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Major Article

Total outward leakage of face-worn products used by the general public for source control

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Background: During Coronavirus disease 2019 pandemic, the general public used any face-worn products they could get to overcome the shortage of N95 respirators and surgical masks. These products, often not meeting any standards, raised concerns about their effectiveness in reducing the spread of respiratory viruses.
Methods: This study quantified total outward leakage (TOL) of units from 9 face-worn product categories used by members of the general public. A benchtop system was devised to test 2 units from each category on 2 different-sized headforms with silicone elastomer skin. Each unit was donned 5 times per headform.
Results: Both face-worn product category and headform size significantly affected TOL (P value < .05). The TOL of tested face-worn products varied from 10% to 58% depending on both model and headform size. Face-worn products donned on the medium headform had a higher mean TOL compared to those donned on the larger headform.
Conclusions: Overall, single-layer cloth masks are the least effective measure for source control due to their highest TOL among the tested face-worn products. Three-layer disposable face masks may be a favorable option for source control among the public. A standard should be developed for face-worn product design and manufacturing to accommodate different facial sizes.

BACKGROUND

Human respiratory activities, including breathing, talking, coughing, and sneezing, produce aerosols ranging from 0.1 to 1,000 µm.[1-3] The majority of these aerosols are under 5 µm, with a significant number smaller than 1 µm.[4] Breathing activities significantly impact the concentration of generated particles by size. Vocalizations, such as speaking, singing, and shouting, produce more particles greater than 10 µm compared with normal breathing.[5] The tiny aerosols can carry viruses such as severe acute respiratory syndrome conronavirus 2 and influenza, which are often found in aerosols < 5 µm in size.[6] Notably, Severe acute respiratory syndrome conronavirus 2 is concentrated in particles between 0.94 and 4.7 µm.[3,7,8] Airborne transmission, a primary route for the spread of these viruses, poses a significant risk for global pandemics.[3,4,9,10]

The Centers for Disease Control and Prevention recommended that members of the general public wear well-fitting masks to provide source control and reduce the spread of viral particles through airborne transmission. According to the Centers for Disease Control and Prevention, source control refers to the use of a face-worn product that covers a person's mouth and nose to reduce the spread of large respiratory droplets to others when the person talks, sneezes, or coughs.[11]

The Coronavirus disease 2019 pandemic led to a global shortage of personal protective equipment, including N95 filtering facepiece respirators (FFRs) and surgical masks (SMs), which were prioritized for health care personnel. Face-worn products, such as disposable face masks and cloth masks, have gained increasing attention to fulfill the demand for source control among the general public.[12,13] As more companies began designing and manufacturing reusable and washable face-worn products for the general public,[14] information on these

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products' effectiveness in preventing respiratory infections was needed to develop more standardized guidance on their use.

In past years, standards have been introduced for masks, such as the American Society for Testing and Materials (ASTM) standard F2100, Standard Specification for Performance of Materials Used in Medical Face Masks, which classified medical masks used for health care services into 3 barrier-level performance categories: level 1, level 2, and level 3.[15] However, there is limited standard guidance for face-worn products intended to be used by the general public. The recently developed ASTM F3502, Standard Specification for barrier face coverings (BFCs), began to address this gap, defining BFCs as products worn on the face, specifically covering at least the wearer's nose and mouth. BFCs are classified according to filtration efficiency (level 1 and level 2) and breathability (level 1 and level 2) and are designed with the primary purpose of providing source control and a degree of particulate filtration to reduce the inhalation of particulate material.[16] The National Institute for Occupational Safety and Health provided performance recommendations for Enhanced Performance and Enhanced Performance Plus BFCs.[6]

However, most cloth masks, whether homemade or those existing in the market, have not been evaluated to determine how they perform, and they may not meet the requirements of the ASTM F3502 standard.[17] ASTM F3502 standard aids in guaranteeing the filtration efficiency of fabrics utilized in the production of face-worn products, but there is a lack of guidance on their use for source control due to various forms of outward leakage, including penetration through the filtration material, leakage around the faceseal, and emission through an exhalation valve (if present).

