A Pilot Respiratory Health Assessment of Nail Technicians: Symptoms, Lung Function, and Airway Inflammation

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Background *Recent surveys suggest nail technicians, particularly artificial nail applicators, have increased respiratory symptoms and asthma risk.*
Methods *We examined lung function ($n = 62$) and a marker of airway inflammation, i.e., exhaled nitric oxide (ENO) ($n = 43$), in a subset of nail technician and control participants in a pilot health assessment.*
Results *Bivariate analysis of technicians demonstrated that job latency was inversely correlated with FEV1 percent predicted (FEV1PP) ($r = -0.34$, $P = 0.03$) and FVCPP ($r = -0.32$, $P = 0.05$). Acrylic gel contact hours were inversely correlated with FEV1PP ($r = -0.38$, $P = 0.02$) and FVCPP ($r = -0.47$, $P = 0.003$). Current smoking was inversely and significantly ($P \leq 0.05$) associated with ENO in bivariate analysis. Log 10 ENO levels were directly correlated with job latency ($P = 0.012$) and gel nail application ($P = 0.026$) in multivariable analyses.*
Conclusions *These positive pilot respiratory test results warrant additional future investigation.* Am. J. Ind. Med. 52:868–875, 2009. *© 2009 Wiley-Liss, Inc.*

KEY WORDS: nail technicians; artificial nails; lung function; exhaled nitric oxide; smoking

INTRODUCTION

Nail technology, the art and study of nail care including artificial nail application, is a growing part of the worldwide personal care industry. The US Department of Labor projects 10-year employment growth of 28% (national average 7–13%) [Bureau of Labor Statistics 2008–2009 edition]. Concerns have recently emerged that nail technicians, particularly those who apply artificial nails, may be at risk for developing respiratory symptoms and asthma.

Nail technicians work long hours [Bureau of Labor Statistics 2008–2009 edition, Quach et al., 2008] at close range with multiple agents, some of which are potential sensitizers and respiratory irritants. Working with natural nails entails exposures to nail dusts, disinfectants, acetone, ethyl acetate, or n-butyl acetate [Gjølstad et al., 2006, Roelofs et al., 2008]. Artificial (acrylic) nail applications use similar compounds as well as acrylic monomers and polymers and cyanoacrylate containing adhesives.

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The predominant acrylic monomer used is ethyl methacrylate (EMA), which has largely replaced methyl methacrylate (MMA) monomer in nail salons in the US and several other countries due to concerns about health effects. The most common acrylic nail application entails mixing acrylic polymer powder and liquid EMA monomer. This mixture produces the paste that is molded onto the nail where it hardens and is subsequently filed, and then coated with nail finish. Gel application is another method in which nails are coated with premixed methacrylate oligomers then UV light cured [Gjølstad et al., 2006]. The less common ''resin'' and ''powder'' methods involve repeated applications of cyanoacrylate adhesive, solvent curing spray, and acrylic polymer powder. Ambient EMA levels have consistently been found in nail salons and vocational/cosmetology schools [Beasley-Spencer et al., 1997]. Gjølstad et al. (2006) evaluated 22 Norwegian nail salons applying acrylic nails, and found 92.5% of air samples contained EMA, mean concentration 0.88 ppm [Gjølstad et al., 2006]. While there are case reports of cyanoacrylate associated asthma [Lozewicz et al., 1985], the low ethyl 2-cyanoacrylate concentrations measured in that study were attributed to the short time to apply adhesive in all but the resin method.

There are very few publications evaluating nail technician respiratory issues. The two most recent were survey studies. Kreiss et al. (2006) studied 524 licensed Colorado nail technicians; 65.1% had 5 years or less time in trade [Kreiss et al., 2006]. There was a significant association between artificial nail application and post-hire asthma diagnosis, RR 2.83 (95% CI 1.64–4.88). Roelofs et al. (2008) studied 71 Boston Vietnamese-American nail technicians and found a significant relationship between work-related respiratory symptoms and reports of ''poorer air quality''($P = 0.003$), ''not enough fresh air'' ($P = 0.003$), and ''absence of ventilation devices'' ($P = 0.016$) [Roelofs et al., 2008]. To our knowledge, previous nail technician studies have not included objective measurements of lung function or airway inflammation. We collected spirometry and exhaled nitric oxide (ENO) measurements during the health assessment phase of an ongoing pilot project assessing nail technicians' health and workplace exposure. The purpose of the current analysis is to describe and contrast these measurements and reported symptoms among nail technicians who did and did not apply artificial nails and control participants.

