REVIEW ARTICLE

Trends and Future Research in Face Masks Performance against Acute Respiratory Infections (ARI): A Scientometrics Analysis

Reza Pourbabaki[1, 2], MSc; Mojtaba Emkani[1,2], MSc; Zabiholah Damiri[3], PhD; Moslem Alimohammadlou[4], PhD; Mehdi Jahangiri[2], PhD

[1]Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Department of Occupational Health and Safety Engineering, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran
[3]Department of Occupational Health, Faculty of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[4]Department of Management, Faculty of Economic, Management, and Social Science, Shiraz University, Shiraz, Iran

Correspondence:
Mehdi Jahangiri, PhD;
Department of Occupational Health and Safety Engineering, School of Health, Shiraz University of Medical Sciences, P.O. Box: 71645-111, Shiraz, Iran
Tel/Fax: +98 71 37256006
Email: Jahangiri_m@sums.ac.ir
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Abstract

Background: One of the major causes of morbidity and mortality among infectious diseases is acute respiratory infections. Masks are often recommended as proper personal protective equipment for preventing the spread of respiratory infections. This study aims to provide valuable insights into historical and current trends in research on mask performance, with a particular focus on hotspots and trend studies.

Methods: In this Systematic Review, relevant studies on face mask efficacy were retrieved from the Web of Science (data extracted on July 15, 2023). The selected articles were analyzed using VOSviewer, R (Bibliometrix package), and Tableau to visualize geographic distributions, conduct bibliometric analyses, and map research trends across countries, institutions, keywords, and journals.

Results: The number of articles published in 2020 and 2021 has increased significantly. Overall, 1193 papers were identified, published by authors from 88 countries. According to literature citations, the journal "PloS ONE" published the most research on the topic. Fabric mask filtration performance was evaluated in the two documents with the highest total link strength. With the outbreak of COVID-19 around the world, studies were more focused on fit tests and filtration of surgical, medical, and N95 masks, indicating that researchers are exploring the effectiveness of masks to ensure the effectiveness of face masks.

Conclusion: This study suggests potential knowledge gaps regarding the effectiveness of face masks, so future research should focus on challenges such as uncertain efficacy and fitness.

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Introduction

Many respiratory infectious diseases, such as tuberculosis, influenza virus, rubella virus (measles), varicella-zoster virus (chicken pox), and coronavirus disease 2019 (COVID-19) are transmitted via aerosols and droplets.[1-4] Infectious diseases, specifically acute respiratory infections,[5] are a leading cause of global disease and mortality.[6] Annually, it is estimated that approximately four million deaths are associated with ARIs, particularly lower respiratory tract infections. Mortality rates are particularly high among the elderly, children, and infants, especially in low- and middle-income countries.[5, 7]

ARIs are one of the most common reasons for consultation or admission to health-care facilities.

ARIs are characterized by a broad spectrum of symptoms caused by respiratory viruses.[8, 9] Humans are infected with these viruses through direct or indirect contact, respiratory droplets, and fine-particle aerosols.[2, 10] Viruses or mixed viral–bacterial infections, such as influenza viruses, rhinoviruses, and coronaviruses, are the most common pathogens that cause ARIs. ARIs with epidemic or pandemic potential and the ability to pose a threat to public health require special safeguards and preparedness.[11] The process by which an infectious organism spreads from one host to another and produces disease is referred to as infectious disease transmission. The virus is transmitted from an infected host through coughing, sneezing, and speaking.[12]

Coronavirus disease (COVID-19) is caused by a virus called severe acute respiratory syndrome.[13] Several guidelines and instructions were provided by WHO to the general public to control the spread of COVID-19, such as maintaining social distancing, wearing masks in public, and avoiding social gatherings.[14-16] The US Centers for Disease Control and Prevention (CDC) recommended face masks for the ongoing COVID-19 pandemic.[17] Additionally, governments and the WHO suggest masks during this COVID-19 epidemic to control further spread of SARS-CoV-2. Various types of masks are recommended for COVID-19 pandemics by the WHO. Among these masks are cloth face masks, medical and surgical masks, as well as respirators (filtering facepiece respirators, full-length face shields, and self-contained breathing apparatus (SCBA).[18] Therefore, masks are often recommended as proper personal protective equipment for preventing the spread of respiratory infections. Data from experiments shows that mask micropores block dust particles or pathogens larger than the pores. For example, N95 mask materials have 8μm in diameter that effectively prevent penetration of vision.[19, 20]

The face mask is one of the most important personal protective equipment (PPE) against COVID-19 infection, which protects against infectious respiratory droplets and particles like aerosols containing coronaviruses.[21, 22] Since the period of the Spanish influenza, it has been believed that facemasks can prevent nosocomial infections.[23] The effectiveness of facemasks in household, social, and hospital settings has been evaluated by several studies.[24-26] According to studies conducted in community or healthcare settings, facemasks are often helpful against influenza-like illness, or even against severe acute respiratory syndrome.[25, 27, 28] The main advantage of face masks and other covers is that they minimize respiratory aerosol emissions during coughing and other activities.[29]

The efficiency of cloth masks varies depending on the type and structure.[30-32] The efficacy of face and respiratory masks usage to prevent transmission of respiratory infections has been shown in several studies. However, the protective effect of face and respiratory masks among healthy individuals in a community setting remains unclear. Therefore, the objective of our study was to survey the performance of face masks against respiratory infections.

In a wide range of scientific and technical disciplines, scientometric analysis is a useful method of identifying research trends and hot topics based on historical publications.[33]

The following factors are often measured in conventional scientometric analysis: keywords, publications from countries, research institutes, journals, and categories of topics. However, this method does not fully reveal a research field's development trends.[34] According to scientometric analysis, only a few studies have assessed the effectiveness of face masks in the prevention of respiratory infections.

In this research, we aimed to present a comprehensive overview of the research trends, the most important topics, and the research gaps in the performance of face masks. Synthetic scientometric analysis methodologies and indicators were utilized to investigate the research trends and hot topics of performance of face masks against respiratory infections.

Methods

Literature Search

The 'Web of Science Core Collection' is an endorsed database extensively utilized in the analysis of scientometric and citation networks. It is known for its comprehensive coverage of most academic disciplines and high data quality[25, 26] and has been selected to conduct the literature search.[27] The relevant studies on face mask efficacy were retrieved from the Web of Science (data extracted on July 15, 2023).

To examine the contents that institutions and individuals prioritize, we used VOSviewer to conduct cooperation network analysis. Simultaneously, we can also analyze potential future research directions through keyword co-occurrence network analysis. These main steps are divided into the following five steps:

Step 1: Collecting data from WOS based on the search query, exporting the research results, and saving them in a text format recognizable by VOSviewer.

Step 2: Cleaning the data by merging synonyms that express the same meaning and removing meaningless words such as conjunctions and nouns.

Step 3: Importing the research results into VOSviewer, Tableau software, and R package.

Step 4: Selecting the research content that needs to be analyzed, the period, and the pruning method in the software.

Step 5: Generating a visual representation and analyzing the graph.

The search terms used were 'face mask (Topic)' AND 'Performance (Topic)' AND 'Virus (Topic)'. All articles published before 2022 were analyzed. The data were exported to Excel with 'full record' and manually screened. Subsequently, the export content was set to 'Full record and cited references,' and the export format was set to 'Plain Text File' for all the documents retrieved.

