Review Article

Effectiveness of Using Face Masks and Personal Protective Equipment to Reducing the Spread of COVID-19: A Systematic Review and Meta-Analysis of Case–Control Studies

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Abstract

Recently published researches show that 59% of all transmission came from asymptomatic transmission and at the time of diagnosis health-care workers (HCWs) tend to present without respiratory symptoms. These evidences have raised questions on whether an essential policy for use of personal protective equipment (PPE) is the best approach in HCW and other people or not. Therefore, this study conducted to investigate the effectiveness of using face masks and PPE in reducing the spread of COVID-19 in health-care and non-health-care settings. This systematic review and meta-analysis study was prepared according to the preferred reporting items for systematic review and meta-analysis statement and guided by meta-analysis of observational studies recommendations. Searches in databases were conducted from December 2019 to July 2021. Random-effects meta-analysis was performed to investigate the effect of using face masks and PPE on spread of COVID-19. Heterogeneity among studies was assessed using Cochran's Q test and the I^2 metrics. In total, 9920 individuals from 14 studies were included in this study. In all settings, application of PPE or any type of masks was associated with reduction in risk of COVID-19 (odds ratio [OR] = 0.44; 95% confidence interval [CI]: [0.29, 0.65]; I^2 = 85.21%). In the HCW subgroup, the protective effect had a combined OR of 0.33 (95% CI: (0.15,0.73), I^2 = 82.61%). Six studies were found protective effects of wearing mask in non-HCWs (OR = 0.58, 95% CI: (0.31, 1.06), I^2 = 85.63%). Results suggest that there is association between face mask/PPE use and reduction of COVID-19.

Keywords: Case–control study, COVID-19, face mask, meta-analysis, personal protective equipment, systematic review

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Introduction

In December 2019, a new beta coronavirus (severe acute respiratory syndrome coronavirus (SARS-CoV-2) caused an acute respiratory syndrome (COVID-19) in Wuhan, Hubei province, China.[1,2] COVID-19 is a respiratory infectious disease which is transmitted through droplets during unprotected close contact (within 1 meter) with someone who has respiratory symptoms.[3,4] SARS-CoV-2 seems to have considerable transmissibility than previous coronaviruses that caused SARS and the Middle East respiratory syndrome (MERS).[5] After 4291 deaths and 118,000 infected patients in 114 countries, on March 11, 2020, the World Health Organization[4] classified this outbreak as a pandemic.[6,7] Today, the outbreak of COVID-19 becomes a global health crisis and imposes high burden on human societies.[8] Especially, health-care systems in all over the world encountered new challenges due to the pandemic.[9]

World Health Organization (WHO) health officials recommended people to follow several preventive behaviors in the individual level such as staying at home, keeping distance from others, avoid going to public and crowded places, reducing contact, wearing mask, and washing and

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sanitizing hands.[10,11] Since, specific antiviral treatment and effective vaccine is not yet explored, adherence to preventive behaviors is the first choice to reduce the spread of disease.[12] There is an urgent need to identifying the most at-risk groups in conjunction with effective preventive behavior for them. This may help to improve strategies to better control this new situation. Frontline health-care workers are at a notable occupational risk attributed to exposure to an infected patients, either symptomatic or asymptomatic.[13] Although there is a universal agreement that personal protective equipment (PPE), especially face masks provide the best possible care for health-care worker (HCW) and others, previous studies and recommendations regarding the use of PPE as a protective behavior against COVID-19 have been controversial.[14,15]

Recently published researches show that 59% of all transmission came from asymptomatic transmission and at the time of diagnosis HCWs tend to present without respiratory symptoms.[16,17] These evidences has raised questions on whether an essential policy for use of PPE is the best approach in HCW and other people or not. Previous systematic reviews on the effectiveness of using PPE and face mask mainly focused on HCWs and household setting including studies of other infectious diseases such as H1N1 influenza, SARS and MERS with most of them with low quality.[18-21] When an outbreak like COVID-19 occurs, answers in medical field must be obtain quickly. Case–control studies are easy, inexpensive, and quick in comparison to other study designs. According to these advantages, case–control studies are especially suitable for investigating outbreaks.[22] Therefore, we designed and conducted a systematic review and meta-analysis of the scientific literature with case–control studies on the effectiveness of using face masks and PPE in reducing the spread of COVID-19 in health-care and non-health-care settings.