METHODS

Pilot Project Population

The pilot health assessment was conducted using a convenience sample of participants enrolled between January 2007 and February 2008 at seven Midwestern US locales. Several different recruitment strategies were piloted. Initially, regional vocational/cosmetology school students were sought following in-class presentations. Student controls were recruited later by placing posters on authorizing Greater Cincinnati campuses. An enrollment cut-off of 30 control students was applied during the poster recruitment effort due to logistical considerations. Nail technician recruitment was also expanded to target nail technicians licensed during the previous 5 years residing in selected urban or suburban locales in the Illinois, Indiana, Michigan, Missouri, and Ohio licensure databases. English fluency was required, as translations of informed consents and medical histories were beyond the scope of the original pilot project. Written informed consent to collect medical histories, ENO and urine samples (for cotinine), and conduct pulmonary function tests (PFTs), was obtained from each participant upon enrollment. Participants were reimbursed for time ($25–$50) and offsite travel ($50). Testing took place in local classrooms and hotel conference rooms. Medical history information provided by all participants and controls in the broader project was used in the respiratory health analyses. This project had NIOSH Institutional Review Board approval.

Respiratory and Exposure History

Participants completed written medical history forms detailing demographic features, respiratory symptoms, health conditions, smoking history, and contact with manicure related products and processes. Selected items from the American Thoracic Society (ATS) Epidemiology Standardization Project questionnaire were adapted and used [Ferris, 1978].

Cotinine

This tobacco-specific nicotine metabolite was measured in post-shift urine samples using a solid-phase competitive chemiluminescent immunoassay (Immulite® 2000 Nicotine Metabolite, Diagnostic Products Corporation, Los Angeles, CA). Frozen samples were stored at −20°C prior to analysis.

Spirometry

PFTs were conducted according to 2005 ATS spirometry guidelines [Miller et al., 2005]. Trained technicians performed tests with a volume displacement spirometer (Sensormedics Corp., Yorba Linda, CA) retrofitted with a steel faceplate, and OMI spirometry software (Occupational Marketing, Inc., Houston, TX). All test results were interpreted using the NHANES III [Hankinson et al., 1999] Asian American race adjustment factor of 0.94 [Pellegrino et al., 2005].

ENO

Offline ENO samples were collected prior to PFTs using an ATS compliant bag collection and sampling kit (Sievers Instruments, Boulder, CO). Collection involved inhalation through individual bacterial/viral and ENO scrubbing inspiratory filters and then exhalation into a 12 L Mylar bag. Participants were instructed to exhale for 10 s while maintaining a 13.5 cm H_2O expiratory pressure (approximates 3.5 L/s flow rates). Samples were measured offsite using a NIOX® Nitric Oxide chemiluminescence analyzer (Aerocrine, Solna, Sweden). Spiked (50 ppb) samples were analyzed in tandem.

Statistical Methods

Data were entered with verification. Statistical analyses were performed with SAS 9.1 (SAS Institute, Cary, NC) and Microsoft Excel 2003 (Microsoft Corporation, Redmond, WA). Variables were preliminarily reviewed for missing or implausible values, normality departures, and outliers. Descriptive statistics were then generated. Relationships between respiratory outcomes (ENO and lung function PP values) and job exposures (job latency and contact hours with acrylic liquid, gel, and glue as continuous and dichotomous variables) were examined with and without adjustment for smoking status. Bivariate statistical comparisons were conducted using Spearman or Pearson correlation coefficients, Wilcox rank sum [two-sided], χ^2, Fisher's exact test, or two-sample t-tests depending on the variable distributions.

