

Characteristics Associated With Health Care Worker Knowledge and Confidence in Elastomeric Half-Mask Respirator Use

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Objective: This study evaluated health care workers' (HCWs') knowledge and confidence in using elastomeric half-mask respirator (EHMR) attributes known to influence usage. **Methods:** Health care workers were surveyed regarding their EHMR donning and doffing experience. Respondents were categorized into competency categories based on their scores. Category differences were analyzed using χ^2 and multiple logistic regression. **Results:** Seventy-two percent showed high levels of EHMR donning and doffing knowledge and confidence (mastery); however, 21% had greater confidence than knowledge (misinformed). Respiratory therapists had greater odds of mastery than other HCWs ($P < 0.05$), whereas those working in medical/surgical and pediatric units had greater odds of doubt than other HCWs ($P < 0.01$). **Conclusions:** Although most HCWs show high knowledge and confidence with EHMR use, strategies to confirm respirator use competency may ensure greater HCWs protection.

Keywords: elastomeric respirator, respiratory protection, health care workers, training, confidence, knowledge, reusable respirator, airborne precautions, COVID-19

With each of the 21st century's infectious disease pandemics, health care respiratory protection needs grew exponentially quickly, depleting the supply of disposable respirators in common use, such as N95 filtering facepiece respirators (N95 FFRs).¹⁻³ Many hospitals deployed reusable elastomeric half-mask respirators (EHMRs) or facepiece respirators often for the first time, to fill or augment their respirator supplies.⁴ These respirators can be equipped with filters capable of filtering 95% of airborne particles such as N95 FFRs do or, with more highly efficient filters, able to filter even more. Because EHMRs

carry the same assigned protection factor as disposable N95 FFRs (assigned protection factor, 10), hospitals quickly trained and fit tested their employees for these types of respirators despite their uncommon use in health care previously.⁵

Regardless of respirator type, health care workers (HCWs) must undergo initial and then annual respirator training and fit testing (for tight-fitting respirators), in accordance with the US Occupational Safety and Health Administration Respiratory Protection Standard (29 CFR 1910.134). Pompeii et al.⁶ found that HCWs could rapidly undergo fit testing and training to use EHMRs. The researchers reported that the time to achieve fit was not significantly different than with N95 FFRs and that performance scores for use were high. These results suggested that HCWs could competently use EHMRs, even though HCWs might find their style to be unfamiliar.

Competent use of any respirator requires accurate knowledge and ample confidence in the process of donning and doffing. Failure in this process may result in an inadvertent exposure to a respiratory hazard, leading to further spread of disease, missed time at work for critical employees during a respiratory-related pandemic, potential disease sequelae, or even death.^{7,8} According to psychology research, confidence in performing a skill does not necessarily match one's ability to perform the skill, especially for those in the lower quartiles of performance.^{9,10} People systematically overestimate their abilities and are unable to recognize that their performance is poor, because they lack the knowledge to judge, whether they are correct or incorrect, which is termed the Dunning-Kruger effect.^{9,10} To evaluate this effect, both knowledge and the confidence in that knowledge must be considered.

Knowledge contains two components: an understanding of information and the ability to act on that information. Both must be considered when evaluating how individuals acquire, retain, and manage knowledge to perform tasks safely and effectively.¹¹ In addition, an individual must be confident enough so that the knowledge can be used to make decisions, solve problems, and select/execute actions. The confidence in being correct is required to qualify as knowledge. This confidence may differ depending on the importance of the consequences for being incorrect.¹¹ Both the individual's correctness in one's knowledge and one's confidence in this correctness allow for a two-dimensional information-referenced assessment (Fig. 1), creating categories^{12,13} that may assist in determining who has the requisite knowledge and confidence to perform and who needs remediation or validation.

In prior literature, nurses in general reported more correct EHMR practices than other HCWs.¹⁴ Because HCWs working in emergency and critical care areas perform greater numbers of aerosol-generating procedures,¹⁵ their confidence may be bolstered because of increased respirator use. Job role and setting, frequency of use, and training should be considered to determine their influence in HCW knowledge and confidence in respirator donning and doffing.