Materials and Methods

This systematic review and meta-analysis study was prepared according to the preferred reporting items for systematic review and meta-analysis statement and guided by meta-analysis of observational studies recommendations.[23,24]

Eligibility criteria

Studies meeting the following criteria were selected for systematic review and consequent meta-analysis: (1) case–control studies, (2) concerning the relationship between using PPE or mask and preventing of COVID-19, and (3) studies with laboratory evidence for diagnosis of SARS-CoV-2, 4) given complete data of controls and cases for calculating the effect size (i.e., odds ratio [OR]) with 95% confidence interval (CI). Therefore, the exclusion criteria were as follows: (1) insufficient data to calculating the effect size, (3) review article, letter to editor, conferences/meetings abstracts, case series, cross-sectional, clinical trial, short survey, editorials, case report, news articles, books, and studies involving not human subjects were excluded.

Information sources

The systematic search strategy of English-language literature was developed in consultation with a medical librarian and performed in line with recommendations in the Cochrane Rapid Review guide.[25] Searches were conducted electronically in multiple databases including MEDLINE via PubMed, Web of Science, EMBASE, Scopus, CINAHL, ProQuest, and Cochrane Database of Systematic Reviews up to July 2021. As suggested in the Cochrane guideline, Google Scholar database was searched as the gray literature source. Meeting abstracts, theses, and conference papers will be searched in ProQuest, ISI, and Scopus databases. Systems of thesaurus, containing MeSH, Emtree, and free text method, as well as relevant papers and abstracts were applied to find the synonyms of search components. The search process was conducted using the following keywords: "mask," "face mask," "respirators," "N95," "*mask," "Personal Protective Equipment," "severe acute respiratory syndrome coronavirus 2," "2019-nCoV," "COVID-19," "n-SARS-COV-2019," and "SARS-CoV-2" and "transmission" combined with AND/OR. Case reports, editorials, short survey, case series, all kind of reviews, news articles, conferences/meetings abstracts, letters to editor, books, and studies involving not human subjects were excluded.

Study selection

EndNote was used for uploading the search results. Unique citations were kept and screened. Screening of titles and abstracts was done for identification of probably eligible studies. Afterward, eligible studies underwent full-text review for study inclusion using fixed exclusion and inclusion criteria. Literature screening and assessment of eligibility was performed independently by two reviewers (MHM, EM) and reasons for exclusion were documented at each stage.

Data extraction

Data extraction was done separately by two authors (ASM, EM) using a piloted data extraction form. Opinion from senior authors was invited to resolve the conflicts. The following information was extracted from the included studies by two reviewers (ASM, EM), separately: authors' name, year of publication, country, continent, setting (HCW or non-HCW), type of protective equipment (PPE or Mask), sample size in case and control groups, number of persons who had use protective equipment in each groups (cases and controls), and any comment.

Risk of bias assessment

The risk of bias assessment as well as methodological quality of preliminary studies was conducted independently by two reviewers (MHM, EM), according to Newcastle–Ottawa Scale (NOS). NOS scale has eight segments covering parts of selection, comparability, and outcome.[26] The total scores of 0-6 were considered high risk of bias for observational studies.

Statistical analysis

All statistical analyses and meta-analyses were performed using Stata (version 16.0; Stata Corp, College Station, TX) software.

