were later changed to triple layered masks in 1919.[31] Low rates of respiratory infections amongst HCWs were observed after using these masks. Cloth masks were also thought to be effective for preventing secondary transmission of diphtheria and scarlet fever in the patients and HCWs of an Army camp in 1918.[36] Cotton masks made up of various layers were used by HCWs and the public during the 1918 Spanish influenza pandemic, however the number of influenza cases continued to rise despite regular mask use.[37-40] Low perceived effectiveness of the masks used during that pandemic was attributed to the poor quality of masks, inappropriate use of masks.[40] In comparison, the rate of infection was very low amongst HCWs who used masks made of a half-inch thick cotton pad enclosed by two layers gauze, during the Manchurian Epidemic in 1920–1921.[41] HCWs have also been documented with using pillow slips and celluloid to make masks during the 1924 epidemic of plague in Los Angeles.[42] The use of cloth and gauze masks continued during the 1930's and 40's by nurses for the prevention of TB.[43-45] These masks continued to be recommended for use during the 1950s and 1960s, even though by then a few disposable masks had been introduced into the market.[46]

The extent to which cloth masks are currently being used in the low and middle-income countries is impossible to gauge, as the data currently available are limited. However, based on anecdotal information, it is believed that the practice is widespread in Asia, for example in China and Vietnam.[28-30] Furthermore, there were reports that cotton masks were used by HCWs during the SARS outbreak in China.[29,47] In the initial phase of the SARS outbreak in Vietnam, approximately 70% of HCWs wore a cloth or surgical masks, however, after the first week there was 100% N95 respirator use.[48] However, in many of these settings, from our experience of conducting clinical research, a wide range of unproven practices occur, including double-masking, extended or re-use of masks and washing of masks using various different techniques. There is little evidence of cloth mask use in high income countries, however some researcher have recommended the use of cloth masks in case of adverse effects during the long use of respirators.[49,50] In addition to that some regional pandemic influenza plans discuss the use

of cloth masks in certain situations. For example; in California, Sonoma County Department of Health Services developed plan for pandemic influenza and recommended cotton masks in the event of a shortage of N95 respirators and surgical masks.[51]

Effectiveness of cloth masks

The first study on cloth masks was published by Weaver in 1918.[35] He examined the rate of diphtheria and scarlet fever among the nurses before and after the use of two layered gauze masks. He reported a significant reduction in the incidence of diphtheria (23.5% to 5.2%) and scarlet fever (8% to 0%) amongst the nurses. In a second study, he tested masks in a controlled environment, which had been made up with various layers and reported an improvement in the effectiveness of gauze masks associated with increasing fineness of the cloth and the number of layers.[31] In 1959, Shooter and colleagues evaluated three types of masks to prevent the spread of staphylococci from the wearer. They compared a four layer cotton mask, with a mask made from two layers of woven cambric with a piece of paper in between and a paper mask surrounded by cellulose wadding. All three masks were found effective in preventing spread of staphylococcal infection.[52] A couple of years later, Greene and Vesley evaluated a two layer gauze mask and found that it was effective in blocking particles greater than 4 um (99.6%) and less than 4 um (96.7%).[53] Lastly in 1975, Quesnel assessed various types of surgical and cotton masks and concluded that well designed cotton masks may be effective in preventing infection.[46]

During the middle of the 20th century, the focus of research around mask use was to protect HCWs from tuberculosis (TB). McNett developed a series of masks and checked their effectiveness by estimating the rate of infection among the nurses. A 50% reduction in the prevalence of TB was observed amongst nurses who used the 6 layer cloth mask.[44] Cloth masks were also found effective in protecting rabbits against the inhalation of tubercle bacilli.[43] Since the development of surgical masks and respirators, very little research has been conducted on cloth masks recently. To our knowledge, only three studies were done on cloth masks during the 21st century, and all in a laboratory setting. Dato and colleagues tested a handmade mask, made from cotton T-shirt material, for fit testing and filtration. After introducing the challenge aerosol, substantial protection and good fit were reported.[54] In the 2nd study, Sandy and colleagues studied respirators, surgical and cloth masks and concluded that all three products provide respiratory protection to a degree, with respirators providing the maximum protection and homemade cloth masks the minimum.[55] Lastly, Rengasamy and colleagues tested the filtration performance of various types of cloth masks and concluded that respiratory protection is minimal by cloth masks but that certain types of cloth fabric may have more protective value than others.[56]