Multivariable analysis of direct FEV1 and FVC volumes was precluded given the small sample size and the large number of covariates required for this regression analysis. In preparation for multivariable analysis of ENO among nail technicians, candidate variables were examined for inclusion in the models. Candidates included age, education, sex, height, weight, smoking status (current smoking status, past smoking status, urinary cotinine levels, reported passive tobacco smoke exposure, total years smoked), time between ENO sample collection and analysis, and field site. Dietary nitrate intake in the past hour was obtained on a subset (n = 20). Those candidate variables that neared significance ($P \leq 0.15$) with ENO in bivariate analyses were retained as potential covariates. A log 10 transformation was applied to ENO for the regression analyses. Separate regressions of the relationship between log 10 ENO and job exposure, with adjustment for potential covariates, were performed for the four exposure variables (job latency and contact hours with acrylic liquid, gel, and glue). Due to the small sample size, a variable reduction strategy was used. Only covariates that changed the coefficient of the relationship between the job exposure variable and log 10 ENO by 10% or more were eligible for inclusion. Main effects (job exposure variables) were forced to remain in the models, with additional covariates added forward (stepwise) and retained if they approached significance ($P \leq 0.15$) in the model. Regression diagnostics were performed.

RESULTS

Pilot Project Population

Nail technician participants (n = 51) included five of eight targeted nail tech students (63%) plus 46 nail technicians. There were 7,735 invitation letters and non-participant feedback forms mailed to licensees, with 90.2% (n = 6,977) delivered and 9.8% (n = 758) returned to sender. While the licensed nail technician response rate was low, the percentage of those targeted who declined versus were ineligible is unknown. We assume 50% or more of those targeted by mail were eligible based on the returned non-participation surveys (n = 265). Among the 134 presumed eligible non-participants, most who declined (68.7%) cited time or schedule constraints. Other common reasons cited were lack transportation or distance to study site, parental responsibilities, insufficient reimbursement, or disinterest in the project. Among the 131 non-participant respondents who cited ineligibility criteria, most (80.9%) reported they were not currently working as nail technicians. A lack of English fluency was cited (13.7%) and was likely underestimated as recruitment materials were in English; and fewer (5.3%) were no longer residing within the study area. Control participants included 31 students scheduled after class presentations (n = 2) or after viewing campus posters (n = 29).

All participants were at least 18 years of age. Selected demographic characteristics of all 82 participants are presented in Table I by subgroup. The nail technicians who had contact with acrylic liquid, gels and/or powder were included in the "acrylic group", whereas those who did not were included in the "non-acrylic" group. Nail technicians were six years older than controls and were more likely to have completed an associate / technical or college degree than student controls. In addition, there were relatively more Asians and African Americans among the nail technicians than among the controls. Approximately one-third of nail technicians and only one control were current smokers.

All but five reported FVC values met the criteria for an acceptable plateau. In three of the five cases, there was another FVC trial within 10–20 ml that achieved an acceptable plateau. All five participants appeared to provide continuous, maximal expiratory efforts. A multiracial participant who was included under "other" in descriptive analyses was coded as "Asian" for the PFT analysis.

Thirty-nine of 43 nail technicians provided both pre- and post-shift ENO samples; 32 had at least 4 samples (2 pre- and 2 post-shift), 7 had 3 samples (1 pre- and 2 post-shift), and 4 had

TABLE I. Selected Demographic and Respiratory Related Characteristics of Nail Technician and Control Participants