Research Tool and Data Process

The selected articles were analyzed using VOSviewer, R (Bibliometrix package), and Tableau to visualize geographic distributions, conduct bibliometric analyses, and map research trends across countries, institutions, keywords, and journals.

The unit of analysis for "co-authorship" was "organizations" and "countries," respectively; when studying "co-occurrence," "all keywords" was the unit of analysis; for "citation" analysis, "documents," "countries," and "sources" were selected as the analysis unit column.

VOSviewer provides three types of visual maps: overlay visualization, network visualization, and density visualization. Items (such as nations, authors, documents, and journals) are represented with colored circles and labels connected by lines in the network representation. The larger the label and the circle of an object, the greater its weight (which typically relates to its frequency of occurrence). The colors signify various clusters based on the relatedness of the elements. The distance between two things on the map also reflects their association.

To verify specified items, we displayed the results of analysis as tables before receiving the maps. We summarize the number of documents, the item name, and the number of citations, ranking them based on overall link strength in the table.

Results

Based on the WOS database, 1573 documents were identified. After the further manual screening, 892 publications were excluded for publishing year 2023, other documents, non-English language, and clear topic (Figure 1). Finally, 1193 studies related to the performance of face masks were included in the scientometric analysis. We excluded all documents except for articles and reviews. The number of research articles (984) was 82.5%, and the Review (209) accounted for 17.5%.

The Annual Trend of Literature

The number of articles published annually increased from 1 in 2003 to 449 in 2021. In the years 2003 to 2019, only 81 (6.8%) articles were published, while in 2020 to 2022, 1112 (93.2%) studies related to face mask performance were published. Between 2003 and 2019, among the 81 articles published, 15 were review articles. Specifically, 15 review articles were published during this period. The first article on the face mask performance was presented in 2003 in the Hong Kong by Winghong Seto et al.[27]

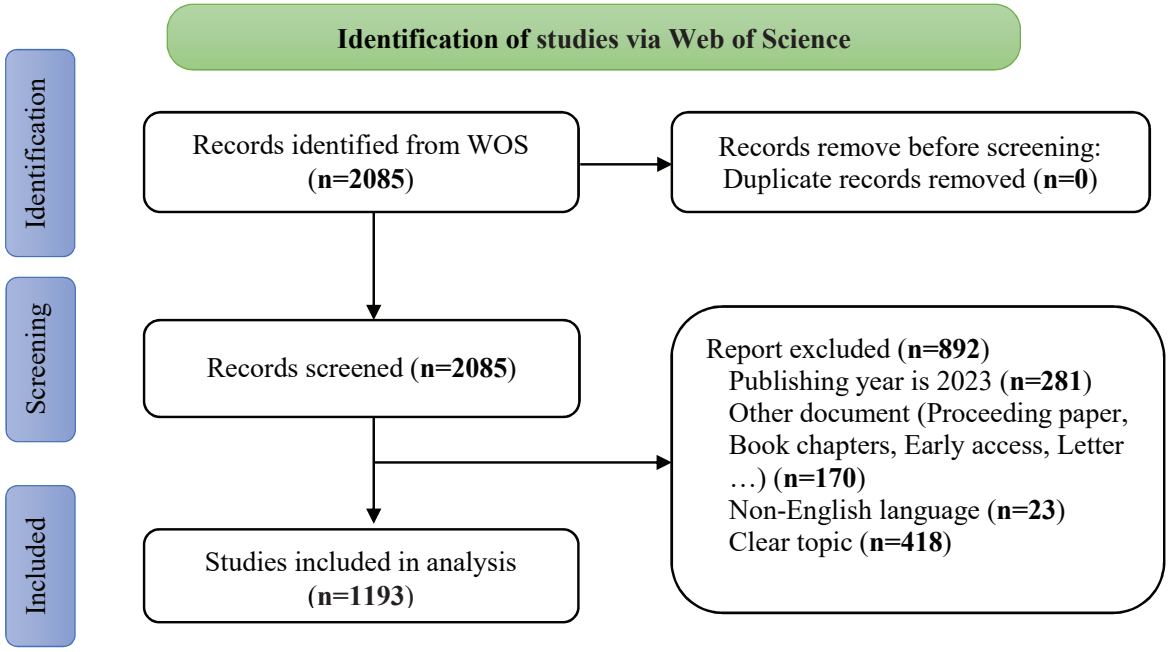

Figure 1: The flow chart of searching and selecting literature. (Designed by Authors)

The number of articles published in 2020 and 2021 has increased significantly. The outbreak of COVID-19 in late 2019 has led to a significant increase in the use of face masks in order to prevent the spread of this virus. After that, the most important researchers in the field of research were concerned about the performance and quality of the face masks. The explosive growth of studies in recent years is definitely affected by this event.

Geographical Distribution

Overall, the 1193 papers identified in the present study were published by authors from 88 countries. Almost one third (36.19%, n=257) were conducted in the USA, followed by China (n=96; 13.52%), Canada (n=58; 8.16%; Figure 2), and Australia (n=48; 6.76%). If we consider co-authorships and collaborations among countries (Figure 3), the scientific output from the USA is even more predominant; however, countries such as Germany, Brazil, Spain, and Iran have produced more publications in recent years.

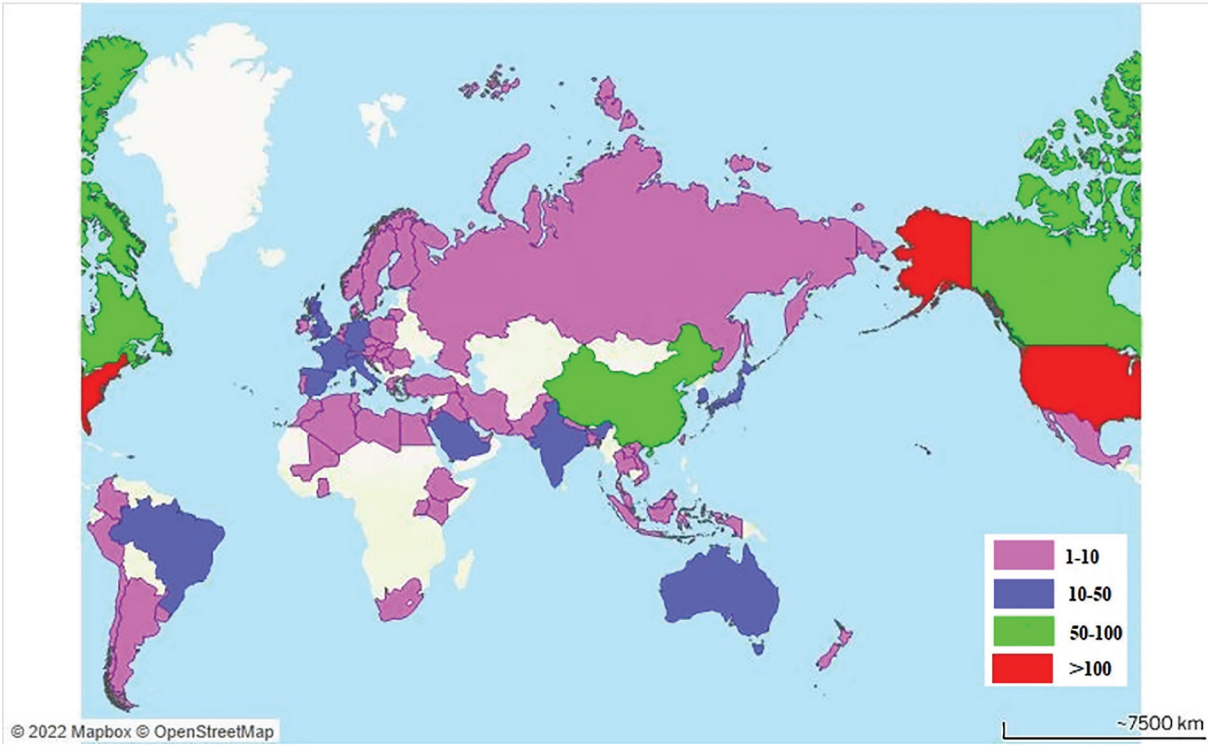

Figure 2: Geographical aspects of scientific production on the performance associated with masks. (Designed by Authors)