To better understand the effectiveness of face-worn products used for source control, total outward leakage (TOL) was used as a metric to assess the performance of face-worn products in reducing the leakage of exhaled aerosol.[18] TOL was defined as the overall percentage of aerosols emitted from the face-worn product to the ambient when used for source control, which is calculated by dividing the concentration outside the face-worn product by the concentration inside the face-worn product. The TOL of face-worn products accounts for any leakage that occurs around the edges of the face-worn product through gaps in the faceseal and through the filter material (ie, penetration).

The penetration, a component of TOL, is dependent on the filtration efficiency of filtering materials. Over the years, various studies have been conducted to evaluate the filtration efficiency of fabric materials. A recent study evaluated the filtration efficiency of masks, SMs, and N95 FFRs on an anthropometric face filtration mount where the edges of the face-worn product were firmly affixed to the testing fixture.[17] The study found that only 2 out of the 11 sealed masks achieved the minimum ASTM F3502 standard filtration efficiency of > 20% for exhalation. This is much lower than the filtration efficiency of sealed SMs and N95 FFRs, which exceeded 90%. Other research also indicated that cloth masks were less effective than N95 FFRs and SMs for source control.[19-22] Various materials, including linen, silk, polyester, and hybrid fabrics, along with cotton, have been used to manufacture face-worn products.[23,24]

Additionally, the combination of nonwoven materials and cloth has been demonstrated to significantly enhance filtration efficiency.[25,26] Specifically, Neupane et al[26] conducted a study to evaluate the filtration efficiency of 5 prototype cloth masks, a cloth mask featuring a pocket (CMP) for inserting additional filters such as polypropylene fabric, and 16 regular cloth masks. The prototype cloth masks had a much higher average filtration efficiency of 60% compared with regular cloth masks at 13%. CMPs with particulate matter (PM) 2.5 filter insert showed a low penetration of 3% to 5% against PM 2.5 particles.[27] Despite the insertion of filters or nonwoven materials into the cloth masks, their performance in reducing inward leakage was improved marginally when they were used for wearer protection.[27-29]

Although cloth masks are less effective than N95 FFRs and SMs, they still play a role in reducing TOL for specific particle size ranges. The study found that homemade cloth masks used for source control during simulated coughs captured 76% of particles between 4.7 and 7 µm, but their effectiveness dropped to 28% for particles smaller than 0.6 µm.[22] Similarly, Asadi et al[30] reported that wearing homemade masks significantly reduced the proportion of large particles (> 0.8 µm) generated during coughing.

When face-worn products are used for source control, leakage through the faceseal gap is a crucial concern. Therefore, their effectiveness should be evaluated beyond the filtration efficiency. A recent study by Lindsley et al[22] found that 3-layer cotton cloth masks, single-layer polyester neck gaiters, and double-layer polyester neck gaiters reduced Potassium chloride aerosol emission by 51%, 47%, and 60%, respectively. Another study by Lindsley et al[21] reported that cloth masks had aerosol collection efficiencies, defined as the percentage of aerosol particles that were blocked by the face mask, neck gaiter, or face shield compared with experiments without a device, between 17% and 71% during coughing and 35% and 66% during exhalation conditions. Li et al[29] noted a 77% reduction in cough-generated aerosols with cloth masks.

