ORIGINAL PAPER

doi: 10.5455/medarh.2020.74.342-345
MED ARCH. 2020 OCT; 74(5): 342-345
RECEIVED: SEP 11, 2020 | ACCEPTED: OCT 22, 2020

Four-type of Masks and its Effectiveness Based on Reduced Level of Expiratory Carbon-monoxide

Noni Novisari Soeroso[1], Tengku Kemala Intan[2], M. Ichwan[3], M. Hanif Fadlurrahman[1], Fannie Rizki Ananda[1]

[1]Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Universitas Sumatera Utara, Utara, Indonesia
[2]Department of Pathology, Faculty of Medicine, Universitas Sumatera Utara, Utara, Indonesia
[3]Department of Pharmacology and Therapeutics, Faculty of Medicine, Universitas Sumatera Utara, Utara, Indonesia

Corresponding author: Noni Novisari Soeros. Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Universitas Sumatera Utara, University of Sumatera Utara Hospital, Jl. Dr. Mansyur no. 5, Medan 20155, Sumatera Utara, Indonesia. E-mail: noni@usu.ac.id

ABSTRACT

Introduction: Carbon-monoxide (CO) is a major component of motor-vehicles related air pollution. Motor-vehicles emissions are a major source of air pollution in urban areas and give significant adverse effects on human life. **Aim:** This study aimed to assess the change of expiratory carbon-monoxide levels after using four-type of masks in people around Universitas Sumatera Utara. **Methods:** This was an experimental study with a consecutive sampling technique involved 100 non-smoker subjects. They were divided into four groups based on masks given: fabric, surgical, carbon, and an N95 mask. Expiratory CO was measured by a smokerlyzer device. Data were analyzed using SPSS software with Wilcoxon and Kruskal Wallis Test. **Results:** There was a significant change of carbon-monoxide mean level after using the mask for 8 hours in a surgical mask, N95 mask, and carbon mask (p-value: 0.002; 0.000; 0.000). After analyzed using Kruskal Wallis Test, there was a significant difference in the change of mean of pre and post wearing mask (ΔCO) among four-type of masks with p-value < 0.001. Post Hoc Analysis showed the significant difference was in the comparison between N95 mask vs Fabric Mask and Carbon Mask vs Fabric Mask (p-value: 0.002; 0.021). **Conclusion:** All three type of masks such as surgical mask, N95 mask, and carbon mask was effective to reduce CO levels from air pollution with the most significant was N95 and carbon mask. Fabric mask has the poorest protection from CO levels.

Keywords: Mask, Carbon monoxide, Expiratory carbon monoxide, Smokerlyzer.

1. INTRODUCTION

Air pollution was the contamination of modification of gases and solids from indoor or outdoor and harm humans, animals, and plants (1). The most common outdoor pollutants that harmed to human and environmental were sulfur dioxide (SO2), carbon-monoxide (CO), nitrogen oxides (NOx), ozone (O3), volatile organic compounds (VOC), carbon dioxide (CO2), polycyclic aromatic hydrocarbon (PAH), and various kind of particulate matter (PM) (2, 3).

Air pollution responsible for many serious impacts on human life. Air pollution is responsible for about seven million premature deaths every year, caused by respiratory, cardiovascular, and cerebrovascular disease (2, 4). Motor-vehicles emissions are a major source of air pollution in urban areas and give significant adverse effects (5, 6). Carbon monoxide is a major component of motor-vehicles related air pollution (7, 8). In the US, motor-vehicles contributes to 75% CO emissions (9). It is an odorless and colorless gas that sourced from incomplete combustion of carbonaceous fuel indoor or outdoor (10). After inhaled, CO diffuses through the alveolar-capillary membrane then binds to hemoglobin. This carboxyhemoglobin (COHb) complex has a greater affinity than oxygen. The result is impaired tissue oxygen delivery in all over the body (7). It affects metabolic reaction and after the concentration is greater than 10%, the symptoms will appear. The most common symptoms are dizziness, dyspnea, confusion, headache, nausea/vomiting, fatigue, chest pain, and loss of consciousness (11).

