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Occupational Exposures Among Hair and Nail Salon Workers: a Scoping Review

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Abstract

Purpose of Review To review the literature published from 2014 to 2019 on hair and nail salon workers concerning exposure assessment, reproductive and respiratory endpoints, and endocrine disruption, in relation to workplace exposures.

Recent Findings We identified 29 relevant peer-reviewed publications. Overall, there were insufficient studies to determine whether working in these settings is associated with reproductive health endpoints, although prior studies suggest that reproductive effects are of concern. There is consistent evidence that working in hair and nail salons may increase the risk of respiratory effects. Also, despite the fact that many hair and nail care products contain endocrine disrupting compounds, no recent studies have evaluated endocrine-related endpoints. Moreover, few studies have evaluated chemical exposures in these settings and biomonitoring studies are sparse.

Summary Improved exposure assessment of chemical hazards in hair and nail salons is necessary to properly characterize occupational exposures and assess their potential health risks. Further studies on endpoints related to endocrine disruption and reproductive health outcomes among hair and nail salon workers are needed. Improved exposure and epidemiologic studies will help inform chemical exposure mitigation efforts in a vulnerable occupational population, as well as policies related to workplace and consumer product safety.

Keywords Occupational exposures · Hair and nail salon workers · Hairdressers · Reproductive · Respiratory · Endocrine

Introduction

In the United States, the hair and nail salon industry employs approximately one million people, and over 90% of hair and nail salon workers are women, many of whom are of reproductive age [1]. It is estimated that 42% of nail salon workers are Asian immigrants [2•], while Black women and Latinas respectively comprise 14% and 18% of hair salon workers and

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cosmetologists [1]. Hair and nail salon workers are continually exposed to multiple chemicals, including known and suspected carcinogens, reproductive toxicants, respiratory irritants, and endocrine disruptors [3•, 4, 5••, 6, 7]. Still, few US studies have evaluated chemical exposures in hair and nail salons. Additionally, the disproportionate composition of workers from marginalized groups in nail salons, and the use of potentially harmful ethnic hair products among hairdressers primarily serving a multicultural clientele, underscores the importance of evaluating occupational chemical exposures and associated health risks [8••, 9].

Ingredients in products used in hair and nail salons include endocrine disrupting compounds (EDCs) like parabens and phthalates [10••]. EDCs can mimic or block endogenous endocrine function, with wide-ranging health implications, including reproductive effects [11]. Many of the chemicals contained, emitted or formed from the use of hair and nail products are also known or suspected respiratory irritants and sensitizing agents, including volatile organic compounds (VOCs) like formaldehyde in hair straighteners and nail polishes, ammonia in hair dyes, persulfates in bleaches, and phthalates added for fragrance or as solvents [12–15]. Several studies indicate that women in this occupational group may disproportionately suffer from adverse respiratory effects [16, 17], although some studies have not observed these associations [18•]. Inconsistent findings across epidemiologic studies on hair and nail salon workers may, in part, be due to the use of job title to assess workplace exposures as well as differences in products used, clientele served, and outcomes assessed.

Despite the potential increased risk of adverse effects among hair and nail salon workers, recent studies evaluating chemical exposures and health endpoints among individuals employed in the cosmetology industry are limited. In this review, we sought to synthesize the literature from the past 5 years on hair and nail salon worker exposures focusing on studies that evaluated reproductive, respiratory, and endocrine-related endpoints, as well as studies that assessed occupational chemical exposures using environmental or biological monitoring. We also reviewed current data gaps to inform future studies.

Methods

Developing Key Terms and Search Strategy

We followed the guidelines from the Centre for Reviews and Dissemination [19] and the Cochrane Handbook for Intervention Reviews to develop search terms and a search strategy [20]. Key search terms applicable to occupational and environmental health studies in hair and nail salons were guided by the Population, Exposure, and Outcome (PEO) framework as outlined below [21]:

- *Population*: hair and nail salon workers; given that these occupational workgroups consist of >90% females, we focused on summarizing information on female workers of all ages, races, and ethnicities.
- *Exposure*: toxic salon products, indoor air pollution, and other occupational chemical-related exposures.
- *Outcome*: reproductive, respiratory, and endocrine disrupting-related endpoints among hair and nail salon workers.