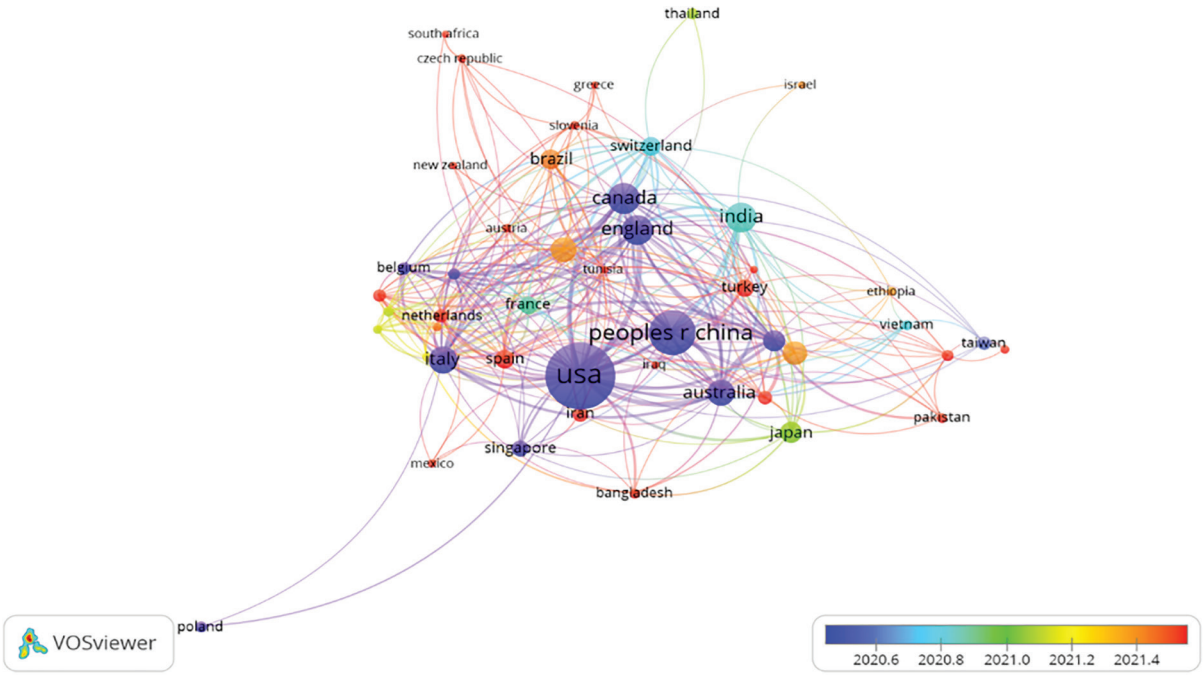

Figure 3: Clusters of scientific production per year involving performance and masks. (Designed by Authors)

Table 1: The number of documents and citations of the top 10 organizations (ranked according to their link strength)

Organization	Documents	Citations	Average Number of Citations per Document	Total link strength*
University of Florida (USA)	12	552	46	106
Stanford University (USA)	15	656	43.73	100
Harvard Medical School (USA)	11	161	14.63	88
Centers for Disease Control and Prevention (UAS)	8	389	48.62	77
King Saud University (Saudi Arabia)	12	736	61.33	74
Baylor College of Medicine (USA)	5	341	68.2	72
University of Colorado (USA)	5	323	64.6	70
Children's Hospital Colorado (USA)	3	302	100.66	66
Brigham and Women's Hospital (USA)	6	83	13.83	65
George Washington University (USA)	4	340	85	65

*The total link strength represents how strong the co-authorship links are between a specific institution and other institutions.

Table 2: The number of documents and citations of the top 10 Journals about the performance of face masks

Source	Documents	Citations	Total link strength*	Impact Factor (2022)
ACS Nano	14	1744	546	17.1
Annals of occupational hygiene	8	925	389	-
American journal of infection control	23	1059	380	1.11
Plos ONE	56	796	364	3.7
Scientific reports	36	577	291	4.6
International journal of environmental research and public health	36	350	280	4.61
Journal of occupational and environmental hygiene	18	392	233	3.35
Journal of Hospital Infection	18	418	222	6.9
Physics of fluids	19	867	204	4.98
Polymers	12	143	172	5

*The total link strength indicates the total strength of the citation links of a given journal with other journals.

Analysis of Research Institutions

There were 2185 affiliated institutions in co-authorship analysis that had been published on the performance of face masks. According to Table 1, based on the number of co-authored documents, Stanford University ranked first in total link strength. In the top ten institutions, seven were from the USA. Stanford University with 12 documents was the highest rank. Bond University (Australia), published only seven papers, but these studies had the highest citation (828), and the average number of citations per document was 118.29, which is the highest among the articles of the top 10 institutions.

Analysis of Highly Cited Journals and Documents

The topic "face mask performance" was covered in 1193 articles published in 366 different journals. Table 2 shows the 10 most important SCI journals cited in the subject, according to literature citations, where the minimum document of each journal is set to "1", and 366 journals reached the threshold. In total, 162 articles were published in the top 10 journals on the topic of "face mask performance", which accounted for 22.81% of the total articles. The journal "PloS ONE" published the most research on the topic, while the journal "ACS Nano" had the highest citations (1344) with a total link strength of 389. Figure 4 presents an overlay visualization map of highly cited SCI journals that focused on "face mask performance" studies. In this map, the minimum number of documents for each journal was "8," and 26 journals had met this threshold. "ACS Nano", "American Journal of Infection Control", "Annals of Occupational Hygiene", "Physics of Fluids" and "PloS ONE" were the highly cited journals. In contrast, most citations in recent years have come from journals such as "International Journal of Environmental Research and Public Health"," Science of the Total Environment", and "Polymers".