	Nail technicians			
Characteristics	**Acrylic group (n = 40)**	**Non-acrylic group (n = 10)**	**Combined (n = 51)[a]**	**Controls (n = 31)**
Age, mean (SD) in years (n = 82)	30.7 (10.4)	32.0 (6.8)	30.9 (9.6)[b,c]	24.2 (9.4)
Sex (%) (n = 82)				
Female	95.0	90.0	94.1	93.6
Male	5.0	10.0	5.9	6.4
Race/ethnicity (%) (n = 82)				
African American	30.0	30.0	29.4[b,d]	22.6
Asian	20.0	20.0	21.6	3.2
Caucasian	45.0	50.0	45.1	67.7
Other	5.0	0	3.9	6.4
Smoking status (%) (n = 81)				
Current	35.0	30.0	34.0[b,d]	3.2
Ever	52.5	40.0	50.0[b,d]	9.7
Passive smoke, mean (SD) hr/day (n = 77)	8.4 (14.9)	12.5 (17.3)	9.3 (15.3)[c,e]	2.5 (4.9)
Cotinine, mean (SD) ng/ml (n = 77)	1,907 (3,949)	930 (1,260)	1703 (3,570)[b,c]	105 (535)
PFTs, mean (SD) with [5th and 95th percentiles] (n = 62)[g]				
FEV1 % of predicted	99.3% (13.3%)	99.9% (10.9%)	99.0% (12.9%)	102.6% (10.7%)
	[79.4%, 121.5%]	[84.6%, 113.8%]	[80.6%, 120.0%]	[88.2%, 120.5%]
FVC % of predicted	100.8% (13.0%)	104.7% (13.8%)	101.0% (13.4%)	103.3% (11.0%)
	[77.7%, 123.8%]	[84.4%, 123.1%]	[77.5%, 123.4%]	[88.7%, 119.1%]
Ratio (%), % of predicted	98.8% (7.2%)	95.8% (5.6%)	98.4% (7.0%)	99.9% (6.4%)
	[85.2%, 109.8%]	[88.9%, 106.1%]	[86.9%, 109.2%]	[87.1%, 107.8%]
FEF 27-75, % of predicted	99.9% (24.6%)	90.9% (21.6%)	97.7% (23.8%)[e,f]	106.7% (21.7%)
	[56.8%, 142.3%]	[67.9%, 131.7%]	[62.4%, 138.9%]	[67.3%, 138.2%]
Exhaled NO, mean (SD) in ppb (n=43)	15.5 (8.4)	14.6 (2.5)	15.1 (7.5)	[h]

[a]Includes one nail technician for whom acrylic versus non-acrylic group status was not determined.
[b]$P \leq 0.05$.
[c]Wilcoxon rank sum test (two-sided).
[d]Fisher's exact test (two-sided).
[e]$P \leq 0.15$.
[f]*T*-test for independent samples (two-sided).
[g]Statistical comparisons were made for adjusted values (% of predicteds) only.
[h]Only two control group NO samples were valid.

2 samples (2 pre- or 2 post-shift). Mean differences in ENO between the two duplicate samples collected in tandem ranged from 0.4 ppb (SD 4.2) pre-shift to 0.9 ppb (SD 4.7) post-shift. The average difference between the pre-shift and post-shift means was 0.84 ppb (SD 5.5); therefore each participant's mean ENO is a summation of all maneuvers they preformed. The mean time between the 39 pre- and post-shift samples was 7.1 hr (SD 2.8). Mean time between collection and analysis was 22.2 hr (SD 5.9). One or more room air "grab" samples were also measured at all but one study site.

Respiratory and Exposure History

Table I describes and contrasts smoking exposure information provided by nail technicians in the acrylic and non-acrylic groups and by controls. Nail technicians reported significantly fewer physician diagnosed sinus problems ($P = 0.028$) while wheezing (defined apart from colds) approached a significant elevation ($P = 0.143$) compared to controls. Wheezing was also higher (non-significantly) among the technicians compared to controls (9.1% vs. 3.3%, respectively) when only non-smokers were examined. Differences between nail technicians and controls did not approach significance for reported allergic rhinitis, usual cough or phlegm, shortness of breath, eczema, eye irritation, hoarseness, or physician confirmed asthma, hay fever, bronchitis, and non-drug allergies (positive skin tests).

