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Short report

A close shave? Performance of P2/N95 respirators in healthcare workers with facial hair: results of the BEARDS (BEnchmarking Adequate Respiratory DefenceS) study

I. Sandaradura [†], E. Goeman [†], G. Pontivivo, E. Fine, H. Gray, S. Kerr, D. Marriott, J. Harkness, D. Andresen*

St Vincent's Hospital, Sydney, Australia

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SUMMARY

P2/N95 filtering face piece respirators (FFRs) protect healthcare workers (HCWs) from airborne infections. This study assessed the impact of facial hair on quantitative respirator fit in 105 male HCWs, of whom 38 were clean shaven, and assessed the prevalence of male facial hair at the study facility. Only 34 (32%) male HCWs overall achieved an adequate FFR fit, including 47% of clean-shaven men. No full-bearded HCWs achieved a fit. Adequate respirator fit decreased significantly with increasing facial hair ($P<0.01$ for trend). Facial hair was present on 49% of male employees. This study supports quantitative fit testing prior to P2/N95 respirator use.

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Introduction

There is increasing recognition of the importance of protecting healthcare workers (HCWs) from pathogens transmissible via the airborne route. Hospitals institute airborne precautions for potential infections with novel and/or virulent viral pathogens, and routinely for the care of patients with measles, varicella and pulmonary tuberculosis [1]. An important component of airborne precautions is the use of respirators — personal protective equipment (PPE) devices that cover, at a minimum, the mouth and nose. Respirators are distinct from surgical masks which provide barrier protection against droplets and large respiratory particles, but do not effectively filter small particles or prevent leakage around mask edges during inhalation [1,2].

Filtering face piece respirators (FFRs, also known as disposable particulate respirators) are single-use devices [1] which filter air by mechanical impaction and electrostatic capture by charged polypropylene. FFRs are the most

* Corresponding author. Address: IBAC Clinic, Level 4, Xavier Building, St Vincent's Public Hospital, 390 Victoria Street, Darlinghurst, NSW 2010, Australia. Tel.: +61 421 705 361; fax: +61 2 8382 2090.
E-mail address: david.andresen@svha.org.au (D. Andresen).

† IS and EG contributed equally to study design, execution, data analysis and manuscript preparation.

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commonly used type of respirator in healthcare settings due to their convenience, ease of use and low cost relative to other types of respirators, such as elastomeric face piece respirators and powered air-purifying respirators. FFRs have either a raised dome or 'duckbill' shape, or a flat-folded design. A tight seal is necessary around the edges.

The US National Institute for Occupational Safety and Health defines the minimum level of filtration for occupational settings as N95. A N95 respirator filters out at least 95% of airborne particles during worst-case testing using the most penetrating particle size [2]. The equivalent European standard, BS EN 143:20003, is termed 'P2' [3]. N95 and P2 are effectively synonymous.

Fit testing of respirators for employees working in at-risk clinical areas is recommended at commencement of employment and at regular intervals [1]. Fit testing may be qualitative, using atomized saccharine or Bitrex solution (Macfarlan Smith, Edinburgh, UK). Mask fit is assessed by the HCW's report of tasting the solution. Quantitative fit testing, using a particle counter, is considered more accurate and less subjective. Despite this, uptake of the quantitative methodology in healthcare settings in Australia is low [4]. In part, this is due to the substantial cost of the equipment (approximately AUD$22,000 per Portacount device).

After a peak in the 1890s and resurgence in the 1960s [5], facial hair among men has once again become common. In industrial settings, the presence of facial hair has been associated with 20—1000-fold increases in respirator leakage [6]. However, no published studies have examined the impact of facial hair on the fit of modern disposable FFRs using current quantitative fit-testing technology. As increasing numbers of male HCWs have facial hair, which may impact the effectiveness of respirators, this study examined the fit of standard FFRs among a cohort of hospital-based male HCWs.

Methods

The BEARDS (BEnchmarking Adequate Respiratory DefenceS) study was conducted in 2015 at St Vincent's Hospital, Darlinghurst, a 350-bed public tertiary/quaternary referral and teaching hospital in Sydney, Australia. Ethical approval for both components of the study was obtained through St Vincent's Hospital Sydney Human Research Ethics Committee (LNR/14/SVH/409).