Three factors were highlighted in these studies in regards to the filtration capacity of a cloth mask: 1) closeness of the gauze/cloth threads; 2) number of gauze/cloth layers and 3) type of gauze/cloth. Generally, the filtration capacity improved when the number of threads increased in the gauze and the mesh become finer compared to course gauze with lower thread counts.[31,40,57] Similarly, the number of layers was found to be directly proportional to the filtration capacity in most of the laboratory studies. In these studies, the filtration effectiveness significantly improved with increasing the number of layers in the mask.[31,40,58,59] Certain types of cloth provides better protection than other; e.g. fine muslin (loosely-woven cotton fabric) was better than the gauze,[58] gauze padded with cotton were better than simple gauze or paper masks[60] and towels were more effective than other fabrics.[56] Cloths masks were generally found to be effective against large particles (>4 um),[53] however some evidence exists against small particles as well.[43] Presence of moisture, distance traveled by the droplets and the design of mask were some other factors affecting the filtration capacity. In summary, the filtration capacity of wet masks has been reported as being lower compared to dry masks.[58, 60] The distance traveled by the droplets is associated with the filtration capacity and filtration capacity is generally decreased by decreasing distance.[31, 61] Finally, the design of a mask is also important and some designs are more effective than others, particularly those with a tight seal around the face.[40,54,61,62]

There are many limitations in the available research around cloth masks. Firstly, most of the studies were conducted in first half of the 20th century. After the

development of disposable surgical masks in the 1960's, very few studies have been conducted on cloth masks, and to date there have been no randomized, controlled clinical trials of cloth masks. Recently published RCTs and other studies have focused only on surgical masks and respirators.[21, 63-67] Secondly, most of the studies on the use of these products have been in laboratory settings, using bio-aerosols and manikins.[46,52,53,62,68] Thirdly, extended use and re-use of cloth mask have not been discussed in much detail in the literature. Extended use refers to 'using a mask or respirator by the same wearer for a prolong time'. Staff may continue to use the same mask over a period of time without removing it or may don/doff the mask between patients. A recent survey in Vietnam revealed that HCWs use masks for varied lengths of time.[30] Reuse after decontamination refers to the mask being reused over multiple days/weeks/months by either the same or different HCW. Cloth masks are typically washed or decontaminated between uses. Various decontaminated methods have been documented, for example; autoclave, isopropyl alcohol, bleach, hydrogen per oxide, microwave, soap and water, ultraviolet radiation and dry heat.[25] While, the material of cloth masks is unlikely to degrade with standard means of disinfection (e.g., chemicals, heat, and radiation), unlike other types of disposable facemasks or respirators, there is currently little evidence about the effectiveness of these decontamination methods.

As a result of these laboratory studies, the use of cloth masks was recommended for HCWs,[31,35] particularly during epidemics and pandemics in the early 19th century.[37-42] Therefore, whilst these studies were only conducted to examine the spread of infections from the wearer, the same studies were also used to justify the use of masks in preventing infection for HCWs.[35,43,69] During the pandemic of influenza in 1918, authorities quoted the same studies in order to implement compulsory use of mask in the hospitals and public places.[37,38]

Policies and guidelines around the use of cloth masks in health care setting

Reference to or recommendations around the use cloth masks are currently not made in any publically available guidelines regarding the use of PPE for routine care to protect against respiratory virus transmission. A review of publically available pandemic influenza policy documents reveals that none of the guidelines mention the use of cloth masks.[70] However, the use of cloth masks has been discussed for other infective diseases. In cases of non-availability of surgical masks, CDC recommends using cotton masks made from four or five layers of cotton cloth for infection control of viral hemorrhagic fevers in the African health care setting.[71] The WHO discouraged masks use in the community setting during influenza A (H1N1) outbreaks due to lack of evidence, however, the option of use and reuse of various types of cloth masks is discussed. In case of cotton masks, WHO advises washing cloth masks with house hold detergent after use.[72]