We scanned database subject thesauri and studies identified through a Google Scholar search to compile a list of relevant key terms. We focused our search on epidemiologic, environmental monitoring, and biomonitoring studies in hair and nail salons. We generated a list of key terms for each concept (Appendix 1) and combined them with Boolean operators (AND, OR) [22]. The search strategy is presented in Appendix 2 and was checked for syntax errors against the Peer Review of Electronic Search Strategies Checklist [23].

Data Selection, Extraction, and Management

On February 21, 2019, the public health librarian (NT) conducted a search in 29 EBSCO databases, PubMed (U.S. National Library of Medicine), Web of Science (Clarivate Analytics), and Public Health (ProQuest) (Appendix 3). Peer-reviewed studies published from January 2014–February 2019 were included. The search results were imported into Zotero for title/abstract screening and duplicate records were removed. A trained research assistant (LKK) initially screened articles, and the principal investigators (LQA and AZP) conducted a final review of preliminary studies. We recorded the search process and findings from the literature using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [24] as shown in Appendix 4. While some articles included both males and females, we focused on synthesizing results observed among females whenever possible and limited our search to studies published in English.

Results

Our searches yielded a total of 2176 records from 2014 to 2019. After removing duplicate titles and abstracts, 978 studies remained and were screened. The 29 studies meeting eligibility criteria were read in full and included in this summary. Both reviewers (LQA and AZP) agreed on the final full-text articles included in this review.

Environmental Exposures and Biomonitoring Studies

Hair Salons

We identified five studies that measured indoor air quality and air concentrations of chemicals in hair salons, including VOCs, particulate matter (PM), and phthalates [3•, 15, 25–27]. A study by Nilsson et al. [15] focused on the physical and chemical characterization of particle emissions during simulated client sessions using a hair bleach marketed as "dust-free" and one without this labeling. Levels of particle emissions were evaluated to assess exposures among 12 hairdressers performing hair bleaching in a controlled environment. Particulate matter (PM) <10 μm was detected during hair bleaching when regular bleaching powder was prepared, while dust-free bleaching powder emitted particles >10 μm. Persulfate exposure was lower with dust-free bleaching powder. Another study by Saraga et al. [25] measured respirable particulate matter or RPM (i.e., suspended particle fraction with aerodynamic diameter<4 μm) in the breathing zone of Greek volunteers, including two hairdressers and eight customers in a hair salon. A hairdresser using hairspray and a hairdryer was exposed to the highest levels of RPM (286 μm^{-3}).

Subedi et al. [26] measured phthalate dust concentrations in five hair salons in Kentucky, Indiana, and Texas and in other locations, including 11 residences in five states and 11 childcare facilities in seven states. Estimated daily intake of phthalate and non-phthalate plasticizers via dust in hair salons was approximately three times higher than those estimated for residential environments. Among non-phthalate plasticizers, acetyl tri-*n*-butyl citrate (ATBC) and diisobutyl adipate were found at concentrations 3–10 times higher in salons compared to residences and childcare facilities. ATBC is used in cosmetics, food contact wrappings, and toys [28], and diisobutyl adipate is used as a fragrance ingredient, plasticizer, as an emollient in skin-conditioning agents, and as a solvent [29]. Another study by Chang et al. [3•] measured indoor air contaminants and assessed indoor air quality parameters in five hair salons in Taipei. Four of the five phthalates measured were detected in >69% of samples. Dibutyl phthalate (DBP), diethyl phthalate (DEP), and di[2-ethylhexyl] phthalate (DEHP) were detected in 97–100% of samples. The authors reported higher phthalate, isopropanol, butyl acetate, and ethyl acetate concentrations than previously reported in residences. For formaldehyde, 83% (25/30) of the samples exceeded the Taiwan Environmental Protection Agency's Indoor Air Quality (IAQ) standard of 98.4 $\mu g/m^3$ and the National Institute of Occupational Safety and Health Recommended Exposure Limit (NIOSH REL) of 19.68 $\mu g/m^3$. The number of workers, number of perming treatments, and frequency of formaldehyde-releasing product use was linked to indoor formaldehyde air concentrations. Additionally, some CO_2 readings exceeded guidelines by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and Taiwan's IAQ Act threshold (1000 ppm). Another study [27] conducted among 13 Palestinian hairdressers measured ammonia levels in hair salons. Researchers detected ammonia in all salons; ammonia concentrations were positively correlated with the size of the salon, number of salon workers, and number of customers served.

