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The Association Between Occupational Exposures and Cigarette Smoking Among Operating Engineers

OiSaeng Hong, RN, PhD, FAAN; Sonia A. Duffy, RN, PhD, FAAN; Seung Hee Choi, RN, PhD; Dal Lae Chin, RN, PhD

ABSTRACT. The purpose of this study was to determine the relationship between occupational exposures and cigarette smoking among operating engineers. A cross-sectional survey was conducted with operating engineers ($N = 412$) from a midwestern state in the United States. The survey included validated questions on cigarette smoking, occupational exposures, demographics, comorbidities, and health behaviors. About 35% were current smokers. Those exposed to asphalt fumes, heat stress, concrete dust, and welding fumes were less likely to smoke (odds ratio [OR] = .79, 95% confidence interval [CI]: .64–.98). Other factors associated with smoking included younger age (OR = .97, 95% CI: .94–.99), problem drinking (OR = 1.07, 95% CI: 1.03–1.12), lower Body Mass Index (OR = .95, 95% CI: .90–.99), and being separated/widowed/divorced (OR = 2.24, 95% CI: 1.19–4.20). Further investigation is needed for better understanding about job-specific exposure patterns and their impact on cigarette smoking among operating engineers.

KEYWORDS: blue-collar workers, operating engineers, occupational exposure, smoking

Blue-collar workers are at significant risk for cancer in that 35% are current smokers compared with 20% of white-collar workers.¹ Compared with other workers, blue-collar workers are more likely to smoke and are less successful in quitting despite a similar rate of quit attempts.^{1,2} Cigarette smoking is the health behavior that has the single largest impact on health inequalities.¹

The high rate of smoking among blue-collar workers is of particular concern given that many are exposed to occupational carcinogens, such as silica, diesel exhaust, fumes, and asbestos, which might increase disease risks associated with smoking.³ Although many have studied on factors contributing to elevated tobacco use in blue-collar workers, limited research has focused on work environment that may influence workers' smoking. From an analyses of the US

National Health Interview Survey, Sterling and Weinkam⁴ found that smoking was much more prevalent among workers who were also more exposed to hazards (such as irritating, toxic dusts, and fumes) in the workplace and much less prevalent among those less exposed to such hazards. Sorensen et al⁵ reported that blue-collar workers reporting exposure to chemical hazards on the job were significantly more likely to be smokers than were unexposed workers. Similarly, in a recent examination of data from building trades workers ($N = 1,817$), Chin and her colleagues⁶ found that exposures to dust and chemicals at work were significantly associated with an increased likelihood of current smoking. On the other hand, Okechukwu et al⁷ found no significant difference in the association between exposure to occupational hazards (eg, dust, chemicals, noise,

OiSaeng Hong and Dal Lae Chin are with the School of Nursing, University of California San Francisco, San Francisco, California, USA. Sonia A. Duffy is with the Departments of Nursing, Otolaryngology, and Psychiatry, University of Michigan, Ann Arbor, Michigan, USA; and VA Center for Clinical Management Research, VA Ann Arbor Healthcare System, Ann Arbor, Michigan, USA. Seung Hee Choi is with the School of Nursing, University of Michigan, Ann Arbor, Michigan, USA.

and ergonomics strain) and smoking among blue-collar workers.

Operating engineers (those who are responsible for the operation of heavy earth moving equipment to construct buildings, bridges, and roads) have a high percentage of smokers⁸ and are at particular risk for cancers of the lung,⁹ head and neck,¹⁰ and trachea and bronchi.¹¹ Operating engineers are also exposed to a variety of occupational hazards at work. Hence, the purpose of this study was to determine the relationship between occupational exposures (eg, asbestos, asphalt fumes, benzene, lead/lead paint, silica, solvents, etc) and cigarette smoking among operating engineers, controlling for other covariates known to be associated with cigarette smoking.

METHODS

Study design and participants

The cross-sectional survey was conducted among operating engineers in a midwestern state in the United States. The study participants were recruited from 16,000 workers in the entire state of Michigan attending either a 3-year apprenticeship program or an 8-hour Hazardous Materials (HAZMAT) training during the winter of 2008. The instructor for the HAZMAT course explained the study and passed out the survey packets, including a study information sheet, questionnaire, and return envelope, until a quota of 500 was reached. Ninety percent of the operating engineers who were asked to participate agreed and returned the self-administered survey. Among the returned surveys, 2 were incomplete and 86 had missing data on either smoking status or occupational exposures or other covariates; thus, 412 were included in the analysis in the present study. All participants received a \$10 gasoline gift card for completing the survey. All study protocols were approved by the University of Michigan Institutional Review Board.