$P < 0.05$ was considered statistically significant. The association of PPE or mask use with COVID-19 was assessed with ORs with a 95% CI. Heterogeneity among studies was assessed using Cochran's Q test and the I^2 metrics. According to the amount of heterogeneity among studies, meta-analyses were conducted using a DerSimonian and Laird random-effects model. Pooled effect estimates were obtained by calculating the OR for binary outcome (case/control) along with 95% C). Categorical variables such as type of participants (HCWs vs. non-HCWs) and continent were included in the subgroup analysis. Higgins I^2 statistic was used to qualitatively and quantitatively assess the heterogeneity between studies. Publication bias was assessed using Begg's test for small-study effects and visual inspection of funnel plots. A pooled OR was estimated using the generic inverse variance method and heterogeneity was assessed.

Results

The systematic search resulted in 5672 publications. Finally, 14 case–control studies of using PPE or face mask were included in the meta-analysis [Figure 1].[27-37]

Characteristics of included studies

In total, 9920 individuals (case: 2497 (25.17%); control: 7423 (74.83%)) were included in this study. The studies which met our inclusion criteria were conducted in Iran, China, Thailand, UK, France, Brazil, Colombia, Turkey, and India. Of these, six studies investigated non-HCW populations, and other studies focused on health-care workers. All patients in case groups had laboratory evidence. Tables 1 and 2 summarizes the characteristics of each study.

PPE or any type of masks and risk of COVID-19 in all settings

In all settings (HCWs and non-HCWs), application of PPE or any type of masks in case group compared to control group was associated with reduction in risk of Covid-19 infection [OR = 0.44; 95% CI: (0.29, 0.65); I^2 = 85.21%, random-effects DerSimonian–Laird model; Figure 2]. By analyzing geographic locations as subgroups, results showed that using PPE or face mask could reduce the risk of COVID-19: South America (OR = 0.53, 95% CI: 0.26, 1.07, I^2 = 60.08%), Asia (OR = 0.45, 95% CI: 0.76, 0.78, I^2 = 89.77%), and Europe (OR = 0.32, 95% CI: 0.14, 0.76, I^2 = 63.44%) [Figure 2]. After adjusted possible confounding variables (adjustment variables including sex, age, contact place, the shortest distance of contact, duration of contact, sharing dishes, or cigarettes and handwashing), the estimate was 0.31 [95% CI: (0.12, 0.49), I^2 = 66.8%; Figure 3] and the protection of masks was still statistically significant.

Using masks and risk of COVID-19 in all settings

Ten studies with 8115 participants reported the effectiveness of wearing a mask. In general, masks can effectively prevent the spread of SARS-CoV-2. Wearing a mask is significantly reduced the risk of COVID-19 in all settings (HCW and non-HCW), with an OR of 0.46, [95% CI: (0.27, 0.76),

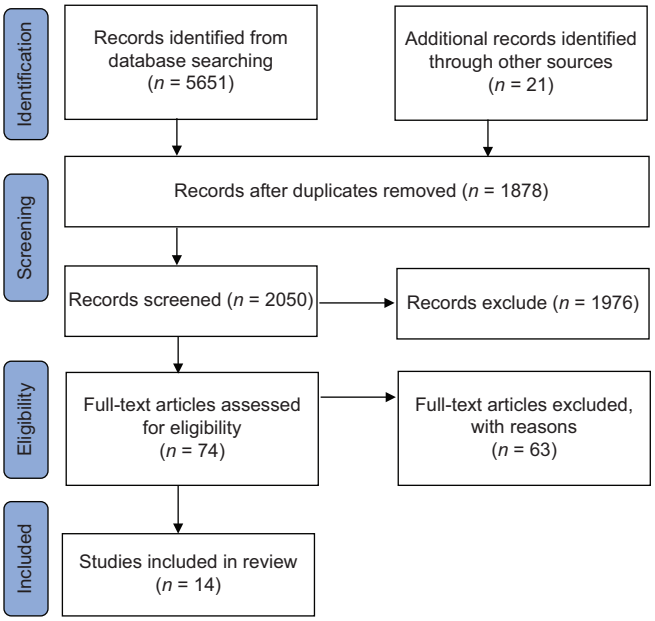

Figure 1: Preferred reporting items for systematic review and meta-analysis flow diagram

