

A Study of Strategies to Achieve Proper N95 Respirator Use by Regular N95 Respirator

Nuttakarn Tontiruck, Phanumas Krisorn , Naesinee Chaiear  and Thanaphoom Aupongkaroon 

Department of Community, Family and Occupational Medicine, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand

Correspondence:

Phanumas Krisorn, MD, MSc
Department of Community,
Family and Occupational Medicine
Faculty of Medicine, Khon Kaen
University, 123 Mittrapharp
Highway, Muang, Khon Kaen,
40002, Thailand.
E-mail: phankr@kku.ac.th

Received: February 8, 2025;

Revised: May 27, 2025;

Accepted: July 23, 2025

ABSTRACT

OBJECTIVE To explore different strategies for achieving proper use of N95 respirators by hospital staff, including viewing the donning process in a mirror, receiving assistance from a Buddy during donning, and using a bouffant cap to cover the hair after donning an N95 respirator. This study evaluated the fit factor, the time required for donning a respirator, and the practical usability of each strategy.

METHODS This quasi-experimental study involved 60 healthcare workers. Demographic and medical information were collected using Occupational Safety and Health Administration (OSHA) compliant questionnaires. Facial dimensions were measured and classified into three face-size groups according to the NIOSH bivariate panel. Participants practiced one of four different N95 respirator donning strategies after watching a training video: using a mirror, receiving Buddy assistance, and using a bouffant cap. A quantitative fit test (QNFT) was conducted before and after practicing each strategy following a modified OSHA protocol. After completing each of the strategies, participants indicated their preferred donning method. They were subsequently randomly divided into three groups to further practice one of the strategies, with repeated QNFTs to ensure consistency.

RESULTS Post video training, participants had a higher fit factor (FFs) (median, IQR) (113.50 [48.50, 200]) and an increased passing rate (61.67%) on the fit test compared to no training which had an FF of 65.50 [18.50, 118.50]) and a passing rate of 25.00%. Practice with the Buddy and Mirror strategies resulted in significantly higher FFs for small, medium, and large face sizes. The Bouffant cap strategy showed significantly higher FF than post video training alone for small face sizes: (102 [50.5, 143]) and (50 [18, 108]), respectively.

CONCLUSIONS The study found significant differences in FF for different facial sizes, with participants having medium and large face sizes achieving higher FFs compared to those with small face sizes. For individuals with small face sizes, FF improved significantly post video training using alternative strategies (Mirror, Buddy, and Bouffant cap) compared to no training. Using a mirror during donning allowed wearers to inspect the mask fit more effectively, while the Buddy strategy proved more efficient in identifying and addressing leaks compared to self-checking.

KEYWORDS N95 respirator, Quantitative Fit Tests, face sizes, health care workers, strategies

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INTRODUCTION

Precautions are essential for preventing the transmission of infectious agent spread through airborne droplet nuclei. These precautions apply to diseases such as measles, SARS, varicella, and tuberculosis (TB), and require the use of personal respiratory protection along with specialized ventilation and air handling systems (1).

Thailand is one of the 30 highest TB-burdened countries according to the updated global lists released by the World Health Organization (WHO) in June 2021 (2, 3).

Healthcare workers (HCWs) involved in caring for patients with TB and multidrug-resistant tuberculosis (MDR-TB) have at least a two- to three-fold higher risk of contracting the disease than the general population (4). HCWs who performed aerosol-generating procedures (AGPs) and who did not have a *Bacillus Calmette-Guérin* (BCG) scar had a significant association with contraction of latent tuberculosis infection (LTBI). It was determined that the infections of nine of the fifteen individuals who were diagnosed with work-related TB were due to two important factors: prolonged daily exposure time to an infected TB patient, and aerosol-generating procedures conducted without adequate respiratory protection (5).

The WHO has established a global system of infection prevention and control (IPC) interventions aimed at interrupting the cycle of nosocomial TB transmission. The guidelines for TB IPC include three core practices: administrative controls, environmental controls, and respiratory protective equipment (6). Among these, respiratory protection, such as N95 respirators, serve as a critical barrier against airborne transmission, particularly in high-risk healthcare settings. The N95 respirator is a particulate filter respirator certified by the CDC and NIOSH and is designed for protection against airborne mycobacterium TB.