From a larger study about hospital EHMR use, the purpose of this article is to evaluate HCW knowledge of EHMR donning and doffing steps and their confidence in EHMR donning and doffing. We used data from a larger survey of HCW perceptions about EHMR use to examine this relationship. We also examined how job category,

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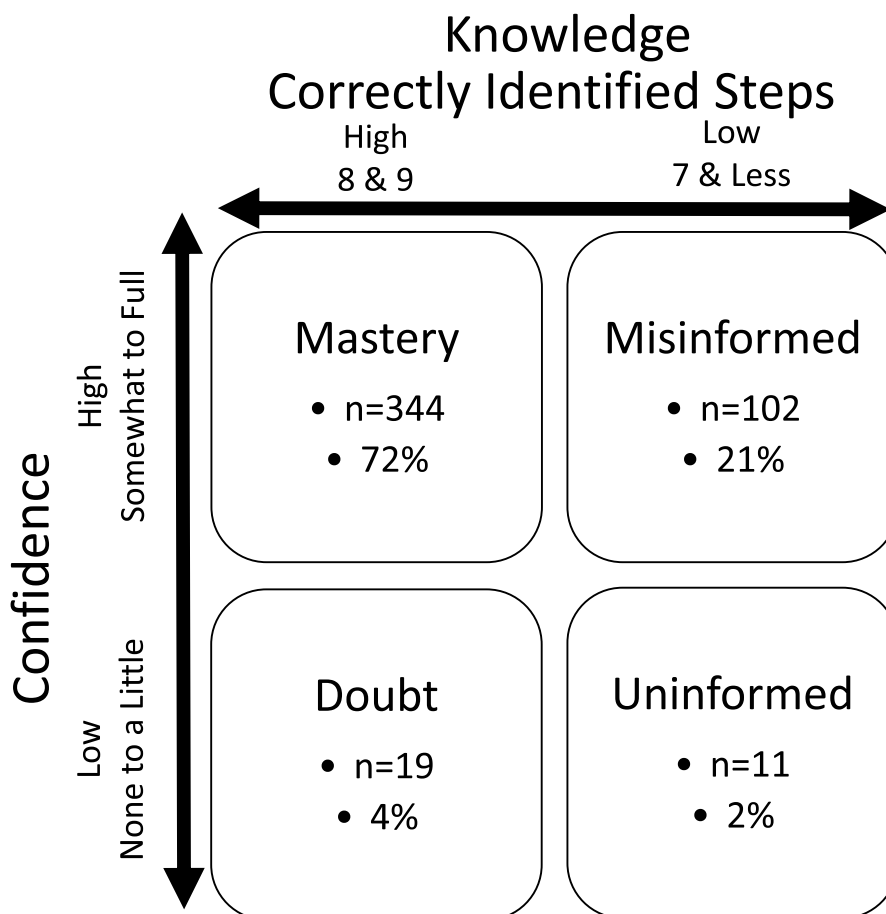


FIGURE 1. A two-dimensional information-referenced assessment of an individual's correctness in their knowledge and their confidence in this correctness of EHMR donning and doffing.

work environment, and frequency of EHMR usage significantly influenced this relationship.

METHODS

Sample and Setting

We conducted this survey in April 2021 (during the US public health emergency declaration for COVID-19) at an academic medical center that employs more than 9000 employees. These employees included 1300 faculty physicians and 950 residents. This center admits more than 26,000 patients annually into its 800 beds, which includes a pediatric and neonatal critical care unit and six adult critical care units. Health care units at this facility are only permitted to use the respirators they have been trained to use and for which they have undergone fit testing (for tight-fitting respirators). During this time, HCWs were required to wear respiratory protection during any aerosol-generating procedure or while caring for a patient on airborne or enhanced droplet precautions.¹⁶ Via email invitation, we recruited participants to complete the survey from the medical center's respirator dispensing database list of 2419 employees who were fit tested and using EHMRs. Health care workers could also complete the survey via a tablet computer, which was brought to units with high respirator use. Respondents were surveyed between 8 and 12 months after their fit test and training; all had received the same training in the donning and doffing process. Those who completed the survey were provided an electronic \$20 gift card. The survey closed when it reached 480 completions. This sample size was determined based on a goal to sample