Measures

Dependent Variable: Smoking Status

Smoking status was measured by a single question that asked participants to circle the best answer: (1) I currently smoke cigarettes; (2) I have smoked in the past, but quit within the last month; (3) I have smoked in the past, but quit within the last 6 months; (4) I have smoked in the past, but quit within the last year; (5) I have smoked in the past, but quit over a year ago; and (6) I have never used tobacco products. According to a 30-day prolonged abstinence measure,¹² smokers were defined as those who currently smoked or those who had smoked in the past but quit within the last month.

Independent Variable: Occupational Exposures

Nine different hazards that are common to heavy equipment operators in construction were included: asbestos, as-

phalt fumes, benzene, concrete dust/milling, heat stress, lead/lead paint, silica, solvents, and welding fumes. These measures were taken from the Occupational Safety and Health Administration (OSHA) form (<http://www.oshatrain.org/pages/library.html>).¹³ The participants were asked to select (yes/no) all types of occupational hazards to which they had ever been exposed. Types of hazards were grouped into 2 distinct categories using explanatory factor analyses (EFA) as described in the Statistical Analysis and Results. EFA, a statistical technique within factor analysis, is based on common factor model and its overall goal is to identify underlying relationships among measured variables.¹⁴ Thus, we chose EFA to reveal common factor structure that may exist among those occupational exposure variables.

Covariates

Since demographic characteristics have shown significant association with smoking,^{1,15-18} age, sex, race, marital status, educational level, and years of experience on the job were included as covariates. Medical comorbidities and depression have also been shown to influence smoking^{19,20}; hence, *medical comorbidities* were assessed by the question "Have you ever been diagnosed or treated for any of the following health problems?" with the list of diseases (cancer, lung disease, heart disease, high blood pressure, stroke, psychiatric problems, diabetes, arthritis, and other) with a yes/no response.²¹ These conditions were then totaled and dichotomized into 2 groups: people who reported no medical comorbidity and those who reported 1 or more comorbid conditions. *Depression* was measured using the 20-item, validated Center for Epidemiologic Studies/Depressed Mood Scale (CES-D).²² Possible scores range from 0 to 60, with a cutoff score of 16 or higher indicating depression. The reliability of the measure in the present study was Cronbach's $\alpha = .74$.

Since earlier studies reported that health-related behaviors would influence smoking,²³⁻²⁸ this study included several behavioral variables such as problem alcohol drinking, body mass index (BMI), and sleep quality. *Alcohol drinking* was measured by the 10-item validated Alcohol Use Disorder Identification Test (AUDIT).²⁹ Possible scores range from 0 to 40, with a cutoff point of 8 or higher indicating problem drinking. The reliability of the measure in the present study was Cronbach's $\alpha = .81$. *BMI* (weight in kilograms divided by the square of height in meters) was calculated based on self-reported height (without shoes) and weight. *Sleep quality* was measured by the 6-item, validated Medical Outcomes Study (MOS) sleep scale.³⁰ The reliability of the measure in the present study was Cronbach's $\alpha = .72$.

Data analysis

Descriptive statistics (frequencies, means, and percentages) were computed for all variables. Internal consistency reliability for each scale was examined using Cronbach's alpha coefficients. Associations between the dependent

variable and the independent variables were assessed using chi-square, Spearman's rho correlation coefficients for categorical variables, and Pearson correlation coefficients for continuous variables.

Participants' responses for the 9 occupational exposures were subjected to a series of EFA to group them in logical manner. EFA was done using oblique rotation (direct oblimin). Oblique rotation does not impose the restriction that factors be orthogonal so results in terminal factors after oblique rotation are, in general, correlated with each other.³¹ The following principles guided EFA: (1) a minimum eigenvalue of 1 as a cutoff value for extraction; (2) the point of discontinuity of the scree plot; and (3) a criterion of .30 as an acceptable minimum loading.^{32,33}

Using a listwise deletion method, multivariable logistic regression analyses were conducted with 2 factors of occupational exposures and significant covariates in bivariate analyses. Assessment for multicollinearity was conducted first to check for high intercorrelations among independent variables. Since age and years of job experience was highly correlated ($r = .64, p < .001$), only age was included in the final multivariable model. Using the rule of 10 participants per factor for regression analysis,³⁴ there was sufficient power to include over 14 variables, since there were 142 smokers and 270 nonsmokers. Analyses were conducted using the Statistical Package for the Social Science (SPSS) version 19 (SPSS, Chicago, IL). A value of $p < .05$ was considered to be significant.