Mask fit is an important aspect of mask efficacy and is typically measured by either qualitative fit testing (QLFT) or quantitative fit testing (QNFT). In QLFT, mask wearers are evaluated based on their ability to detect bitter or sweet aerosolized agents, while QNFT objectively measures the ratio of aerosol concentrations inside and outside the mask (7). Testing the fit of the mask ensures that the correct respirator is chosen to effectively

protect against harmful germs (8). Results from a previous study showed that for N95 filtering facepiece respirators used by HCWs, the overall failure rate was 15.20% (9).

While existing studies have focused on filtration efficiency and fit testing procedures, there remains a significant gap in the literature regarding practical, user-friendly strategies that can enhance fit and usability during routine clinical use of respirators. Factors such as the donning technique, effect of variations in facial features (e.g., hair), and the lack of real-time feedback tools may hinder proper usage, especially in fast-paced healthcare environments.

METHODS

Study design and sample size

This quasi-experimental study was conducted to develop an N-95 Respirator Self-Assessment Tool which can provide efficacy comparable to a formal fit testing process.

The sample size was calculated using the WIN-PEPI program and aimed for a statistical power of 75% and a statistical significance of < 0.05 . The passing rates for proper mask use observed in a previous study were 40% pre-training and 74% post video training (10). The total sample size of the present study was calculated to be 58 individuals; 60 healthcare personnel were recruited and the study was conducted between January and August 2024.

Participants included frontline HCWs aged 18–60 years who had previously passed a medical evaluation. Eligible volunteers were clean-shaven, had no prior experience with fit testing or fit training, and had abstained from smoking for at least 30 minutes prior to undergoing the QNFT. All volunteers were informed about the testing procedures and provided written consent. Researchers collected the signed consent forms. Demographic data, including sex, age, weight, height, and underlying health conditions of the participants were obtained using medical questionnaires compliant with OSHA standards.

Data collection process

The study employed a quasi-experimental design. Facial dimensions were measured and faces were categorized into three groups (small, medium, and large) using the National Institute for Occu-

pational Safety and Health (NIOSH) bivariate panel classification (Figure 1). Facial dimension measurements were made using two types of calipers: a spreading caliper with a range of 300 mm to 450 mm and a 1.0 mm least count caliper (made of brass), both used in accordance with the NIOSH bivariate panel protocol. Face length (menton-sellion) was measured as the straight distance from the menton (the lowest point of the chin) to the sellion (the midline point at the deepest depression of the nasal root between the eyes). Face width (bizygomatic breadth) was measured as the widest horizontal distance between the right and left zygomatic arches (cheekbones). All participants used a 3M 1870+ Aura N95 respirator, the standard model currently used in the study hospital. The 3M 1870+ is widely used across hospitals in Thailand due to its high fit test pass rate, making it a reliable and practical choice for healthcare settings. Volunteers followed four different N95 respirator-donning strategies: 1) post video training: viewing a non-interactive training video. (All participants viewed this video), 2) Mirror training: in addition to the video, participants used a mirror to aid in the proper donning of the N95 respirator, 3) Buddy: in addition to the video, participants received assistance from a Buddy during donning of the respirator to aid with visual inspection, adjustment, and proper mask fit, and 4) Bouffant cap: in addition to the video,

participants used a bouffant cap to cover their hair after donning the N95 respirator. A QNFT was performed before the training. A modified ambient aerosol condensation nucleus counter QNFT protocol was used to measure the filtration of the facepiece of the respirators according to the standard U.S. OSHA protocol. After watching the video, participants donned an N95 respirator using each of the four strategies, and a QNFT was performed after each strategy. After having used each of the four strategies, participants completed a questionnaire to rank their perception of the practicality of each of the four strategies for achieving proper N95 respirator fit. After using all four donning strategies, volunteers were divided into three self-training groups of 20 participants each to test each of the strategies: group 1 used the Mirror strategy, group 2 used the Buddy strategy, and group 3 used the Bouffant cap strategy. Each group repeated the assigned strategy at least three times to ensure familiarity and consistency. After completing each strategy, volunteers returned to the Occupational Health and Safety Office and performed a QNFT. The process is shown in Figure 2.