Table 1: Characteristics of included comparative studies that concerned about wearing face mask

Study	Country	Setting	Case definition	Number of mask use/number of case group	Number of mask use/number of control group	Mask type	Risk of bias*
Gonçalves 2020	Brazil	Non-HCW	Confirmed	184/198	410/421	Any type	7
Guo 2020	China	HCW	Confirmed	7/24	33/48	Any type	9
Chatterjee 2020	India	HCW	Confirmed	310/378	346/373	Any type	8
Çelebi 2020	Turkey	HCW	Confirmed	14/47	97/134	Medical mask	7
Doung-ngern 2020	Thailand	Non-HCW	Confirmed	108/210	323/823	High performance filtering mask	8
Alsaïdi 2021	France	Non-HCW	Confirmed/ suspected	14/29	25/35	Any type	7
Lio 2021	China	Non-HCW	Confirmed	6/24	707/1113	Any type	6
Thomas 2021	UK	Non-HCW	Confirmed	193/198	2572/2615	Any type	7
Rodriguez-Lopez 2021	Colombia	HCW	Confirmed	47/110	51/113	High performance filtering mask	8
Abolnezhadian 2021	Iran	Non-HCW	Confirmed	180/261	712/961	Any type	7

*The Newcastle–Ottawa Scale was used for the risk of bias assessment, with more stars equaling lower risk. HCW: Health-care worker

Table 2: Characteristics of included comparative studies that concerned about personal protective equipment use

Study	Country	Setting	Case definition	Number of PPE use/ number of case group	Number of PPE use/ number of control group	Risk of bias*
Guo 2020	China	HCW	Confirmed	3/24	11/48	9
Chatterjee 2020	India	HCW	Confirmed	321/378	356/373	8
Dev 2021	India	HCW	Confirmed	171/506	131/253	8
Rodriguez-Lopez 2021	Colombia	HCW	Confirmed	97/110	108/113	8

*The Newcastle-Ottawa Scale was used for the risk of bias assessment, with more stars equaling lower risk. HCW: Health-care worker, PPE: Personal protective equipment