We identified two studies that conducted biomonitoring among hairdressers. One study [30] measured resorcinol in urine samples across different occupational groups, including hairdressers. Resorcinol is a synthetic chemical used in cosmetics, including permanent hair dyes where it reacts with a developer (e.g., peroxide) to bond the dye to the hair. Researchers compared urinary resorcinol concentrations between occupationally exposed groups. Hairdressers (n=77) provided three spot urine samples: (1) a first morning-void sample after at least 1 day off from working in the salon, (2) a post-shift sample immediately after a work shift, and (3) a next-morning (first morning-void) sample. Urinary concentrations of resorcinol were higher in post-shift samples and similar between hairdressers and controls (n=101). These findings warrant replication in other populations as product use patterns and ingredients may differ across populations and geographic regions. The other biomonitoring study identified quantified phthalate exposures among 68 Slovakian hairdressers and reported higher urinary phthalate biomarker concentrations among hairdressers compared to controls comprising of university students and staff (n=32) [5••].

Nail Salons

Six studies [31–36] evaluated chemical exposures in nail salons through personal air monitoring, area air monitoring, biomonitoring, or a combination of these. One study conducted personal and area air monitoring of VOCs and carbon dioxide (CO_2) and measured IAQ parameters (e.g., air exchange rate, temperature, and relative humidity) at 17 Michigan salons [36]. Ethyl acetate and *n*-butyl acetate were detected in personal samples in all salons, while toluene, benzene, and formaldehyde were detected in some salons. Methyl methacrylate (MMA), a long-banned chemical, was identified in most salons. Personal VOC monitoring measurements exceeded area measurements, highlighting the importance of personal monitoring in these settings. Nail products were also tested for VOCs and identified ethyl acetate as the main component. Toluene was detected in nail polish and indoor air in eight of 17 salons. The initial threshold screening level, regulated by the Michigan Department of Environmental Quality, was exceeded for 12% of ethyl acetate and 50% of MMA measurements. Ventilation levels during the winter were low, although most salons met ASHRAE ventilation standards.

In a Korean study among 50 nail salon workers from 30 salons, 13 VOCs were detected in personal air samples [34]. Several air samples had acetone, toluene, butyl acetate, and MMA levels exceeding Korean Occupational Exposure Limits. Almost all participants (98%) worked without local exhaust ventilation, while 65% worked in salons with closed windows. Personal protective equipment (PPE) use was infrequent. Temperatures in salons ranged between 23.4 and 35.7 °C, and the mean (SD) relative humidity was below ASHRAE guidelines [mean=55.7 (7.1)%]. Chemical concentrations were higher in salons with general ventilation systems, suggesting that local exhaust may decrease personal exposure more effectively compared to general ventilation systems, which may pull chemicals into breathing zones.

Lamplugh et al. [33] measured VOCs (formaldehyde and BTEX—benzene, toluene, ethylbenzene, and xylenes) using area and personal monitors in six Colorado nail salons. Area monitoring was conducted over three weekdays and one weekend day for 8 hours each day. Formaldehyde concentrations in these salons ranged from 5 to 20 μg/m^3 and exceeded the NIOSH REL (19.6 μg/m^3; 16 ppb) in one salon. Researchers detected benzene, toluene, ethylbenzene, and xylenes in all salons, with toluene at the highest concentrations (26.7–816 μg/m^3). Acetone, ethyl acetate, and *n*-butyl acetate were detected in personal samples in all salons. Despite being banned in Colorado, MMA was detected in two salons, highlighting the need for salon worker and owner education and discouraging the purchase of MMA-containing products [33]. A salon marketed as "non-toxic" had the highest levels of personal exposures to acetone, ethyl acetate, and *n*-butyl acetate, underscoring the importance of greater oversight on labeling and personal care product regulation.