Recently, many studies have reviewed the effectiveness of mask for reducing the impact of air pollution. Unfortunately, almost the majority of recent studies about air pollution discussed the solution to control microparticle of air pollution (12–17), even though the toxic gases also have bad impacts on health directly and indirectly (7).

2. AIM

This study aimed to assess the change of expiratory carbon-monoxide levels after using four-type of masks in people around Universitas Sumatera Utara.

3. METHODS

Study design and population

This is a quasi-experimental study that held from August until October 2018 with a consecutive sampling method. A total of 100 subjects that had the inclusion criteria and did not have the exclusion criteria participated in this study. The inclusion criteria were non-smoker and age 17-60 years old. The exclusion criteria were participants that had respiratory problems such as asthma, COPD, tuberculosis, etc. All these subjects were exposed to carbon-monoxide from traffic and transportation around the environment of the Faculty of Medicine of Universitas Sumatera Utara, Medan, North Sumatera, Indonesia. All the subjects were divided into four groups based on the type of mask used in this study, consisting of N95 mask groups, carbon, surgical, and fabric masks. The type of mask used in this study including; N95 masks was 3M 810 Particulate Respirator N95 made in Korea, carbon mask was Nice purchase disposable charcoal activated carbon mask made in the United States, a surgical mask was Arista surgical mask made in Indonesia, fabric mask was from commercial local brand in Indonesia. Before and after wearing a mask for eight hours, the CO level in expiration was measured using smokerlyzer with BX615 specification for gas detector.

Evaluation of the CO levels in expiration using smokerlyzer with BX615 specification for gas detector was conducted between 8 hours pre and post mask application in this study.

Statistical analysis

Statistical Product and Service Solution version 20.0 were used in this study. Preliminary analysis to assess whether data were normally distributed was performed using the Kolmogorov-Smirnov Test (p-value<0.05). Therefore, the Wilcoxon test was finally used to determine the difference of CO levels between pre and post the application mask. Multivariate analysis (Kruskal Wallis test) was applied to assess the CO levels among the group. Post-Hoc Analysis revealed the superiority of masks among groups.

4. RESULTS

The majority of subjects were male in the productive age group (21-40 years old) and exposed to carbon-monoxide from traffic and transportation more than eight hours each day intermittently. The mean carbon monoxide level was 10.42 ppm. More general characteristics of subjects can be seen in Table 1.

Based on Table 2, there was a significant change of carbon-monoxide mean level after using the mask for eight hours in a surgical mask, N95 mask, and carbon mask (p-value: 0.002; 0.000; 0.000) (Table 2). After analyzed using Kruskal Wallis Test, there was a significant difference in the change of mean of pre and post wearing mask (ΔCO) among four-type of masks with p-value < 0.001. The analyzed through Post Hoc Analysis, the significant difference was seen in the comparison between N95 mask vs Fabric Mask and Carbon Mask vs Fabric Mask (p-value: 0.002; 0.021). Based on Table 3 and Figure 1, the fabric mask was not effective in reducing the carbon-monoxide level. Conversely, N95, carbon, and the surgical mask was effective.