The use of cloth masks during an extended outbreak or pandemic

According to a CDC estimate, approximately 1.5 billion masks and 90 million respirators would be needed by the health sector and around 1.1 billion masks would be needed by the public for a six week influenza pandemic.[25] For most low income countries, it is highly unlikely that they will be able to provide disposable masks, let alone respirators for that extended period of time and may have to ration the use of these products. During an extended outbreak or influenza pandemic, the use of cloth masks may be the only option available in low resource settings. In a survey conducted in Japan during the SARS outbreak, around 40% HCWs agreed that gauze masks may be used to protect from SARS.[73] Recently, the high demand for masks and the potential reliance on cloth masks during an influenza pandemic, was acknowledged by the Institute of Medicine (IOM) when preparing their report on the reusability of facemasks. The committee members did not advise against the use of cloth masks, however they recommended further research be undertaken on the use of cloth masks, including commonly used fabrics like T-shirts, handkerchiefs and scarves.[25] One of the issues is that the quality and nature of cloth masks used around the world are varied and not subject to any regulation. Currently, only N95 respirators are subject to regulation around filtration capacity. It is currently not clear whether the wide range of cloth masks or improvised masks can meet the standards set by regulatory bodies.[25] Interestingly, it should be noted that surgical masks are similarly not subject to any regulation, and face the same issue.

There is currently a concern that cloth mask use may give users a false sense of protection in the absence of proven efficacy that will encourage risk taking and/or decrease attention to other hygiene measures.[25,56]

Conclusion

Although cloth masks are commonly used in low/middle income countries, there is minimal policy acknowledgment of the need for cloth masks, and a lack of evidence on their efficacy and use. Cloth masks are generally not mentioned in any policies on the use of PPE during an influenza pandemic. The lack of recommendations for respiratory protection may be due to a lack of evidence on their efficacy. Despite the lack of evidence and the little attention paid to cloth masks in guidelines and policies, they continue to be widely used around the world, particularly in resource-poor countries. In many settings, the high cost of masks and respirators (around $0.14USD per surgical mask and $0.63USD per N95 respirator for products manufactured by a leading company) is probably one of the main factors inhibiting the regular use of these products. More concerning is the fact that cloth masks are widely used in countries which have been historically important for the emergence of new infections such as China and Vietnam. There is an urgent need for research to quantify the efficacy of cloth masks with a RCT, and to study the various associated practices such as re-use and sterilization techniques globally. Future research questions could focus on clinical efficacy, filtration efficacy, length of use, methods of decontamination and fit testing. The use of cloth masks should be addressed in policy documents to inform current practice in low and middle income countries.

References

1. Occupational Safety and Health Administration. Pandemic Influenza Preparedness and Response Guidance for Healthcare Workers and Healthcare Employers. U.S. Department of Labor, 2009.
2. Bell D, Nicoll A, Fukuda K, *et al.* Nonpharmaceutical Interventions for Pandemic Influenza, National and Community Measures, World Health Organization Writing Group. *Emerging Infectious Diseases* 2006; **12(1):** 88-94.
3. Centers for Disease Control and Prevention (CDC). Interim guidance on planning for the use of surgical masks and respirators in health care settings during an influenza pandemic. 2006 [cited 2012 24 March]; Available from: http://www.flu.gov/planning-preparedness/hospital/maskguidancehc.html#intro.
4. Institute of Medicine (IOM) National Academy of Sciences. Preparing for an influenza pandemic, personal protective equipment for healthcare workders. 2007.
5. Siegel JD, Rhinehart E, Jackson M, *et al.* Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings. 2007.
6. World Health Organization (WHO). Epidemic-prone & pandemic-prone acute respiratory diseases: Infection prevention and control in health-care facilities. 2007.
7. Center for Disease Control and Prevention (CDC). Prevention Strategies for Seasonal Influenza in Healthcare Settings. [cited 2012 15 May]; Available from: http://www.cdc.gov/flu/professionals/infectioncontrol/healthcaresettings.htm#settings
8. Center for Disease Control and Prevention. Interim Guidance on Infection Control Measures for 2009 H1N1 Influenza in Healthcare Settings, Including Protection of Healthcare Personnel. [cited 2012 3 May]; Available from: http://www.cdc.gov/h1n1flu/guidelines_infection_control.htm.
9. Department of Health UK. The use of face masks during an influenza pandemic. 2007 [cited 2012 29 Feb]; Available from: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_077276.
10. Public Health Agency of Canada. Prevention and Control of Influenza during a Pandemic for All Healthcare Settings. 2010. http://www.health.gov.nl.ca/health/publichealth/cdc/pandemic_precautions.pdf
11. Department of Health and Aging Australia. Australian Health Management Plan for Pandemic Influenza 2006. http://www.health.gov.au/internet/main/publishing.nsf/Content/851B7469ADF70118CA257202001E8989/$File/ahmppi-print.pdf
12. Center for Disease Control and Prevention. Public Health Guidance for Community-Level Preparedness and Response to Severe Acute Respiratory Syndrome (SARS). 2004. http://www.cdc.gov/sars/guidance/index.html
13. Health Protection Agency UK. SARS - hospital infection control guidance. 2005. http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1194947350823
14. Health Canada. Infection control guidance for health care workers in health care facilities and other institutional settings–Severe Acute Respiratory Syndrome (SARS). In: Health Canada Ottawa, editor. 2003.
15. Department of Health and Ageing and the Communicable Disease Network of Australia. Interim Australian Infection Control Guidelines for Severe Acute Respiratory Syndrome (SARS). 2004. http://www.health.gov.au/internet/main/publishing.nsf/Content/AF6930AC75BDE030CA256F19000539B6/$File/3_icg.pdf
16. World Health Organization (WHO). WHO policy on TB infection control in health-care facilities, congregate settings and households. 2009. http://www.who.int/tb/publications/2009/infection_control/en/index.html
17. Center for Disease Control and Prevention. Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health-Care Settings. *Morbidity and mortality weekly report*. 2005; 54(No. RR-17).
18. National Institute for Health and Clinical Excellence (NICE) UK. Clinical diagnosis and management of tuberculosis, and measures for its prevention and control. 2011. http://www.nice.org.uk/nicemedia/live/13422/53642/53642.pdf
19. National Health and Medical Research Council (NHMRC). Australian Government. Australian guideline for the Prevention and Control of Infection in Healthcare. 2010. http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/cd33_complete.pdf