A study of 109 Polish salons [32] measured VOC levels (ethanol, acetone, toluene, 2-propanol, 2-butanone, ethyl acetate, isopropyl acetate, *n*-butyl acetate) among 145 female nail salon workers and 145 healthy female volunteers employed in other occupations. Median area VOC levels in nail salons were all below Polish regulatory occupational limits. VOC concentrations were usually higher in the winter; however, seasonal variation may be driven by differences in the nail salons across seasons. Longer-term measurements would be informative since these findings reflect only short-term breathing zone measurements, which could underestimate true exposures. Pavilonis et al. [35] detected VOCs and CO_2 in 10 New York city salons. The median total VOC (TVOC) concentration was 4.0 ppm across salons, and concentrations were strongly correlated with CO_2 (r=0.81). Lastly, one study conducted short-term measurements of several IAQ parameters (CO_2, temperature, relative humidity, TVOCs, $PM_{2.5}$) during working hours in 21 nail salons in Boston [31]. CO_2 levels exceeded 800 ppm in 15 of 21 salons, suggesting that some salons may have inadequate ventilation. Higher TVOC and $PM_{2.5}$ levels were observed in salons with less ventilation, and average TVOC, CO_2, and $PM_{2.5}$ levels were consistent within salons. Higher TVOC concentrations were also observed when tasks were being performed; however, these concentrations were not associated with the number of tasks being performed.

No studies within the last 5 years have evaluated biomarkers of exposure to chemicals that may affect the reproductive, respiratory, and endocrine systems among nail salon workers. In addition, biomonitoring studies beyond our 5-year scoping period are limited. Available evidence indicates that nail products contain reprotoxic and endocrine disrupting chemicals, and further studies are needed to adequately assess occupational exposures among these workers. Urinary biomonitoring in hair salon workers indicate feasibility of collecting biospecimens from nail salon workers and stress the importance of obtaining exposure estimates [5••, 30].

Reproductive Endpoints

We identified four studies [37–40] on reproductive endpoints among hair or nail salon workers (Table 1). One study examined spontaneous abortion [38] utilizing Korean National Health Insurance records which covered 78% of all Korean births in 2013 and identified women by occupational status in relation to claims data. Employed women in any occupation were at greater risk of spontaneous abortion compared to non-working women [38], and an increased odds of miscarriage was reported for the group comprising hair and nail salon workers. The two reference groups in the study included unemployed women and those employed in education.

Three studies examined birth outcomes [37, 39, 40]. In a record-based study conducted in Ibadan, Nigeria, female hairdressers had the highest proportion of infants with low Apgar scores at 5 minutes after birth of all occupations examined (*n*=1349) [37]. However, only bivariable relationships were examined and there was no adjustment for confounding. No associations between adverse birth outcomes and employment in cosmetology or as a manicurist were reported in a record linkage study in California, which included 81,205 births among cosmetologists and manicurists [39]. However, employment in cosmetology or as a manicurist was associated with increased risk of gestational diabetes and placenta previa [39]. Notably, when restricting analyses to Vietnamese participants, manicurists and cosmetologists had greater odds of small for gestational age births. In this study, researchers used two comparison groups: women employed as teachers, realtors, salespersons, office workers, and food service workers, and a separate comparison group of non-cosmetologists from the general population. This control selection approach can circumvent issues of healthy worker effect. A multisite French study [40] reported an elevated risk of hypospadias for children whose parents were occupationally exposed to EDCs, including hairdressers and beauticians (*n*=300 with

Table 1 Summary of studies examining associations between occupational exposures among hair and nail salon workers based on job title and reproductive outcomes