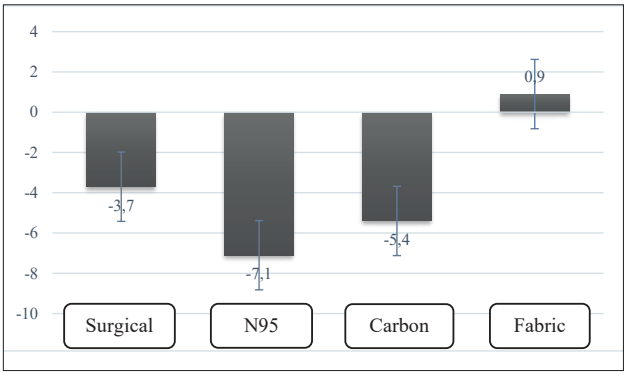

Figure 1. The reduction of CO levels in various type of mask

5. DISCUSSION

There are several types of masks with a wide range in the level of effectiveness, convenience, appearance, and activity limitation (18), such as cotton fabric mask, surgical mask, respirator mask, N95 mask, and carbon mask. In the study, showed that three types of masks gave significant reduction results in carbon-monoxide levels, including surgical mask, carbon mask, and an N95 mask. Based on the Anova Test analysis, the study showed a significant difference among four-type of masks after used for 8 hours. The additional analysis further showed that the significant difference was seen in the N95 mask vs fabric mask and carbon mask vs fabric mask.

Fabric mask is a simple cloth mask that covers the nose and mouth with an elastic strap tied in the backside of the head above the ear (12). It gives marginal protection ineffectively against micropollutants as if PM 2.5 (19). The study also proved that there was no significant difference in CO level before use of a fabric mask for eight hours. A comparison study demonstrated the efficiency of three types of fabric masks and one type of surgical mask; it concluded that a fabric mask with exhaust valve mask has better protection, about 80-90% for Polystyrene latex (PSL) particles (12). In contrast, two types of commercially fabric masks just gave 39-65% protection for PSL particles. In other tested, the efficiency of the fabric mask ranged from 15%-57% for 30, 100, and 500nm (12). Another study in Beijing showed that many commercial face masks could not give adequate protection due to the poor facial cover (20). Similarly, another study also stated that a fabric mask was only effective in reducing particles sizing of more than 10 nm, it is ineffective in filtering the smaller particles and prevent exposure to toxic gases (21). But the data of the efficiency of fabric mask to reduce carbon-monoxide level itself is not known yet.

Meanwhile, the surgical mask was a simple, widely distributed, and has many benefits. It is made of wo-

ven polyester and cellulose with elastic earloops has a cheaper property and only for single-used (14). In general, a surgical mask is used to protect the patients from bioaerosol such as microorganisms from mouth and nasopharynx from the surgeon during surgery (22). A surgical mask is fluid-resistant and protects from large particles, water splashes and sprays, and hazardous fluids for the user (23). It has a high filtration rate and significantly higher than the N95 respirator mask, in line with its function on protecting others from aerosol from the wearers (17).

A study assessed the efficacy of surgical masks to aerosol found that surgical masks had 29-45% efficiency to give protection from saline aerosol (24). But nowadays, a surgical mask was commonly used to give protection from pollutants (20). In this study, there was a significant reduction of CO levels after using a surgical mask for eight hours. Yet no data about the efficiency of a surgical mask for reducing CO levels. Nevertheless, the surgical mask was more effective in protecting from particulate compared with fabric mask for air pollution protection (12). The surgical mask had the face seal leakage to filter ratio which large enough to let the penetrated particles and gases enter through the face seal. This will reduce the efficacy of the surgical mask itself (14, 19).

The N95 mask comprising of the outer and inner layers has a specific function. The first layer or outer layer is a hydrophobic non-woven polypropylene substance preventing oil and non-oil based particles. The deeper layer promotes the basic structure of the mask as wells as maintaining convenience as it directly contacts with the face (25). It is tight-fitting because of its function to protect the wearers from small particle aerosols and large droplets (23). This respirator has been evaluated and approved by the National Institute for Occupational Safety and Health (NIOSH) 42 part 84. It has the respirator filter which can filter particles between 1 to 10 micron with 95% efficiency in certification test (13, 26).

