

Discomfort and Exertion Associated with Prolonged Wear of Respiratory Protection in a Health Care Setting

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The nature of discomfort and level of exertion associated with wearing respiratory protection in the health care workplace are not well understood. Although a few studies have assessed these topics in a laboratory setting, little is known about the magnitude of discomfort and the level of exertion experienced by workers while they deliver health care to patients for prolonged periods. The purpose of this study was to determine the magnitude of discomfort and level of exertion experienced by health care workers while wearing respiratory protection for periods up to 8 hr when performing their typical occupational duties. This project was a multiple cross-over field trial of 27 health care workers, aged 24–65, performing their typical, hospital-based occupational duties. Each participant served as his/her own control and wore one of seven respirators or a medical mask for 8 hr (or as long as tolerable) with interposed doffing periods every 2 hr. Self-perceived discomfort and exertion were quantified before each doffing: self-perceived level of discomfort using a visual analog scale, and self-perceived level of exertion using a Borg scale. Overall, and as would be expected, discomfort increased over time with continual respirator use over an 8-hr period. Interestingly, exertion increased only marginally over the same time period. The relatively low level of exertion associated with eight respiratory protective devices, including models commonly used in the U.S. health care workplace, is not likely to substantially influence workers' tolerability or occupational productivity. However, the magnitude of discomfort does appear to increase significantly over time with prolonged wear. These results suggest that respirator-related discomfort, but not exertion, negatively influences respirator tolerance over prolonged periods. Discomfort may also interfere with the occupational duties of workers.

Keywords discomfort, exertion, health care, respirator, tolerance, workers

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INTRODUCTION

There is widespread debate about the best and most appropriate types of respiratory protection that health care workers (HCWs) should don during influenza and other infectious disease outbreaks.^(1–5) Recent reports^(1,6) of HCWs' experiences when responding to disease outbreaks have suggested that some respirators may not be well tolerated, especially among workers who are not accustomed to wearing them for extended periods. Problems with respirator tolerability have been attributed to overall discomfort;^(6–10) diminished visual,^(8,11,12) vocal,^(11,12) or auditory⁽¹¹⁾ acuity; excessive humidity⁽⁷⁾ or heat;^(7,10,12,13) headaches,^(6,14) facial pressure;⁽⁷⁾ skin irritation or itchiness;^(6,7,12,13) excessive fatigue or exertion;^(6,7,9,10,12,13) malodorousness;^(7,10) anxiety or claustrophobia;^(6,13,15,16) and other interferences with occupational duties.^(10,17–19) However, few studies have formally field tested the tolerability of respirators commonly worn by HCWs⁽¹⁾ who may be called on to wear respiratory protection in extreme scenarios for the duration of their work shifts during a large-scale infectious disease outbreak.^(5,20,21) The likelihood of U.S. health care workers tolerating respirators for 8 or more hours

per day over the days and weeks of an evolving outbreak is unknown.

While infection control guidelines^(2,5,20,22) call for discarding disposable respirators after each patient contact, recent experiences during the 2009 H1N1 pandemic suggest that this approach may not be plausible. Limited supplies, production capabilities, and financial resources may require respirator rationing.^(20–24) During an outbreak, one way to decrease costs and extend the usable period of respirators might be to cover each disposable respirator with a medical mask that would be discarded after close patient contact.⁽²²⁾ However, this approach has the potential to affect the seal to the face and might alter respirator discomfort or exertion necessary to breathe through the device.⁽²⁵⁾ Another way to decrease costs is to use reusable respirators. An improved understanding of the factors affecting tolerability in extreme respirator use scenarios could provide evidence-based recommendations about respirator selection and use.

METHODS

Subjects

This study was approved by the North Florida/South Georgia Veteran Affairs Medical Center (VAMC) institutional review board and research oversight committees. Twenty-seven volunteers (mean age, 48 years [SD, 11 years; range 25–65 years]; 15 women) participated in the study (Table I). To be included, participants must have previously worn a respirator in the context of their occupational duties, making them accustomed to wearing N95 filtering facepiece respirators (FFR). Participants with systemic disease or pregnancy were excluded from the study. All participants were non-smokers. The sample

comprised 16 nurses, 2 nurse practitioners, 4 nurse technicians, 2 telemetry technicians, 2 respiratory therapists, and 1 clerical assistant from the intensive care unit (15), emergency department (6), and medical/surgical ward (6). Each participant was provided written informed consent. Each participant also underwent a pre-participation examination (OSHA form and brief history and physical) and was fit tested for each respirator worn in the study. All subjects were instructed to simulate the circumstances of an airborne-transmissible disease outbreak (e.g., influenza pandemic) in which their use of a respirator for the duration of their work shift would be necessary.