The fit of face-worn products has been identified as crucial, with loose fit leading to increased inward leakage when used for wearer protection. However, less is known about the impacts of fit on the performance of face-worn products employed for source control. Konda et al[20] noted that gaps created by poor fit can increase inward leakage by over 60%. Freeman et al[17] emphasized the role of faceseal in cloth masks.[7] Given that some face-worn products are reused by the general public, the process of multiple donning and doffing may impact the fit of these products. A previous study has proven that the multiple donnings affected the fit of N95 FFRs, but the effect of multiple donnings on the fit of other types of face-worn products also needs to be investigated.[31] Existing test methods, such as ASTM F3502-21, which tests the filtration efficiency of masks with a complete seal on the filter holder adapter, do not always represent real-world conditions, especially for source control, where fit plays a critical role.[16]

This study aimed to address a critical knowledge gap related to the effectiveness of face-worn products used as source control measures, utilizing TOL as a metric. The study also evaluated the impact of multiple donnings on TOL of different types of products. Additionally, the fit of face-worn products on differently sized headforms was considered as a factor affecting TOL. The study examined 9 categories of face-worn products using 2 pliable headforms of different sizes under normal breathing conditions, with a flow rate set at 28 L/min. Each test was conducted with 5 donnings for each face-worn product unit.

METHODS

The TOL of face-worn products was evaluated using the same test system employed in our previous study,[18] which is shown in Figure 1. To evaluate the fit of face-worn products on users with various facial dimensions, 2 headform sizes representing the medium and large head and face sizes of the US civilian worker population developed from a 2003 anthropometric survey were used to assess the effect of face size on TOL.[32] Additionally, these advanced headforms had a compressible silicone elastomer skin to better simulate the interface between the face-worn products and a user's face. A dynamic breathing machine was employed to simulate human breathing activities (Warwick Technology Limited, Warwick, Warwickshire, UK). A 3-way valve was used and served as a pivotal connection point between the aerosol generation chamber, the headform situated in the leakage test chamber, and the breathing machine. This setup ensured that the particles generated in the aerosol chamber were drawn into the

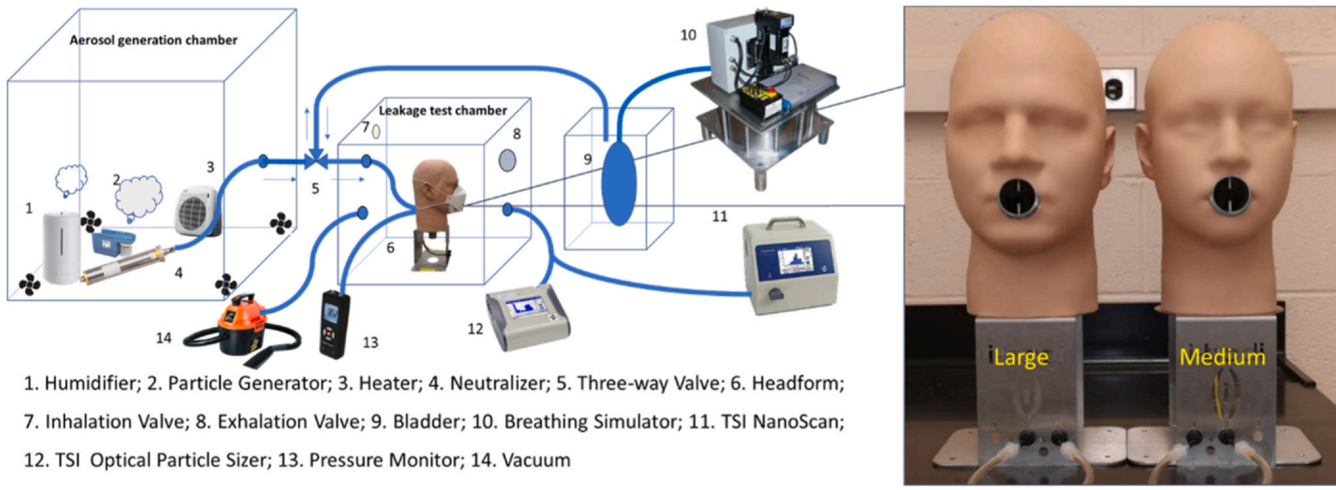

Fig. 1. The total outward leakage test system and headforms with artificial skin surface.[18]

headform in the leakage test chamber by the breathing machine; moreover, these particles were only exhaled into the face-worn product without inhalation.