Table II characterizes nail product and process exposures in nail technicians in the acrylic and non-acrylic groups. Job latency was defined as the time between first reported nail

TABLE II. Mean Exposure Characteristics of Nail Technicians in the Acrylic and Non-acrylic Use Groups*,**

	Nail technicians[a]	
Exposure characteristics	**Acrylic group (n = 40)**	**Non-acrylic group (n = 10)**
Job latency (years)	4.6 (4.1)	3.4 (1.2)
Nail polish contact (hr/day)	5.1 (3.1)[b]	3.5 (2.5)
Nail base or top coat contact (hr/day)	5.0 (3.2)[b]	3.2 (2.7)
Nail hardener contact (hr/day)	3.6 (3.8)[b]	1.2 (1.7)
Nail thickener contact (hr/day)	2.2 (3.6)	0.5 (1.2)
Nail polish remover contact (hr/day)	5.2 (3.2)[b]	3.0 (2.8)
Acrylic nail glue contact (hr/day)	2.7 (3.1)[c]	0.1 (0.3)
Acrylic nail glue remover contact (hr/day)	2.3 (3.2)[c]	0.2 (0.5)
Acrylic nail liquid contact (hr/day)	3.6 (3.0)[c]	—
Acrylic nail primer contact (hr/day)	2.8 (3.1)[c]	—
Acrylic nail powder contact (hr/day)	3.6 (3.0)[c]	—
Gel nail application contact (hr/day)	1.6 (2.9)[c]	—
Gel nail removal contact (hr/day)	1.1 (2.9)[b]	—
Acrylic nail dust contact (hr/day)	3.9 (3.5)[c]	0.5 (1.1)
Sculpt nails with drill (times/month)	36.2 (65.9)[b]	0.2 (0.4)
Sculpt nails with file (times/month)	82.4 (72.5)	54.7 (64.8)
Hair spray contact (hr/day)	2.5 (3.2)	1.2 (1.9)
Hair bleach, henna, or products with karaya or silk protein contact (hr/day)	1.7 (2.9)	1.6 (2.1)
Other hair product contact (hr/day)	2.3 (3.1)	2.3 (3.6)

*Wilcoxon rank sum tests (two-sided) were used to test differences in exposures between nail tech groups.
**Mean and (SD) Note: dash indicates mean = 0.0 and SD = 0.0.
[a]One of 51 nail technicians for whom job latency was available was excluded as information for "acrylic" versus "non-acrylic" group status assignment was not reported.
[b]$P \leq 0.15$;
[c]$P \leq 0.05$: significance levels based on comparison of acrylic and non-acrylic nail tech group exposure groups.

tech job and the pilot assessment. Licensure date (adjusted for the mean difference between the date of licensure and the date of the first nail tech job) was used as a proxy where first nail technician job date data were missing. Nail technician students were assigned a job latency of 0.5 years to distinguish them from the controls. Job latency was not significantly different between nail technician acrylic and non-acrylic groups. Contact with nail or salon products was defined by the hours the products were reportedly breathed or handled during the month prior to the pilot assessment. Significant differences ($P \leq 0.05$) in contact with acrylic glue, glue remover, acrylic liquid, primer, powder, gel application, and acrylic nail dust distinguished acrylic and non-acrylic nail technician groups. Many nail technicians reported contact with acrylic liquids and gels, and the combined hours per day of contact with both also differed significantly ($P = 0.0001$) between these groups. Contact with gel removal, nail polish, nail base or top coat, nail hardener, polish remover, and nail drilling approached significance ($P \leq 0.15$) between acrylic and non-acrylic nail technician groups. Nail drilling and filing were defined by the number of times the procedure was conducted per month. Contact hours with each of the various acrylic nail products in Table II were significantly correlated ($P \leq 0.05$) among the nail technicians.

ENO

A total of 43 exhaled breath samples collected from nail technicians were included in the ENO analysis (Fig. 1). Exhaled breath samples from an additional 35 participants (four nail technicians and all control students) were lost due to mechanical problems that occurred on the days of sample analyses. Also, four participants reported having had a chest illness during the 3 weeks prior to testing and, therefore, were not included in the ENO analysis.