Author and year	Study population	Age range or mean ± SD	Years during which the study was conducted	Study design	Outcomes evaluated	Main findings
Omokhodion et al. 2018 [37]	*N*=1349, mothers who registered pregnancy at an tenatal clinics in Ibadan Nigeria	20-19 year (*n*=713) 30-45 year (*n*=633) Unknown (*n*=3)	Not provided	Cross-sectional	Apgar scoring used as an index of neonatal asphyxia	Occupations with lower socio-economic status or those requiring physical exertion (e.g., tailoring, catering and hairdressing) recorded higher rates of low Apgar scores at 1 min (*p*=.08) Although np significant association was observed, mothers engaged in hairdressing had high rates (7.5%) of low Apgar scores at 5 min. *Main cofounders considered:* Gender and health facility
Park et al. 2017 [38]	N=430,343, pregnancies abstracted from Korean National Health Insurance claim data: Working women (*n*=210,576) Non-working women (*n*=219,767)	Working women 31.09 ± 3.94 years None-working women 31.12 ± 4.46 years	2013	Cross-sectional	Obstetric outcomes: Rates of miscar-riage Threatened abortion Preterm labor Intrauterine growth restriction	The percentages of all adverse obstetric outcomes were higher in working women than in non-working women. Working women had higher and statistically significant adjusted ORs for miscarriage in 18 of the 21 industries assessed. The age and income-adjusted OR for miscarriage for all working women was 1.26 (95%CI, 1.23 ± 1.28) *Main confounders considered:* Age and income
Quach et al. 2015 [39]	N=81,205, births among cosmetologists and manicurists in California: Manicurists (*n*=24,832) Cosmetologists (*n*=56,373) *N*=459,081, comparison group: Other working groups (e.g., teacher, realtors, salespeople, bankers, office workers, and food service worker) (*n*=53,056) General population (*n*=406,025)	Cosmetologists and manicurists: 25–34 years at delivery, (64.6% cosmetologists) (70.2% manicurists) Control group: 25–34 years at delivery (52.0% general female population).	1996–2009	Population-based retrospective linkage study	Birth outcomes: Birth weight Preterm delivery Gestational age Selected birth Defects infant death Maternal health outcomes: Preeclampsia Gestational diabetes Chronic diabetes Prolonged labor	An association for small for gestational age was observed among Vietnamese manicurists (OR, 1.39; 95%CI, 1.08–1.78) and cosmetologists (OR, 1.40; 95%CI, 1.08–1.83) when compared to other working women. Some maternal complications were observed, notably an increased risk for gestational diabetes (OR, 1.28; 95%CI, 1.10–1.50 for manicurists; OR, 1.19; 95%CI, 1.07–1.33 for cosmetologists) compared with the general population, which further increased when restricted to Vietnamese workers (OR, 1.59; 95%CI, 1.20–2.11, for manicurists; OR, 1.49; 95%CI, 1.04–2.11 for cosmetologists). An association was observed for placenta previa among manicurists (OR, 1.46; 95%CI, 1.08–1.97) and cosmetologists (OR, 1.22; 95%CI, 1.02–1.46) compared with the general population. *Main confounders considered:* Race/ethnicity, parity/birth order, maternal education, maternal age (< 35 vs. ≥ 35 years of age), and month prenatal care began.

Table 1 (continued)

Author and year	Study population	Age range or mean ± SD	Years during which the study was conducted	Study design	Outcomes evaluated	Main findings
					Precipitous labor Premature rupture of membranes Abruption placenta Placenta previa	
Kalfa et al. 2015 [40]	N= 300, boys whose parents were occupationally exposed to EDCs, including hairdressers and beauticians, presenting with isolated hypospadias (E.g., no micropenis, no cryptorchidism) in France N= 302, controls, normal boys (e.g., no congenital malformation; no urological, genital, or nephrological pathology; no inguinal hernia; no endocrine disease)	Not provided	2009–2014	Multicenter case-control	Hypospadias	Fetal exposure to EDCs around the window of genital differentiation was more frequent in the case of boys with hypospadias (40.0% vs. 17.6%, respectively; OR, 3.13, 95%CI, 2.11–4.65). The substances to which fetuses were exposed were paints/solvents/adhesives (16.0%), detergents (11.0%), pesticides (9.0%), cosmetics (5.6%), and industrial chemicals (4.0%). Jobs with EDC exposures were more frequent in mothers of boys with hypospadias (19.73% vs. 10.26%, P = 0.0019), especially cleaners, hairdressers, beauticians, and laboratory workers. *Main confounders considered:* Gestational age in weeks