In this study, 9 categories of face-worn products with ear loop suspension systems were evaluated. For each face-worn product category, 2 different models were selected as specimens. The tested face-worn products are as follows: (1) ASTM F2100-compliant level 3 masks (model #1 and #2), (2) ASTM F2100-compliant level 2 masks (model #3 and #4), (3) ASTM F2100-compliant level 3 masks (model #5 and #6), (4) single-layer cloth masks (model #7 and #8), (5) 3-layer disposable face masks (model #9 and #10), (6) CMPs for PM 2.5 tested with filters (model #11 and #12), (7) CMPs for PM 2.5 tested without filters (model #13 and #14), (8) CMPs for high efficiency particulate air (HEPA) tested with filters (model #15 and #16), and (9) CMPs for HEPA tested without filters (model #17 and #18). The ASTM-compliant masks were considered as the reference group compared with the other masks that were not ASTM-compliant face-worn products.

This study employed tidal breathing at a minute ventilation flow rate of 28 L/min (25 breaths per minute × 1.12 L/breath) to simulate the breathing patterns of the general public during moderate work rate activities. The minute ventilation flowrate was calculated according to "ISO/TS 16976-1; Respiratory protective devices - Human factors - Part 1: Metabolic rates and respiratory flowrates."[33] The Sodium chloride aerosol utilized in the study was generated using the same particle generator (model 8026; TSI, Inc) as in previous research evaluating SMs and respirators for use in health care settings.[18] The upstream aerosols exhibited a count median diameter of around 0.113 µm and a geometric standard deviation of 1.72.

The headform wearing the face-worn product was tested following the procedure in the previous study on the masks and respirators used for health care settings.[18] TOL was calculated according to Equation (1):

$$TOL = (C_{out} - C_{bg})/C_{in} \times 100\% \quad (1)$$

where C_{bg} is the average background concentration before breathing across 3 data points inside the leakage test chamber when it reached the stable concentration level; C_{in} is the average concentration of 3 samplings inside the cavity of the face-worn products during breathing when it reached the stable concentration level; and C_{out} is the average concentration after breathing across 3 samplings outside the face-worn products in the leakage test chamber when it reached the stable concentration level.

The experimental design in this study utilized a 3-factor full factorial design approach to investigate the impact of 2 factors, including face-worn product category and headform size, on the TOL from the face-worn products.[34]

The linear statistical model for this factorial design is as follows:

$$y_{ijkl} = \mu + \tau_i + \beta_j + \gamma_k + (\tau\beta)_{ij} + (\beta\gamma)_{jk} + (\tau\gamma)_{ik} + (\beta\gamma\delta)_{ijk} + \epsilon_{ijkl}$$
$$\begin{cases} i = 1,\ 2,\ 3,\ 4,\ 5,\ 6,\ 7,\ 8,\ 9 \\ j = 1,\ 2 \\ k = 1,\ 2,\ 3,\ 4,\ 5 \\ l = 1,\ 2 \end{cases} \quad (2)$$

where μ is the overall mean effect; τ_i represents the effect of the ith level of the face-worn product category; β_j represents the effect of the jth level of headform; γ_k represents the effect of kth donning; $(\tau\beta)_{ij}$ represents the effect of the interaction between τ_i and β_j; $(\tau\gamma)_{ik}$ represents the effect of the interaction between τ_i and γ_k; $(\beta\gamma)_{jk}$ represents the effect of the interaction between β_j and γ_k; $(\tau\beta\gamma)_{ijk}$ represents the effect of interaction among τ_i, β_j, and γ_k, respectively; and ϵ_{ijkl} is a random error component.