In Table 3, the top 10 papers are summarized based on the total citations of the 1193 papers analyzed. Fabric mask filtration performance was evaluated in the two documents with the highest total link strength. These two studies were published in April 2020 and October 2010 respectively, as the first peak of the COVID-19 and influenza epidemic, when the world community was facing a shortage of standard masks. These studies evaluate the filtration performance of common fabric masks. Therefore, these studies are the reference studies to other researchers that show the proper protective function of these masks against the viruses.[30, 35] The third highest total link strength was conducted by Viscusi et al. to develop a test system to evaluate the effectiveness of procedures for decontamination of respirators contaminated with viral droplets. Based on the findings of this study, it may be possible to develop a standard method for testing respirator decontamination.[36]

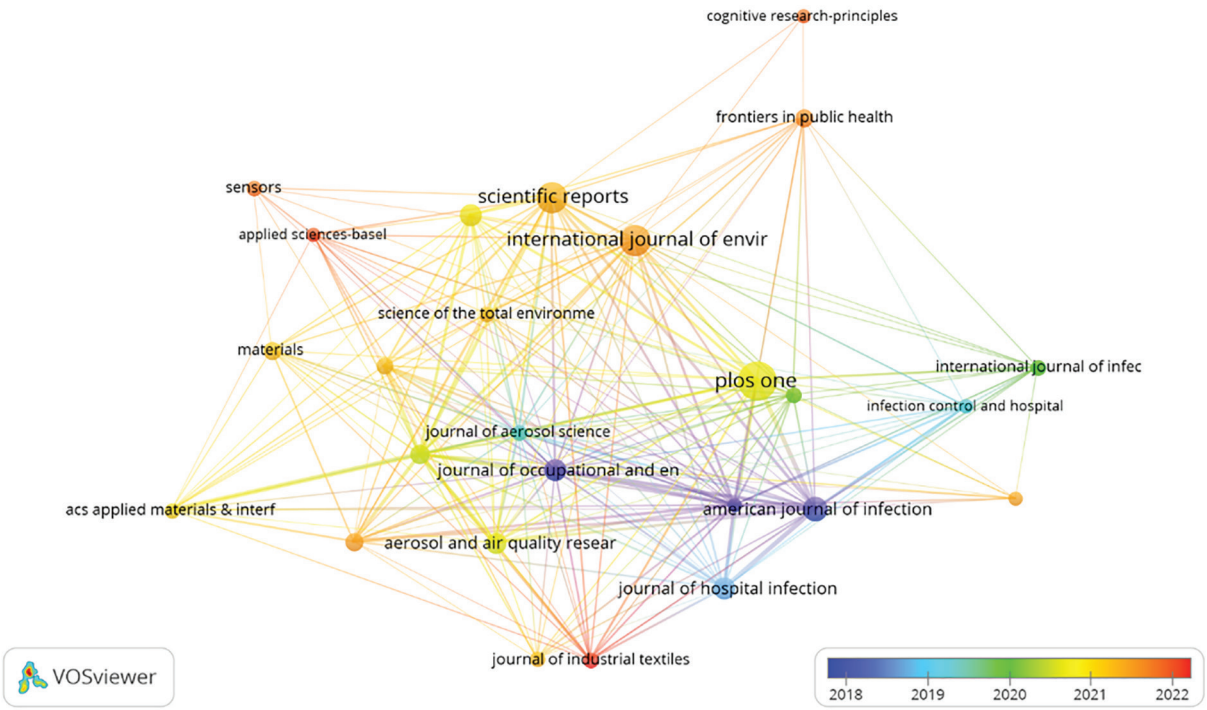

Figure 4: Distribution of "Face Masks Performance" literature in journals based on citation years. (Designed by Authors)

Table 3: Summary of the titles and citations of the top 10 documents

Authors	Title	Citations	Total link strength*
Konda et al. (2020)[30]	Aerosol Filtration Efficiency of Common Fabrics Used in Respiratory Cloth Masks	536	184
Rengasamy et al. (2010a)[35]	Simple Respiratory Protection-Evaluation of the Filtration Performance of Cloth Masks and Common Fabric Materials Against 20-1000 nm Size Particles	221	112
Liao et al. (2020)[37]	Can N95 Respirators Be Reused after Disinfection? How Many Times?	264	109
Viscusi et al. (2009)[38]	Evaluation of Five Decontamination Methods for Filtering Facepiece Respirators	248	101
Eikenberry et al. (2020)[39]	To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic	501	88
Balazy et al. (2006)[40]	Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks?	250	84
Chua et al. (2020)[41]	Face masks in the new COVID-19 normal: materials, testing, and perspectives	270	81
Tcharkhtchi et al. (2020)[42]	An overview of filtration efficiency through the masks: Mechanisms of the aerosol's penetration	163	77
Zhao et al. (2020a)[43]	Household Materials Selection for Homemade Cloth Face Coverings and Their Filtration Efficiency Enhancement with Triboelectric Charging	146	74
Mills et al. (2018)[44]	Ultraviolet germicidal irradiation of influenza-contaminated N95 filtering facepiece respirators	166	72

* The total link strength indicates the total strength of the citation links of a given document with other documents.

Research on Co-Occurring Keywords

VOSviewer software identified 3638 keywords through co-occurring analysis. By setting "15" as the minimum number of co-occurrences of keywords, the threshold of 83 was met. The time trend of research keywords in the performance of face masks is shown in Figure 5. Before the outbreak of COVID-19, researchers were primarily focused on terms such as "Transmission," "Infection," and "Virus" when studying the effectiveness and performance of masks. This focus is evident from co-occurrence keywords during that period, including topics like the filtration and efficiency of surgical masks or N95 respirators, seasonal epidemics, and pathogen infections. However, with the outbreak of COVID-19 in the world, studies were more focused on fit test and filtration of surgical, medical, and N95 masks, indicating that researchers are exploring the effectiveness of masks to ensure the effectiveness of face masks. Table 4 shows the top ten co-occurrence keywords according to the total link strengths. Besides the search terms ("face mask" and "performance"), the most frequently searched keywords were "COVID-19", "Performance", "Transmission", and "N95 Respirators".

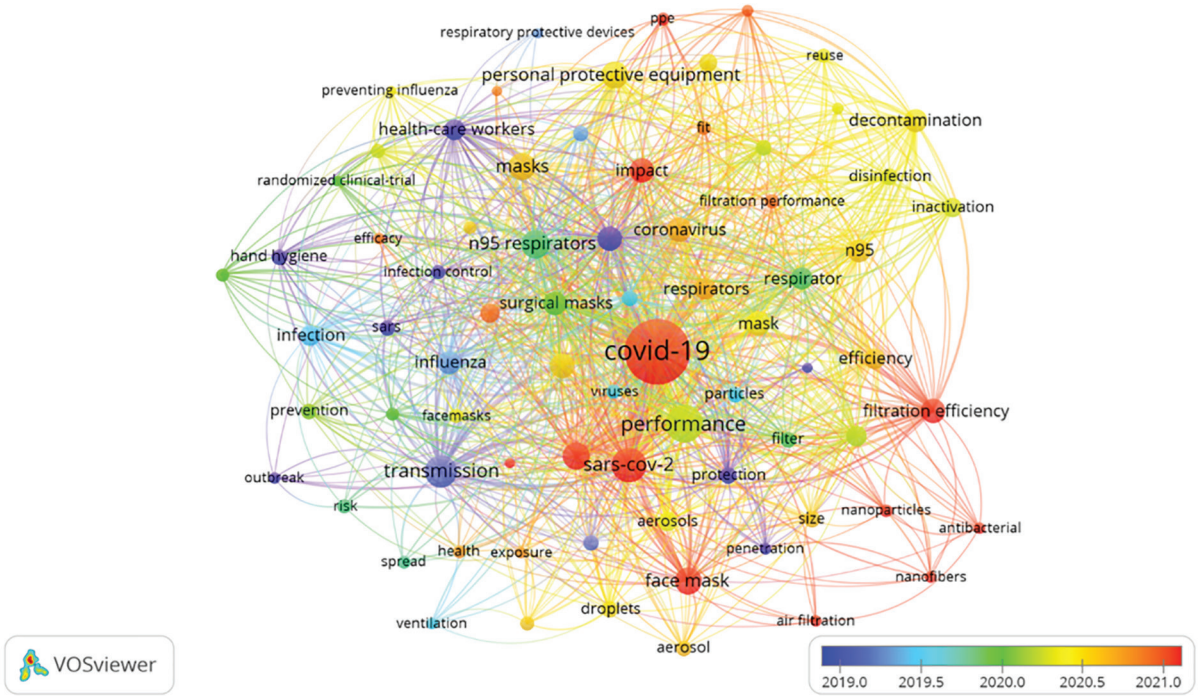

Figure 5: Overlay visualization of co-occurrence keywords for "Face Masks Performance". (Designed by Authors)

