Characteristics Associated with Miscarriages in Utah Nail Technicians

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Abstract

Objective: Previous studies suggest possible worker over-exposure to hazardous chemicals in nail salons. The purpose of this study was to identify exposure characteristics among nail technicians that might be associated with adverse reproductive health outcomes.

Methods: Using a cross-sectional design, 937 nail technicians licensed in Utah were invited to complete an online questionnaire regarding general and reproductive health, working career, and common health and safety practices. The relationship between nail technicians who had been pregnant and experienced at least one miscarriage was compared to nail technicians with a history of pregnancy but no miscarriages to identify potentially relevant characteristics.

Results: Ninety (90) nail technicians participated in the survey. Of those who reported ever having been pregnant, 36% (17/47) reported having had at least one miscarriage. Those who had experienced a miscarriage were significantly younger (mean ~10 years) than those who had been pregnant but did not report a history of miscarriage. Although those who had a history of miscarriage were less likely to use exposure control equipment, that difference was not statistically significant.

Conclusion: High miscarriage rates in participants indicate that further study is needed. Since selection bias may have affected who chose to complete the survey, a larger sample size and additional community engagement is needed.

Implications: Future research should seek to obtain a higher participation rate, quantify chemical exposures directly, examine health symptoms, and understand what exposure control measures are most effective. With continued research, the hope is that technicians can see improved health and safety over their working careers.

Introduction

Occupational exposures experienced by cosmetologists are associated with a significantly increased risk of adverse reproductive health effects, including infertility, reductions in fetal growth, fetal death, and preterm delivery.[1-4] Specifically, chemicals found in nail products (e.g., formaldehyde, toluene, dibutyl phthalate, etc) have been shown to result in increases in fertility problems or pregnancy loss,[5,6] congenital birth defects,[7] effects similar to Fetal Alcohol Syndrome,[8,9] and possible epigenetic risks transmitted to later generations.[10] Most cosmetologists are reproductive-age women, with nail technicians being an especially vulnerable population. A large percentage of nail technicians are racial/ethnic minorities, with one estimate for the US indicating 72% are Vietnamese,[11] and many experience inadequate pay and personal protections.[12] With approximately 163,600 manicurists and pedicurists employed today, and a projected growth of 22% by 2031, additional research is needed to determine what associations, if any, exist between hazardous chemical exposure and adverse reproductive health outcomes among nail technicians.[13]

Previous studies examining workplace exposures in nail salons are limited, but literature that is available points to a concerning trend towards overexposure

to hazardous chemicals, including acetone, butyl acetate, ethyl acetate, ethyl methacrylate (EMA), formaldehyde, isopropyl acetate, methacrylic acid, methyl methacrylate (MMA), and phthalates.[14-19] Air monitoring of nail salons within the state of Utah found formaldehyde concentrations were above the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) in 58% of establishments studied, with MMA (banned in Utah) found in a majority of establishments as well.[17] Exposure controls (engineering, administrative practices, and personal protective equipment) are a key to reducing/preventing exposure, but their use in practice appears to be lacking.[20,21] It is well understood that some exposure controls that remove a chemical before it can reach workers (e.g., local ventilation) are more effective than controls that rely on workers to use them properly (e.g., masks).[5] Therefore, this study sought to investigate the protective practices for exposure, and reproductive health outcomes of nail technicians.

Methods

This cross-sectional study surveyed nail technicians who are currently or formerly licensed in the state of Utah via an online questionnaire regarding general and reproductive health, working career, as well as common health and safety practices. The study was reviewed by the University of Utah Institutional Review Board (IRB) and considered exempt.

Participants

The list of all nail technicians who are currently or formerly licensed in Utah (as of October 2020) was obtained from the Utah Department of Occupational and Professional Licensing (DOPL) (n=10,109). The information obtained included the following: full name, address, date of license, date of license expiration, phone number, and email address (optional). The study included nail technicians with both active and expired licenses to reduce the risk of bias linked to the healthy worker effect; i.e. this method included nail technicians who have potentially retired, quit working due to health complications, or left the industry.

Out of all 10,109 nail technicians formerly or currently licensed with the state, a computerized random number generator was used to randomly select a subset of 1,000 to invite to complete the questionnaire. The questionnaire was then distributed via two means: first, a postcard listing the URL of the survey was sent to the mailing address of each participant. For those participants with email addresses on file (n=710), a total of three email reminders with the survey address were also sent. Potential participants were incentivized to complete the survey by an entry into a gift card drawing.

Questionnaire

The questionnaire was administered using SurveyMonkey, a mobile-friendly platform that was easily accessible on either a computer or a smartphone. SurveyMonkey was also selected due to the ability to offer participants their choice of preferred language between Vietnamese and English. The survey was translated into Vietnamese by a certified translator and verified by a native-speaker who works in healthcare. The survey was conducted between November 2020 and January 2021.

The questionnaire was designed to be completed in approximately 20 minutes and is a modified version of a previously used tool for assessing lifetime reproductive outcomes.[22] The survey consisted of questions regarding general health, menstrual history, sexual history, becoming pregnant/conceiving, pregnancy outcomes, fertility, fertility treatment, and demographic information. The survey also contained questions regarding work history and the use of exposure controls such as local ventilation or personal protective equipment (PPE) during work. A question was also included asking participants to comment and evaluate the survey with the aim of improving future iterations.