A total of 180 observations were performed in this study, with each face-worn product unit undergoing 5 donnings on 2 different headform sizes (9 face-worn product categories × 2 products per category × 2 headform sizes × 5 donnings). The test sequence of each observation was randomized. The group data were compared using a 3-way ANOVA with the significance level of $\alpha = 0.05$. The statistical analysis was conducted with JMP software (JMP Statistical Discovery).[35] The Student t- test was conducted as post hoc analysis that followed ANOVA.

RESULTS

Table 1 presents the ANOVA results for the TOL of face-worn products, considering the effects of face-worn product category, headform, donning, and their interactions. The analysis followed standard procedures for ANOVA, with statistical significance determined at the P value < .05 level. The study revealed a statistically significant difference in the TOL of different face-worn product categories. Headform size was also found to have a significant impact on the TOL. However, the analysis did not reveal any significant effect on the TOL for the interaction between face-worn product category and headform size. In addition, the TOL did not differ by donning or other interactions.

Table 1
The ANOVA results of TOL as face-worn product category, headform, donning, and their interactions

Source	DF	SS	MS	F	*P* value
Category	8	22,574.85	2,821.856	99.3597	< .0001*
Headform	1	361.925	361.925	12.7437	.0006*
Category*Headform	8	246.75	30.844	1.086	.3802
Donning	4	28.649	7.162	0.2522	.9076
Category*Donning	32	457.002	14.281	0.5029	.985
Headform*Donning	4	47.102	11.776	0.4146	.7977
Category*Headform*Donning	32	335.739	10.492	0.3694	.9989

DF, degrees of freedom in the source; *F*, F-statistic; *MS*, mean sum of squares due to the source; *SS*, sum of squares due to the source; *TOL*, total outward leakage.
*There is a statistically significant difference.

Figure 2 presents the TOL of each face-worn product on the 2 different headform sizes, without accounting for the donning effects. Overall, the Figure 2 reveals that the nonwoven masks performed better than the cloth masks. Depending upon the mask model, the nonwoven masks ranged from 10% to 38% TOL. Depending upon the model and headform size, the cloth mask TOL values ranged from 36% to 58%.

Table 2 presents the mean MFF and mean TOL of each face-worn product category. The Student t test based on the results of ANOVA compared the TOL of each product category. The mean TOL values in Table 2 decreased with the ascending order of superscript letters, where the values not connected by the same letter are significantly different. The single-layer cloth masks exhibited the highest mean TOL of 52.3%. The ASTM F2100 level 2-compliant masks displayed a notably lower mean TOL of 16.4%. The mean TOL values for 3-layer disposable face masks, as well as ASTM-compliant level 1 and level 3 masks, were relatively similar, falling within the range of approximately 27.4% to 35.4%. The CMP face-worn products with HEPA or PM 2.5 filter inserts displayed a similar mean TOL within the range of 40.9% to 49.3%. The TOL exhibited a slight increase when the filters were removed for both CMP face-worn product types.

Table 3 presents the mean TOL for different models of face-worn products within each category. Notably, 2 categories exhibited significant variations between models. In the category of CMP for PM 2.5 without a filter, model #15 and model #16 had TOL values of 49.0% and 44.6%, respectively, showing a significant difference. Similarly, in the category of ASTM-compliant level 2 masks, model #3 and model #4 had significantly different TOL values of 11.6% and 21.2%, respectively. Other categories, however, showed consistent TOLs between different models.

On average, the TOL of face-worn products on the medium headform exhibited a higher value of 39.9% than those on the large headform with a value of 37.1%. However, some face-worn products, such as CMP for PM 2.5 with filter model #11, CMP for PM 2.5 without filter model #16, and 3-layer disposable face mask model #9, had a lower TOL of 36.5%, 43.1%, and 32.7%, respectively, when used on the medium headform as compared with 43.3%, 49.2%, and 33.0% on the large headform.