Table 4: The top 10 co-occurrence keywords for "face masks performance"

Keyword	Occurrences	Total link strength*
Covid-19	536	1526
Performance	175	873
Transmission	135	607
N95 Respirators	98	575
Influenza	71	406
Surgical Mask	70	404
Virus	74	401
Masks	92	390
Filtration efficiency	79	364
Personal protective equipment	94	363

*The total link strength indicates the total strength of the co-occurrence links of a given keyword with other keywords.

This showed that the studies of the performance of face masks, in the last two years, had attracted a considerable amount of research. Using face masks as one of the personal protection equipment and paying attention to their performance play an effective role in preventing the transmission of infectious diseases.

Figure 6 shows the co-occurrence keywords cluster density map. Four major keywords clusters were identified in the VOSViewer, based on their correlation, as follows: (1) filtration, protection and efficiency of face masks in surgical mask, N95 respirator, which are derived from the keyword, such as performance, efficiency, filtration, protection, surgical mask, N95 respirator, etc.; (2) using personal protective equipment such as masks to protect the person against pandemic of corona virus, such as COVID-19, pandemic, disinfection, personal protective equipment, masks, etc.; (3) the importance of hand hygiene and medical masks against infectious agents in healthcare workers from the keywords, such as healthcare workers, medical masks, transmission and hand hygiene, etc.; and (4) protective effect of respiratory masks against aerosols, such as prevention, aerosols and face masks, etc.

Authors and Most Cited Countries in Publications on ARI

In Figure 7A, the timeline is used to illustrate the production of these top authors over the years. The production of an author is defined by the number of publications and the total number of global citations of their documents. Grinshpun SA., Li Y., and Wang Y. have published the highest number of research papers in this field, with 11 papers each (since 2006, 2005, and 2010, respectively), followed by Maclntyre CR., who has 10 publications on ARIs research; as shown in Figure 7B, the two most influential researchers were Cui Y. and Macintyre CR. with the total citations per year of 66 and 63, respectively. Based on their local citations, this paper lists the top 10 authors in Figure 7B.

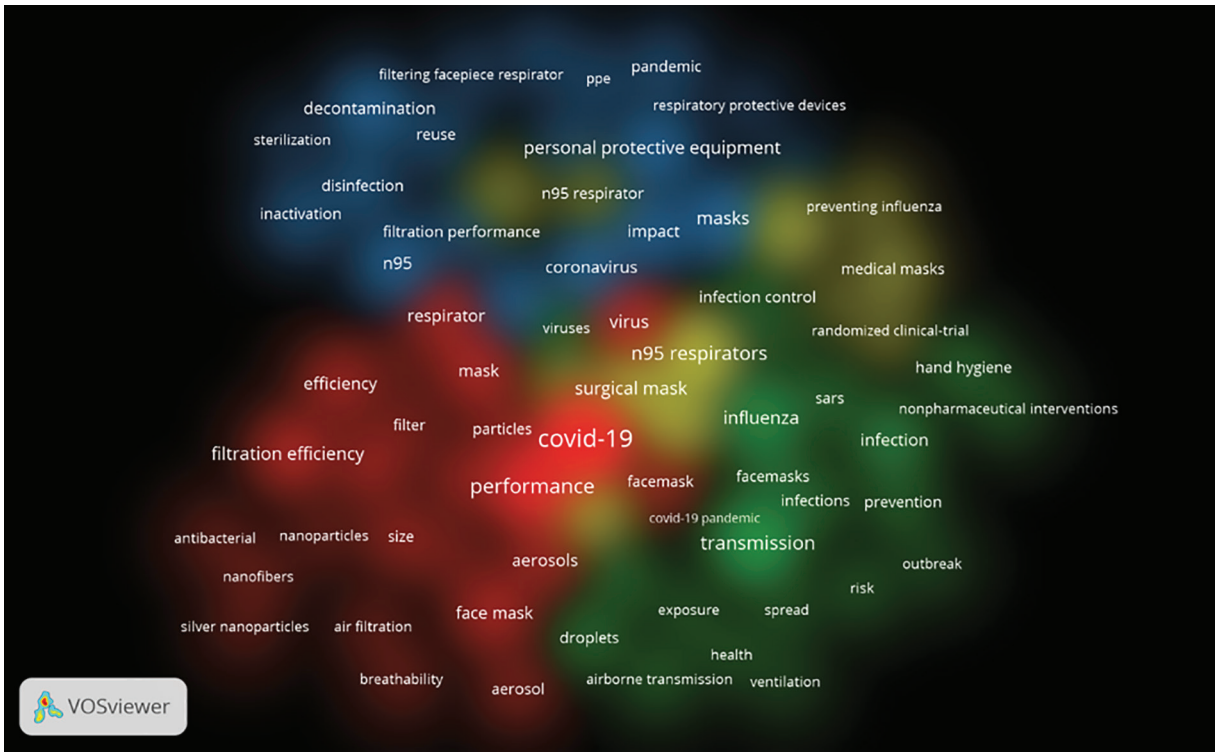

Figure 6: Cluster density of "Face Masks Performance" co-occurrence keywords. (Designed by Authors)