approximately 20% of the eligible participants and have 80% power, with an α of 0.05 to classify user comfort ratings with an effect size as measured by Hines et al,¹⁴ combined with budget for participant payments. The University of Maryland, Baltimore Institutional Review Board, approved this study (HP-00094424, January 26, 2021).

Measures

HCW EHMR Survey

A 55-question survey assessing current HCW EHMR use, perceptions, and practices was designed in the fall of 2020. The survey incorporated questions from prior respirator use surveys and new questions tailored to assess hospital-specific practices.¹⁷⁻¹⁹ Participants responded to questions about their education level, years of service, role, work setting, methods of respirator training and their perception of adequacy, and donning/doffing steps and confidence. The questionnaire was designed to be completed in 10 to 20 minutes and was administered using the REDCap platform.^{20,21}

Assessment of EHMR Confidence and Knowledge

Health care workers were asked to rate their confidence in donning and doffing an EHMR on a four-point Likert-like scale. This scale included fully confident (can do correctly every time), somewhat confident (can do correctly most of the time), a little confident (can do correctly less than 50% of the time), and not confident at all (can do correctly less than 25% of the time). Confidence score was dichotomized to low and high to facilitate creating a knowledge and confidence matrix and to maximize the number of participants in each cell

TABLE 1. Demographics

	n (480)	%
Time in current profession		
<1 y	47	10
1–2 y	67	14
2–4 y	140	29
≥ 5 y	226	47
Education level		
Associate education or degree	41	9
4-y college degree	225	47
Graduate degree	182	38
Other	29	6
Clinical unit or area (may include more than one)*		
ICU	290	60
ED	72	15
Pediatrics	63	13
Medical/surgical	146	30
OR	78	16
Other	119	25
Job title		
Physician, physician assistant, nurse practitioner	95	20
Nurse	255	53
Nursing or patient care assistant	29	6
Respiratory therapist	26	5
Technologist, therapist	27	6
Other	46	10
Frequency of EHMR use during shift		
0–1 time	161	34
2–5 times	161	34
5–10 times	88	19
>10 times	62	13
Percent of time respirator worn during shift		
<25%	254	53
25–50%	148	31
50–75%	51	11
>75%	23	5

*Percentages will sum >100% because respondents could select multiple types of clinical units.

ED, emergency department; EHMR, elastomeric half-mask respirator; ICU, intensive care unit; OR, operating room.

for analysis. Those who rated their confidence as a little confident or not confident at all were given a low confidence rating, whereas those who rated their confidence as somewhat or fully confident were given a high confidence rating.

Health care workers were also asked to select the steps included in donning and doffing an EHMR. Each respondent received one point for each step that was correctly selected. These items were adequately related to each other with a Cronbach α of 0.75; thus, these points were summed, providing a score ranging from 0 to 9. This total score was dichotomized to high and low knowledge with a cut point at eight. Because improper respirator use could result in failed respiratory protection, we required a higher score for classification into the “high knowledge.” Those with total scores of 0 to 7 were given a low knowledge rating, and those who scored 8 or 9 were given a high knowledge rating.

Respondents were grouped into the four knowledge-confidence categories using these dichotomized ratings as follows: those with high confidence and high knowledge ratings were assigned to the mastery group; low confidence and high knowledge ratings—doubt category; high confidence and low knowledge ratings—misinformed category; and low confidence and low knowledge ratings—uninformed category.