Research tools

The TSI PortaCount 8048 (serial number 8048231721) was used to evaluate the fit factor (FF) of N95 respirators through QNFT, integrating data

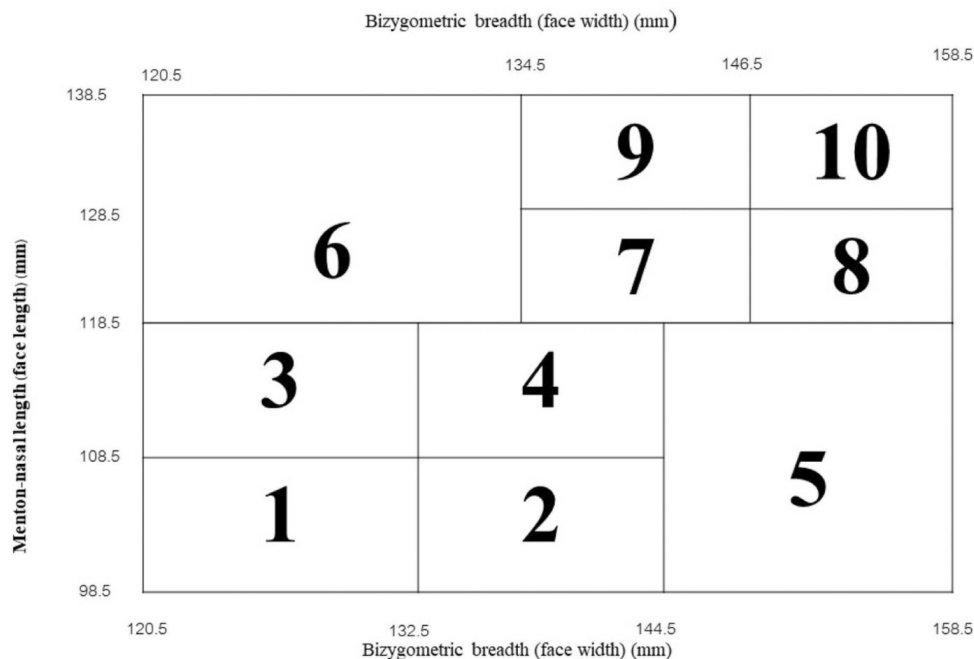


Figure 1. The NIOSH Bivariate Panel (NIOSH Panel) includes ten individual member cells defined by face width and face length (mm)