If participants did not wish to answer any one question, they could do either by skipping the question or answering with "Prefer not to answer." To prevent unnecessary confusion, the online survey was designed with skip logic; for example, if a participant answered "Never" to the question "How many times have you been pregnant?" the survey would automatically skip them from answering questions pertaining to pregnancies and live births. Therefore, the number eligible to respond varied for each question. If participants failed to answer any of the questions pertaining to the variables included in the statistical analysis (number of miscarriages, years worked, hours worked per week, smoking status, drinking status, age, race, and house

hold income), they were excluded from further analysis (i.e., complete case analysis).

Responses were submitted without personally identifiable information. IP address tracking was also turned off to further remove any identifying information. Responses from the questionnaire were stored and maintained in Excel (Microsoft, Redmond, Washington) and statistical analysis was performed using SAS statistical software (SAS Institute, Cary, NC).

Data Analysis

Respondents were grouped based on their history of pregnancy and/or miscarriage, including (1) never been pregnant, (2) prior pregnancy but no miscarriages, and (3) at least one miscarriage, i.e., analysis by outcome group (case control). Due to the small sample size, fisher's exact test was used to compare the groups with prior pregnancy (with and without miscarriage) across the various categories of interest. For continuous variables a t-test was used to compare group means between the miscarriage vs non-miscarriage groups. When there were unequal variances, a Welch test was performed. Statistical analyses were performed using SAS statistical software.

There is limited research in the area of nail salon exposure controls, so a novel approach to analyzing those data is presented here. For this, a protective equipment usage score was developed specially for this work and was calculated for each respondent, as shown in Figure 1. For each type of control equipment used, a different value was given to each, based on the potential control it provided, including: a score of 2 for a loose mask (e.g., surgical mask) and/or a large fan (i.e., room fan), a score of 3 for gloves and/or a small fan (i.e., personal/table fan), a score of 4 for a snug mask (e.g., N95) and/or a ventilated table, and a score of 5 for a cartridge respirator and/or a local exhaust ventilation hood. These scores were based on the hierarchy of controls, such that more protective engineering controls (e.g., ventilation) were given higher priority than personal protective equipment (e.g., loose mask).[5] As an additional variable, the frequency of use for each piece of equipment was incorporated into a "weighted score". In this case, "Never" = 0, "Several clients per year" = 0.1, "Several clients per month" = 1.2, "Several clients per week" = 4.8, and "Every client" = 10. For example, somebody who used a loose mask for every client would get 20 pts, and if that person also used a ventilated table for several clients per week, they would get an additional 19.2 pts for a total of 39.2 pts.

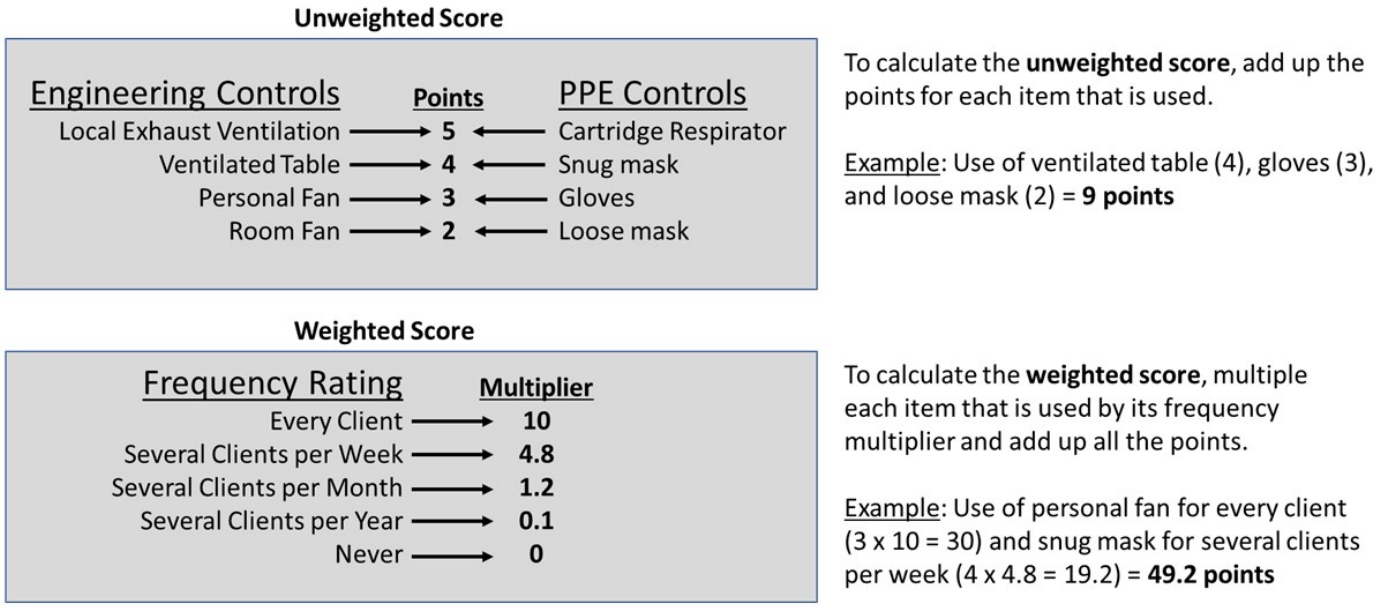

Figure 1: Scoring system developed for evaluating nail salon exposure controls, including both unweighted and weighted calculations.

Results

Overall Respondent Characteristics

Out of the 1,000 randomly chosen participants who were mailed a postcard, 101 were returned as undeliverable. Out of the 710 emails sent, 38 emails were bounced back on all three attempts. Ultimately, 63 participants either did not have emails on file, had incorrect emails, or had undeliverable postcards; a total of 937 participants either received an email or a postcard inviting them to participate (Figure 2).