EDCs endocrine-disrupting compounds; *OR* odds ratio; *95%CI 95%* confidence interval

hypospadias, *n*=302 no malformation) [40]. Participants were free from genetic mutations that increased risk of hypospadias among offspring; parental occupation and an in-depth job exposure matrix was used to assess potential exposures to EDCs. Evaluation of the endpoint was a study strength, but the authors did not control for any potential confounders.

Select records-based studies reviewed were strengthened by the use of two comparison groups [38, 39]. These included women who do not work outside the home and those in education [38], as well as a broader range, comprising teachers, realtors, retail, office, and food service workers [39]. The inclusion of food service and retail workers in the comparison group aligns occupations of similar socioeconomic status, which may minimize selection bias. The potential for unemployed women to be more fecund than women in the workforce was another potential source of bias in select studies. This occurs because women with young children have lower employment rates [41]. Using alternate comparison groups is one approach to address this and is particularly important when information on parity and gravidity is unavailable. Ascertainment of outcomes of miscarriage and pregnancy loss was identified by health insurance records [38] or birth certificates [39]. For evaluating pregnancy loss, these sources are not ideal. Women with early pregnancy losses may not see a doctor, leading to missing data. This information bias may be non-differential but could result in bias in either direction [42]. Study limitations in the studies reviewed include lack of biomonitoring to confirm chemical exposures, small sample sizes, and lack of adjustment for important confounders, such as age. Future studies should consider modeling approaches that formulate analysis plans a priori and are not dependent on a statistical threshold. Given limited recent studies of reproductive outcomes and lack of cohesion across health endpoints, further research is necessary to determine if reproductive health endpoints are related to working in hair or nail salons.

Respiratory Endpoints

Hairdressers

We identified 10 articles [5••, 27, 43–50] related to respiratory outcomes (Table 2). Four studies assessed respiratory symptoms via questionnaires [43–46], while six additionally collected biospecimens and/or measures of lung function or inflammation [5••, 27, 47–50]. One study in New Zealand [47] reported an increased odds of self-reported chronic bronchitis symptoms among participants who had ever reported working as a hairdresser, although no associations with objective measures of lung function or chronic obstructive pulmonary disease (COPD) were observed. Lysdal et al. [46] reported higher prevalence of respiratory symptoms among hairdressers with adult asthma onset, as assessed by a mail-in questionnaire among 5239 Danish hairdressing school graduates. Twenty-seven percent of respondents reported difficulty breathing or shortness of breath after contact with bleaching products. Other studies reported increased respiratory symptoms, including among hairdressers or hairdressing apprentices in Denmark [43, 44], Palestine [27, 49], Turkey [50], Sweden [48], and Egypt [45].

Several studies incorporated biospecimen collection and/or measures of lung function or inflammation [5••, 27, 47–50]. Diab et al. [48] studied Swedish hairdressers (*n*=17) and two control groups (*n*=19 asymptomatic hairdressers; *n*=10 females with pollen-driven rhinitis) for 30 days. Nasal reactivity to persulfate was evaluated via nasal lavage at work after >2 weeks of vacation. Hairdressers had increased nasal symptoms and eosinophil cationic protein, a marker of eosinophilic bronchial inflammation. Atopic hairdressers reported the most respiratory symptoms. Nemer et al. evaluated lung function over 5 years among 161 non-smoking female Palestinian hairdressers [49]. Hairdressers reported more respiratory symptoms and experienced decrements in lung function at the end of the follow-up period compared to baseline. Lung function was worse for hairdressers in salons with ammonia levels >25 ppm compared to hairdressers exposed to lower ammonia levels. In another study [27], the authors reported higher neutrophilic airway inflammation, as well as elevated exhaled nitric oxide (eNO) and blood C-reactive protein levels, a measure of systematic inflammation, among Palestinian hairdressers (*n*=33) compared to controls (*n*=35).