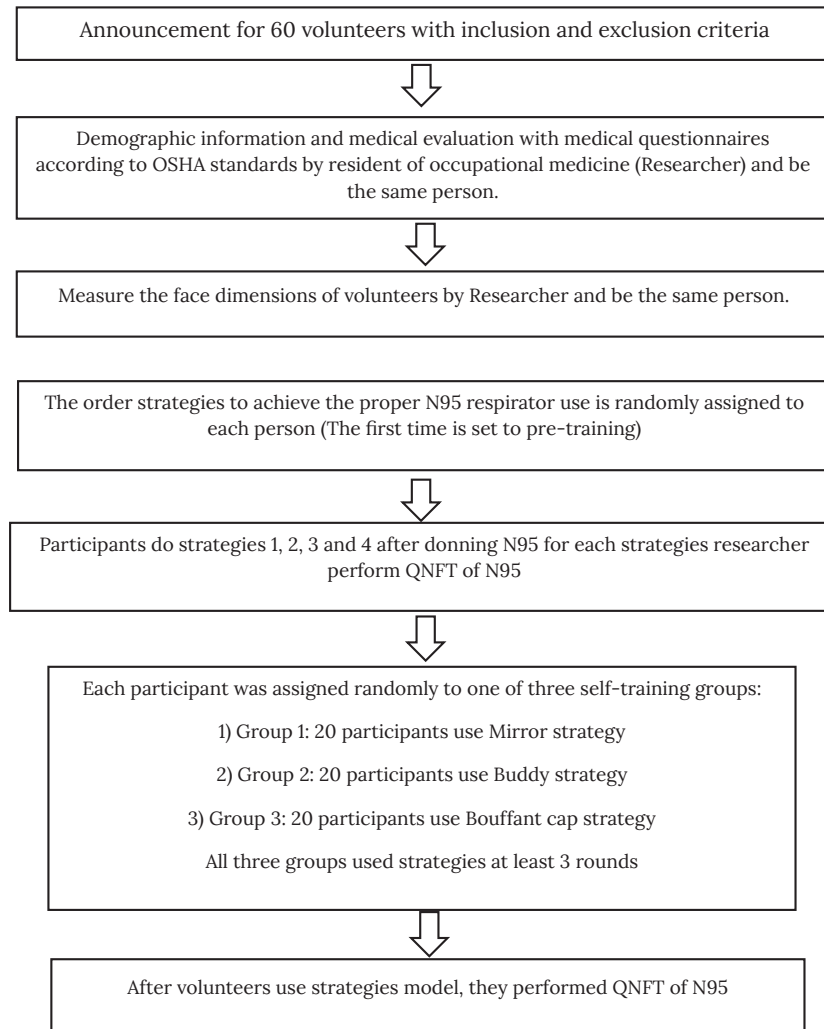


Figure 2. Data collection flow chart

from four exercises performed by the participant (bending over, talking, moving head side-to-side and moving head up-and-down). The device measured the results of the individual exercises as well as the overall FF using particle concentration measurements inside and outside the mask. The overall FF was calculated as the average of the four exercises.

Data recorded on participants included age, sex, anthropometric measurements. In addition, data on overall FFs and time required to don an N95 respirator prior- and post video training as well as using the Mirror, Buddy and Bouffant cap methods, was also recorded.

Statistical analysis

Descriptive statistics were used to analyzed the data including SPSS version 28 (IBM SPSS

Statistics for Macintosh, Version 28.0, IBM Corp., Armonk, NY, US). The analysis included general characteristics of the participants including sex, face size, occupation, and fit test results presented as frequencies and percentages. Age, BMI, facial dimensions, and FF are presented as mean and standard deviation or median and interquartile range, depending on the data distribution.

The Wilcoxon Signed Ranks Test was used to compare FF between no training and the alternative strategies with statistical significance set at a $p < 0.05$ using the paired-sample t-test to compare before self-training and after self-training with statistical significance set at $p < 0.05$. The McNemar test were used to compare the pass rates after training and after three rounds of self-training. Statistical significance was set at a $p < 0.05$.

Ethics

The Khon Kaen University Ethics Committee approved this study for human research based on the Declaration of Helsinki and the ICH Good Clinical Practice Guidelines (HE 661359). Participants in the study and their personal identification information remained undisclosed. The data provided did not influence the participants' professional obligations.

RESULTS

A total of 60 participants who met the criteria were enrolled. The mean age of the participants was 30.57 ± 6.40 years with males accounting for 35.00% and females for 65.00%. Most participants were nurses (36.70%), physicians (20.00%), or medical students (20.00%). Most participants were normal weight (50.00%), with a mean BMI of 21.76 ± 4.25 kg/m² (Table 1). Most participants were of small face size (51.70%) (Table 1). Facial measurements showed a median face width of 130 mm and a median face length of 119.7 mm. The highest FF (median, IQR) were observed with the following strategies: Buddy [189, (149,200)], Mirror [161.50, (79,200)], and Bouffant [147, (82.75,199.75)] (Table 2).

Statistical comparisons of FF between no training and post video training and among the alternative strategies (Mirror, Buddy, and Bouffant cap) were conducted using the Wilcoxon Signed Ranks Test. It was determined that there was significant difference in FF between no training and

post video training as well as Mirror, Buddy, and Bouffant cap ($p < 0.05$). The passing fit test rate (FF > 100) was 76.67%, 73.33%, 68.33%, 61.67%, and 25.00%, with the Buddy, Bouffant cap, Mirror training, post video training, and no training, respectively (Table 3).

Statistical comparisons of FF between post video training and using the mirror, Buddy, and Bouffant cap methods across different face sizes were conducted using the Wilcoxon Signed Ranks Test with statistically significant difference in FF set at $p < 0.05$. Significant differences in FF were found for small face sizes and total face sizes between post video training and Mirror, Buddy,

Table 1. Personal characteristics of participants (N = 60)

Variables	N (%)
Sex	
Female	39 (65.00)
Male	21 (35.00)
Body mass index (kg/m ²)	
Underweight (< 18.5)	12 (20.00)
Normal (18.5-22.9)	30 (50.00)
Overweight (23-27.5)	11 (18.30)
Obese (> 27.5)	7 (11.70)
Occupation	
Medical Student	12 (20.00)
Nurse	22 (36.70)
Nurse Assistant	5 (8.30)
Physician	12 (20.00)
Dentist	9 (15.00)
Experience using an N95 respirator	
Less than 5 years	15 (25.00)
More than 5 years	45 (75.00)