Apparatus

The respirator models most commonly used by the study centers were selected for inclusion and were acknowledged as commonly used models in many Veterans Health Administration hospitals and clinics across the United States (V. Wilkes, Department of Veterans Affairs, Washington, D.C., July 15, 2008, pers. comm.). The following ensembles were included: Medical Mask (MM); Duckbill N95 (DB); Cup N95 (N95); Cup N95 + Exhalation Valve (N95+V); Cup N95 + Medical Mask (N95+MM); Cup N95 + Exhalation Valve + Medical Mask (N95+V+MM); Half-face Elastomeric Respirator (HER); and Powered Air-Purifying Respirator (PAPR) (Table II). A medical mask (MM) was placed over two of the models to gauge the combined affect on tolerance.

Procedure

This was a multiple cross-over field trial of 27 health care workers, aged 24–65, while performing their typical, hospital- and clinic-based occupational duties. Each served as his/her own control and wore one of seven respirators ensembles or a medical mask for 8 hr, or as long as tolerable, with interposed doffing periods every 2 hr. This was repeated such that each participant wore each respirator ensemble, with one exception (one participant failed the duckbill N95 fit test and did not wear that ensemble during the measured trials). Each health care worker had three scheduled breaks from wearing the devices throughout the day: 15 min at the 2-hr and 6-hr mark, and 30 min at the 4-hr mark. Subjects were asked to rate their self-perceived discomfort using a 1–10 visual analog scale⁽²⁶⁾ and exertion levels using a Borg exertion scale⁽²⁷⁾ at donning, after 30 min and each subsequent 120 (\pm 15) min, and at doffing. The study sessions were terminated when subjects expressed a need to remove the respirator within “the next 10 minutes” because of intolerance or completed an 8-hr session. Only one participant terminated early.

Analyses

Means and standard deviations for discomfort and exertion levels were calculated. Missing discomfort and exertion outcomes were imputed by carrying the last observation forward based on our understanding of missing mechanism in this study. Linear mixed-effect models were used to examine if discomfort and exertion levels were different among different respirators and changed over time, where random effects were

TABLE I. Characteristics of Subjects (N = 27)

	Number	Percent Total (%)
Gender		
Female	15	55.6
Male	12	44.4
Location		
MICU ^A	2	7.4
MICU/SICU	6	22.2
SICU ^B	7	25.9
ED ^C	6	22.2
Medical/surgical ward	6	22.2
Occupation		
Nurse practitioner	2	7.4
Nurse	16	59.3
Nurse technician	4	14.8
Telemetry technician	2	7.4
Clerical assistant	1	3.7
Respiratory therapist	2	7.4

^AMedical intensive care unit.

^BSurgical intensive care unit.

^CEmergency department.

TABLE II. Commonly Used Respiratory Protective Devices with or without an Overlying Medical Mask

Type	Model	Exhalation Style	Surgical Mask Valve Model	Overlying	Mfr.	Filter	Cartridge
Control (no respiratory protective equipment)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Half-mask filtering facepiece	Cup-shaped	No	No	3M	1860	N95	N/A
Medical mask	Loose-fitting	No	N/A	Precept	15320	N/A	N/A
Half-mask filtering facepiece	Duckbill	No	No	Kimberly Clark	PFR95170	N95	N/A
Half-mask filtering facepiece	Cup-shaped	No	Yes	3M; Precept	1860; 15320	N95	N/A
Half-mask filtering facepiece	Cup-shaped	Yes	No	3M	8511	N95	N/A
Powered air-purifying	Hooded	No	No	3M	Air-Mate	HEPF	451-02-01
Half-mask filtering facepiece	Cup-shaped	Yes	Yes	3M; Precept	8511; 15320	N95	N/A
Half-mask elastomeric	Half-face	Yes	No	North	5500	P100	7580P100

Notes: All respirators certified by NIOSH.

N95 – Filters at least 95% of airborne particles. Not resistant to oil.

P100 – Filters at least 99.97% of airborne particles. Strongly resistant to oil.

HEPF – High-efficiency particulate filter.

Surgical mask – Precept Medical Products, Arden, North Carolina.

North 5500 – North Safety Products, Cranston, Rhode Island.

Duckbill filtering facepiece respirator- Kimberly-Clark Corporation, Irving, Texas.

Cup-shaped filtering facepiece respirator- 3M Corporation, St. Paul, Minnesota.

included for clustering by subject and location to account for the correlation within cluster. In all models, we controlled for effects of gender, age, and physical activity. Standard model diagnostics were used to assess model adequacy. To account for the Type I error inflation, we used the Bonferroni stepdown method to adjust p-values, shown to be more powerful than the classic Bonferroni adjustment while maintaining strong control of the family-wise Type I error.^(28,29)

RESULTS

Twenty-seven of 28 subjects who consented met eligibility criteria and completed the study. Figures 1 and 2 show the mean discomfort and exertion ratings, respectively, for all ensembles during 8 hr, and *p*-values <0.05 compared with the PAPR to provide a standardized comparison.