20. Public Health Agency of Canada. Tuberculosis Prevention and Control. The Lung Association Canada. Canadian tuberculosis standards, sixth edition. 2007. http://www.phac-aspc.gc.ca/tbpc-latb/pubs/tbstand07-eng.php
21. MacIntyre CR, Wang Q, Seale H, *et al.* A randomised clinical trial of three options for N95 respirators and medical masks in health workers. *American Journal of Respiratory and Critical Care Medicine* 2013; **187(9):** 960-966. http://dx.doi.org/10.1164/rccm.201207-1164OC
22. MacIntyre CR, Wang Q, Cauchemez S, *et al.* A cluster randomized clinical trial comparing fit-tested and non-fit-tested N95 respirators to medical masks to prevent respiratory virus infection in health care workers. *Influenza and Other Respiratory Viruses* 2011; **5(3):** 170-179. http://dx.doi.org/10.1111/j.1750-2659.2011.00198.x
23. Institute of Medicine (IOM) National Academy of Sciences. Preventing Transmission of Pandemic Influenza and Other Viral Respiratory Diseases: Personal Protective Equipment for Healthcare Personnel Update 2010. The National Academies Press Washington D.C. 2010. http://www.iom.edu/Reports/2011/Preventing-Transmission-of-Pandemic-Influenza-and-Other-Viral-Respiratory-Diseases.aspx
24. Seale H, Dwyer D, Cowling B, *et al.* A review of medical masks and respirators for use during an influenza pandemic. *Influenza and Other Respiratory Viruses* 2009; **3:** 205-206. http://dx.doi.org/10.1111/j.1750-2659.2009.00101.x
25. Institute of Medicine (IOM) National Academy of Sciences. Reusability of Facemasks During an Influenza Pandemic: Facing the Flu - Committee on the Development of Reusable Facemasks for Use During an Influenza Pandemic. 2006. http://www.nap.edu/openbook.php?record_id=11637&page=R1
26. Breiman RF, Evans MR, Preiser W, *et al.* Role of China in the quest to define and control Severe Acute Respiratory Syndrome. *Emerg Infect Dis* 2003; **9(9):** 1037-1041. http://dx.doi.org/10.3201/eid0909.030390
27. Perdue ML, Swayne DE. Public health risk from Avian Influenza Viruses. *Avian Diseases* 2005; **49(3):** 317-327. http://dx.doi.org/10.1637/7390-060305R.1
28. Dung TC, Hien NT, Nga PT, *et al.* Use of cloth masks amongst healthcare workers in hospitals in Hanoi, Vietnam. Accepted at *Journal of Preventive Medicine, Vietnam*.
29. Yang P, Seale H, MacIntyre C, *et al.* Mask-wearing and respiratory infection in healthcare workers in Beijing, China. *Braz J Infect Dis* 2011; **15(2):** 102-108.
30. Seale H, MacIntyre R, McLaws M-L, *et al.* Health care worker practices around face mask use in hospitals in Hanoi, Vietnam. 15th ICID Abstracts / *International Journal of Infectious Diseases* 2012; **16S:** e317–e4732012. p. e384.
31. Weaver GH. Droplet Infection and its prevention by the face mask. *The Journal of Infectious Diseases* 1919; **24(3):** 218-230. http://dx.doi.org/10.1093/infdis/24.3.218
32. Rockwood CA, O'Donoghue DH. The surgical mask: its development, usage, and efficiency: A review of the literature, and new experimental studies. *Arch Surg* 1960; **80(6):** 963-71. http://dx.doi.org/10.1001/archsurg.1960.01290230081010
33. Hamilton A. Dissemination of streptococci through invisible sputum in relation to scarlet fever and sepsis. *JAMA* 1905; **44:** 1108-1111. http://dx.doi.org/10.1001/jama.1905.92500410032001g
34. Belkin NL. The evolution of the surgical mask: filtering efficiency versus effectiveness. *Infection Control and Hospital Epidemiology* 1997; **18(1):** 49-57. http://dx.doi.org/10.1086/647501