DISCUSSION

In this study, we assessed various categories of face-worn products, including masks compliant with ASTM F2100 (levels 1, 2, and 3), single-layer cloth masks, 3-layer disposable face masks, CMPs for HEPA filters (tested with and without filter inserts), and CMPs for PM 2.5 filters (tested with and without filter inserts). Unlike previous methods that only measured filtration efficiency of fabric or filter

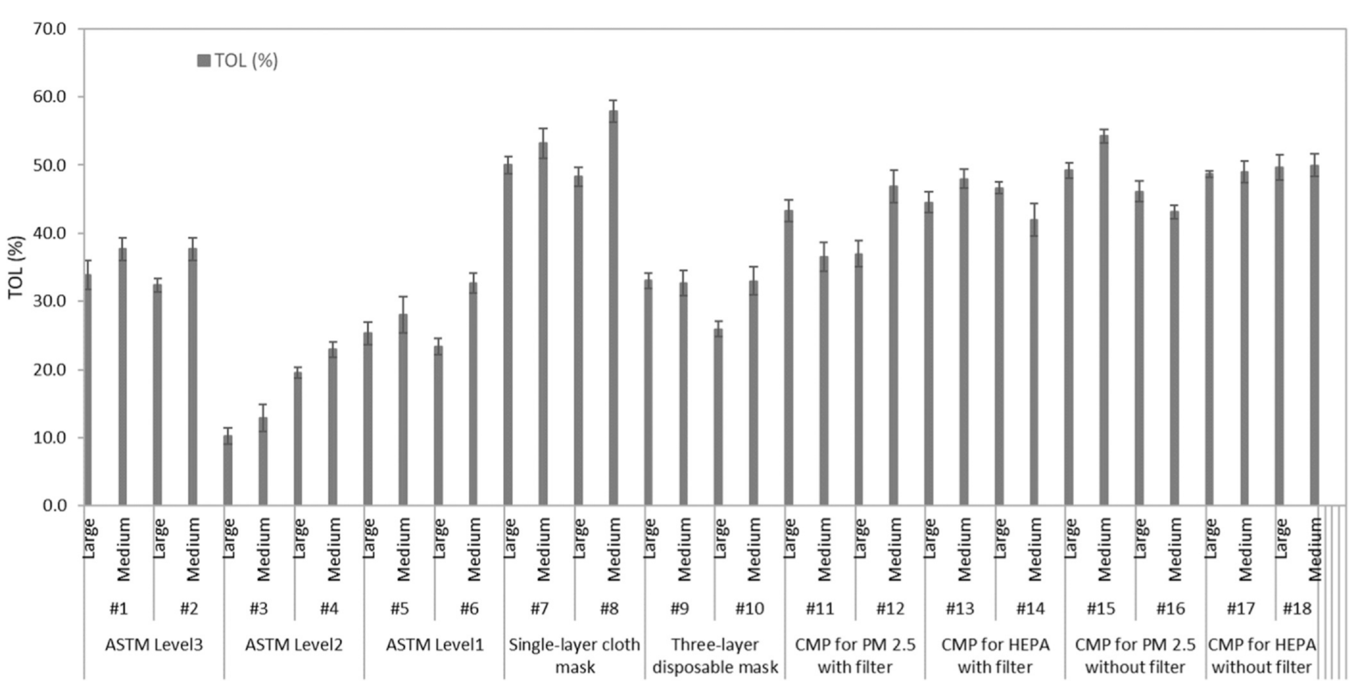

Fig. 2. The mean TOL of each face-worn product on 2 headforms with different sizes across 5 donnings. Each error bar is constructed using 1 standard error from the mean. ASTM, American Society for Testing and Materials; CMP, cloth mask featuring a pocket; PM, particulate matter; TOL, total outward leakage.