After 2 months, 90 nail technicians responded to the survey (response rate of 9.6%). The mean proportion of the survey that was completed for each participant was 82%, with a mean completion time of approximately 12 minutes. A total of 85 (94%) participants submitted the survey in English and 5 (6%) submitted the survey in Vietnamese. However, only 68 people had usable information regarding the birth related outcomes. Nine (9) respondents did not answer those questions. A further thirteen (13) provided conflicting answers, for example the number of miscarriages was greater than the number of pregnancies. In those cases where the answers did not match, the data were not included in the analysis. The primary analysis included here is for those with a history of pregnancy, broken out by those with (n=17) and without (n=30) a history of miscarriage. Summary data for all respondents and those who had never been pregnant are provided in supplemental material (Table S1 and S2).

The mean age of registered nail technicians who responded was 33.6 years old. Participants were predominantly White (63.3%) and Vietnamese (13.3%). The mean number of years worked as a nail technician was 7.8 years with a median of 5 years. The mean number of hours worked per week for nail technicians was 25.5 hours. 36% (n=17) of participants who had been pregnant (n=47) experienced at least one miscarriage in their life. About half, 48.9% (n=44) of nail technicians reported having received training on how to reduce their exposures to chemicals at work. It was found that 65.6% of nail technicians who responded reported having a monthly period, 28.9% reported adult acne, 10% reported thyroid disease, 11.1% reported high blood pressure, and 3.3% reported a cancer diagnosis.

Participants indicated relatively healthy habits: 81% of the participants were non-smokers and 71% do not drink any alcohol regularly (see Table S1). The overall health of the study population may be reflected in Utah's wider population, as Utah was ranked the seventh healthiest state by the United Health Foundation in 2022, and has very low rates for use of tobacco or alcohol.[23]

Comparison of Respondents with and without Miscarriages

Respondents who reported having at least one miscarriage were on average younger by approximately 10 years (p=0.004) (see Table 1). They were also more likely to be single compared to the non-miscarriage and never pregnant groups (25% vs 11.5%), although that difference was not statistically significant (p=0.128). The miscarriage group was more likely to have a BMI >30 (52.9%) compared to the non-miscarriage group (30%), but that relationship was also not statistically significant.

In terms of their work, the miscarriage group had less experience than the non-miscarriage group (median of 2 years vs 9 years; p=0.017) and saw fewer clients per day (median = 2 vs 4; p=0.03). The miscarriage group was also more likely to work <20 hours per week compared to the non-miscarriage group (81.3% vs 44.8%), which was not quite a significant difference (p=0.063). These variables are likely related to the fact that the miscarriage group was much younger on average than the non-miscarriage group.

The clinical characteristics for the miscarriage and non-miscarriage groups are shown in Table 2. The non-miscarriage group reported a median number of live births of 2 compared to the miscarriage group, with a median of 1. Again, this could be explained by the age difference between these groups. It is also interesting to note that the miscarriage group reported 13.3% rate of low birth weight babies, compared to 7.1% in the non-miscarriage group. Overall, there were no statistically significant differences between the miscarriage group and the non-miscarriage group for the clinical characteristics of interest.

The calculated protective equipment scores and the frequency of use for different control methods are shown in Table 3. The median weighted protective equipment usage score for nail technicians with no

Table 1. Descriptive statistics for respondents with a history of pregnancy, with and without at least one miscarriage.

Characteristics	Pregnancy, Non-Miscarriage n=30		Pregnancy, 1+ Miscarriage n=17		p-value
	n	%	n	%	
Birth year					
Mean (SD)	1981 (11.40)		1991 (5.64)		**0.004**
Median (Q1, Q2)	1983 (1974, 1991)		1991 (1987, 1997)		
(Max, Min)	(1956, 1997)		(1979, 1998)		
Race					
White	24	80.0	15	88.2	0.692
Other	6	20.0	2	11.8	
Ethnicity					
Non-Hispanic	24	92.3	15	93.8	0.999
Hispanic	2	7.7	1	6.3	
Missing/Unknown	4	-	1	-	
Marital status					
Married	18	69.2	12	75.0	0.128
Divorced	5	19.2	-	-	
Single	3	11.5	4	25.0	
Missing/Unknown	4	-	1	-	
Household income					
<= 25,000	5	20.0	5	35.7	0.539
$25,001-50,000	6	24.0	4	28.6	
50,001-75,000	6	24.0	1	7.1	
0ver $75,000	8	32.0	4	28.6	
Missing/Unknown	5	-	3	-	
Baseline BMI					
Underweight (<18.5)	1	3.3	-	-	0.371
Normal weight (18.5-24.9)	9	30.0	5	29.4	
Overweight (25-29.9)	11	36.7	3	17.7	
Obese (>30)	9	30.0	9	52.9	
Missing/Unknown	-	-	-	-	
Age at first period (years)					
Mean (SD)	12.73 (1.84)		12.71 (1.21)		0.956
Median (Q1, Q2)	12 (12, 14)		13 (12, 14)		
(Max, Min)	(10,17)		(11, 15)		
Insurance type					
Private insurance (employer)	6	23.1	7	46.7	0.411
Private insurance (spouse/parent)	10	38.5	6	40.0	
Medicaid	5	19.2	2	13.3	
Healthcare exchange	2	7.7	-	-	
No insurance	3	11.5	-	-	
Missing/Unknown	4	-	2	-	
Average soda per day in last month					
0	10	34.5	5	29.4	0.927
less than 1	7	24.1	4	23.5	
1+	12	41.4	8	47.1	
Missing/Unknown	1	-	-	-	
Average coffee per day in last month					
0	14	46.7	11	64.7	0.205
less than 1	3	10.0	3	17.7	
1+	13	43.3	3	17.7	
Missing/Unknown	-	-	-	-	
Average alcohol per week					
0	21	72.4	15	88.2	0.282
1+	8	27.6	2	11.8	
Missing/Unknown	1	-	-	-	
10 pack cigarette life time					
No	25	86.2	15	88.2	0.999
Yes	4	13.8	2	11.8	
Missing/Unknown	1	-	-	-	
Start age of nail technician (years)					
Mean (SD)	24.89 (9.27)		23.94 (3.69)		0.638
Median (Q1, Q2)	21 (19, 25)		22 (21, 26)		
(Max, Min)	(18, 48)		(19, 30)		
Nail technician training					
No	13	48.2	3	17.7	0.176
Yes	14	51.9	11	64.7	
Missing/Unknown	3	-	3	-	
Currently nail technician					
No	10	38.5	4	26.7	0.512
Yes	16	61.5	11	73.3	
Missing/Unknown	4	-	2	-	
Number of years as nail technician (years)					
Mean (SD)	11.02 (9.58)		4.37 (5.98)		**0.017**
Median (Q1, Q2)	9 (2,15)		2 (0.75, 5)		
(Max, Min)	(<1, 36)		(<1, 22)		
Average number of hours per week					
<=20	13	44.8	13	81.3	0.063
21-40	13	44.8	3	18.8	
41+	3	10.3	-	-	
Missing/Unknown	1	-	1	-	
Average number of clients per day					
Mean (SD)	4.15 (2.59)		2.4 (2.03)		**0.030**
Median (Q1, Q2)	4 (1, 7)		2 (1, 4)		
(Max, Min)	(1, 9)		(1, 8)		