35. Weaver GH. The value of the face mask and other measures in prevention of diphtheria, meningitis, pneumonia, etc. *JAMA* 1918; **70(2):** 76-78. http://dx.doi.org/10.1001/jama.1918.02600020010005
36. Capps JA. Measures for the prevention and control of respiratory infections in military camps. *JAMA* 1918; **71(6):** 448-451. http://dx.doi.org/10.1001/jama.1918.26020320008010a
37. New South Wales Department of Public Health. Report on the influenza epidemic in New South Wales in 1919. Part 1, Epidemiology and Administration. http://wwwhealthnswgovau/pubs/2007/influenza_reporthtml.
38. Whitelaw TH. The practical aspects of quarantine for influenza. *Can Med Assoc J* 1919; **9(12):** 1070-1074.
39. Brooks WA. The open air treatment of influenza. *The American Journal of Public Health* 1918; **8:** 276-750. http://dx.doi.org/10.2105/AJPH.8.10.746
40. Kellogg WH, MacMillan G. An experimental study of the efficacy of gauze face masks. *American Journal of Public Health* 1920; **10(1):** 34-42. http://dx.doi.org/10.2105/AJPH.10.1.34
41. Wu L. A treatise on pneumonic plague. League of Nations, Health Organisation, 1926.
42. Viseltear AJ. The Pneumonic Plague Epidemic of 1924 in Los Angeles. *Yale J Biol Med* 1974; **47(1):** 40-54.
43. Lurie MB, Abramson S. The efficiency of gauze masks in the protection of rabbits against the inhalation of droplet nuclei of tubercle bacilli. *The American review of tuberculosis* 1949; **59(1):** 1-9.
44. McNett EH. The face mask in tuberculosis. How the cheese-cloth face mask has been developed as a protective agent in tuberculosis. *American journal of nursing* 1949; **49(1):** 32-36. http://dx.doi.org/10.1097/00000446-194901000-00030
45. Wheeler CA. A study of the nursing care of tuberculosis patients. *The American Journal of Nursing* 1938; **38(9):** 1021-1037. http://dx.doi.org/10.1097/00000446-193809000-00017
46. Quesnel LB. The efficiency of surgical masks of varying design and composition. *British Journal of Surgery* 1975; **62(12):** 936-940. http://dx.doi.org/10.1002/bjs.1800621203
47. Pang X, Zhu Z, Xu F, *et al.* Evaluation of Control Measures Implemented in the Severe Acute Respiratory Syndrome Outbreak in Beijing. *Journal of Preventive Medicine* 2003; **2(129):** 3215-3221.
48. Ha LD, Bloom SA, Hien NQ, *et al.* Lack of SARS transmission among public hospital workers, Vietnam. *Emerging Infectious Diseases* 2004; **10(2):** 265-268. http://dx.doi.org/10.3201/eid1002.030707
49. Foo CCI, Goon ATJ, Leow Y-H, *et al.* Adverse skin reactions to personal protective equipment against Severe Acute Respiratory Syndrome–a descriptive study in Singapore. *Contact dermatitis* 2006; **55(5):** 291-294. http://dx.doi.org/10.1111/j.1600-0536.2006.00953.x
50. Tan K, Greaves M. N95 acne. *The international journal of dermatology* 2004; **43:** 522-523. http://dx.doi.org/10.1111/j.1365-4632.2004.02338.x
51. Sonoma County Department of Health Services C. Pandemic influenza – phase 6 infection control recommendations template. 2006. http://www.sonoma-county.org/health/topics/pdf/infectioncontrol/phase6icrecommendations.pdf.
52. Shooter RA, Smith MA, Hunter CJW. A study of surgical masks. *British Journal of Surgery* 1959; 47: 246–249. http://dx.doi.org/10.1002/bjs.18004720312
53. Greene VW, Vesley D. Method for evaluating effectiveness of surgical masks. *J Bacteriol* 1962; **83(3):** 663-667.
54. Dato V, Hostler D, Hahn M. Simple Respiratory Mask. Emerg Infect Dis 2006; **12(6):** 1033–1034. http://dx.doi.org/10.3201/eid1206.051468