In preparation for conducting regression analyses of relationships between ENO and exposures, bivariate relationships between log 10 ENO, candidate exposure variables, and other candidate variables were explored. Results of the bivariate analysis of mean ENO levels (non-transformed) and dichotomized exposure variables (job latency, reported daily

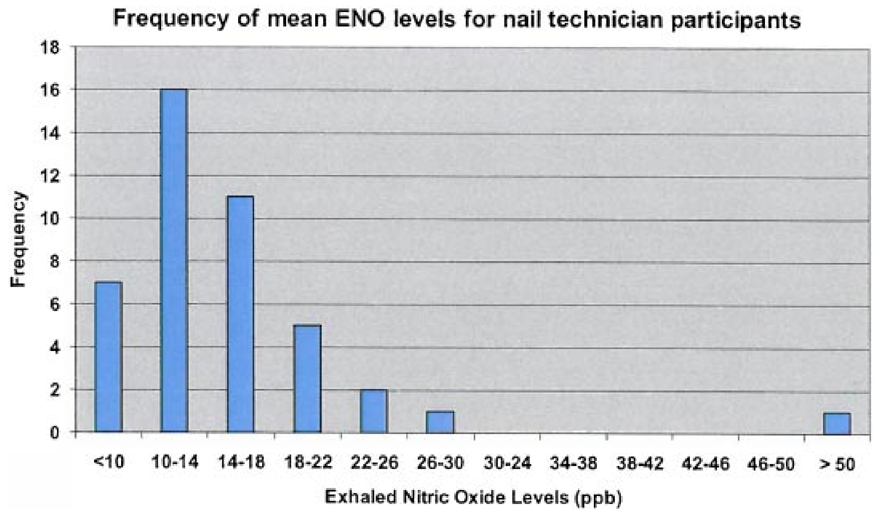

FIGURE 1. Frequency of mean ENO levels for nail technician participants. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

contact with acrylic liquid, gel, and glue) are described in Table III for nail technicians in acrylic and non-acrylic groups (combined). Job latency alone approached a significant bivariate correlation ($P = 0.062$) with non-transformed ENO. Hours of contact with all of the various acrylic nail application related products described in Table II, however, were either significantly correlated ($P < 0.05$) or approached significance ($P \leq 0.15$) with log 10 transformed ENO levels; these findings were anticipated based on a high degree of inter-correlation between these acrylic exposure variables. There were no significant bivariate correlations between log 10 ENO and hours of contact with non-acrylic nail products used by manicurists or with specified hair products (spray or bleach, henna, or products with karaya or silk protein). A subanalysis of acrylic nail applicators who are current nonsmokers (n = 21) was also conducted. The highest mean

TABLE III. Mean ENO Levels and PFT Results* by Exposure Category Among Nail Technicians Only

Exposure status[a]	NO (n = 43)	FEV1 (n = 40)	FVC (n = 40)	FEV1/FVC (n = 40)
Job latency years[b]				
Low [n = 25]	13.0 (3.7) [25]	101.3 (10.5) [24]	103.6 (11.6) [24]	98.3 (6.1) [24]
High [n = 18]	18.1 (10.3) [18][c]	95.4 (15.4) [16]	97.1 (15.4) [16][e]	98.4 (8.3) [16]
Acrylic liquid contact hr:				
Low [n = 20]	14.5 (4.6) [20]	100.3 (14.3) [19]	104.2 (13.7) [19]	96.2 (6.6) [19]
High [n = 21]	16.1 (9.7) [21]	97.3 (10.2) [19]	97.8 (11.1) [19][e]	100.2 (7.1) [19][d]
Gel application contact hr:				
Low [n = 28]	14.4 (4.0) [28]	102.8 (10.1) [24]	106.1 (11.3) [24]	97.3 (5.2) [24]
High [n = 13]	18.0 (12.6) [12]	91.7 (13.7) [13][c]	91.9 (10.6) [13][c]	100.0 (9.8) [13]
Acrylic glue contact hr:				
Low [n = 21]	14.2 (4.7) [21]	99.2 (13.4) [20]	102.4 (13.3) [20]	97.0 (7.2) [20]
High [n = 20]	16.5 (9.8) [20]	98.4 (11.4) [18]	99.5 (12.2) [18]	99.5 (6.9) [18]