Discomfort

The fitted, linear mixed-effect model showed average discomfort level was significantly different among respirators (*p* = 0.0351) and over time (*p* < 0.0001) (Figure 1). Specifically, the N95 had a significantly greater discomfort level than PAPR at 6 hr (adjusted *p* = 0.0065) and at 8 hr (adjusted *p* = 0.0072).

The N95+MM had a significantly greater discomfort level than the PAPR at 4 hr (adjusted *p* = 0.0280), 6 hr (adjusted *p* = 0.0042), and 8 hr (adjusted *p* = 0.0015). In addition, the N95+V+MM had a significantly greater discomfort level than PAPR at 6 hr (adjusted *p* = 0.0441) and at 8 hr (adjusted *p* = 0.0088), while the N95+V+MM and N95+V did not have a significantly greater discomfort level (adjusted *p* > 0.1). Finally, the N95 + MM and N95 did not have a significantly greater discomfort level (adjusted *p* > 0.9). Of note, participants received a 45-min break at the first 4 hr and a 15-min break after the subsequent 4 hr of investigation. The longer break time of the first 4 hr may have been a factor given that the N95 and N95+V+MM had no difference compared with PAPR at 4 hr.

Exertion

On average, self-perceived exertion level rose proportionately, approximately two points on the validated Borg scale (Figure 2), which corresponds to an energy expenditure of approximately one to two metabolic equivalents (METs).^(30,31) The fitted, linear mixed-effect model showed average exertion level was significantly greater among some respirators and over time (*p* < 0.0001). Specifically, DB had a significantly different exertion level than PAPR at 6 hr (adjusted

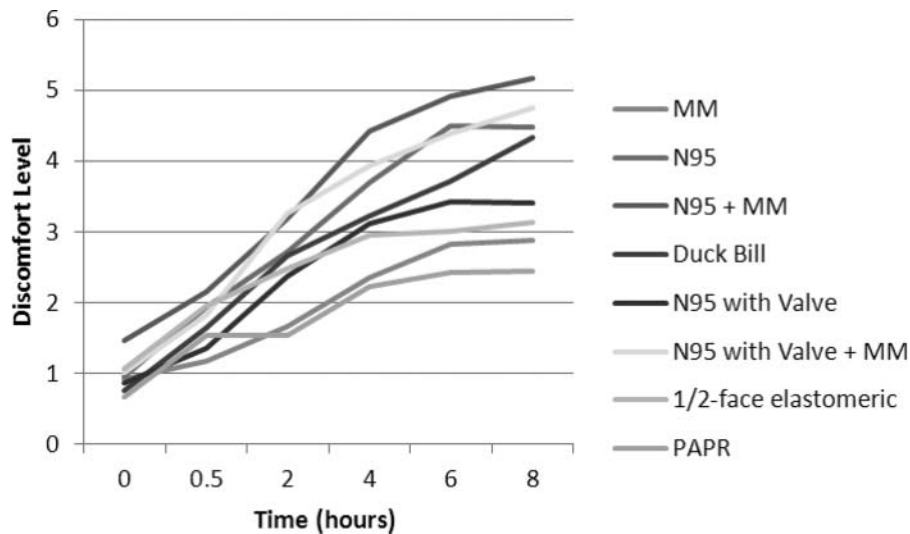


FIGURE 1. Mean discomfort level over 8-hr work shift. *Notes:* Interrupted y-axis to improve visualization of data. Fitted linear mixed-effect model showed: average discomfort level was significantly different among respirators ($p = 0.0351$) and over time ($p < 0.0001$). N95 had significantly different discomfort level from PAPR at 6 hr (adjusted $p = 0.0065$) and at 8 hr (adjusted $p = 0.0072$). N95+MM had significantly different discomfort level from PAPR at 4 hr (adjusted $p = 0.0280$), 6 hr (adjusted $p = 0.0042$), and 8 hr (adjusted $p = 0.0015$). N95+V+MM had significantly different discomfort level from PAPR at 6 hr (adjusted $p = 0.0441$) and at 8 hr (adjusted $p = 0.0088$). N95+V+MM and N95+V did not have significantly different discomfort level (adjusted $p > 0.1$). N95 + MM and N95 did not have significantly different discomfort level (adjusted $p > 0.9$).

$p = 0.0256$) and marginally at 8 hr (adjusted $p = 0.0510$). The N95 had a marginally greater exertion level than the PAPR at 6 hr and 8 hr (adjusted $p = 0.0510$). The N95+V+MM and N95+V did not have a significantly different exertion level (adjusted $p > 0.5$). Similarly, the N95 + MM and N95 did not have a significantly different exertion level (adjusted $p > 0.5$).