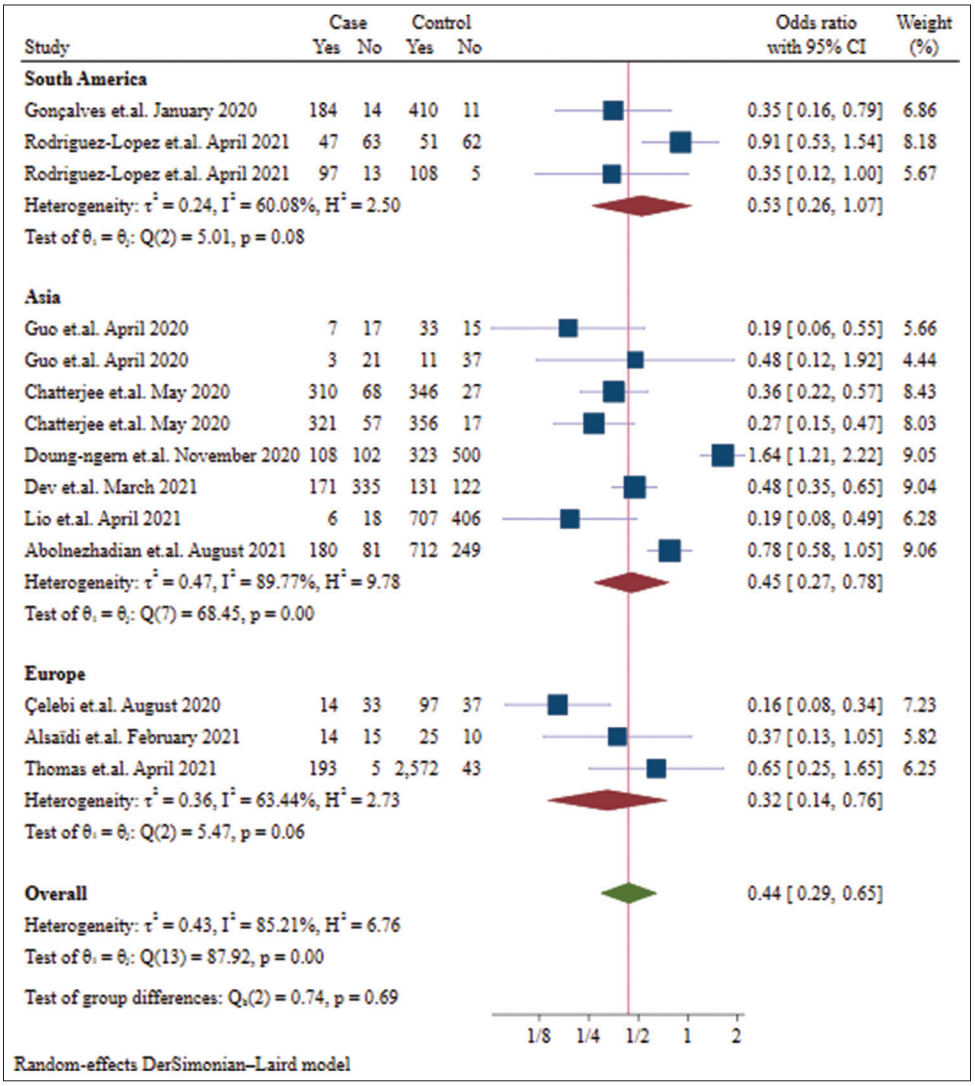

Figure 2: Meta-analysis of evidence on association between application of PPE or any type of masks and covid-19 infection using random effect model in all settings (HCW and non-HCW) by continent

I^2 = 87.51%, random-effects DerSimonian–Laird model; Figure 4].

Adjusted value of OR after considering possible confounding variables (adjustment variables including sex, age, contact place, the shortest distance of contact, duration of contact, sharing dishes, or cigarettes and handwashing) was reported in six out of 14 studies. Combined adjusted ORs with 95% CI are presented in Figure 5.

Non-health-care workers

Combining the result of six studies showed protective effect of wearing mask in non-HCWs [OR = 0.58, 95% CI: 0.31, 1.06), I^2 = 85.63%; Figure 4].

Health-care workers

In the HCW subgroup from four studies, the protective effect of wearing face masks on the risk of COVID-19 was more considerable, with a combined OR of 0.33 [95% CI: (0.15,

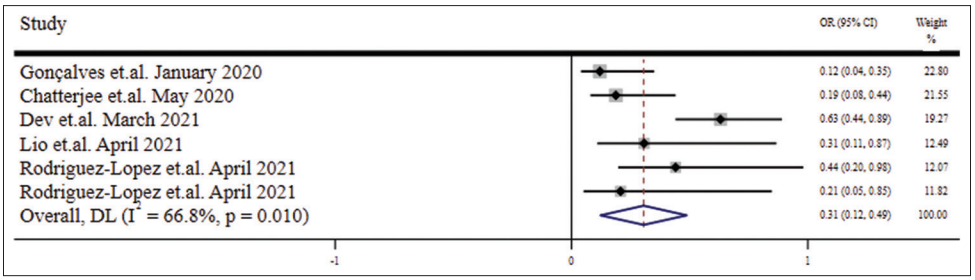

Figure 3: Meta-analysis of evidence on association between application of PPE or any type of masks and covid-19 infection using random effect model in all settings (HCW and non-HCW), using adjusted odds ratio