RESULTS

Characteristics of the participants

The characteristics of the study participants are shown in Table 1. Participants were predominantly middle aged (mean age = 43.2 years), male (91.2%), and white (91.8%). About 67.6% of the participants were married and 59.8% had a high school education or less. The majority (81.3%) of the participants worked more than 10 years. Approximately 34.5% (142/412) were current smokers. Almost half (46.7%) screened positive for depressive symptoms (≥ 16 scores), and 31.2% scored positive for problem drinking (≥ 8 scores). The mean BMI was 30.2, and the majority of the participants were overweight (25–29.9, 41.1%) or obese (≥ 30 , 42.8%). Mean of sleep quality was 70.4, a bit lower when compared with population norms of 72.³⁰

Figure 1 shows the distribution of self-reported occupational hazardous exposures. The participants were exposed to various occupational hazards: heat stress (75.7%), concrete dust/milling (75.5%), welding fumes (71.4%), asphalt fumes (63.6%), solvents (58.0), silica (56.8%), asbestos (51.2%), lead/lead paint (40.3%), and benzene (37.9%).

Two factors of occupational exposures

Simple bivariate correlations among the 9 items ranged from Spearman's rho = .20–.53 for the study sample. Con-

Table 1.—Characteristics of the Study Participants (N = 412)*

Characteristics	Mean	SD	Range
Age	43.24	9.28	18–70
CES-D (Depressive symptoms)	16.48	6.56	0–45
AUDIT (Alcohol problems)	6.01	5.51	0–29
BMI	30.20	5.95	18.26–58.25
Sleep quality	70.44	16.78	0–100
	<i>n</i>	<i>%</i>	
Smoking Status			
Current smokers	142	34.5	
Nonsmokers	270	65.5	
Gender			
Male	363	91.2	
Female	35	8.8	
Race			
White	359	91.8	
Nonwhite	32	8.2	
Marital status			
Married	271	67.6	
Separated/widowed/divorced	66	16.5	
Nonmarried	64	16.0	
Education			
High school or lower	239	59.8	
College or higher	161	40.3	
Job experience			
Up to 9 years	75	18.8	
10 or more years	325	81.3	
Medical comorbidities			
None	196	49.1	
One or more	203	50.9	
CES-D (Depressive symptoms)			
Yes (≥ 16 scores)	182	46.7	
No (< 16 scores)	208	53.3	
AUDIT (Alcohol problems)			
Yes (≥ 8 scores)	124	31.2	
No (< 8 scores)	273	68.8	
BMI			
Underweight (< 18.5)	1	0.3	
Normal (18.5–24.9)	63	15.9	
Overweight (25–29.9)	163	41.1	
Obese (≥ 30)	170	42.8	

*Participant numbers in each variable do not always add up to the total number of participants because of missing data.

sistent positive intercorrelations were found among the items. The appropriateness of the correlation matrix for factor analytic methods was determined by computing Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. Bartlett's test of sphericity can be used to test the hypothesis that the correlation matrix is an identity matrix. The value of the test statistic for sphericity was large ($\chi^2 = 956.446$) and the associated significance levels were small ($p < .001$) for the study participants. The KMO measure of sampling adequacy is an index for comparing the observed correlation coefficients and the partial correlation coefficients. Reasonably large values for the KMO coefficient are needed for factor analysis of the variables.³² The