Table 2
The TOL of different categories of the face-worn product

Category	n	TOL			
		Mean	SD	Lower 95%	Upper 95%
Single-layer cloth mask	20	52.3%^{A}	5.1%	50.0%	54.7%
CMP for HEPA without filter	20	49.3%^{AB}	3.2%	47.8%	50.8%
CMP for PM 2.5 without filter	20	48.2%^{BC}	4.8%	45.9%	50.4%
CMP for HEPA with filter	20	45.3%^{C}	4.1%	43.4%	47.2%
CMP for PM 2.5 with filter	20	40.9%^{D}	6.2%	38.0%	43.8%
ASTM-compliant level 3	20	35.4%^{E}	4.1%	33.4%	37.3%
Three-layer disposable face mask	20	31.2%^{F}	4.5%	29.0%	33.3%
ASTM-compliant level 1	20	27.4%^{G}	5.2%	24.9%	29.8%
ASTM-compliant level 2	20	16.4%^{H}	5.9%	13.7%	19.2%

NOTE. Levels not connected by same letter are significantly different.
ASTM, American Society for Testing and Materials; *CMP*, cloth mask featuring a pocket; *HEPA*, high efficiency particulate air; *PM*, particulate matter; *TOL*, total outward leakage.

material, this study evaluated the TOL for different face-worn product categories as a function of headform size and repeated donning.

This study observed that TOL of face-worn products significantly depends on the face-worn product model and the test headform size (medium or large); however, the study did not establish a significant impact of donning on TOL. When the same face-worn product was placed on the headform multiple times, there was no observable change in the TOL, implying the product units have some level of reusability.

It should be noted that the ASTM-compliant level 3 masks, which were expected to have comparable TOL to the level 2 masks because of the same designed filtration efficiency (≥ 98%) according to ASTM F2100,[15] actually exhibited a higher mean TOL (35.40%) compared with ASTM-compliant level 2 (16.43%) masks. This may be due to a poor manikin fit of the ASTM-compliant level 3 masks tested in this study, which may because of design, material, size, and so on. Another plausible explanation is that the high filtration efficiency of ASTM-compliant level 3 masks could have contributed to increased breathing resistance, potentially resulting in a less-effective faceseal.

This study revealed that CMPs with filters outperformed single-layer counterparts in reducing TOL, and the incorporation of PM 2.5 and HEPA filters resulted in only marginal enhancements to their source control capabilities. Similarly, adding filters to CMP face-worn products was found to reduce particulate exposure.[26] The source control ability of CMP for HEPA with filters inserted (TOL = 40.91%) and CMP for PM 2.5 with filters inserted (TOL = 45.27%) did not correspond to the high filtration efficiency of these filters. Theoretically, HEPA filters can remove ≥ 99.97% of 0.3-µm particles.[36] Cherrie et al[27] reported that CMPs with PM 2.5 filters inserted had a penetration of 3% to 5% when completely sealed.

The single-layer cloth masks had an average TOL of 52.3%, which is similar to the previously reported TOL of single-layer gaiters ranging from 44.2% to 64.7%.[21] High outward leakage through single-layer cloth masks raises concerns about their effectiveness for source control.

Additionally, the study observed the effect of headform size on TOL. This study found that for the face-worn products examined in this study, there was lower TOL when placed on the large headforms than when placed on medium headforms on average. This observation could be attributed to the greater contact surface area between the face-worn products and the larger headform, leading to an improved faceseal. However, some models had more TOL on the medium headform than on the large headform. This variation among different models in fitting different facial sizes may result from a lack of standardization in design and manufacturing, which also may lead to the significant difference among models within the same category.

It should be noted that this study had certain limitations. First, the sample size within each category was limited, which may impact the ability to fully understand the variability among different manufacturers for face-worn products not compliant to ASTM F2100. To obtain a more comprehensive understanding of this variability, a larger sample size should be considered in future studies. This limitation may affect the evaluation of real-world performance of face-

Table 3
The mean TOL of different models within each category of the face-worn product