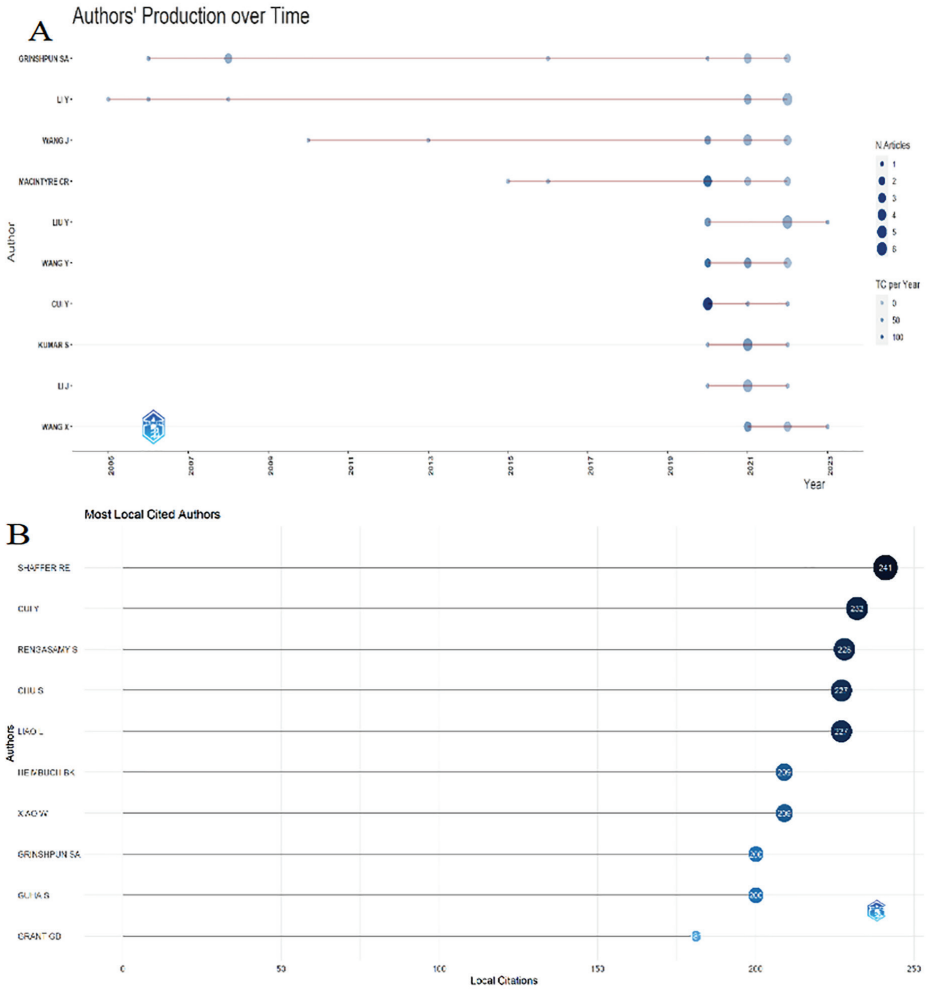

Figure 7: A) Top authors' production over time B) Most local cited authors. (Designed by Authors)

The top 2 most locally cited authors were as follows: Shaffer RE (241 local citations) and Cui Y (232 local citations).

Counting the number of articles with authors from different countries and articles with authors from the same country was used to analyze international collaboration. Consequently, articles were classified into two categories: single country publications (SCPs) and multiple country publications (MCPs). A SCP publication represents an intra-country collaboration between all authors who reside in the same country. International collaboration was represented in MCP by authors from different countries. SCPs and MCPs for the top 20 countries are presented in Figure 8. USA, China, and Australia ranked first, second, and third, based on the percentage of MCPs (of the total number of publications per country). There is a higher level of collaboration between authors from these countries and authors from other countries. For the 20 countries listed in Figure 8, the number of single-country publications was higher than multiple-country publications, except for Saudi Arabia. The USA, China, and India ranked first and second, respectively, in terms of SCP percentage.

Discussion

As with other epidemics over the past century, the COVID-19 pandemic has accounted for the transmission of acellular and cellular microorganisms in respiratory aerosols. Patients, healthcare professionals, and the public had used surgical face masks, non-surgical face masks, and respirators as a basic form of personal protective equipment (PPE) to reduce the transmission of disease. Consequently, the manufacturing industry has experienced an indiscriminate increase in demand.[45]

This research analyzed 1,193 research articles on the performance and protective effects of face masks as a control method against infectious diseases using scientometric analysis. In summary, the following recommendations and conclusions are presented. Over the last three years, research on the performance of face masks has grown significantly, and the number of yearly publications is continually increasing. This indicates that the effectiveness of face masks has received increasing attention, and different methods for their performance and reuse are currently under investigation. With a significant number of publications and citations, the United States and China are at the forefront of this research. Prominent institutions such as Stanford University and Harvard Medical School, both in the USA, have made significant contributions to this research. The journal 'ACS Nano' has published numerous articles, reflecting a high amount of interest in face masks. Researchers may find it a valuable source for collecting and sharing publications in this field. In addition to the search terms 'face mask,' 'performance,' and 'infection,' 'COVID-19,' 'Performance,' 'Transmission,' and 'N95 Respirators' were four main keywords, indicating hotspots in research. These trends suggest potential knowledge gaps regarding the effectiveness of face masks, so future research should focus on challenges such as uncertain efficacy and fitness. Based on the findings of this study, it was concluded that wearing face masks can present various difficulties and potential issues, including uncertainty regarding their effectiveness, proper fit, and availability. There is less external protection provided by surgical and cloth masks due to their weaker barrier capabilities. Due to the way the mask fits, when someone releases pressurized droplets or aerosolized particles, like when coughing or sneezing, these particles will escape from the sides more than the front. There are open sides on cloth masks so that the air can circulate

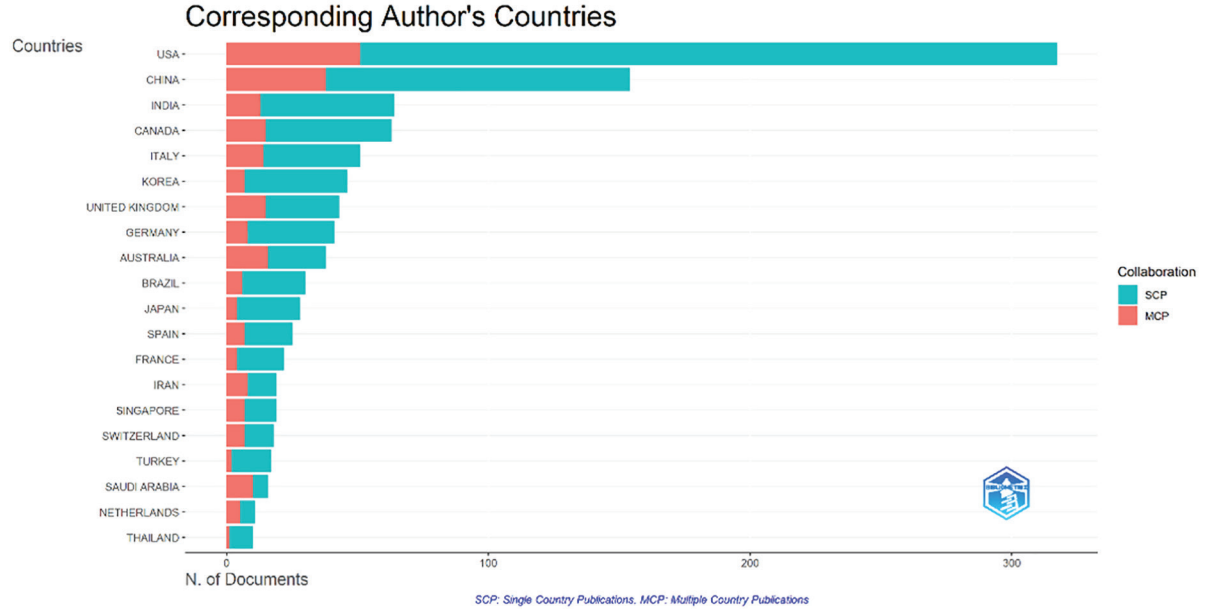

Figure 8: Corresponding author's countries (Designed by Authors)

through them.[46] It is imperative that the mask forms an airtight seal with the wearer to achieve a successful outcome. Additionally, various studies emphasize key arguments in favor of wearing face masks, including the potential for a false sense of security (protecting only nearby people), proper usage, and communication errors. Researchers around the world have highlighted several issues related to the use of face masks, such as their long-term usage, reuse, and decontamination. N95 masks, for example, can typically be worn for up to eight hours due to the exposure time.[47] It is possible to reuse a face mask after proper disinfection. Wearing a face mask over a respirator can make cleaning and disposal easier. However, there is a supply constraint when compared to global demand.[48] It is crucial to provide face masks on a large scale to combat infectious diseases effectively. Additionally, the availability of suitable masks remains a challenge in developing countries. Eventually, the country will transition to local production due to a shortage of commercially available disposable face masks.[49] However, some unauthorized industries may produce masks that do not meet the required quality standards to meet the immediate demand.