In recent studies, it was described that the filter efficiency of the N95 mask was higher than the surgical mask (13, 14, 26). In this study, we found a significant reduction of CO level after eight hours of N95 mask. Unfortunately, other studies about the efficiency of an N95 respirator mask in reducing toxic gases levels including carbon-monoxide was under published yet. Mostly the studies were about the efficacy of N95 mask in filtering micro-organisms such as influenza virus (27, 28), rhinoviruses (27), and Methicillin-Resistant Staphylococcus aureus (MRSA) (29), B. Anthracis (30), and various size of particulate (13, 14, 16, 17, 26). All of these studies stated that the N95 mask was effective in protecting the wearer from microorganisms and small particles from air pollution in a good face seal (13, 14, 17, 19, 26–34). The limitations of these masks are it is disposable and must be changed after visiting a patient or after aerosol-generating procedures. It also makes the wearer becomes difficult to breathe (23).

A carbon mask is an additional respirator mask with activated carbon. This mask is composed of polyester and polyamide filter, fiber-formed active carbon (density of 200 g/m2) (35). Active carbon has a large surface area because of its microscopic characteristics that composed of microspore and mesopore that play an important role in gas absorption (36). This activated carbon can absorb toxic gases more effectively than other respirator masks (21). In this study, we found a significant reduction of CO levels after wearing a carbon mask for 8 hours. This is in line with Khayan study that showed the significant difference of COx levels among various kinds of masks, with the most significant was in the combination of carbon, spun-bond, and meltdown compared with control (p-value < 0.001) (21). Another study showed that carbon mask also had a positive impact on reducing exposure of anticancer drug vaporized (35). A literature review showed that additional active carbon in respirator carbon provides a large surface area that absorbed particulate and biological aerosol more effectively than other respirators (37).

The limitations of this study are that there were few confounding factors including cigarette exposure, occupation, and its correlation with the duration of being outdoor and exposed by carbon-monoxide, and the concordance of the participants in using the masks for eight hours. All these factors contribute to expiratory carbon-monoxide levels that difficult to eliminate.

6. CONCLUSION

The reduction of CO levels was observed among the three-type of masks such as surgical mask, N95 mask, and carbon mask from air pollution. Additionally, the fabric mask has the poorest performance and no significant result obtained from the study. Therefore, the implementation of the proper protective equipment in tackling CO exposure should be performed indispensably, particularly for the high-risk population such as people with a long duration of being outdoor, immune-compromised patients including children, geriatric, and have respiratory problems. Furthermore, future studies are needed to ascertain the levels of CO exposure that would secure the protection or avoidance of any confounding using large cohort studies.

- **Patients Consent Statement**: The first author confirms that patients consent to enroll in the study was obtained. The authors certify that they have obtained all appropriate patient consent.
- **Author contribution**: Each author were involved to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Final proof reading was made by the first author.
- **Conflict of interest**: There are no conflicts of interest.
- **Financial support and sponsorship**: Nil.

REFERENCES

1. What is Air Pollution? [Internet]. 2018 [cited 2019 Aug 7]. Available from: http://maps.who.int/airpollution/
2. Air Pollution, Climate and Health the calculation is simple [Internet]. [cited 2019 Aug 7]. Available from: https://www.who.int/sustainable-development/AirPollution_Climate_Health_Factsheet.pdf
3. John KS, Feyisayo K. Atmospheric and Climate Sciences. 2013 [cited 2019 Aug 7];3:510–4. Available from: http://dx.
4. Rees N, UNICEF. Clear the air for the children : the impact of air pollution on children. UNICEF; 2016. 100 p.