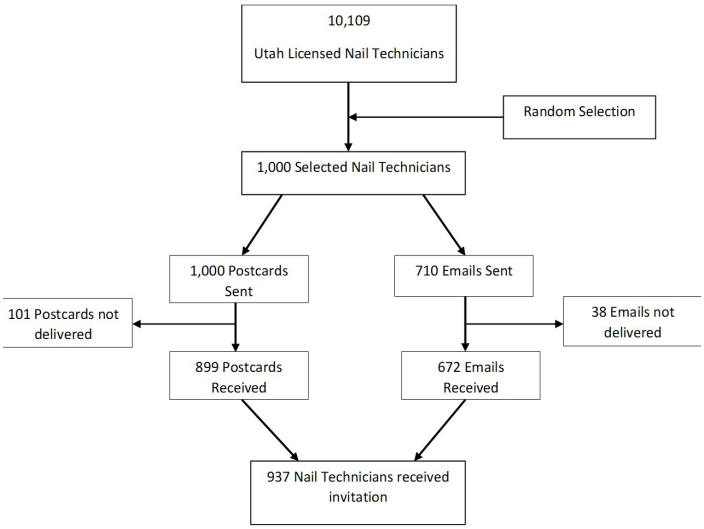

Figure 2: Participant Recruitment Method for Email and Postcard Invitation

history of miscarriage was 43.5, compared to a median of 26.2 for those with at least one miscarriage. This corresponds to fewer types of protective equipment used and/or less frequent use of any such equipment for those with a miscarriage, although this difference was not statistically significant (p=0.837). Nail technicians, on average, used ventilated downdraft tables the most (34.5% in the non-miscarriage group and 25% in the miscarriage group used them for every client), followed by a loose mask (30% use for every client, n=27). The least used control method was half-face cartridge respirators, with 100% of respondents with a history of pregnancy having never used one. In both groups, more than half of respondents (62.1% of non-miscarriage group and 68.8% of the miscarriage group) reported never using gloves when performing their work.

Discussion

This study offers fresh insight into an understudied and potentially vulnerable occupational population. Based on the limited use of protective equipment, there exists a potential for high chemical exposures and thereby pregnancy complications. It also provides insight into contacting nail technicians and overcoming barriers associated with the typical nail-salon (i.e., smaller, family-run, non-English speakers), as well as a novel way to quantify the use of exposure control strategies.

The small sample size prevents definitive conclusions, and limits reliance on statistical significance, but there

Table 2. Clinical characteristics for respondents with a history of pregnancy, with and without at le one miscarriage.

Characteristics	Pregnancy, Non-Miscarriage n=30		Pregnancy, 1+ Miscarriage n=17		Comparison of 2 Pregnancy Groups (p-value)
	n	%	n	%	
Number of live births					
Mean (SD)	2.37 (1.45)		1.71 (1.36)		0.132
Median (Q1, Q2)	2 (1, 4)		1 (1, 5)		
Number of low birth weight babies					
(Max, Min)	(0, 2)		(0, 1)		n/a
Number of sexual partners					
Mean (SD)	8 (20, 27)		3 (2,15)		0.220
Median (Q1, Q2)	2 (1, 6)		2 (1, 4)		
Low birth weight (binary)					
No	26	92.9	13	86.7	0.602
Yes	2	7.1	2	13.3	
Missing	2	-	2	-	
Monthly menstrual period					
No	9	31.0	5	29.4	0.999
Yes	20	69.0	12	70.6	
Unknown	1	-	-	-	
Period same length and heaviness					
No	12	40.0	6	35.3	0.999
Yes	18	60.0	11	64.7	
Unknown	-	-	-	-	
Period at least 3 days					
No	4	13.3	1	5.9	0.640
Yes	25	86.7	16	94.1	
Unknown	-	-	-	-	
Adult acne					
No	21	70.0	14	82.4	0.492
Yes	9	30.0	3	17.7	
Anemia					
No	27	90.0	15	88.2	0.999
Yes	3	10.0	2	11.8	
Pelvic pain					
No	21	70.0	14	82.4	0.492
Yes	9	30.0	3	17.7	
Painful period					0.999
No	18	60.0	10	58.8	
Yes	12	40.0	7	41.2	
Painful intercourse					
No	24	80.0	13	76.5	0.999
Yes	6	20.0	4	23.5	
Thyroid disease					
No	25	83.3	15	88.2	0.999
Yes	5	16.7	2	11.8	
Excess hair growth					
No	27	90.0	15	88.2	0.999
Yes	3	10.0	2	11.8	
High blood pressure					
No	24	80.0	15	88.2	0.692
Yes	6	20.0	2	11.8	