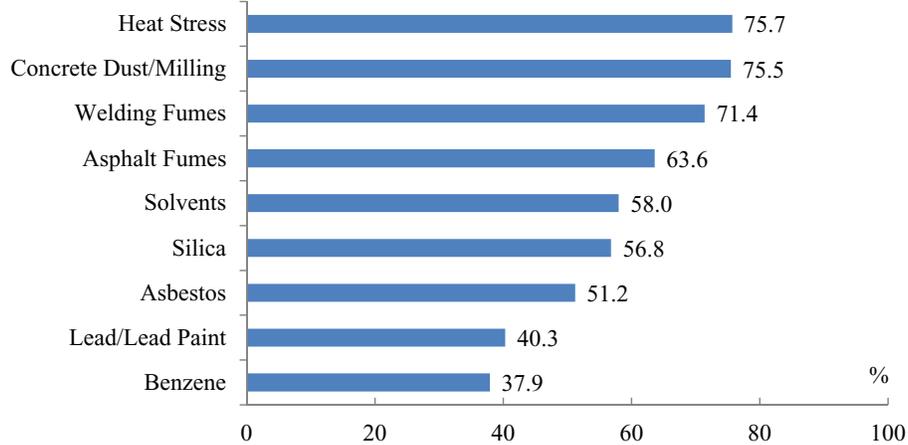


Fig. 1. Occupational exposures among operating engineers (N = 412) (color figure available online).

value of the KMO statistics for the study participants was .87. These 2 measures confirmed that the items cohered psychometrically and the use of the factor model was appropriate for these data.³²

Principal components factor analysis with oblique rotation (direct oblimin) yielded 2-factor solution, as summarized in Table 2. All of the 9 exposure variables loaded strongly on only 1 of the 2 factors, with loadings of .46 or greater. Exposure factor 1 included 5 types of occupational hazards: lead/lead paint, asbestos, benzene, solvents, and silica. Exposure factor 2 had 4 types of hazards: asphalt fumes, heat stress, concrete dust, and welding fumes. The 2 factors explained 54.21% of variance (41.1% and 13.1% by exposure factors 1 and 2, respectively).

Bivariate relationships with smoking

Bivariate relationships of cigarette smoking with the independent variables (exposure factors 1 and 2) and covariates are summarized in Table 3. Both occupational exposure factors 1 and 2 showed significant inverse relationships to

smoking, indicating that workers who reported more occupational exposures were less likely to smoke ($p = .006$, $p = .001$). Among other covariates, age, marital status, job experience, medical comorbidities, alcohol use, and BMI were significantly associated with smoking. Compared with nonsmokers, smokers were more likely to be younger ($p = .015$), to be separated/widowed/divorced ($p = .015$), to have fewer years of job experience ($p = .020$), to have no medical comorbidities ($p = .023$), to have higher alcohol use ($p < .001$), and to have lower BMI ($p < .001$). There were no differences in gender, race, and educational level between smokers and nonsmokers. Interestingly, no significant differences were found in depressive symptoms between smokers and nonsmokers (16.80 vs 16.31; $p = .519$). Both groups included equally high percentages of workers with depression (47.4% vs 46.3%). In addition, the 2 groups did not show differences in sleep quality.

Multivariable logistic regression analysis

The results of the multivariable logistic regression analysis for occupational exposure factors are summarized in Table 4. Whereas occupational exposure factor 1 (lead/lead paint + asbestos + benzene + solvents + silica) was not significantly associated with current smoking, occupational exposure factor 2 (asphalt fumes + heat stress + concrete dust + welding fumes) was significantly associated with smoking (odds ratio [OR] = .79, 95% confidence interval [CI]: .66–.95; $p = .012$). Two demographic factors were significant correlates of smoking: younger workers were more likely to smoke than older workers (OR = .97, 95% CI: .94–.99; $p = .033$), and workers who were separated/widowed/divorced were more likely to smoke compared with those who were married (OR = 2.24, 95% CI: 1.19–4.20; $p = .013$). Two health behavior factors were also significantly associated with smoking: BMI (OR = .95, 95% CI: .90–.99; $p = .015$) and problem drinking (OR = 1.07, 95% CI: 1.03–1.12; $p = .001$). As expected, the

Table 2.—Factor Analysis of Occupational Exposure (N = 412)

Occupational exposure	Exposure factor 1	Exposure factor 2
Lead/lead paint	.859	
Asbestos	.764	
Benzene	.747	
Solvents	.531	
Silica	.455	
Asphalt fumes		.814
Heat stress		.812
Concrete dust/milling		.636
Welding fumes		.587

Table 3.—Bivariate Relationship of Predictors With Smoking (N = 412)