5. Faiz A. Automotive emissions in developing countries-relative implications for global warming, acidification and urban air quality. Transp Res Part A Policy Pract [Internet]. 1993 May 1 [cited 2019 Aug 7];27(3):167–86. Available from: https://www.sciencedirect.com/science/article/pii/096585649390057R
6. Colvile R, Hutchinson E, Mindell J, Warren R. The transport sector as a source of air pollution. ATMOS Env; 35: 1537-1565 [Internet]. 2001 [cited 2019 Aug 7]; Available from: http://discovery.ucl.ac.uk/894/
7. Levy RJ. Carbon monoxide pollution and neurodevelopment: A public health concern. Neurotoxicol Teratol [Internet]. 2015 [cited 2019 Aug 12];49:31–40. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25772154
8. Academies N. Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8 Committee on Acute Exposure Guideline Levels; Committee on Toxicology; National Research Council [Internet]. 2010 [cited 2019 Aug 12]. Available from: http://www.nap.edu/catalog/12770.html
9. US EPA O. Carbon Monoxide (CO) Pollution in Outdoor Air. [cited 2019 Aug 12]; Available from: https://www.epa.gov/co-pollution
10. Iqbal S, Clower JH, Hernandez SA, Damon SA, Yip FY. A Review of Disaster-Related Carbon Monoxide Poisoning: Surveillance, Epidemiology, and Opportunities for Prevention. Am J Public Health [Internet]. 2012 Oct [cited 2019 Aug 12];102(10):1957–63. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22897556
11. Hampson NB, Piantadosi CA, Thom SR, Weaver LK. Practice Recommendations in the Diagnosis, Management, and Prevention of Carbon Monoxide Poisoning. Am J Respir Crit Care Med [Internet]. 2012 Dec 5 [cited 2019 Aug 12];186(11):1095–101. Available from: http://www.atsjournals.org/doi/abs/10.1164/rccm.201207-1284CI
12. Shakya KM, Noyes A, Kallin R, Peltier RE. Evaluating the efficacy of cloth facemasks in reducing particulate matter exposure. J Expo Sci Environ Epidemiol. 2017 May 1; 27(3): 352–357.
13. Balazy A, Toivola M, Reponen T, Podgórski A, Zimmer A, Grinshpun SA. Manikin-based performance evaluation of N95 filtering-facepiece respirators challenged with nanoparticles. Ann Occup Hyg [Internet]. 2006 Apr [cited 2019 Aug 14];50(3):259–269. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16344291
14. Grinshpun SA, Haruta H, Eninger RM, Reponen T, McKay RT, Lee S-A. Performance of an N95 filtering facepiece particulate respirator and a surgical mask during human breathing: two pathways for particle penetration. J Occup Environ Hyg [Internet]. 2009 Oct [cited 2019 Aug 14];6(10):593–603. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19598054
15. Wcherrie J, Apsley A, Cowie H, Steinle S, Mueller W, Lin C, et al. Effectiveness of face masks used to protect Beijing residents against particulate air pollution. Occup Environ Med. 2018;75(6):446–452.
16. Qian Y, Willeke K, Grinshpun SA, Donnelly J, Coffey CC. Performance of N95 respirators: filtration efficiency for airborne microbial and inert particles. Am Ind Hyg Assoc J [Internet]. 1998 Feb [cited 2019 Aug 23];59(2):128–32. Available from: http://www.ncbi.nlm.nih.gov/pubmed/9487666
17. He X, Reponen T, McKay RT, Grinshpun SA. Effect of particle size on the performance of an N95 filtering facepiece respirator and a surgical mask at various breathing conditions. Aerosol Sci Technol. 2013;47(11): 1180–1187.
18. Laumbach R, Meng Q, Kipen H. What can individuals do to reduce personal health risks from air pollution? Journal of Thoracic Disease. Pioneer Bioscience Publishing; 2015; 7: 96–107.
19. Lawrence RB, Duling MG, Calvert CA, Coffey CC. Comparison of performance of three different types of respiratory protection devices. J Occup Environ Hyg. 2006 Sep 1; 3(9): 465–574.