Table 3. Protective equipment usage scores for respondents with a history of pregnancy, with and without at least one miscarriage.

Characteristics	Pregnancy, Non-Miscarriage n=30		Pregnancy, 1+ Miscarriage n=17		p-value
Protective equipment usage scores					
Unweighted					
Mean (SD)	13.4 (11.8)		14.24 (15.35)		0.839
Median (Q1, Q2)	14.8 (1.2, 20.1)		10 (0, 23.4)		
(Min, Max)	(0, 37.2)		(0, 50)		
Weighted					
Mean (SD)	42.50 (38.75)		45.39 (54.27)		0.837
Median (Q1, Q2)	43.5 (3.6, 70.2)		26.2 (0, 69.6)		
(Min, Max)	(0, 120.4)		(0, 170)		
Individual equipment usage	**N**	**%**	**N**	**%**	
Gloves (Score = 3)					
Never	18	62.1	11	68.8	0.903
Sometimes	6	20.7	2	12.5	
Every client	5	17.2	3	18.8	
Missing/Unknown	1	-	1	-	
Loose mask (e.g., surgical) (Score = 2)					
Never	16	57.1	9	60.0	0.999
Sometimes	7	25.0	3	20.0	
Every client	5	17.9	3	20.0	
Missing/Unknown	2	-	2	-	
Snug mask (e.g. N95) (Score = 4)					
Never	26	92.9	11	91.7	0.668
Sometimes	1	3.6	-	-	
Every client	1	3.6	1	8.3	
Missing/Unknown	2	-	5	-	
Cartridge respirator (Score = 5)					
Never	28	100.0	16	100.0	N\A
Missing/Unknown	2	-	1	-	
Small fan (e.g., personal fan) (Score = 3)					
Never	14	48.3	11	73.3	0.240
Sometimes	8	27.6	1	6.7	
Every client	7	24.1	3	20.0	
Missing/Unknown	1	-	2	-	
Large fan (e.g., room fan) (Score = 2)					
Never	22	75.9	10	66.7	0.514
Sometimes	5	17.2	2	13.3	
Every client	2	6.9	3	20.0	
Missing/Unknown	1	-	2	-	
Local Exhaust Hood (Score = 5)					
Never	24	85.7	13	81.3	0.335
Sometimes	2	7.1	-	-	
Every client	2	7.1	3	18.8	
Missing/Unknown	2	-	1	-	
Ventilated Table (Score = 4)					
Never	14	48.3	10	62.5	0.693
Sometimes	5	17.2	2	12.5	
Every client	10	34.5	4	25.0	
Missing/Unknown	1	-	1	-	

are several findings that may inform future research. One finding of concern was that 36% of respondents who had been pregnant reported having experienced at least one miscarriage, a number that seems high compared to the ~10-20% of all known pregnancies in the general population that end in miscarriage[24]; about 25% of women experience a miscarriage in their lifetime.[25] The percentage found here is also higher than a previous study of nail technicians on the East Coast of the United States which found 15.6% of nail technicians who have been pregnant experienced at least one miscarriage.[26] It is possible that selection bias, such that the respondents do not reflect the overall population of interest based on self-selection into the study, may over-estimate the miscarriage rate.

Additionally, the <10% response rate may also affect interpretation of this finding, but additional research is still warranted. A higher response rate may help confirm if miscarriages are in fact more prevalent in this population and whether the variables that were found to be significant here remain important. The known reproductive toxicity of many of the chemicals in nail products[5-10] also supports this association, but further epidemiological research is clearly warranted in this area.

Of concern, ~34% (n=31) of all respondents indicated that they had not received training on how to reduce their exposure to chemicals at work, and ~17% (n=15) were unsure of whether they had received such

training. This represents an important target for outreach related to occupational health and safety in this population. In the hierarchy of controls, training is considered a critical administrative control that helps ensure workers understand their potential exposure and how to properly use available control methods.[5] However, barriers to reaching nail technicians have not yet been resolved. Results from this study indicate that a response rate of 10% could be expected for simple email/postcard recruitment. Additional recruitment strategies, including community engagement, would help increase participation, especially in non-English speaking technicians and other demographics that may have been under-represented among these respondents. For example, connecting with community and/or religious groups to build trust around participation in such research activities is recommended for future work with this population.

Additionally, variables such as obesity,[27-31] uncontrolled diabetes,[32] uncontrolled thyroid disease,[33,34] and alcohol consumption[31,35] have been shown to be associated with miscarriage. Future studies should account for these additional risk factors in this population.