Conclusion

Masks may be more effective if they are worn correctly and consistently, but this is still a big challenge. Since the included studies all have markedly different methods and there is a high risk of bias in a few of them, further well-designed and controlled studies using standardized methodologies are greatly recommended. The government and public health agencies need to endorse rational recommendations on appropriate mask use in conjunction with other preventive measures, including hand hygiene. According to the World Health Organization, people with respiratory symptoms or those caring for someone with symptoms should wear face masks. Also, vulnerable populations, including elderly people and those with medical conditions, should wear masks. If supplies permit, face masks could be used universally. Urgent research on the duration of protection offered by face masks, measures to prolong the life of disposable masks, and the invention of reusable masks should be encouraged in parallel.

Authors' Contribution

M. J: Study design and supervision, screening and eligibility assessment, quality assessment of included articles, review and editing of the manuscript. R. P and M. E: Study design, systematic search in databases, screening and eligibility assessment, writing the manuscript, and quality assessment of included articles. Z. D: screening and eligibility assessment, review and editing of the manuscript. M. A: Review and editing of the manuscript.

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References

1 Van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med. 2020;382(16):1564-7. doi: 10.1056/NEJMc2004973. PMID: 32182409; PMCID: PMC7121658.

2 Tellier R, Li Y, Cowling BJ, Tang JW. Recognition of aerosol transmission of infectious agents: a commentary. BMC Infect Dis. 2019;19(1):1-9. doi: 10.1186/s12879-019-3707-y. PMID: 30704406; PMCID: PMC6357359.

3 Nissen K, Krambrich J, Akaberi D, Hoffman T, Ling J, Lundkvist Å, et al. Long-distance airborne dispersal of SARS-CoV-2 in COVID-19 wards. Sci Rep. 2020;10(1):1-9. doi: 10.1038/s41598-020-76442-2. PMID: 33177563; PMCID: PMC7659316.

4 Bhardwaj J, Hong S, Jang J, Han C-H, Lee J, Jang J. Recent advancements in the measurement of pathogenic airborne viruses. J Hazard Mater. 2021;420:126574. doi: 10.1016/j.jhazmat.2021.126574. PMID: 34252679; PMCID: PMC8256664.

5 Nair H, Brooks WA, Katz M, Roca A, Berkley JA, Madhi SA, et al. Global burden of respiratory infections due to seasonal influenza in young children: a systematic review and meta-analysis. Lancet. 2011;378(9807):1917-30. doi: 10.1016/S0140-6736(11)61051-9. PMID: 22078723.

6 Kalantary S, Pourbabaki R, Jahani A, Sadeghi Yarandi M, Samiei S, Jahani R. Development of a decision support system tool to predict the pulmonary function using artificial neural network approach. Concurr Comput Pract Exp. 2021;33(16):e6258. doi: 10.1002/cpe.6258.

7 Organization WH. The World health report: 2004: changing history: World Health Organization; 2004.

8 Berman S. Epidemiology of acute respiratory infections in children of developing countries. Reviews of infectious diseases. Clin Infect Dis. 1991;13(Supplement_6):S454-S62. doi: 10.1093/clinids/13.Supplement_6.S454.

9 Nichols WG, Peck Campbell AJ, Boeckh M. Respiratory viruses other than influenza virus:

impact and therapeutic advances. Clin Microbiol Rev. 2008;21(2):274-90. doi: 10.1128/cmr.00045-07. PMID: 18400797; PMCID: PMC2292575.

10 Shiu EY, Leung NH, Cowling BJ. Controversy around airborne versus droplet transmission of respiratory viruses: implication for infection prevention. Curr Opin Infect Dis. 2019;32(4):372-9. doi: 10.1097/QCO.0000000000000563. PMID: 31259864.

11 Shope RE, Oaks SC. Emerging infections: Microbial threats to health in the United States. Washington (DC): National Academies Press (US). 1992. doi: 10.17226/2008. PMID: 25121245.

12 Killingley B, Nguyen-Van-Tam J. Routes of influenza transmission. Influenza Other Respir Viruses. 2013;7:42-51. doi: 10.1111/irv.12080. PMID: 24034483; PMCID: PMC5909391.

13 Cheng VC-C, Wong S-C, Chuang VW-M, So SY-C, Chen JH-K, Sridhar S, et al. The role of community-wide wearing of face mask for control of coronavirus disease 2019 (COVID-19) epidemic due to SARS-CoV-2. J Infect. 2020;81(1):107-14. doi: 10.1016/j.jinf.2020.04.024. PMID: 32335167; PMCID: PMC7177146.

14 Olliaro P, Torreele E, Vaillant M. COVID-19 vaccine efficacy and effectiveness—the elephant (not) in the room. Lancet Microbe. 2021;2(7):e279-e80. doi: 10.1016/S2666-5247(21)00069-0. PMID: 33899038; PMCID: PMC8057721.

15 Kaur SP, Gupta V. COVID-19 Vaccine: A comprehensive status report. Virus Res. 2020;288:198114. doi: 10.1016/j.virusres.2020.198114. PMID: 32800805 PMCID: PMC7423510.

16 Tajvar A, Aghamolaei T, Mohseni S, Fakherpour A, Damiri Z, Jahangiri M, Ghaffari H. Knowledge, performance, and attitude towards mask use to prevent and control COVID-19 outbreak among a group of Iranian people: A cross-sectional study. Shiraz E Med J 2021;22(11). doi: 10.5812/semj.111491.

17 Abd-Elsayed A, Karri J. Utility of substandard face mask options for health care workers during the COVID-19 pandemic. Anesth Analg. 2020;131(1):4-6. doi: 10.1213/ANE.0000000000004841. PMID: 32243300; PMCID: PMC7172555.

18 Setti L, Passarini F, De Gennaro G, Barbieri P, Perrone MG, Borelli M, et al. Airborne transmission route of COVID-19: Why 2 meters/6 feet of inter-personal distance could not be enough. Int J Environ Res Public Health. 2020;17(8):2932. doi: 10.3390/ijerph17082932. PMID: 32340347, PMCID: PMC7215485.

19 Barasheed O, Almasri N, Badahdah A-M, Heron L, Taylor J, McPhee K, et al. Pilot randomised controlled trial to test effectiveness of facemasks in preventing influenza-like illness transmission among Australian Hajj pilgrims in 2011. Infect Disord Drug Targets. 2014;14(2):110-6. doi: 10.2174/1871526514666141021112855. PMID: 25336079.

20 Lee S-A, Grinshpun SA, Reponen T. Respiratory performance offered by N95 respirators and surgical masks: human subject evaluation with NaCl aerosol representing bacterial and viral particle size range. Ann Occup Hyg. 2008;52(3):177-85. doi: 10.1093/annhyg/men005. PMID: 18326870; PMCID: PMC7539566.

21 Ho K-F, Lin L-Y, Weng S-P, Chuang K-J. 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. PMID: 32480154; PMCID: PMC7233209.

22 Kumar A, Sangeetha D, Yuvaraj R, Menaka M, Subramanian V, Venkatraman B. Effect of gamma sterilization on filtering efficiency of various respiratory facemasks. medRxiv. 2020;6(4):2020-06. doi: 10.1101/2020.06.04.20121830.