Model within each category	n	Mean	SD	Lower 95%	Upper 95%
[Single-layer cloth mask] #8	10	53.1%^{A}	6.0%	50.3%	55.8%
[CMP for PM 2.5 without filter] #15	10	51.7%^{AB}	3.4%	49.0%	54.5%
[Single-layer cloth mask] #7	10	51.6%^{AB}	4.1%	48.8%	54.4%
[CMP for HEPA without filter] #18	10	49.8%^{ABC}	2.5%	47.1%	52.6%
[CMP for HEPA without filter] #17	10	48.8%^{BC}	3.8%	46.1%	51.6%
[CMP for HEPA with filter] #13	10	46.2%^{CD}	3.6%	43.5%	49.0%
[CMP for PM 2.5 without filter] #16	10	44.6%^{DE}	3.1%	41.8%	47.4%
[CMP for HEPA with filter] #14	10	44.3%^{DE}	4.5%	41.5%	47.1%
[CMP for PM 2.5 with filter] #12	10	41.9%^{EF}	7.0%	39.1%	44.7%
[CMP for PM 2.5 with filter] #11	10	39.9%^{F}	5.4%	37.1%	42.7%
[ASTM-compliant level3] #1	10	35.8%^{G}	4.5%	33.0%	38.6%
[ASTM-compliant level3] #2	10	35.0%^{G}	4.0%	32.2%	37.8%
[Three-layer disposable mask] #9	10	32.9%^{GH}	3.2%	30.1%	35.6%
[Three-layer disposable mask] #10	10	29.5%^{HI}	5.1%	26.7%	32.2%
[ASTM-compliant level1] #6	10	28.0%^{I}	5.6%	25.3%	30.8%
[ASTM-compliant level1] #5	10	26.7%^{I}	4.9%	23.9%	29.4%
[ASTM-compliant level2] #4	10	21.2%^{J}	2.8%	18.5%	24.0%
[ASTM-compliant level2] #3	10	11.6%^{K}	3.7%	8.8%	14.4%

NOTE. Levels not connected by the same letter are significantly different.
ASTM, American Society for Testing and Materials; *CMP*, cloth mask featuring a pocket; *HEPA*, high efficiency particulate air; *PM*, particulate matter; *TOL*, total outward leakage.

worn products and should be taken into consideration when interpreting the results of this study. Furthermore, this study only simulated a normal breathing condition, which may not fully represent real-world situations such as coughing or sneezing by users. Further studies incorporating different breathing work rates that more closely mimic actual user behaviors are warranted to provide a more comprehensive understanding of the effectiveness of face-worn products for source control. Moreover, the performance of face-worn products for source control was not examined when placed on the complete set of 5 ISO static-advanced headform sizes due to limited budget and time.

CONCLUSIONS

This study assessed the TOL of various categories of face-worn products, including masks compliant with ASTM F2100 standards (levels 1, 2, and 3), single-layer cloth masks, 3-layer disposable face masks, and cloth masks with pockets with and without PM 2.5 and HEPA filters. Our study also examined the impacts of differently sized headforms and repeated donning practices on the TOL.

Each category of face-worn product had a significantly different TOL. ASTM-compliant level 3 masks unexpectedly exhibited higher TOL than Level 2 masks, indicating the importance of fit. ASTM-compliant masks performed comparably with SMs. Three-layer disposable face masks not compliant with ASTM F2100e showed promise, with TOL rates comparable to ASTM 2100-compliant level 1 masks. The insert of filters to CMPs provided marginal improvement in reducing TOL. Single-layer cloth masks should be selected with caution as a source control measure for reducing airborne transmission of virus-laden aerosols, given the high total TOL observed in this study.

In this study, repeated donning was not found to affect the TOL. However, the study showed that headform size was a significant factor for TOL, thus implying that masks used for source control may need to be made in multiple sizes to accommodate different facial sizes. Future research should address the study limitations for a more comprehensive understanding of face-worn products' efficacy for source control.

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

ATTRIBUTION

N95 and National Institute for Occupational Safety and Health-Approved are certification marks of the US Department of Health and Human Services registered in the United States and several international jurisdictions.

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