A survey of facial hair types and lengths among male hospital employees was conducted in all inpatient wards and outpatient clinical areas. Four teams, each of two investigators, simultaneously visited predesignated areas and counted the total numbers of staff members, identifying whether they were male or female, recording their clinical role and categorizing the males' facial hair. Facial hair was categorized as 0 = clean shaven, 1 = light stubble, 2 = medium to heavy stubble, 3 = full beard and 4 = other (e.g. moustache without beard, goatee beard and sideburns), according to a published visual standard (see online supplementary material) [7]. All data were collected anonymously.

Recruitment of male HCWs (hospital employees with direct patient contact, such as medical staff, nurses and allied health workers) for FFR fit testing was conducted via posters and flyers, word-of-mouth, announcements at staff functions, e-mails and electronic staff bulletins, a foyer stall, and visits to the emergency department, intensive care unit, operating theatres and the respiratory ward. Written informed consent was obtained and a frontal facial photograph was taken of each participant. Participants completed a written questionnaire, indicating age, height, weight, ethnicity, current role in the hospital, years of experience in health care, previous training in PPE use, and relevant medical/dental history.

Facial photographs of all fit-testing participants were examined independently by two investigators (DA, HG), who were blinded to the results of the fit test, and facial hair was categorized as described above. Test—retest repeatability was not assessed. Discrepancies in facial hair categorization were resolved through re-examination and discussion by the two assessors.

Disposable 3M Flatfold 1870 Health Care Particulate N95 FFR Respirators (3M, St Paul, MN, USA) were chosen for the study as they are widely utilized in Australian hospitals [4]. Quantitative respirator fit testing was performed according to the US Department of Labor Occupational Health and Safety Administration (USDLOHSA) 29CFR1910.134 ambient aerosol condensation nuclei counter protocol [8] using a PortaCount Pro+ Respirator Fit Tester 8038 (TSI, Shoreview, MN, USA) following the manufacturer's directions. Prior to donning, each FFR had a sampling port installed to enable the Portacount to draw an air sample from inside the respirator during use. Investigators received training in quantitative fit testing from an occupational hygienist. PortaCount daily checks and maintenance were performed according to the manufacturer's instructions.

Each fit-testing participant was instructed in respirator usage. A visual check was performed by one of three investigators (IS, EG, GP) for satisfactory respirator fit, and the participant did a fit check of the seal by gently exhaling and inhaling. Each participant was asked to rate their perception of fit as satisfactory or unsatisfactory. According to the USDLOHSA protocol, each participant waited 2—5 min between respirator donning and commencement of fit testing. The 8-min testing protocol then included seven cycles: normal breathing, deep breathing, talking, and movements such as head turning side-to-side, head nodding up and down, and bending over [8].

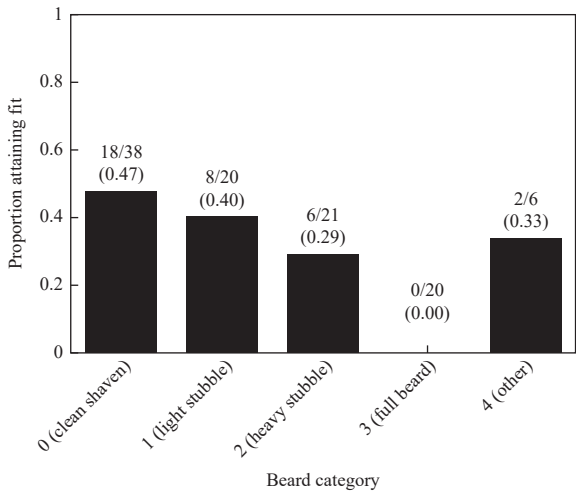

Figure 1. Likelihood of fit by beard category (excluding miscellaneous category), and trend analysis. *P* for trend = 0.0003 excluding miscellaneous category.

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Table I
Subject characteristics: univariate analysis by quantitative fit pass or fail groups