Table 2. Facial dimensions of participants

Facial dimensions	Mean $\pm$ SD (mm)	95%CI	Median (IQR)
Face width			130 (122.75,140.00)
Face length			119.70 (115.95,125.00)
Subnasal-Sellion length	52.65 $\pm$ 7.16	50.76-54.53	
Nose protrusion	26.47 $\pm$ 5.74	24.95-27.97	
Nose breadth	36.79 $\pm$ 4.10	35.71-37.87	
Nasal root breadth	13.20 $\pm$ 2.58	12.54-13.89	
Interpupillary distance	54.56 $\pm$ 7.44	52.58-56.49	
Head breadth	148.76 $\pm$ 7.92	146.66-150.82	
Minimum frontal breadth	103.19 $\pm$ 16.95	101.90-107.76	
Bigonial breadth	108.50 $\pm$ 12.98	105.11-111.88	
Facial size	N (%)		
Small	31 (51.70)		
Medium	17 (28.30)		
Large	12 (20.00)		

Table 3. FF and passing rate of no training, video training and alternative strategies to achieve the proper N95 respirator

Alternative strategies	Fit factor (FF) median, (IQR)	p-value** (FF)	Passing rate of fit test (FF > 100) Number passing (%)
1. No-training	65.50 (18.50, 118.50)	1	15 (25.00)
2. Post video training	113.50 (48.50, 200)	< 0.001*	37 (61.67)
3. Mirror	161.50 (79, 200)	< 0.001*	41 (68.33)
4. Buddy	189 (149, 200)	< 0.001*	49 (76.67)
5. Bouffant cap	147 (82.75, 199.75)	< 0.001*	44 (73.33)

*Statistically significant at $p < 0.05$, **The p-value resulting from the Wilcoxon Signed Rank Test

Table 4. Comparisons were conducted between post video training and the alternative strategies for each facial size

Strategies	Size small (N=31)		Size medium and large (N=29)		Total face size (N=60)		
	Size	Fit factor Median (IQR)	p-value**	Fit factor Median (IQR)	p-value**	Fit factor Median (IQR)	p-value
1. Post video training		50 (18, 108)	1	200 (130, 200)	1	113.50 (48.50, 200)	1
2. Mirror		94 (37.50, 159)	< 0.001*	200 (177, 200)	0.001*	161.50 (79, 200)	0.003*
3. Buddy		150 (64.5, 181.5)	< 0.001*	200 (200, 200)	0.001*	189 (149, 200)	< 0.001*
4. Bouffant cap		102 (50.5, 143)	0.002*	174 (150, 200)	0.857	147 (82.75, 199.75)	0.002*

*Statistically significant at $p < 0.05$, ** The p-value from the Wilcoxon Signed Ranks Test

Table 5. Association between other factors associated with passing the rate of fit test

Factor		Pass rate		OR (95%CI lower, upper)	p-value
		Pass	Not pass		
Face size (Fit test:300 tests)	Medium and large	122 (84.10%)	23 (15.20%)	7.54 (4.36, 13.05)	< 0.001
	Small	64 (41.30%)	91 (58.70%)		
Time (Fit test:300 tests)					< 0.001
< 40 seconds	≥ 40	156 (78.00%)	44 (22.00%)	8.27 (4.80, 14.24)	
≥ 40 seconds	< 40	30 (30.00%)	70 (70.00%)		

and Bouffant cap. For medium and large face sizes, significant differences in FF were observed post video training between Mirror and Buddy (Table 4).

Face size and the average time required to don an N95 respirator were associated with passing rates on fit tests. Our results indicate that face size has a significant association with fit test success. Participants with medium and large face sizes were approximately 7.5 times more likely to pass the fit test compared to those with small face sizes (OR 7.54, 95%CI: 4.36–13.05). Similarly, the average time taken to don the N95 respirator was also significantly associated with passing rates. Participants who took more than 40 seconds to don the mask were about eight times more likely to pass the fit test compared to those who took

less than 40 seconds (OR 8.27, 95%CI: 4.80–14.24) (Table 5). The 40-second threshold was selected because it was the shortest donning time that showed a statistically significant association with fit test outcomes.