Analysis

Demographics, respirator training, knowledge, and confidence were analyzed using frequencies, medians, and means. Four partici-

pants had missing knowledge and confidence scores, leaving 476 surveys for analysis. Comparisons between the knowledge-confidence categories and the respondents' roles and unit types were conducted with Fisher exact test because of small cell sizes. Statistical analyses were limited by low cell counts using the knowledge-confidence categories. The mastery, misinformed, uninformed, and doubt categories were analyzed separately using logistic regression by job role, unit type, training, and percentage of time the EHMR was worn during the shift as predictors in both bivariate and multivariate analyses. Respondents were able to select multiple unit types in this survey. For comparisons, unit types were collapsed in a prioritized scheme, meaning that those in the “other” category only selected “other,” and those who selected “other” and medical/surgical and pediatrics were categorized to medical/surgical and pediatrics. Those participants who selected intensive care or emergency were categorized as intensive care or emergency regardless of any other unit, which was selected. In each analysis, mastery was compared with the others, misinformed was compared with the others, uninformed was compared with others, and doubt was compared with the others. The analyses were conducted using IBM SPSS Statistics for Windows version 23 (IBM Corp, Armonk, NY).

RESULTS

Most respondents (Table 1) had worked in their current profession 5 years or more (47%) and had a 4-year college degree (47%). More than half of respondents were also nurses (53%) and worked in an intensive care unit (60%). Most respondents reported that they usually wear an EHMR less than 5 times per shift (68%) and less than 50% of their total shift duration (84%). Note that, because this survey was taken during a public health emergency that increased the usage of respiratory protection, results cannot be generalized for a non-public health emergency situation.

Knowledge and Confidence

In the steps for EHMR donning (Table 2), all participants correctly identified that the respirator should be correctly positioned on the face. Proper hand hygiene before use, correctly placed straps, and user checks seals were correctly identified by 96%, 94%, and 92%, respectively. Proper hand hygiene after use and no facial hair under seal were the two steps most frequently not selected (80% and 71%, respectively). In the steps for EHMR doffing, proper hand hygiene after use was most frequently selected, followed by removed properly (using straps), and then proper hand hygiene before use (93%, 89%, and 86%, respectively). The overall median knowledge score was 8.5 (interquartile range, 1) ranging from 0 to 9. Fifty percent of the respondents correctly identified all nine steps in EHMR donning/doffing, with another 26% correctly identifying eight of the

TABLE 2. Knowledge in EHMR Donning/Doffing Steps

Survey Question	Survey Choices	Point	n (480)	%
Do you routinely perform the following steps in donning? (check all that apply)	Proper hand hygiene before use?	1	460	96
	Positioned correctly on face?	1	480	100
	No facial hair under seal?	1	340	71
	Straps correctly placed?	1	451	94
	User seal checked?	1	441	92
Do you routinely perform the following steps in doffing? (check all that apply)	Proper hand hygiene after use?	1	386	80
	Proper hand hygiene before use?	1	415	86
	Removed properly (used straps)?	1	429	89
	Proper hand hygiene after use?	1	447	93
Total score			9	

EHMR, elastomeric half-mask respirator.

TABLE 3. Confidence in EHMR Donning/Doffing

Survey Question	Survey Choices	Point	n (480)	%
How confident are you with donning and doffing the EHMR?	Fully confident (can do correctly every time)	3	255	53
	Somewhat confident (can do correctly most of the time)	2	191	40
	A little confident (can do correctly less than 50% of the time)	1	27	6
	Not confident at all (can do correctly less than 25% of the time)	0	3	1

EHMR, elastomeric half-mask respirator.

nine steps, leaving 24% correctly identifying seven or fewer steps. In rating their confidence (Table 3), 54% of respondents rate themselves as fully confident (can do correctly every time) in EHMR donning/doffing. Forty percent of respondents rated themselves as somewhat confident (can correctly do most of the time), leaving 6% rating themselves with a little (can do correctly less than 50% of the time) to no confidence in EHMR donning/doffing.