One study [5••] applied biomonitoring to ascertain occupational exposures to select agents and examined associations with respiratory outcomes. Kolena et al. [5••] conducted a cross-sectional study among 68 Slovakian hairdressing apprentices (97% female) to assess occupational phthalate exposures and associations with pulmonary function as compared to controls (*n*=32 university students and staff; 66% female). Median phthalate metabolite concentrations were higher among hairdressing apprentices compared to controls. Greater phthalate metabolite concentrations were also inversely associated with select lung function measures, although the authors did not control for any potential confounders. Other limitations include the small sample size and inclusion of a higher proportion of male controls compared to hairdressers. Personal care products (PCPs) are a major source of phthalate exposure and PCP use is higher among females; to rule out the possibility that greater phthalate biomarker concentrations were due to personal care product use unrelated to occupational exposures, more female controls should have been included in the study [55].

In summary, several studies report an increased risk of adverse respiratory outcomes, including respiratory symptoms, lung function decrements, and inflammation among hairdressers from several countries. Some limitations noted in these recent studies include the cross-sectional design [5••,

Table 2 Summary of studies examining associations between occupational exposures among hair salon workers and respiratory outcomes

Author and year	Study population	Age range or mean ± SD	Years during which the study was conducted	Study design	Exposure assessment	Outcomes evaluated	Main findings
Kolena et al. 2017 [5••]	*N*= 68, hairdressing apprentices attending vocational training schools in western part of Slovakia Females (*n* = 66) Male (*n*=2) *N*= 32, control group, students and staff from Constantine the Philosopher University in Nitra, Slovakia Female (*n* = 21) Male (*n*=11)	Hairdressing apprentices 17.7 ± 1.2 years Controls 23.8 years	Not provided	Cross-sectional	Urinary phthalate biomarker concentrations	Exposure to phthalates from first-morning-void urine sample Pulmonary function	Urinary phthalate metabolite concentrations were higher in hairdressing apprentices compared to those in the control group (median and 95th percentiles) of MEHHP, MEOHP, MEHP, sum of DEHP, MnBP, but lower 95th percentiles of MiBP. Urinary concentration for MiBP ($p \leq 0.05$) was significantly higher in hairdressing apprentices compared to the control group. Inverse associations were observed between MEHP, MEOHP, MEHHP, sum of MEHP, MEHHP, MEOHP and vital capacity and also between MEHP and FVC. Duration of exposure was associated with biomarker concentrations of MnBP, MEHHP, and MEP. Positive associations between pulmonary function FVC% of PV for females and negative associations between ratios of forced expiratory volume in 1 s (FEV1) to FVC (FEV1/FVC). *Main confounders considered:* Adipose tissue could play role as confounding factor in urine excretion of phthalates because of their lipid solubility and accumulation.
Foss-Skiftesvik et al. 2017 [43]	*N*= 504, hairdressing apprentices in Denmark, female (94.4%) *N*= 1400, controls, female (95.7%)	Hairdressing apprentices: 22.0 ± 3.8 years Controls: 22.0 ± 4.1 years	April–July 2013	Cross-sectional, web-based questionnaire study	Exposure was based on job title.	Rhinitis and asthma symptoms (e.g., wheezing and coughing)	1-year prevalence of rhinitis symptoms was higher in hairdressing apprentices than in controls (58.1 vs 46.6%; OR, 1.59; 95%CI, 1.30–1.98). The prevalence of rhinitis symptoms was higher among hairdressing apprentices in the last years of training compared to those in the first year of training (62.4% vs 41.8%, $p = 0.003$). Current smoking was more common in hairdressing apprentices (28.4% vs 17.2%, $p < 0.001$). Asthma symptoms were equally common in the 2 groups; however, hairdressing apprentices had a later age of onset of wheezing than controls (18 vs 14 years; $p < 0.0001$) and a decreased risk of wheezing (OR, 0.72; 95%CI, 0.54–0.95).