20. Cherrie JW, Apsley A, Cowie H, Steinle S, Mueller W, Lin C, et al. Effectiveness of face masks used to protect Beijing residents against particulate air pollution. Occup Environ Med [Internet]. 2018 Jun 1 [cited 2019 Aug 12]; 75(6): 446–452. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29632130
21. Khayan K, Anwar T, Wardoyo S, Lakshmi Puspita W. Active Carbon Respiratory Masks as the Adsorbent of Toxic Gases in Ambient Air. J Toxicol. 2019; 2019.
22. Lipp A, Edwards P. Disposable surgical face masks for preventing surgical wound infection in clean surgery. Sao Paulo Med J [Internet]. 2012; 130(4): 269–269. Available from: http://onlinelibrary.
23. CDC, Niosh, NPPTL. Infographic - Understanding the Difference, Surgical Mask, N95 Respirator.
24. Bowen LE. Does That Face Mask Really Protect You? [Internet]. Vol. 15, www.absa.org Applied Biosafety. 2010. Available from: www.absa.org
25. Zhou SS, Lukula S, Chiossone C, Nims RW, Suchmann DB, Ijaz MK. Assessment of a respiratory face mask for capturing air pollutants and pathogens including human influenza and rhinoviruses. J Thorac Dis [Internet]. 2018 Mar [cited 2019 Aug 12];10(3): 2059–2069. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29707364
26. Lee SA, 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 [Internet]. 2008 Apr [cited 2019 Aug 14];52(3):177–185. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18326870
27. Steve Zhou S, Lukula S, Chiossone C, Nims RW, Suchmann DB, Ijaz MK. Assessment of a respiratory face mask for capturing air pollutants and pathogens including human influenza and rhinoviruses. J Thorac Dis. 2018 Mar 1; 10(3): 2059–2069.
28. Loeb M, Dafoe N, Mahony J, John M, Sarabia A, Glavin V, et al. Surgical Mask vs N95 Respirator for Preventing Influenza Among Health Care Workers. JAMA. 2009 Nov 4; 302(17):1865.
29. Ferguson DD, Smith TC, Donham KJ, O'shaughnessy PT. Evaluation of the Filtration Efficiency of the N95 Filtering Facepiece Respirator for Airborne Methicillin-Resistant Staphylococcus aureus. J Agric Saf Health. 1074; 20(4): 255–265.
30. Qian Y, Willeke K, Grinshpun SA, Donnelly J, Coffey CC. Performance of N95 respirators: Filtration efficiency for airborne microbial and inert particles. Am Ind Hyg Assoc J. 1998; 59(2): 128-132.
31. Davidson CS, Green CF, Gibbs SG, Schmid KK, Panlilio AL, Jensen PA, et al. Performance evaluation of selected n95 respirators and surgical masks when challenged with aerosolized endospores and inert particles. J Occup Environ Hyg [Internet]. 2013 [cited 2019 Aug 23];10(9):461–7. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23915331
32. Eninger RM, Honda T, Adhikari A, Heinonen-Tanski H, Reponen T, Grinshpun SA. Filter performance of n99 and n95 facepiece respirators against viruses and ultrafine particles. Ann Occup Hyg [Internet]. 2008 Jul [cited 2019 Aug 23];52(5):385–96. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18477653
33. Birgersson E, Tang EH, Lee WLJ, Sak KJ. Reduction of carbon dioxide in filtering facepiece respirators with an active-venting system: A computational study. PLoS One. 2015 Jun 26; 10(6).
34. Atrie D, Worster A. Surgical mask versus N95 respirator for preventing influenza among health care workers: a randomized trial. CJEM [Internet]. 2012 Jan [cited 2019 Aug 14];14(1):50–2. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22417959
35. Sato J, Kogure A, Kudo K. Effectiveness of activated carbon masks in preventing anticancer drug inhalation. J Pharm Heal Care Sci. 2016 Dec;2(1).
36. Herawan SG, Hadi MS, Ayob MR, Putra A. Characterization of activated carbons from oil-palm shell by CO2 activation with no holding carbonization temperature. Sci World J. 2013; 2013.
37. Abbasinia M, Karimie S, Haghighat M, Mohammadfam I. Application of Nanomaterials in Personal Respiratory Protection Equipment: A Literature Review. Safety. 2018 Oct 22; 4(4): 47.