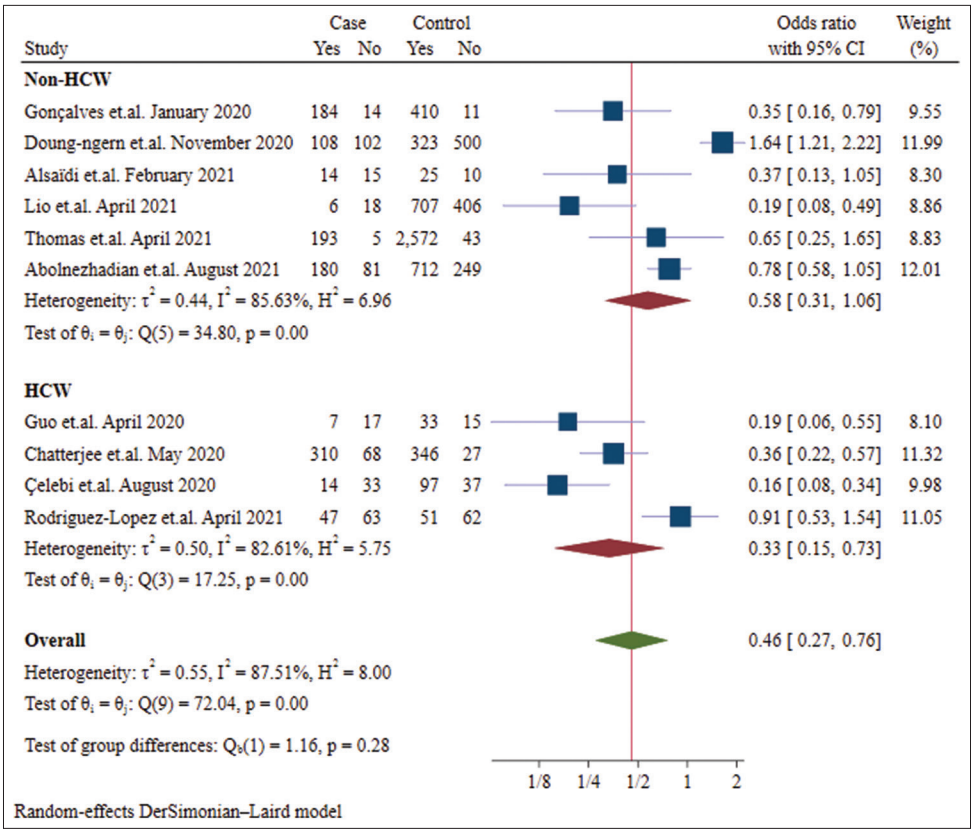

Figure 4: Meta-analysis of evidence on association between application of masks and covid-19 infection by setting (HCW and non-HCW), using random effect model

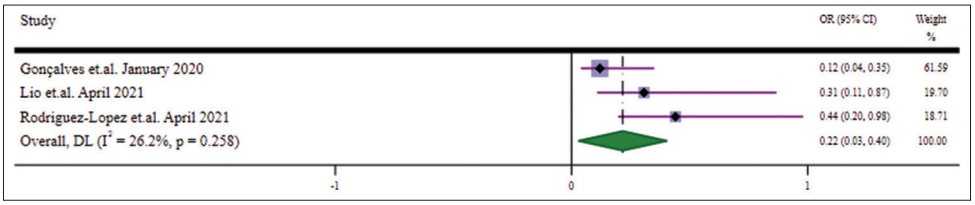

Figure 5: Meta-analysis of evidence on association between application of masks and covid-19 infection using random effect model in all settings (HCW and non-HCW), using adjusted odds ratio

0.73), I^2 = 82.61%; Figure 4]. Four studies assessed the effectiveness of using PPE on the risk of COVID-19 in HCWs. Pooled effect size showed a reduction of 59.0% in COVID-19 infection with an OR of 0.41, [95% CI: (0.31, 0.54), I^2 = 6.01%; Figure 6]. Figure 7 showed evidence on association between application of personal protective equipment and COVID-19 infection in health-care workers, using adjusted odds ratios. The result of leave-one-out meta-analysis and publication bias are presented in Figures 8 and 9, respectively.