*Mean, (SD), [n]; note ENO expressed in parts per billion (ppb) and PFT results presented as percentages of predicted values.
[a]Job latency is defined as years since first nail technician job dichotomized into "low" (< 4.4 years) versus "high" (≥ 4.4 years) categories at the mean. Hours per day of reported contact with acrylic products was dichotomized into "low" versus "high" categories at the medians for acrylic liquid (< 2 vs. ≥ 2 hr/day), gel (0 vs. > 0 hrs/day), and glue (< 0.75 vs. ≥ 0.75 hr/day).
[b]One PFT/NO participant for whom no smoking information or exposure contact hours were obtained is included in the "all" ("high") category for job latency only.
[c]$P \leq 0.05$;
[d]$P \leq 0.10$;
[e]$P \leq 0.15$: significance based on comparison of high versus low exposure categories for "all" technicians.

ENO levels were in the high exposure categories for job latency, and acrylic liquid, gel, and glue contact hours, but cell sizes were small and only job latency and acrylic glue approached bivariate significance with ENO ($P < 0.15$).

Reported job latency, and hours of contact with acrylic liquid and gel were selected to represent the major application methods as main effects in three separate regression analyses. Other candidate variables considered for the ENO regression models were described in methods. By each definition of tobacco smoke exposure, smoking was inversely related to log 10 ENO, and current smoking reached significance ($P < 0.05$) with this outcome. ENO was non-significantly lower among those who recently consumed nitrates. Height, testing site, and race also reached or approached significance ($P < 0.15$) with log 10 ENO. Due to the small sample size, a variable reduction strategy was employed to evaluate the potential covariates (smoking status, height, and testing site). Race was moderately correlated with current smoking status, and so it was not included. Only those covariates that changed the coefficient of the relationship between each exposure variable and log 10 ENO by 10% or more were evaluated in the full regression models. The multivariable regression results are presented in Table IV. Log 10 ENO was directly and significantly correlated with both job latency ($P = 0.012$) and gel application ($P = 0.026$) contact hours (Models "A" and "C", respectively), and approached, but did not reach significance with acrylic liquid hours (Model "B"). Regression diagnostics were performed, and influential outliers were identified within each model. This was not unanticipated given the small sample size, and these outliers were retained, as no basis for their removal was discovered.

Preliminary reports from another laboratory suggest ENO levels obtained by the offline method we used were not directly comparable to levels measured online. Therefore, the ENO levels in our tables should not be interpreted as representative of online levels.

Spirometry

Sixty-two participants remained in the PFT analysis after 20 (24%) were excluded due to recent respiratory illnesses (past 3 weeks) and PFTs that were not conducted due to health contraindications. Pre- and post-shift PFTs, available for a subset of 55 participants, differed on average by 0.1% (SD = 3.2%) for FEV1PP and 0.3% (SD = 3.7%) for FVCPP. Maximum FEV1PPs and FVCPPs from either pre- or post-shift tests (and their ratios) were, therefore, analyzed.

PFT PP results (adjusted for age, height, race, and sex) are presented by group (Table I) and by levels of dichotomized exposure variables (Table III). In bivariate analyses, FEV1PP, FVCPP, FEV1/FVCPP, and FEF25-75PP were all slightly lower among nail technicians (combined) than controls, however, the difference approached significance only for FEF25-75PP ($P = 0.15$). Bivariate analysis of technicians only showed that job latency was inversely correlated with FEV1 percent predicted (FEV1PP) ($r = -0.34$, $P = 0.03$) and FVCPP ($r = -0.32$, $P = 0.05$). Acrylic gel contact hours were inversely correlated with FEV1PP ($r = -0.38$, $P = 0.02$) and FVCPP ($r = -0.47$, $P = 0.003$). Acrylic liquid contact hours were positively associated ($P = 0.006$) with FEV1/FVCPP ratios. As seen in Table III, however, the higher mean ratios among those with "high" acrylic liquid (above the median) contact occurred in tandem with lower mean FVCPP values. In Table III, those with higher than average job latency and acrylic liquid contact (above the median) had somewhat lower FEV1PP and FVCPP values, while the difference approached significance for FVCPP ($P \leq 0.15$) only. Those reporting acrylic gel contact hours above the median had significantly lower FVCPP ($P = 0.0006$) and FEV1PP ($P = 0.008$). Relationships between exposure variables in Table III and FEF25-75PP (not shown) did not approach significance. Smoking was also significantly ($P \leq 0.15$) related to these outcomes. Adjustment of PFT PP values for "ever" versus "never" smoking status plus an exposure × smoking status