Predictor	Smokers (n = 142, 34.5%)		Nonsmokers (n = 270, 65.5%)		p value*
	Mean	SD	Mean	SD	
Age	41.63	8.91	44.05	9.38	.015
CES-D (Depressive symptoms)	16.80	7.85	16.31	5.79	.519
AUDIT (Alcohol use)	7.71	5.97	5.14	5.07	<.001
BMI	28.62	5.35	30.96	6.08	<.001
Sleep quality	68.22	17.44	71.58	16.35	.057
Occupational exposure factor 1 ^a	2.11	1.84	2.62	1.74	.006
Occupational exposure factor 2 ^b	2.54	1.44	3.03	1.21	.001
	<i>n</i>	(%)	<i>n</i>	(%)	
Gender					.737
Male	119	90.2	244	91.7	
Female	13	9.8	22	8.3	
Race					
White	111	88.1	248	93.6	
Nonwhite	15	11.9	17	6.4	.098
Educational level					.315
High school or less	84	63.6	155	57.8	
College or more	48	36.4	113	42.2	
Marital status					.015
Married	82	61.7	189	70.5	
Separated/widowed/divorced	32	24.1	34	12.7	
Never married	19	14.3	45	16.8	
Job experience					.020
Up to 9 years	34	25.6	41	15.4	
10 or more years	99	74.4	226	84.6	
Medical comorbidities					.023
None	76	57.6	120	44.9	
One or more	56	42.4	147	55.1	

^aOccupational factor 1: lead/lead paint + benzene + asbestos + solvents + silica.

^bOccupational factor 2: asphalt fumes + heat stress + concrete dust + welding fumes.

*p value for t test or chi-square test.

Table 4.—Multivariable Logistic Regression (N = 412)

Predictor	Odds ratio	95% CI	p value
Occupational exposure factor 1 ^a	.99	.85–1.16	.956
Occupational exposure factor 2 ^b	.79	.64–.98	.033
Age (continuous)	.97	.94–.99	.033
Marital status			.009
Married (Reference)			
Separated/widowed/divorced	2.24	1.19–4.20	.013
Never married	.61	.30–1.23	.163
Medical comorbidities			
None (Reference)			
One or more	.76	.47–1.23	.269
Alcohol drinking (AUDIT) (continuous)	1.07	1.03–1.12	.001
BMI (continuous)	.95	.90–.99	.015

^aOccupational factor 1: lead/lead paint + benzene + asbestos + solvents + silica.

^bOccupational factor 2: asphalt fumes + heat stress + concrete dust + welding fumes.

participants with lower BMI and higher AUDIT scores (indicating problem drinking) were more likely to smoke. Medical comorbidities were not significantly associated with current smoking.

COMMENT

The present study is one of the first ones to examine the relationship between specific occupational hazardous exposures and smoking among operating engineers. The study found exposures to certain type of hazards (asphalt fumes + heat stress + concrete dust + welding fumes) demonstrated an inverse relationship to operating engineers' smoking (ie, workers with higher exposure to occupational hazards were less likely to smoke). This finding contradicts earlier work that reported higher exposure to occupational hazards, such as chemicals and dust, was associated with increased current smoking among workers,^{4–6} albeit previous studies did not include specific types of occupational hazards and several of these studies are old.

In talking with our community partners at the operating engineers training site to explain these results, hazards such as heat stress, asphalt fume, and concrete dust are more related to outdoor road work, which is highly physical and labor-intensive. Since asphalt and concrete dry quickly, operating engineers must work very quickly and may not have time to take a smoking break. It is also possible that operating engineers who require labor-intensive work might be more health conscious because losing their health may mean losing their work. Thus, they may be less likely to smoke to maintain good physical health to enhance their work performance. An additional anecdotal explanation from workers was that one of their asphalt concrete companies has a no smoking policy, which might have influenced at least some of the operating engineers' smoking behavior.

Recent work by Chin and her colleague⁶ showed that workers with greater concern about their exposure to occupational hazards were less likely to smoke. The current study did not assess operating engineers' concerns about hazardous exposures on the job and its relationship with smoking. However, it may be possible that operating engineers in the study became more concerned about their health when they were exposed to visually recognizable hazards such as asphalt fumes, heat stress, concrete dust, and welding fumes; thus, they had a less likelihood of smoking. Workers' concerns about their exposures to hazardous agents at work may be an important influence in smoking behavior.