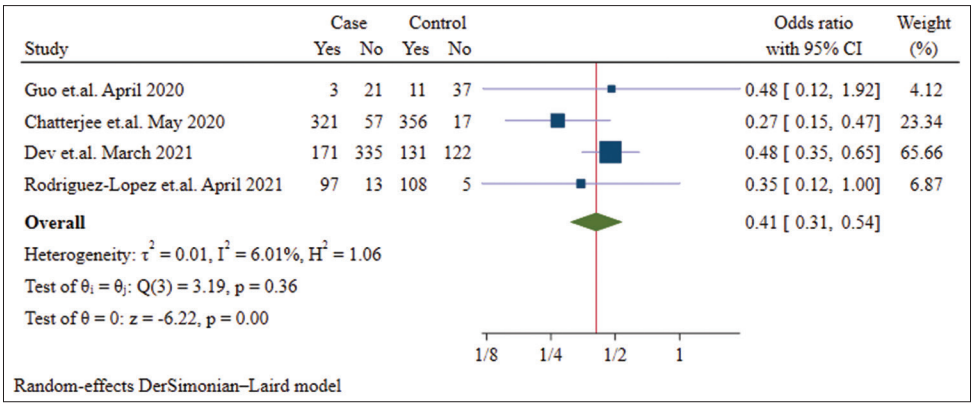

Figure 6: Meta-analysis of evidence on association of PPE use and risk of COVID-19 infection in HCWs, using random effect model

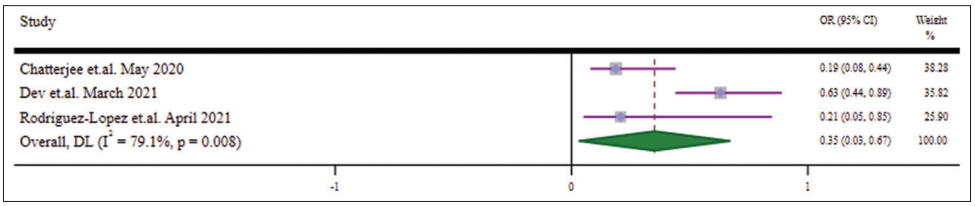

Figure 7: Meta-analysis of evidence on association between application of PPE and covid-19 infection using random effect model in HCWs, using adjusted odds ratios

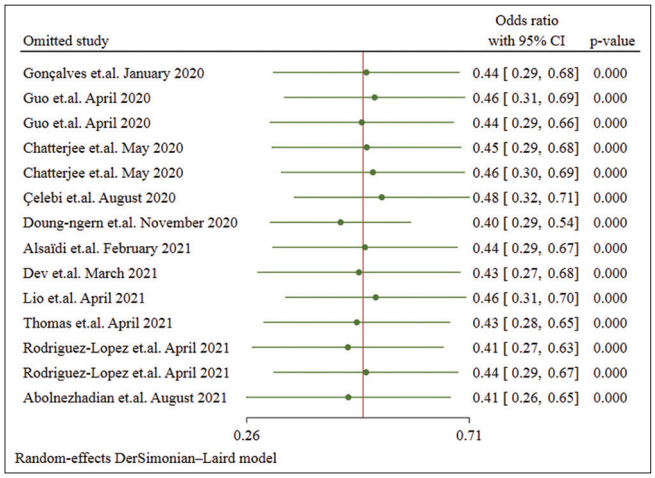

Figure 8: Leave-one-out meta-analysis of evidence on association between application of PPE or any type of masks and covid-19 infection using random effect model in all settings (HCW and non-HCW)