TABLE IV. Relationships Between Exhaled NO and Acrylic Nail Application Exposure Variables and Other Covariates Among Nail Technicians: Final Multivariable Regression Models

Model	Covariates:[a] Exposures	Current smoker	Height	Site	N:	Adjusted R^2:	Model:
A	Job latency						
	$B = 0.95, P = 0.012$	$\beta = -2.14, P = 0.151$	$\beta = -0.93, P = 0.048$	—	42	0.224	$F = 4.94, P = 0.005$
B	Acrylic liquid contact hr						
	$B = 0.76, P = 0.1702$	$\beta = -3.38, P = 0.078$	—	—	41	0.097	$F = 3.14, P = 0.055$
C	Acrylic gel contact hr						
	$B = 1.90, P = 0.026$	$\beta = -4.05, P = 0.021$	—	$\beta = -3.63, P = 0.025$	40	0.227	$F = 4.82, P = 0.006$

[a]Betas (β) presented were obtained from substituting non-transformed ENO levels in otherwise identical models for interpretability.

interaction term produced only slight differences (i.e., less than $\pm 2\%$ predicted) in adjusted versus unadjusted PFT PP means for outcomes in Table III. Statistical tests of differences in exposure variables in models with ‘‘ever’’ smoking status and their interaction was precluded due to small cell size, as was adjustment of PFT PP means for ‘‘current’’ smoking. Six participants had values below the lower limits of normal for FEV1/FVC (one nail technician and two controls), FVC (two nail technicians), or FEV1, FVC, and FEV1/FVC (one nail technician). Asthma was reported by two participants who had low ratios.

COMMENTS

The results indicate that job latency and possibly hours of contact with methacrylates have measurable effects on PFT results and inflammation levels (ENO), as did smoking, in a select population of nail technicians. Despite a small sample, small but significant decrements in lung function were seen in tandem with increased airway inflammation for several exposure variables. Also, nail technicians reported more wheezing apart from colds and eye irritation than the controls, but the differences were non-significant. Smokers generally had lower ENO.

These findings are not conclusive, but do warrant further investigation. Bias due to disproportionate enrollment of nail technicians and controls with health concerns was very likely present given the low response rate. Exclusion of nail technicians who were not fluent in English may have altered the exposure profiles described in Table II. These results, therefore, may not be generalizable. Control participants, included in the PFT but not ENO analyses, were younger than the nail technicians, but the PFT percent predicted results were adjusted for age and other strong confounders. Race also differed between these groups, and controls were recruited from one part of the Midwest while nail technicians were recruited from across the region. Comparisons between the acrylic and non-acrylic nail technician groups may be less subject to bias to the extent that both subgroups were equally likely to take part.

Use of translators and translated instruments is advised for future studies in multilingual settings. It is also critical that PFT reference values for Asians be validated for use among the subpopulation(s) under study. Longitudinal follow-up and inclusion of tests of airway responsiveness to enhance asthma detection are recommended for future studies of lung function in these workers. Also, worksite air sampling would strengthen exposure characterization.

In conclusion, these findings suggest lung function and airway inflammation may be adversely influenced by nail technicians’ work environments. Future research is indicated to: (1) confirm whether or not unselected groups of nail technicians are experiencing measurable respiratory health effects due to their workplace exposures; (2) identify which exposures confer potential risks; and (3) establish effective ways to reduce nail technicians exposure risks.

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