Covariate	N95 respirator fit		*P*-value
	Fail (*N*=71)	Pass (*N*=34)	
Age (years)	31 (28–40)	34.5 (25–46)	0.91
Years in health work	5.5 (2–14)	7 (3–13)	0.45
Weight (kg)	79 (72–86)	76 (70–90)	0.58
Height (m)	1.78 (1.72–1.83)	1.75 (1.73–1.80)	0.21
Body mass index (kg/m^2)	24.8 (23.0–27.4)	25.0 (22.7–29.1)	0.73
Male sex	71 (100%)	34 (100%)	1.0
Career group			0.17
Allied health	5 (7%)	6 (18%)	
Medical	36 (51%)	18 (53%)	
Nursing	20 (28%)	9 (26%)	
Other	10 (14%)	1 (3%)	
Ethnicity			0.55
Aboriginal/Torres Strait Islander	7 (10%)	3 (9%)	
Polynesian/Melanesian	1 (1%)	0	
North West European	32 (45%)	18 (53%)	
Southern European	3 (4%)	3 (9%)	
North African/Middle Eastern	3 (4%)	0	
South East Asian	7 (10%)	1 (3%)	
Southern or Central Asian	6 (8%)	3 (9%)	
North East Asian	0	1 (3%)	
People of the Americas	0	1 (3%)	
Other/unknown	3 (4%)	2 (6%)	
No answer	9 (13%)	2 (6%)	
Beard category			0.001
0 (clean shaven)	20 (28%)	18 (53%)	
1 (light stubble)	12 (17%)	8 (24%)	
2 (heavy stubble)	15 (21%)	6 (18%)	
3 (full beard)	20 (28%)	0	
4 (miscellaneous)	4 (6%)	2 (6%)	
Training in the last 5 years			0.95
No	31 (44%)	15 (44%)	
Yes	35 (49%)	16 (47%)	
Unsure	5 (7%)	3 (9%)	
Training in the last 12 months			0.36
No	45 (63%)	23 (68%)	
Yes	21 (30%)	11 (32%)	
Unsure	5 (7%)	0	
Craniofacial surgery			0.70
No	63 (89%)	31 (91%)	
Yes	8 (11%)	3 (9%)	
Facial shape abnormality			0.28
No	65 (92%)	34 (100%)	
Yes	4 (6%)	0	
Unsure	2 (3%)	0	
Dental surgery			0.72
No	64 (90%)	7 (10%)	
Yes	32 (94%)	2 (6%)	
Dental prosthetics			0.64
No	65 (92%)	30 (88%)	
Yes	5 (7%)	4 (12%)	
Unsure	1 (1%)	0	
Glasses			0.64
No	38 (53%)	18 (53%)	
Yes	15 (21%)	5 (15%)	
Sometimes	18 (25%)	11 (32%)	

(*continued on next page*)

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Table I (*continued*)

Covariate	N95 respirator fit		*P*-value
	Fail (*N*=71)	Pass (*N*=34)	
Sinus condition			0.33
Yes	50 (70%)	27 (73%)	
No	21 (30%)	28 (27%)	
Skin condition			0.27
Yes	67 (94%)	30 (88%)	
No	4 (6%)	4 (12%)	
No eye condition	71 (100%)	31 (100%)	1.0

Continuous covariates are presented as median (interquartile range) and categorical covariates are presented as *N* (%). Percentages are rounded and may not total 100%.

An overall fit factor (FF_T) of 100 is required for an N95 FFR [8]. The fit factor for each test cycle was calculated using the formula $FF_i = \frac{CB_i+CA_i}{2CR_i}$, where FF_i is the fit factor for test cycle *i*, CB_i is the particle concentration in the ambient sample before the respirator sample, CA_i is the particle concentration in the ambient sample after the respirator sample, and CR_i is the particle concentration in the respirator sample. FF_T was calculated by combining the results of the seven cycle fit factors using the formula: $FF_T = \frac{n}{\frac{1}{FF_1}+\frac{1}{FF_2}+\ldots\ldots+\frac{1}{FF_7}}$. A dichotomous fit-test result for each participant was recorded as pass ($FF_T \geq 100$) or fail ($FF_T < 100$) [8].

Statistical methods

Based on an expected fit rate of 80% for clean-shaven male staff [4] and an absolute reduction in fit rate of 25% due to facial hair regarded as potentially clinically significant, a sample size of 54 subjects in each group would give 80% power to detect this difference at a two-sided significance level of 5%. Statistical analysis was conducted using Stata 14 (StataCorp, College Station, TX, USA). Continuous characteristics were compared between pass and fail outcome groups using *t*-test or Wilcoxon test. Categorical and binary covariates were compared between outcome groups using Chi-squared test or Fisher's exact test. Logistic regression was used to calculate odds ratios (OR) and 95% confidence intervals (95% CI) for covariates for the outcome of mask fit.

Results

The hospital-wide facial hair prevalence survey included a total of 674 hospital employees, 517 (76.7%) of whom were clinical staff (nursing, medical and allied health). Of 179 clinical male staff, 83 (46%) had facial hair, with 41 (23%) having more than light stubble. In the clinical group, facial hair was most common among nurses (21/38, 55%) (see online supplementary material).