Discussion

Current systematic review and meta-analysis of all available case–control studies provides the latest evidence of the effectiveness of masks and PPEs in preventing the spread of COVID-19 for both health-care workers and people in the community. Evidence show that the main route of transmission in infectious diseases that caused by SARS-COV-2 virus such as severe acute respiratory syndrome-related CoV (SARS-CoV) and Middle East respiratory syndrome CoV (MERS-CoV) is aerosol transmission.[38-40] In a recent study, results showed that air samples of two patients with COVID-19 were PCR positive for SARS-CoV-2. In addition, laboratory tests showed respiratory particles of sizes 1–4 and >4 μm.[41] Furthermore, other studies provide evidence about positive air samples in isolation rooms of patient with COVD-19.[41-44] Hence, wearing mask and keeping distance are the most important preventive behaviors. Wearing mask prevents the inhalation of large droplets and aerosols. Previous studies have shown that masks can filter dust particles even in submicron scale.[45]

Meta-analysis of the eligible studies showed that the use of PPEs and face mask was associated with a significant reduction in risk of COVID-19 infection. These findings are consistent with the previous evidence which have shown relation between PPE and face mask use and reduced risk of viral infection.[18-21,46] Feasibility of using face masks is a debating choice in media and public health advisors especially for general population.[47] Based on the result of this systematic review and meta-analysis, health-care policy makers should consider the airborne transmission of COVID-19 and recommend the application of face masks and PPEs as acceptable advice for general population, HCWs, and people who care for COVID-19 patients.

Six studies concerned with the general population included in this review. Results show that the use of face masks had a protective effect for people who exposed with COVID-19 infection in community. This finding is similar to the result of other systematic review and meta-analysis studies.[29,30,32,34,36,37] The safety of health professionals is of paramount importance for many reasons, including promoting continuous patient care, preventing viral infections of themselves and other patients, and the moral obligation to protect those who are most important to them. Our results show that the use of

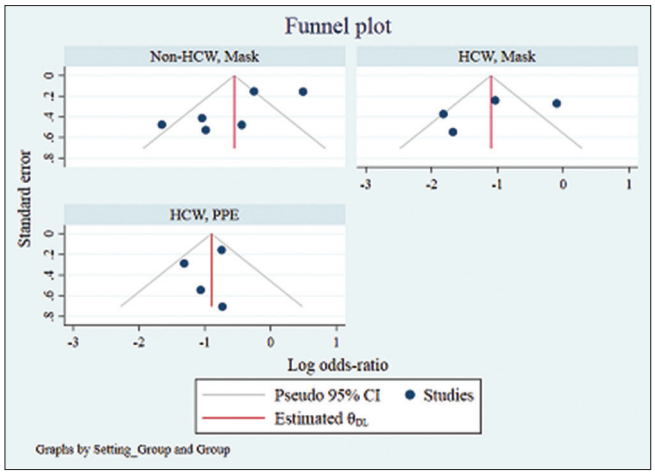

Figure 9: Funnel plot of PPE or any type of masks and covid-19 infection

masks reduces the risk of contracting COVID-19 70% of health-care personnel. Therefore, despite the novelty of SARSCoV2, long-term interventions in intensive care units around the world should be sufficient to protect frontline staff from the virus.[48]

This study has some strengths compared with other investigations carried out in this field. First, the association of the PPE and face mask use with COVID-19 was evaluated in this study based on case–control studies. Most of previous meta-analysis studies considered face masks for other viral infections (MERS and SARS). Second, according to inclusion of data for 9920 participants from case–control studies, we reached to good statistical power and reliable results in this study. Third, this is the first study that included a population based primary study from Iran. Geographical distribution will increase confounding effect of demographics, and it can affect the COVID-19 outcome.[49] However, the present meta-analysis also had several limitations. First, currently, more research is focused on the fast diagnosis and effective treatment of COVID-19. Therefore, the sample size of included studies is relatively small. Second, the available studies that provided data for different subgroup analyses were limited, thus the results should be interpreted with caution. Third, in this study, a meta-analysis on the adjusted data was done. However, the primary studies did not make the same adjustments. This issue may affect the heterogeneity of the final results.

Conclusion

Results suggest that there is association between face mask and PPE use and reduction of COVID-19. Based on the airborne transmission nature of COVID-19, it is rational to use PPE and face masks as an acceptable advice in health-care workers and general population.

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Conflicts of interest

There are no conflicts of interest.

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