55. Sande MVD, Teunis P, Sabel R. Professional and home-made face masks reduce exposure to respiratory infections among the general population. *PloS One* 2008; **3(7):** e2618. http://dx.doi.org/10.1371/journal.pone.0002618
56. Rengasamy S, Eimer B, Shaffer R. Simple respiratory protection—Evaluation of the filtration performance of cloth masks and common fabric materials against 20–1000 nm size particles. *The Annals of Occupational Hygiene* 2010; **54(7):** 789-798. http://dx.doi.org/10.1093/annhyg/meq044
57. Doust BC, Lyon AB. Face masks in infections of the respiratory tract. *JAMA* 1918; **71(15):** 1216-1218. http://dx.doi.org/10.1001/jama.1918.26020410011008c
58. Leete HM. Some experiments on masks. *The Lancet* 1919; **193(4984):** 392–393. http://dx.doi.org/10.1016/S0140-6736(01)49329-9
59. Haller DA, Colwell RC. The protective qualities of the gauze face mask - experimental studies. *JAMA* 1918; **71(15):** 1213-1215. http://dx.doi.org/10.1001/jama.1918.26020410008008a
60. McKhann CF, Steeger A, Long AP. Hospital infection - A survey of problem. *Arch Pediatr Adolesc Med* 1938; **55(3):** 579-599. http://dx.doi.org/10.1001/archpedi.1938.01980090127015
61. Blatt ML, Dale ML. A bacteriological study of the efficiency of face masks. *Surg Gynecol Obstet* 1933; **57:** 363-368.
62. Paine CG. The aetiology of puerperal infection. *BMJ* 1935; **1:** 243-246. http://dx.doi.org/10.1136/bmj.1.3866.243
63. MacIntyre C, Cauchemez S, Dwyer D, *et al.* Face Mask Use and Control of Respiratory Virus Transmission in Households. *Emerging Infectious Diseases* 2009; **15(2):** 233-241. http://dx.doi.org/10.3201/eid1502.081167
64. Loeb M, Dafoe N, Mahony J, *et al.* Surgical mask vs N95 respirator for preventing influenza among health care workers: a randomized trial. *JAMA* 2009; **302(17):** 1865–1871. http://dx.doi.org/10.1001/jama.2009.1466
65. Larson EL, Ferng Y-h, Wong-McLoughlin J, *et al.* Impact of non-pharmaceutical interventions on URIs and influenza in crowded, urban households. *Public Health Rep* 2010; 125(2): 178-191.
66. Aiello AE, Coulborn RM, Aragon TJ, *et al.* Research findings from nonpharmaceutical intervention studies for pandemic influenza and current gaps in the research. *American Journal of Infection Control* 2010; **38:** 251-258. http://dx.doi.org/10.1016/j.ajic.2009.12.007
67. Cowling B, Chan K, Fang V, *et al.* Facemasks and hand hygiene to prevent influenza transmission in households: a randomized trial. *Ann Intern Med* 2009; **151(7):** 437-446. http://dx.doi.org/10.7326/0003-4819-151-7-200910060-00142
68. Guyton HG, Decker HM, Anton GT. Emergency respiratory protection against radiological and biological aerosols. *AMA Arch Ind Health* 1959; **20:** 9-13.
69. Lurie MB, Abramson S. Do masks protect? *American Journal of Nursing*. 1949; **49(2):** 100-101.
70. Chughtai AA, Seale H, MacIntyre CR. Availability, consistency and evidence-base of policies and guidelines on the use of mask and respirator to protect hospital health care workers: a global analysis. [Unpublished PhD thesis data]. In press 2012.
71. Center for Disease Control and Prevention. Infection control for viral haemorrhagic fevers in the African health care setting, Section 4: Wear protective clothing [cited 2012 12 March]; Available from: http://www.cdc.gov/ncidod/dvrd/spb/mnpages/vhfmanual/section4.htm
72. World Health Organization (WHO). Advice on the use of masks in the community setting in Influenza A (H1N1) outbreaks. 2009 [cited 2012 24 March]; Available from: http://www.who.int/csr/resources/publications/swineflu/masks_community/en/index.html.
73. Imai T, Takahashi K, Hoshuyama T, *et al.* SARS risk perceptions in healthcare workers, Japan. *Emerging Infectious Diseases* 2005; **11(3):** 404-410.
74. Walker IJ. How can we determine the efficiency of surgical masks. *Surg Gynecol Obstet* 1930; **50:** 266-270.