Limitations

The use of a voluntary questionnaire can have certain biases, particularly selection or volunteer bias. A nail technician who has experienced reproductive issues that they attribute to work as a nail technician may be more likely to fill out the survey compared to someone who does not have known reproductive issues. Alternatively, nail technicians who have had miscarriages may not want to fill out the questionnaire due to past trauma from pregnancy loss. The end of the survey contained an area for participants to provide feedback about the survey. Responses from participants included statements such as "don't ask such personal questions" and "you are asking a lot of personal questions". These statements suggest that it is possible that participants with more reproductive health issues may have declined to answer some questions. Future work needs to help participants understand the importance of information about reproductive health.

Sex was inadvertently left out as a demographic question, so there is the possibility that male technicians were invited to participate but ended up skipping most of the questions since they asked about female reproductive health. The percentage of registered nail technicians who are male in the state of Utah would be something to consider in the future, but the estimate nationally is approximately 2%.[11] The effect on these results is expected to be minimal, especially as the primary analysis was only conducted on those respondents who reported a history of pregnancy. The questionnaire also did not capture the timing of when the miscarriages occurred, although the young age of when the respondents began work as a nail technician (21-22 years old) suggests most miscarriage likely occurred after they began work.

Another limitation of this study was that the actual chemical exposures of the participants were not measured directly. It was assumed that the years worked as a nail technician, the hours worked per week, and the use of an exposure control was related to the total chemical exposure a nail technician would have experienced. However, a nail technician who may have received high chemical exposures at work may have quit being a nail technician early on due to suffering adverse health symptoms. In that case, the nail technician may have received significant chemical exposure but only worked for a few years. Similarly, nail technicians who work for many years or decades and have a lower chemical exposure may be more likely to stay employed in that industry. In that scenario, the prevalence of miscarriages may be decreased even though the number of years worked was high.

Health Implications

The population of nail technicians is understudied in terms of chemical exposures and their resulting health. The goal of this study was to better characterize the nail technician population in Utah, their use of common controls against exposure to VOCs, and understand their reproductive health outcomes. Although no statistically significant association between use of protective equipment and miscarriages was found, a high overall rate of miscarriage was reported for this population. The number of nail technicians who have not received any training on how to limit their exposures to chemicals at work is also concerning. This study could help inform future studies that include a larger and more representative population of nail technicians. It could also justify an education and training initiative to help educate nail technicians on the hazards present

in their workplace. Another goal of this study was to inform future efforts to engage this occupational population, which has been historically difficult to reach due to language and other communication barriers. Research in the future that quantifies the chemical exposure, examines health symptoms, and understands what exposure control measures are being used could help address some of the limitations of the current work. With continued research, the hope is that the population of nail technicians can see improved health and safety over their working careers.

Funding Sources

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Conflict of Interest

This work was funded by the University of Utah Department of Family and Preventive Medicine and the National Institute for Occupational Safety and Health. DS has also received money for other research from the National Institutes of Health (NIH) and the US Department of Defense (DOD). The authors declare no conflicts of interest.

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Disclosures

All study procedures were reviewed and approved by the University of Utah Institutional Review Board. Informed consent was obtained from each participant before data collection. No financial interest or benefit has arisen from the direct application of this research.

Supplementary Materials

Table S1. Descriptive statistics for all respondents, as well as those who were never pregnant, those who had a history of pregnancy with o miscarriage, and those who had a history of pregnancy with at least one miscarriage. The category of "All" respondents includes those who did not have usable data related to pregnancy outcomes, which accounts for the discrepancy in sample sizes.