The highest perception of the mask being very practical in use and confidence in the fit after performing a seal check each time the N95 respirator was worn was for Mirror (45.00%) (Table 6). The Buddy strategy achieved the highest passing rate (76.67%), despite having a lower perceived practicality (21.60%). These results indicate that different strategies result in varying levels of user confidence and fit test success (Table 6).

After participants had used self-training for the N95 respirator, each group was required to

Table 6. Perception of practical value of strategies to achieve proper fit of the N95 respirator

Strategies	N (%)
1. Post video training, passing rate 61.67%	1 (1.60)
2. Mirror, passing rate 68.33%	27 (45.00)
3. Buddy, passing rate 76.67%	13 (21.60)
4. Bouffant cap, passing rate 73.33%	19 (31.60)

use the N95 strategies assigned to them at at least three times in actual hospital situations before returning for QNFT. The average duration for self-training was 13 days. In this study, there were a total of 60 participants. Of these, 20 participants completed the follow-up, while 40 were lost to follow-up. The paired-sample t-test revealed a significant increase in FF after three rounds of self-training ($t = -2.91$, $p = 0.009$), but there was no significant reduction in the time required to put on the N95 respirator ($t = 0.99$, $p = 0.337$). The chi-square statistics demonstrate that self-training is not significantly associated with passing rates on fit tests ($p = 0.5$) (Table 7).

DISCUSSION

Many training methods for protective performance have been developed. These training methods can be categorized into three main types: 1) printed training materials, 2) non-interactive videos viewed on a computer monitor, and 3) computer-based training (CBT). CBT is an interactive program that combines text, images, and video clips, and includes user interactions through a computer interface along with short quiz items designed to reinforce learning (11). We selected non-interactive videos as the training method in this study

which provided detailed instructions on the multi-step process of respirator use, including correctly donning the gear, making adjustments for a secure facial seal, performing fit checks (both positive and negative pressure checks), and properly removing the respirator.

The results show training resulted in a higher FF than no-training and an increased passing rate of the fit test. Training can help improve the process of putting the straps in place, as mistakes in this process were often made during the procedures (12, 13). Practice and experience using N95 respirators can also significantly affect fit (14, 15).

A comparison of the training strategies highlights the advantages of alternative methods (Mirror, Buddy, and Bouffant cap) over video-training strategies. The Mirror strategy demonstrates that positioning the mask while looking into a mirror allows for more precise centering and ensures that both straps of the N95 respirator are correctly placed on the head, offering an advantage over video training alone. The CDC recommends checking the fit of an N95 respirator, and using a mirror is a method that can assist in ensuring that the respirator is properly positioned and forms an effective seal (16). Buddy strategies enhance the fit check process by effectively detecting leakage as observed in this study, which shows increased accuracy in identifying improper respirator seals when a Buddy observer assists with the check. We found that observer-assisted fit checks significantly improved leak detection compared to self-checks alone. Long, dangling hair can interfere with the proper fit of respirator straps and can compromise the seal to the face.

Table 7. Paired t-test comparing no training and post self-training, association between self-training with passing rate of fit test

Fit factor	After training		After three rounds Self training		t	p-value*
	Mean	SD	Mean	SD		
Fit factor	122.85	65.37	138.80	48.58	-2.91	0.009
Time	47.47	7.49	44.89	6.27	0.99	0.337
	Pass rate		OR (95%CI)	p-value**		
	Yes	No				
After training	14	6	1.29 0.32, 5.18)	0.5		
After three rounds of self-training	15	5				

*The p-value resulting from Paired t-test, **The p-value from the McNemar Test

It is recommended that long hair be secured in a low ponytail or bun, positioned between the upper and lower straps, to avoid such issues (17). This study also highlights the benefits of bouffant cap use, which emphasizes strap adjustment prior to donning to ensure correct positioning and to minimize hair-related interference. In addition to containing hair, bouffant caps can reduce the likelihood of strap slippage, a factor that can lead to mask displacement and diminished seal integrity. Proper strap tension and placement over well-contained hair—such as under a bouffant cap—can enhance respirator stability and help maintain a consistent facial seal during physical movement or extended wear.