Table I. Studies on cloth masks

Authors/ year of study	Type of study	Focus of the study (Protect wearer or protect spread to others)	Methodology	Type of material tested	Main findings
Weaver 1918[35]	Observational	Protect HCWs from infections	Rates of diphtheria and scarlet fever were compared in the HCWs in two periods; i.e. before and after use of masks	Two layered gauze mask	Low rate of diphtheria and scarlet fever observed in HCWs after using masks
Capps 1918[36]	Observational	Prevent spread of infection from wearer and protect wearer from infections	Face masks were used by the HCWs and patients in Camp Grant and upon success of the experiment, mask use was started in all medical wards	Cloth masks	The secondary transmission of scarlet fever and measles was reduced in the wards by using the masks
Haller 1918[59]	Laboratory	Prevent spread of infection from wearer	Patients coughed on the petri dishes covered by various gauze masks. Then experiment was revised with double masks, i.e. one on perti dish and one on patient's mouth. Numbers of colonies were counted.	Gauze masks of various types	The number of colonies depends on the type of gauze and number of layer.
Doust 1918[57]	Laboratory	Prevent spread of infection from wearer	Agar pates were placed in front of study subjects, while they spoke, talked and coughed with and without gauze masks. Bacillus prodigiosus was used to test various masks.	Two to ten layers of masks made from coarse gauze, medium gauze, and butter cloth	Three layer butter cloth masks, made of fine gauze, were found to be more effective in preventing spread of infection
Leete 1919[58]	Laboratory	Prevent spread of infection from wearer	The emulsion of staphylococcus was sprayed on the petri dishes covered by gauzes of various types and layers	Dry and wet ordinary surgical gauzes, fine muslin	6 to 8 layer fine muslin provide better protection than then the gauze masks Dry masks are better than the wet masks

Weaver 1919[31]	Laboratory	Prevent spread of infection from wearer	Bacillus prodigiosus (in NaCl solution) was sprayed into the petri dish, through an opening in a cardboard by a hand atomizer. Various types of gauzes were placed onto the opening. The experiment was then repeated with a patient with respiratory infection. The number of colonies in the petri dish (containing nutrient and blood agar) was measured.	Gauze masks of various types and layers were used	The number of colonies in the dishes was decreased by increasing the distance of spray from opening, increasing fineness and number of layer of cloth
Kellogg 1920[40]	Observational and Laboratory	Prevent spread of infection from wearer and protect wearer from infections	Report of State Health Officials on the use of masks in California, during the during the influenza outbreak in 1919, followed by a series of laboratory tests	Gauze masks	Certain types of masks may be effective, (depend on type of cloth and number of layers), however its use should not be compulsory. The leakage around the face increases when thin layer of gauze use.
Walker 1930[74]	Observations and Laboratory	Prevent spread of infection from wearer	Survey in 100 hospitals, 60 hospitals responded, 42 sent masks sample. Masks were worn by student volunteers who were carriers of streptococcus and petri dishes were placed in front of them. The number of colonies were counted at the end.	Various types of masks tested, including a 10 inch gauze mask of two layers, with 6 inch rubber in between.	Of 42 masks, only 7 masks were of good quality. None of them was germ-proof in testing. Gauze mask with rubber in the center was considered germ proof.