Knowledge-Confidence Matrix

Using the knowledge-confidence matrix (Fig. 1), most HCWs (72%) had mastery of EHMR donning and doffing, falling into the upper left quadrant, indicating both high knowledge and high confidence. The next largest category, 21% (n = 102) were misinformed, falling into the upper right quadrant, indicating high confidence with low ability to correctly identify the steps in EHMR donning and doffing. The smallest numbers of HCWs fell into the lower quadrants, indicating doubt (n = 19 [4%]) or being uninformed (n = 11 [2%]). In comparing the unit types (Table 4), those working in medical/surgical and pediatric units (13%) had significantly (P < 0.01) more doubt than those working in intensive care units and the emergency department (2%). Those working in the intensive care units and emergency department had slightly more mastery of EHMR donning/ doffing. There was no statistically significant difference in the proportion of the four knowledge-confidence categories by the respondents' roles (P > 0.05).

Respondents in respiratory therapy roles were 3.6 times more likely (95% confidence interval [CI], 1.03–20.3; P < 0.05) of being in the mastery category than any other category compared with nurses, controlling for unit type, self-reported adequacy of training, or percentage of time the EHMR was worn. Respondents in the nursing role and the provider role were nearly 9 times and 7 times more likely (95% CI,

1.2–75 and 1.1–63, respectively; P < 0.05) than respiratory therapists to be in the misinformed category compared with respiratory therapists, controlling for unit type, self-reported training adequacy, and percentage of time the EHMR was worn. Respondents who reported working primarily in medical/surgical and pediatric settings were nearly 7 times more likely (95% CI, 2.5–25; P < 0.001) to be in the doubt category than those who reported any primary work in intensive care unit and emergency department settings. Those who reported their training as being inadequate were nearly 5 times more likely (95% CI, 1.2–21; P < 0.05) of being in the uninformed category than those who reported it as being adequate.

DISCUSSION

Competent use of a respirator is vital to any respiratory protection program. In this study, although most HCWs (72%) showed mastery of EHMR donning and doffing, 21% were misinformed. These misinformed HCWs are at risk of incorrectly using their respirator, which could lead to inadequate protection. Moreover, they would not recognize the potential for exposure according to the Dunning-Kruger effect, which could place them and health care systems, including patients, at increased risk for occupational or nosocomial illness, worsening pandemic case counts, and even death. Also seen in this study, frequency of EHMR use had no relationship on participants' knowledge of EHMR donning and doffing or confidence. This may reflect a practice of HCWs repeating errors that become ingrained following initial incorrect use on the job.

The Dunning-Kruger effect is not new to health care settings. A study demonstrating this effect among gastroenterologists, for example, led the American Society for Gastrointestinal Endoscopy to develop recommendations for privileging and credentialing endoscopy.²² Another study among radiologists showed the Dunning-Kruger effect during interpretation of chest x-rays,²³ leading to minimal competency requirements for credentialing and training programs. Similarly, a study of 255 HCWs from five different institutions showed overconfidence in basic proficiencies of infection control and protocol adherence, potentially placing patients at risk for hospital-acquired infections.²⁴

Others have found discordance between knowledge and confidence with respirator use. In a multicenter, multiseason, cluster randomized clinical trial,²⁵ HCWs' knowledge of infection control practices related to respiratory protection during influenza season was poor. A study of coal miners in Ukraine²⁶ estimated that, under normal conditions, the probability of failure in the use of a respirator by the end of a work shift was up to 20%; however, under emergency conditions, this probability increased to 50%. Lack of training on proper respirator use and donning and doffing was cited as the reason for failure.