Characteristics	All n=90		Never Pregnant n=21		Pregnancy, Non-Miscarriage n=30		Pregnancy, 1+ Miscarriage n=17	
	n	%	n	%	n	%	n	%
Birth year								
Mean (SD)	1986 (9.77)		1992 (5.31)		1981 (11.40)		1991 (5.64)	
Median (Q1, Q2)	1987 (1982, 1994)		1994 (1989, 1996)		1983 (1974, 1991)		1991 (1987, 1997)	
(Max, Min)	(1956, 2001)		(1982, 2001)		(1956, 1997)		(1979, 1998)	
Race								
White	57	63.3	12	57.1	24	80.0	15	88.2
Other	33	36.7	9	42.9	6	20.0	2	11.8
Ethnicity								
Non-Hispanic	69	76.7	18	94.7	24	92.3	15	93.8
Hispanic	4	4.4	1	5.3	2	7.7	1	6.3
Missing/Unknown	17	18.9	2	-	4	-	1	-
Marital status								
Married	48	53.3	9	45.0	18	69.2	12	75.0
Divorced	7	7.8	-	-	5	19.2	-	-
Single	18	20.0	11	55.0	3	11.5	4	25.0
Missing/Unknown	17	18.9	1	-	4	-	1	-
Household income								
<= 25,000	16	17.8	4	22.2	5	20.0	5	35.7
$25,001-50,000	22	24.4	9	50.0	6	24.0	4	28.6
50,001-75,000	12	13.3	3	16.7	6	24.0	1	7.1
0ver $75,000	18	20.0	2	11.1	8	32.0	4	28.6
Missing/Unknown	22	24.4	3	-	5	-	3	-
Baseline BMI								
Underweight (<18.5)	2	2.2	-	-	1	3.3	-	-
Normal weight (18.5-24.9)	37	41.1	10	47.6	9	30.0	5	29.4
Overweight (25-29.9)	22	24.4	2	9.5	11	36.7	3	17.7
Obese (>30)	29	32.2	9	42.9	9	30.0	9	52.9
Missing/Unknown	-	0.0	-	-	-	-	-	-
Age at first period (years)								
Mean (SD)	12.8 (1.9)		12.16 (2.36)		12.73 (1.84)		12.71 (1.21)	
Median (Q1, Q2)	13 (12, 14)		12 (12, 14)		12 (12, 14)		13 (12, 14)	
(Max, Min)	(5, 17)		(5, 15)		(10,17)		(11, 15)	
Insurance type								
Private insurance (employer)	20	22.2	3	15.8	6	23.1	7	46.7
Private insurance (spouse/parent)	31	34.4	11	57.9	10	38.5	6	40.0
Medicaid	9	10.0	2	10.5	5	19.2	2	13.3
Healthcare exchange	6	6.7	1	5.3	2	7.7	-	-
No insurance	6	6.7	2	10.5	3	11.5	-	-
Missing/Unknown	18	20.0	2	-	4	-	2	-
Average soda per day in last month								
0	21	23.3	5	23.8	10	34.5	5	29.4
less than 1	24	26.7	6	28.6	7	24.1	4	23.5
1+	42	46.7	10	47.6	12	41.4	8	47.1
Missing/Unknown	3	3.3	-	-	1	-	-	-
Average coffee per day in last month								
0	47	52.2	11	52.4	14	46.7	11	64.7
less than 1	11	12.2	4	19.1	3	10.0	3	17.7
1+	31	34.4	6	28.6	13	43.3	3	17.7
Missing/Unknown	1	1.1	-	-	-	-	-	-
Average alcohol per week								
0	63	70.0	11	52.4	21	72.4	15	88.2
1+	25	27.8	10	47.6	8	27.6	2	11.8
Missing/Unknown	2	2.2	-	-	1	-	-	-
10 pack cigarette life time								
No	73	81.1	17	85.0	25	86.2	15	88.2
Yes	15	16.7	3	15.0	4	13.8	2	11.8
Missing/Unknown	2	2.2	1	-	1	-	-	-
Start age of nail technician (years)								
Mean (SD)	24 (6.75)		21.95 (4.41)		24.89 (9.27)		23.94 (3.69)	
Median (Q1, Q2)	22 (19, 26)		21 (19, 24)		21 (19, 25)		22 (21, 26)	
(Max, Min)	(17, 48)		(17, 35)		(18, 48)		(19, 30)	
Nail technician training								
No	31	34.4	10	47.6	13	48.2	3	17.7
Yes	44	48.9	11	52.4	14	51.9	11	64.7
Missing/Unknown	15	16.7	-	-	3	-	3	-
Currently nail technician								
No	27	30.0	8	38.1	10	38.5	4	26.7
Yes	48	53.3	13	61.9	16	61.5	11	73.3
Missing/Unknown	15	16.7	-	-	4	-	2	-
Number of years as nail technician (years)								
Mean (SD)	7.8 (7.9)		4.60 (4.67)		11. 02 (9.58)		4.37 (5.98)	
Median (Q1, Q2)	5 (2,13)		3 (1, 7)		9 (2,15)		2 (0.75, 5)	
(Max, Min)	(<1, 36)		(<1, 17)		(<1, 36)		(<1, 22)	
Average number of hours per week								
<=20	36	40.0	4	20.0	13	44.8	13	81.3
21-40	31	34.4	10	50.0	13	44.8	3	18.8
41+	11	12.2	6	30.0	3	10.3	-	-
Missing/Unknown	12	13.3	1	-	1	-	1	-
Average number of clients per day								
Mean (SD)	4 (2.74)		5.63 (1.86)		4.15 (2.59)		2.4 (2.03)	
Median (Q1, Q2)	5 (2,7)		5 (5, 7)		4 (1, 7)		2 (1, 4)	
(Max, Min)	(1,15)		(1, 10)		(1, 9)		(1, 8)	
Protective equipment usage scores								
Unweighted								
Mean (SD)	17.67 (15,20)		19.99 (16.36)		13.4 (11.8)		14.24 (15.35)	
Median (Q1, Q2)	14.8 (4.8, 29.6)		12 (10, 31.2)		14.8 (1.2, 20.1)		10 (0, 23.4)	
(Min, Max)	(0, 60)		(0, 51.3)		(0, 37.2)		(0, 50)	
Weighted								
Mean (SD)	56.25 (50.91)		63.54 (55.06)		42.50 (38.75)		45.39 (54.27)	
Median (Q1, Q2)	43.5 (14.4, 90.0)		40.2 (20.0, 93.6)		43.5 (3.6, 70.2)		26.2 (0, 69.6)	
(Min, Max)	(0, 190)		(0, 175)		(0, 120.4)		(0, 170)	
Glove								
Never	41	45.6	8	40.0	18	62.1	11	68.8
Sometimes	16	17.8	7	35.0	6	20.7	2	12.5
Every client	21	23.3	5	25.0	5	17.2	3	18.8
Missing/Unknown	12	13.3	1	-	1	-	1	-
Loose mask								
Never	33	36.7	5	25.0	16	57.1	9	60.0
Sometimes	16	17.8	4	20.0	7	25.0	3	20.0
Every client	27	30.0	11	55.0	5	17.9	3	20.0
Missing/Unknown	14	15.6	1	-	2	-	2	-
Snug mask								
Never	64	71.1	15	83.3	26	92.9	11	91.7
Sometimes	4	4.4	3	16.7	1	3.6	-	-
Every client	2	2.2	-	-	1	3.6	1	8.3
Missing/Unknown	20	22.2	3	-	2	-	5	-
Cartridge								
Never	76	84.4	20	100.0	28	100.0	16	100.0
Missing/Unknown	14	15.6	1	-	2	-	1	-
Small fan								
Never	43	47.8	13	65.0	14	48.3	11	73.3
Sometimes	17	18.9	3	15.0	8	27.6	1	6.7
Every client	17	18.9	4	20.0	7	24.1	3	20.0
Missing/Unknown	13	14.4	1	-	1	-	2	-
Large fan								
Never	56	62.2	13	68.4	22	75.9	10	66.7
Sometimes	12	13.3	4	21.1	5	17.2	2	13.3
Every client	8	8.9	2	10.5	2	6.9	3	20.0
Missing/Unknown	14	15.6	2	-	1	-	2	-
Exhaust Hood								
Never	58	64.4	12	66.7	24	85.7	13	81.3
Sometimes	2	2.2	-	-	2	7.1	-	-
Every client	15	16.7	6	33.3	2	7.1	3	18.8
Missing/Unknown	15	16.7	3	-	2	-	1	-
Ventilated Table								
Never	36	40.0	8	44.4	14	48.3	10	62.5
Sometimes	8	8.9	1	5.6	5	17.2	2	12.5
Every client	32	35.6	9	50.0	10	34.5	4	25.0
Missing/Unknown	14	15.6	3	-	1	-	1	-