DISCUSSION

We sought to determine the level of discomfort and exertion experienced by HCWs wearing commonly used respirator models for an 8-hr work shift. Concerns about global shortages⁽³²⁾ of disposable filtering facepiece respirators

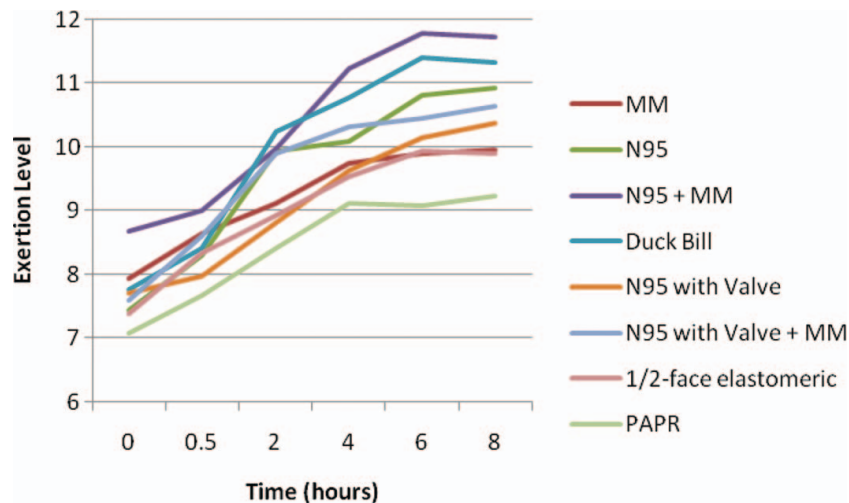


FIGURE 2. Mean exertion level over time. *Notes:* Interrupted y-axis to improve visualization of data. Fitted linear mixed effect model showed: average exertion level was significantly different among some respirators and over time ($p < 0.0001$). DB had significantly different exertion level from PAPR at 6 hr (adjusted $p = 0.0256$) and marginally at 8 hr (adjusted $p = 0.0510$). N95 had marginally different exertion level from PAPR at 6 hr and 8 hr (adjusted $p = 0.0510$). N95+V+MM and N95+V did not have significantly different exertion level (adjusted $p > 0.5$). N95 + MM and N95 did not have significantly different exertion level (adjusted $p > 0.5$).

during periods of peak demand have helped make this a pressing topic.

For participating HCWs, the level of self-perceived discomfort increased over time and across respirators. While this finding hardly seems unexpected, the fact that discomfort increases with prolonged respirator use has not been quantified in this fashion and reported in peer-reviewed literature, to our knowledge. As previously reported,⁽²¹⁾ we found that approximately half the subjects in our study, HCWs who were accustomed to wearing respirators for brief periods, were not willing to wear most respirators or a medical mask for the 8-hr work shift even with interposed break periods. Facial heat,^(7,10,12,13,21) pain,^(6,14,21) and pressure^(7,21) are among the most common complaints associated with discomfort. Placing an MM over an N95 with and without an exhalation valve did not significantly change the discomfort associated with these models.

While discomfort increased notably over time, the influence of respirators on exertion appears to be less robust in the health care environment. Therefore, strategies to primarily reduce discomfort—specifically the heat, pressure, and pain complaints—may be best suited to increase respirator tolerability and compliance. Among commonly used and relatively inexpensive respirator models, an N95 with an exhalation valve was the most comfortable after 8 hr. The medical mask was mildly more comfortable; however, the MM is primarily meant to prevent the spread of contaminants by the wearer instead of protecting the wearer from outside contaminants.⁽²²⁾

Study limitations include the small sample size, locations limited to one hospital system, and a setting that simulated only a pandemic scenario. Health care workers caring for patients with contagious life-threatening illnesses during a pandemic may be willing to tolerate respirators for longer periods than observed in our study, although subjects were asked to imagine themselves in such a setting. It is important to note that infection control procedures and appropriate processes for disinfecting, charging, and maintaining respirators would need to be considered if HCWs were to use respirators for extended wear periods, with use between patients, and with respirator re-use. Likewise, appropriate hand hygiene and contact precautions should always be observed. A participation bias may have led to higher tolerance levels among the study subjects than would be expected in the U.S. health care work force. The most common reason for HCWs declining to participate was unwillingness to wear the respirator equipment for prolonged periods.

Recent undertakings to better understand respirator selection, communication, and speech ineligibility have been completed.^(33,35) Current, topical studies have also investigated physiological respirator impact in persons with mild respiratory disease⁽³⁵⁾ and respirator impact on task performance.⁽³⁶⁾ Further studies will be necessary to better understand the limitations posed by respirators to the health care work force. Engaging HCWs in the design of new models may facilitate development of new respirators with improved comfort and tolerability.

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