Current practice at this and likely many other institutions is annual concurrent training when the HCW is fit tested with no further

TABLE 4. Knowledge-Confidence Grouping by Unit Type and Role

	Mastery		Misinformed		Uninformed		Doubt	
	n = 344 (72%)		n = 102 (21%)		n = 11 (2%)		n = 19 (4%)	
	n	%*	n	%*	n	%*	n	%*
Unit								
Critical care and emergency	222	74	66	22	5	2	6	2
Medical/surgical and pediatrics	45	64	15	21	1	1	9	13
Other	77	72	21	20	5	5	4	4
Role								
Nursing	199	70	67	24	6	2	11	4
Providers	64	70	24	26	1	1	3	3
Respiratory therapy	24	92	1	4	0	0	1	4
Other	56	76	9	12	4	6	4	6

*Percentage of row total.

validation of competence.^{17,27} In this survey, the respondents who fall within the categories outside of mastery need validation, education, or remediation. Those in the doubt category have adequate knowledge but may lack the confidence in EHMR donning and doffing, which may be remedied with additional validation. Those in the uninformed category have inadequate knowledge and confidence in EHMR donning and doffing and need basic education. Those in the misinformed category have inadequate knowledge but have the confidence to use the EHMR. These individuals will need remediation to correct errors in the steps of EHMR donning/doffing with validation.

Mechanisms for enhanced respirator training and use performance could include uncoupling of training from fit testing; use of on-line education followed by in-person performance validation, similar to HCWs' cardiopulmonary resuscitation training; or periodic practical evaluation using a checklist.⁶ This latter strategy mirrors the American Board of Internal Medicine's Mini-Clinical Evaluation Exercise tool used to assess physician-patient interactions and skills and provide feedback among trainees in US postgraduate training programs.²⁸ Identifying error-prone steps and key sites of self-contamination during donning and doffing of personal protective equipment may be used to target areas needing further training.^{29,30} These findings further support a need for validation of competence in respiratory protection practices followed by additional training, if warranted.^{17,27}

This study has several limitations. The sample size reflects the opinions of 20% of those who have been fit tested to use EHMRs. This was a self-report survey with hospital employees, which may have influenced their responses regarding their confidence in EHMR donning and doffing. However, the survey was conducted by research faculty and not hospital administration, which may have lessened participants' concerns about employer oversight. Another limitation regarding the interpretation of the survey responses was facial hair. We assessed lack of facial hair under EHMR seal as a critical knowledge point associated with donning and was the step most frequently missed (29% failed to select). Females without facial hair may not have selected this response, believing it to be not applicable, which may contribute to a score error. In our analysis, these individuals would not have acquired an optimal nine-point knowledge score. However, by allowing participants scoring 8 to be categorized in the high-knowledge category, we believe that these individuals would still be classified appropriately, as they would have answered all other seven questions correctly. Further research is needed regarding the relationship of HCW knowledge and confidence and how to accurately identify those HCWs who need additional training.²⁵

By comparison, HCWs who use N95 FFRs often affirm knowing how to don and doff their respirators, yet they often do not report correct practice.^{17,31–33} In one study, for example, 54% to 57% reported performing a user seal check, which is an expected practice for using N95 FFRs.³³ Similarly, in a direct observation study of US HCWs using N95 FFRs, only 15.5% performed a user seal check, 54.6% placed the straps correctly, 43.3% used the straps to remove the respirator, and 55.3% properly disposed of the respirator.¹⁷ Furthermore, EHMR users have previously reported higher confidence in protection compared with N95 FFR users.¹⁹ Altogether, greater EHMR user knowledge and confidence may promote a more fault-tolerant use practice in comparison to N95 FFRs.³⁴

CONCLUSIONS

The implications of this study are that a minority of HCWs may feel confident enough to use an EHMR but may not have the requisite knowledge to perform the task correctly. More concerning, the unawareness of these HCWs that they are performing these tasks incorrectly may leave them open to exposure. Identification of HCW knowledge-confidence category could help identify opportunities for cross training between those with mastery and those who are misinformed, uninformed, or with doubt. In addition, using HCW knowledge-

confidence categories could identify roles or units that require targeted education to bolster knowledge or confidence. Future efforts should focus on strategies to evaluate EHMR donning and doffing knowledge and competency, particularly regarding absence of facial hair, user seal check performance, positioning on the face, removing with straps, and performing hand hygiene.

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