23 Hobday RA, Cason JW. The open-air treatment of pandemic influenza. Am J Public Health. 2009;99(S2):S236-S42. doi: 10.2105/AJPH.2008.134627. PMID: 19461112; PMCID: PMC4504358.

24 bin-Reza F, Lopez Chavarrias V, Nicoll A, Chamberland ME. The use of masks and respirators to prevent transmission of influenza: a systematic review of the scientific evidence. Influenza Other Respir Viruses. 2012;6(4):257-67. doi: 10.1111/j.1750-2659.2011.00307.x. PMID: 22188875; PMCID: PMC5779801.

25 Rashid H, Booy R, Heron L, Memish ZA, Nguyen-Van-Tam J, Barasheed O, Haworth E. Unmasking masks in Makkah: preventing influenza at Hajj. Clin Infect Dis. 2012;54(1):151-3. doi: 10.1093/cid/cir826. PMID: 22187415.

26 Sim SW, Moey KSP, Tan NC. The use of facemasks to prevent respiratory infection: a literature review in the context of the Health Belief Model. Singapore Med J. 2014;55(3):160. doi: 10.11622/smedj.2014037. PMID: 24664384; PMCID: PMC4293989.

27 Seto W, Tsang D, Yung R, Ching T, Ng T, Ho M, et al. Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS). lancet. 2003;361(9368):1519-20. doi: 10.1016/s0140-6736(03)13168-6. PMID: 12737864 PMCID: PMC7112437.

28 Jefferson T, Foxlee R, Del Mar C, Dooley L, Ferroni E, Hewak B, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review. BMJ. 2009;336(7635):77-80. doi: 10.1136/bmj.b3675. PMID: 19773323; PMCID: PMC2749164.

29 Lindsley WG, Blachere FM, Law BF, Beezhold DH, Noti JD. Efficacy of face masks, neck gaiters and face shields for reducing the expulsion of simulated cough-generated aerosols. Aerosol Sci Technol. 2021;55(4):449-57. doi: 10.1080/02786826.2020.1862409. PMID: 35924077; PMCID: PMC9345365.

30 Konda A, Prakash A, Moss GA, Schmoldt M, Grant GD, Guha S. Aerosol filtration efficiency of common fabrics used in respiratory cloth masks. ACS nano. 2020;14(5):6339-47. doi: 10.1021/acsnano.0c03252. PMID: 32329337.

31 Teesing G, van Straten B, de Man P, Horeman-Franse T. Is there an adequate alternative to commercially manufactured face masks? A comparison of various materials and forms. J Hosp Infect. 2020;106(2):246-53. doi: 10.1016/j.jhin.2020.07.024. PMID: 32763333; PMCID: PMC7403160.

32 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):eabd3083. doi: 10.1126/sciadv.abd3083. PMID: 32917603; PMCID: PMC7467698.

33 Li N, Han R, Lu X. Bibliometric analysis of research trends on solid waste reuse and recycling during 1992–2016. Resour Conserv Recycl. 2018;130:109-17. doi: 10.1016/j.resconrec.2017.11.008.

34 Colman AM, Dhillon D, Coulthard B. A bibliometric evaluation of the research performance of British university politics departments: Publications in leading journals. Scientometrics. 1995;32(1):49-66. doi: 10.1007/BF02020188.

35 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):789-98. doi: 10.1093/annhyg/meq044. PMID: 20584862, PMCID: PMC7314261.

36 Vo E, Rengasamy S, Shaffer R. Development of a test system to evaluate procedures for decontamination of respirators containing viral droplets. Appl Environ Microbiol. 2009;75(23):7303-9. doi: 10.1128/AEM.00799-09. PMID: 19801477 PMCID: PMC2786399.

37 Liao L, Xiao W, Zhao M, Yu X, Wang H, Wang Q, et al. Can N95 respirators be reused after disinfection? How many times? ACS nano. 2020;14(5):6348-56. doi: 10.1021/acsnano.0c03597. PMID: 32368894.

38 Viscusi DJ, Bergman MS, Eimer BC, Shaffer RE. Evaluation of five decontamination methods for filtering facepiece respirators. Ann Occup Hyg. 2009;53(8):815-27. doi: 10.1093/annhyg/mep070. PMID: 19805391; PMCID: PMC2781738.

39 Eikenberry SE, Mancuso M, Iboi E, Phan T, Eikenberry K, Kuang Y, et al. To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. Infect Dis Model. 2020;5:293-308. doi: 10.1016/j.idm.2020.04.001. PMID: 32355904; PMCID: PMC7186508.

40 Bałazy 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):51-7. doi: 10.1016/j.ajic.2005.08.018. PMID: 16490606.

41 Chua MH, Cheng W, Goh SS, Kong J, Li B, Lim JY, et al. Face masks in the new COVID-19 normal: materials, testing, and perspectives. Research. 2020;2020. doi: 10.34133/2020/7286735. PMID: 32832908; PMCID: PMC7429109.

42 Tcharkhtchi A, Abbasnezhad N, Seydani MZ, Zirak N, Farzaneh S, Shirinbayan M. An overview of filtration efficiency through the masks: Mechanisms of the aerosols penetration. Bioact Mater. 2021;6(1):106-22. doi: 10.1016/j.bioactmat.2020.08.002. PMID: 32817918; PMCID: PMC7426537.

43 Zhao M, Liao L, Xiao W, Yu X, Wang H, Wang Q, et al. Household materials selection for homemade cloth face coverings and their filtration efficiency enhancement with triboelectric charging. Nano Lett. 2020;20(7):5544-52. doi: 10.1021/acs.nanolett.0c02211. PMID: 32484683; PMCID: PMC10760933.

44 Mills D, Harnish DA, Lawrence C, Sandoval-Powers M, Heimbuch BK. Ultraviolet germicidal irradiation of influenza-contaminated N95 filtering facepiece respirators. Am J Infect Control. 2018;46(7):e49-e55. doi: 10.1016/j.ajic.2018.02.018. PMID: 29678452; PMCID: PMC7115285.

45 Babaahmadi V, Amid H, Naeimirad M, Ramakrishna S. Biodegradable and multifunctional surgical face masks: A brief review on demands during COVID-19 pandemic, recent developments, and future perspectives. Sci Total Environ. 2021;798:149233. doi: 10.1016/j.scitotenv.2021.149233. PMID: 34329934; PMCID: PMC8302485.

46 Ogbuoji EA, Zaky AM, Escobar IC. Advanced research and development of face masks and respirators pre and post the coronavirus disease 2019 (Covid-19) pandemic: a critical review. Polymers. 2021;13(12):1998. doi: 10.3390/polym13121998. PMID: 34207184; PMCID: PMC8235328.

47 Tirupathi R, Bharathidasan K, Palabindala V, Salim SA, Al-Tawfiq JA. Comprehensive review of mask utility and challenges during the COVID-19 pandemic. Infez Med. 2020;28(suppl 1):57-63. PMID: 32532940.

48 Adanur S, Jayswal A. Filtration mechanisms and manufacturing methods of face masks: An overview. J Ind Text. 2022;51(3_suppl):3683S-717S. doi: 10.1177/1528083720980169.

49 Tucho GT, Kumsa DM. Universal use of face masks and related challenges during COVID-19 in developing countries. Risk Manag Healthc Policy. 2021;14:511. doi: 10.2147/RMHP.S298687. PMID: 33603517; PMCID: PMC7882453.