During the fit-testing study, a total of 105 male HCWs with a median age of 32 years (interquartile range 27–43) were enrolled. Of those, 38 (36.2%) were clean shaven, 20 (19.0%) had a full beard, and the remainder had intermediate degrees of facial hair. Only 34 (32%) achieved an adequate fit ($FF_T \geq 100$). Only 18 (47%) clean-shaven male staff achieved a fit and none of the HCWs with a full beard achieved a fit (Figure 1). Only three of the 71 (4%) staff who did not achieve a fit subjectively recognized this.

Table I describes the subject characteristics according to the results of their fit test. The only covariate significantly associated with the probability of achieving a fit was beard length; therefore, no multi-variate models were developed. As all study participants with a beard category of 3 failed the test, exact logistic regression was used to estimate the OR and median unbiased estimates of the 95% CI for this category.

Increasing length of facial hair was associated with a decrease in the likelihood of a mask fit (see online supplementary material). Relative to those with no facial hair, the OR for respirator fit was 0.74 (95% CI 0.21–2.52, *P*=0.08) for light stubble, 0.45 (95% CI 0. 12–1.57, *P*=0.26) for moderate to heavy stubble, 0.04 (95% CI 0–0.28, *P*<0.001) for full beard and 0.56 [95% CI 0.05–4.48, *P*=0.85] for other types of facial hair. There was a highly significant trend towards less frequent fit and increasing beard length, after excluding participants in the miscellaneous beard category (*P* for trend = 0.0003)

Discussion

In this study, only one in three male HCWs achieved an adequate P2/N95 respirator fit using the respirator type most common in Australian hospitals. The likelihood of an adequate fit decreased with increasing amounts of facial hair. No staff member with a full beard achieved a fit. There were no other significant predictors of fit. Importantly, the failure to achieve a satisfactory fit went unrecognized by the majority of male HCWs. There was a high prevalence of facial hair amongst male clinical staff at the study institution. This indicates that these staff could be at increased risk of respiratory pathogen transmission even when using the approved PPE.

Low rates of successful fit testing have been observed previously, even in clean-shaven HCWs [9]. The largest Australian study of FFR fit testing in 6160 HCWs showed an 83% initial fit rate. Facial hair was not recorded and the study was performed in an era when male facial hair was unfashionable [4]. In a North American healthcare study, facial hair was assessed as responsible for 41.3% of all failed qualitative respiratory fit tests [10].

There is no stated requirement for Australian HCWs in high-risk environments to be clean shaven. The Australian AGPCIH guidelines state that 'healthcare workers who have facial hair (including a 1–2 day beard growth) must be aware that an adequate seal cannot be guaranteed between the P2 [FFR] respirator and the wearer's face', and advise that 'if a good facial seal cannot be achieved (e.g. the intended wearer has a

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beard or long moustache), an alternative respirator such as a powered air-purifying respirator should be used' [1]. Recommendations for bearded people in industrial settings range from shaving to using alternative respirator types.

This study has some limitations. First, a single type of mask was used and each fit test was only performed once. Thus, it is not possible to speculate on the impact of the availability of alternative masks on the likelihood of obtaining a fit, nor the potential impact of additional training or repositioning of the mask. Second, local workforce composition, particularly with respect to culture and ethnicity, may impact the prevalence of facial hair and therefore affect the external validity of the study. Similar studies in other healthcare settings are encouraged. Finally, test–retest reproducibility was not assessed for the facial hair grading instrument, but as this was applied blind to the results of fit testing, no systematic bias is likely to have been introduced.

In conclusion, this study supports routine quantitative fit testing, accompanied by intensive, personalized training and assessment for HCWs who are required to use P2/N95 respirators. Although male staff members with full beards are unlikely to obtain a fit, those with light and heavy stubble may do so. Additional studies are needed to define whether those with light and heavy stubble who attain a fit are able to do so repeatedly over time. In light of the low overall fit rates, institutions should develop strategies to protect those HCWs who cannot obtain an adequate respirator fit, including potentially reallocating those staff to lower-risk settings.

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Conflict of interest statement
None declared.

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A sample box of 3M 1870 Health Care Particulate Respirator and Surgical Masks and training in the use of the PortaCount Pro+ Respirator Fit Tester were provided free of charge by the manufacturer. 3M Australia had no role in the study design, conduct of the study, data analysis or manuscript preparation. The remaining disposable respirators were purchased by the St Vincent's Hospital Department of Infection Prevention Management. Funds for hire of the PortaCount Pro+ Respirator Fit Tester 8038 were provided by the Department of Microbiology, St Vincent's Hospital.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2020.01.006.

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