Interestingly, exposure to the other types of hazards (lead/lead paint, asbestos, benzene, solvents, and silica) did not affect operating engineers' smoking. Although we did not find scientific explanation for this interesting finding, we have a few plausible explanations that came from field workers. These hazards are related more to building and demolition work than road work. Operating engineers who are involved in building and demolition work often have long periods of idle time waiting for parts or sitting around for other trade workers to complete their jobs before performing their tasks. This waiting period may provide operating engineers with ample opportunities to smoke. Another possibility is that, compared with the other group of exposures, these hazards (lead/lead paint, asbestos, benzene, solvents, and silica) are less visible to the naked eye. Therefore, workers may be less aware of their exposures to those hazards. Therefore, smoking cessation interventions raising workers' consciousness of the synergic effects of occupational hazards with smoking on developing pulmonary diseases would be beneficial for operating engineers exposed to those less visible hazards.

The present study shows that operating engineers have a 35% smoking prevalence, which is consistent with the national trend for construction workers or other blue-collar worker groups. Even though the prevalence of current smoking among US adults (aged 18 years or older) has declined during the past 4 decades from 40% in 1964³⁵ to 19% in 2010,³⁶ smoking prevalence was highest among construction workers (38.8%) and lowest among workers employed in the health diagnosing professions (5%), with blue-collar occupa-

tions often having a greater than 30% smoking prevalence.³⁷ However, it is a concern that the high prevalence (35%) of smoking found in the present study is much higher than that of the general working population (19.6%),¹⁵ in particular, white-collar workers (20.3%).¹

Worksite smoking policies such as smoke-free workplaces can reduce cigarette smoking during working hours,³⁸ decrease workers' exposure to second hand smoking,^{39,40} and reduce relapse among smokers who have recently quit.⁴¹ However, as reported earlier, blue-collar workplaces are less likely to have smoke-free policies in place.⁴²⁻⁴⁵ Furthermore, certain groups of workers including operating engineers work outside; thus, they are not subject to indoor air policies on the prohibition of cigarette smoking.

Younger age was significantly associated with current smoking, which supports previous research findings.^{1,15,16} The present study also found separated/widowed/divorced workers were significantly more likely to smoke than married ones, which is consistent with previous studies.^{17,18} The protective effect of marriage on smoking may be because marriage is a marker of social support. Worksite smoking cessation interventions that include social support may enhance quit rates, as previous studies have shown that that social support was likely to improve smokers' intention to quit smoking, confidence in the ability to quit smoking, and actual success in quitting smoking.⁴⁶⁻⁴⁸

The strong association between smoking cigarettes and problem drinking has been reported in many studies.^{24,25,27} It is important to assess the drinking patterns of smokers to improve quitting smoking. The present study also found that current smokers had lower BMI, which is consistent with the reports of previous studies.^{23,26}

Limitations

This was a cross-sectional study; therefore, the direction of causality cannot be determined. The study was conducted with operating engineers who were predominantly white males working in one state in the midwestern region of the United States; thus, the findings cannot be generalized to all operating engineers. Occupational exposure was assessed based on the operating engineer's self-report, with no objective work environment surveillance data. Although we used validated instruments to assess other covariates, such as alcohol drinking, depression, sleep quality, all data were collected as self-report and may not be as accurate as clinical assessment. Nonetheless, the study contributes valuable information with regards to our limited knowledge on occupational exposures among a large group of workers.

Conclusion

Occupational exposure to certain types of hazards (asphalt fumes, heat stress, concrete dust, and welding fumes) that are more likely to occur during road work were significantly inversely associated with smoking. Exposure to

other types of hazards (lead/lead paint, asbestos, benzene, solvents, and silica) showed no association with operating engineers' smoking behavior. The findings of this study suggest that the type of workers' jobs may influence their smoking rates. More studies need to be conducted to better understand job-specific exposure patterns and their impact on cigarette smoking among operating engineers.

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For comments and further information, address correspondence to Oisang Hong, RN, PhD, FAAN, Professor & Director of Occupational and Environmental Health Nursing Graduate Program, School of Nursing, University of California, San Francisco (UCSF), 2 Koret Way, Room N 531D, San Francisco, CA 94143-0608, USA.

E-mail: oisang.hong@nursing.ucsf.edu

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