Blatt 1933[61]	Laboratory / observational	Prevent spread of infection from wearer and protect wearer from infections	A dust-proof tunnel was constructed. Two nurses with respiratory infection were given various masks and asked to cough in the champers. Petri dishes were placed in the champers at various distances and colonies were counted later. New mask use was observed in nurses	Various types of commonly used masked and a newly made cellophane gauze mask.	Simple 6 layer gauze masks were not effective. Newly made cellophane gauze masks were effective and comfortable to wear.
Paine 1935[62]	Laboratory	Prevent spread of infection from wearer	Tested the penetration of the high momentum droplet through various fibers. An apparatus, similar to the shape of face was used, with three holes representing the nares and mouth. Atomizer charged with a broth culture of *Micrococcus lysodeikticus* were sprayed. The colonies were counted on nutrient agar.	Silk, surgical gauze and dental gauze	Two layer of silk, eight double layers of surgical gauze and four layers of dental gauze are effective in reducing the droplet penetration. The design of mask is important.
McKhann 1938[60]	Laboratory	Prevent spread of infection from wearer	Bacteria were sprayed in the petri dishes covered by the various masks. The numbers of colonies were counted.	Gauze mask, impervious mask, paper masks and a new type of filter mask (cotton layers between the gauzes)	New type of filter masks were most effective. Paper masks were not effective as they become wet very quickly.
McNett 1949[44]	Observation	Protect wearer from infections	Developed series of masks and checked their efficacy by various means, including rate of infection among the nurses.	Various types and layers of cloth masks	50% reduction in the prevalence of TB was observed in the nurses after using 6 layer cloth masks

Lurie 1949[43,69]	Animal testing in laboratory	Protect wearer from infections	Bovine TB bacilli were nebulized into a chamber and faces of rabbits were exposed to the TB bacillus. Masked and unmasked rabbits inhaled in the chamber and tuberculin tests were performed to see the rate of infection.	3 to 6 layer of gauze masks	4 to 6 layer gauze masks effectively filter 90 to 95 of the bacillus. Wearing masks was recommended.
Shooter 1959[52]	Laboratory	Prevent spread of infection from wearer	Evaluated three types of masks to prevent the spread of staphylococcus from the volunteer's month. A chamber was made with help of a table and canopy. Volunteers used three types of masks and the number of colonies were counted on the blood agar in the petri dishes placed in the chamber	Four layer cotton mask, double layer woven cambric with a piece of paper in between, a paper mask with outer and inner layer of paper with cellulose wadding between	All masks were found effective in preventing spread of staphylococcus infection
Greene and Vesley 1962[53]	Laboratory	Prevent spread of infection from wearer	Used a specially designed chamber to collect air sample. Study subject breathed into the chamber with and without mask and the number of oral bacteria were counted on blood agar	Masks made of two layers of fine muslin	Masks were effective mainly against the large particle i.e. greater than 4 um
Quesnel 1975[46]	Laboratory	Prevent spread of infection from wearer	Tested five masks of various types and design. Testing chamber used to collect contaminated particles through the mask and around the masks	Four layer cotton masks, various types of surgical masks made of polyester and rayon fibers	All masks were effective against large particles; however three of them were more effective against the small particles. Results of well designed cotton masks are comparable to the synthetic fiber masks.

Dato 2006[54]	Laboratory	Prevent spread of infection from wearer	Cloth mask was used on the panel faces and challenge agent was measured inside and outside the mask with Portacount Plus Respirator fit tester with N95 Companion	Cotton (heavyweight T-shirts) of various layers	Handmade masks can provide good fit and reasonable protection.
Sande 2008[55]	Laboratory	Protect wearer from infections	Healthy volunteers wore respirators and various masks. Protection factor was measured with fixing receptors insides and outside the masks to count free particles. Portacount was used to count the particles.	Compared respirator, surgical mask and homemade cloth mask	All masks provide some protection, however respirator provide maximum protection, followed by surgical masks and then homemade cloth masks
Rengasamy and colleagues 2010[56]	Laboratory	Protect wearer from infections	Tested the filtration performance of various types of cloth masks against the polydisperse and monodisperse aerosol particle in the 20–1000 nm range. TSI 8130 Automated Filter Tester (TSI 8130) was used for test.	Various types of fabrics were tested, including sweatshirts, T-shirts, towels, scarves, and cloth masks	The respiratory protection is minimal by cloth masks and certain type of cloth fabric may impart more protective value than others.