Supplementary Materials

Table S2. Clinical characteristics for all respondents, as well as those who were never pregnant, those who had a history of pregnancy with o miscarriage, and those who had a history of pregnancy with at least one miscarriage. The category of "All" respondents includes those who did not have usable data related to pregnancy outcomes, which accounts for the discrepancy in sample sizes.

Characteristics	All n=90		Never Pregnant n=21		Pregnancy, Non-Miscarriage n=30		Pregnancy, 1+ Miscarriage n=17	
	n	%	n	%	n	%	n	%
Number of live births								
Mean(SD)	2.05 (1.42)		n/a		2.37 (1.45)		1.71 (1.36)	
Median (Q1, Q2)	2 (1, 3)				2 (1, 4)		1 (1, 5)	
Number of low birth weight babies								
(Max, Min)	(0,3)		n/a		(0, 2)		(0, 1)	
Number of sexual partners								
Mean(SD)	5.85 (12.36)		5.45 (6.7)		8 (20, 27)		3 (2,15)	
Median (Q1, Q2)	2 (1, 5)		2 (1, 8)		2 (1, 6)		2 (1, 4)	
Low birth weight (binary)								
No	46	51.1	n/a		26	92.9	13	86.7
Yes	8	8.9			2	7.1	2	13.3
Missing	36	40.0			2	-	2	-
Monthly menstrual period								
No	19	21.1	4	22.2	9	31.0	5	29.4
Yes	59	65.6	14	77.8	20	69.0	12	70.6
Unknown	12	13.3	3	-	1	-	-	-
Period same length and heaviness								
No	30	33.3	7	41.2	12	40.0	6	35.3
Yes	47	52.2	10	58.8	18	60.0	11	64.7
Unknown	13	14.4	4	-	-	-	-	-
Period at least 3 days								
No	9	10.0	2	10.5	4	13.3	1	5.9
Yes	70	77.8	17	89.5	25	86.7	16	94.1
Unknown	11	12.2	2	-	-	-	-	-
Adult acne								
No	64	71.1	10	47.6	21	70.0	14	82.4
Yes	26	28.9	11	52.4	9	30.0	3	17.7
Anemia								
No	84	93.3	21	100.0	27	90.0	15	88.2
Yes	6	6.7	-	-	3	10.0	2	11.8
Pelvic pain								
No	73	81.1	19	90.5	21	70.0	14	82.4
Yes	17	18.9	2	9.5	9	30.0	3	17.7
Painful period								
No	60	66.7	14	66.7	18	60.0	10	58.8
Yes	30	33.3	7	33.3	12	40.0	7	41.2
Painful intercourse								
No	73	81.1	17	81.0	24	80.0	13	76.5
Yes	17	18.9	4	19.1	6	20.0	4	23.5
Thyroid disease								
No	81	90.0	21	100.0	25	83.3	15	88.2
Yes	9	10.0	-	-	5	16.7	2	11.8
Heart disease								
No	89	98.9	21	100.0	29	96.7	17	100.0
Yes	1	1.1	-	-	1	3.3	-	-
Excess hair growth								
No	82	91.1	19	90.5	27	90.0	15	88.2
Yes	8	8.9	2	9.5	3	10.0	2	11.8
High blood pressure								
No	80	88.9	19	90.5	24	80.0	15	88.2
Yes	10	11.1	2	9.5	6	20.0	2	11.8
Cancer								
No	87	96.7	21	100.0	27	90.0	17	100.0
Yes	3	3.3	-	-	3	10.0	-	-
Cystic fibrosis								
No	89	98.9	21	100.0	29	96.7	17	100.0
Yes	1	1.1	-	-	1	3.3	-	-
Ulcerative colitis								
No	89	98.9	21	100.0	29	96.7	17	100.0
Yes	1	1.1	-	-	1	3.3	-	-
Non-Insulin diabetes								
No	63	70.0	20	95.2	29	96.7	17	100.0
Yes	2	2.2	1	4.8	1	3.3	-	-
Any history of sexually transmitted infection								
No	81	90.0	18	85.7	24	80.0	17	100.0
Yes	9	10.0	3	14.3	6	20.0	-	-

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