The Buddy strategy resulted in significantly higher FF than video training alone for small, medium, and large face sizes. However, the Mirror and Bouffant cap strategies showed significantly higher FF than video training only for small face sizes. This may be explained by the fact that individuals with smaller facial dimensions are more prone to respirator leakage, particularly when the N95 is not positioned correctly. Using a mirror for visual guidance during donning and securing hair with a bouffant cap may help optimize the placement and seal of the respirator, thereby compensating for the anatomical challenges associated with smaller face sizes. The Buddy system is effective in identifying correct procedures. In a previous study, sensitivity, defined as the ability to correctly identify correct procedures, was 100.00% for both onsite and remote buddies (18).

It was determined that there were significant differences in FF among facial sizes across all tests. Participants with medium and large face sizes had higher FF compared to those with small face sizes. Our results indicate that face size is significantly associated with passing rates on fit tests. Specifically, participants with medium and large face sizes were approximately 7.5 times more likely to pass the fit tests than those with small face sizes. Larger facial sizes reduced the leakage of half-mask respirators, which were strongly affected by leaks around the nose and chin area, compared to smaller face sizes (19, 20). Large face sizes also showed the highest pass rates with alternative well-fitting masks (21). The fit of the fold-model respirator improved with increasing facial dimensions among the partici-

pants. The percentages of participants passing the QLFT were significantly higher for the medium- and large-size face groups compared to the small-size group (21).

Participants underwent self-training for the N95 respirator at least three times. The paired-sample t-test showed a significant improvement in FF after self-training. However, there was no significant reduction in the time required to don the N95 respirator. Although regular practice of seal checks has been suggested to improve fit test passing rates (22), our study found no statistically significant increase in passing rates with self-training. However, a practice of regular seal checks was associated with a significant improvement in Fit Factor. This indicates that while consistent seal check practice may not directly influence pass/fail outcomes, it can enhance the overall quality of respirator fit.

The mean time required to don an N95 respirator and achieve a proper fit using various alternative strategies was between 42.08 and 48.05 seconds. Our results indicate that the time taken to don an N95 respirator is significantly associated with passing rates on fit tests. Participants who took more than 40 seconds to don the mask were approximately eight times more likely to pass the fit tests compared to those who took less than 40 seconds (OR 8.27, 95%CI: 4.80–14.24). Other findings suggest that both the completeness and correctness of PPE donning are time-sensitive processes. Studies have shown that the time required for donning and doffing other types of protective equipment depends on the complexity of the equipment and ranges from 2 to 4.5 minutes for simpler setups to 10 minutes or more for more complex scenarios, sometimes exceeding 20 minutes (23, 24). However, in this study, the focus was exclusively on the time required for donning an N95 respirator, an average of approximately 45 seconds.

The present study found that individuals with smaller facial dimensions experienced more frequent respirator leakage at the nose and chin, consistent with earlier findings identifying these regions as common leak sites. Leakage was evaluated using a fluorescent tracer aerosol and detected with a forward light scattering photometer, allowing for precise localization of leak points (19).

CONCLUSIONS

This study demonstrates that HCWs with small face sizes have lower fit test pass rates compared to those with larger face sizes. However, the implementation of targeted donning strategies—namely, the Buddy strategy, Mirror strategy, and Bouffant cap strategy—can significantly improve fit factor (FF) scores and pass rates among HCWs with small face sizes. For HCWs with large face sizes, both the Buddy and Mirror strategies also contribute to enhanced FF scores and improved fit test outcomes. Additionally, a longer donning time, particularly a period exceeding 40 seconds, was positively associated with higher fit test pass rates, suggesting that careful and deliberate donning contributes to achieving a better respirator fit.

Limitations

This research used only the N95 respirator model 3M™ Aura™ 1870+; therefore, the results may not be applicable to other N95 models. A larger sample size in future research could better represent the differences in fit factor and passing rates between small and large face sizes. Volunteers whose faces do not fit the N95 respirator model 3M™ Aura™ 1870+ should be excluded from the sample.

One limitation of our study is the loss to follow-up of 40 cases which may have resulted in insufficient data to draw definitive conclusions regarding the effectiveness of self-training.

Another limitation of this study is the potential training effect. Each participant donned the N95 respirator and underwent QNFT five times, which may have allowed them to improve their fit-checking and donning skills, particularly by the final attempt. To minimize this potential bias, however, the order of donning strategies was randomized for each participant.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the participants and the Faculty of Medicine, Khon Kaen University, for their support.

FUNDING

This work was supported by the Faculty of Medicine, Khon Kaen University, Thailand (Grant Number IN67026). This research received no spe-

cific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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