Table 2 (continued)

Author and year	Study population	Age range or mean ± SD	Years during which the study was conducted	Study design	Exposure assessment	Outcomes evaluated	Main findings
							Bleaching products were the most frequently reported cause of rhinitis and asthma symptoms in hairdressing apprentices. *Main confounders considered:* Smoking, education level, and degree of rurality
Foss-Skiftesvik et al. 2017 [44]	*N*= 248, hairdressing apprentices in Denmark Female (96.4%) *N*= 816, controls Female (96.3%)	Hairdressing apprentices 25 ± 4.0 years Controls 25 ± 4.3 years	Baseline study conducted April–July 2013 Follow-up study in April–June 2016	3-year follow-up questionnaire	Exposure was based on job title.	Incidence of respiratory diseases (e.g., urticaria and rhinitis symptoms)[a]	Rhinitis symptoms were significantly increased in hairdressing apprentices (IRR, 1.6; 95%CI, 1.2–2.2); wheezing incidence was similar between hairdresser apprentices and controls. During the follow-up period, 21.8% of the hairdressing apprentices left the trade, and 70.3% of these left due to health complaints, including respiratory symptoms (23.7%). *Main confounders considered:* The authors note that adjustment for smoking and atopic dermatitis could not be performed, owing to small sample sizes.
Nemer et al. 2015 [49]	*N*= 161, non-smoking female hairdressers in Hebron, Palestine	28 ± 8 years	2008–2013	5-year prospective study	Ambient air ammonia levels in 13 salons	Change in reported respiratory symptoms and lung function over the follow-up Dropout from the profession and rationale for dropping out Ambient air ammonia levels in 13 salons	Current hairdressers reported more respiratory symptoms at the end of the follow-up period (2013) compared to baseline (2008). Former hairdressers reported fewer symptoms at follow-up. At follow-up, current hairdressers showed a significant decrease in FVC of 35 mL/year (95%CI, 26–44 mL/year) and of 31 mL/year (95%CI, 25–36 mL/year) for FEV1. 28 (16%) of the hairdressers quit the job during the 5-year follow-up period, and 8 (28%) due to health problems. Hairdressers working for ≥ 4 years at baseline showed a stronger decline in FEV1 compared with those who worked < 4 years (difference in annual decline of FEV1(mL/year) compared with the reference, 13 mL; 95%CI,1–25). *Main confounders considered:* Age, height and BMI.
Hassan et al. 2015 [45]	*N*= 80, female hairdressers in Benha city, Kalyobiya Governorate, Egypt *N*= 50, matched controls, office worker	Hairdressers 32.7 ± 7.0 years Controls 33.3 ± 7.8 years	February–June 2014	Comparative cross--sectional	Exposure was based on job title.	Respiratory disorders	Significant associations between frequent hair treatments (bleaching, dye and wave) and runny nose ($p < 0.05$), and phlegm ($p < 0.05$). Hairdressing is associated with increased risk to respiratory symptoms due to adverse working conditions.

Table 2 (continued)

Author and year	Study population	Age range or mean ± SD	Years during which the study was conducted	Study design	Exposure assessment	Outcomes evaluated	Main findings
							Main confounders considered: None mentioned.
Nemer et al. 2015 [27]	N= 33, non-smoking female hairdressers in Hebron, Palestine *N*= 35, non-smoking controls	Hairdressers 19–50 years Non-smoking controls 18–49 years	October 2012–March 2013	Cross-sectional	Exhaled nitric oxide (eNO) via lung function test Blood and sputum samples were collected from all participants. Concentration levels of atmospheric ammonia were measured in 13 salons.	Inflammatory cells in the sputum Exhaled nitric oxide (eNO) levels Blood C-reactive protein (CRP) as a measure of systemic inflammation Exposure to ammonia in salons and any association between air concentration levels of ammonia and measured outcomes	Hairdressers had a higher level of sputum neutrophil count compared to controls: Absolute numbers/mg sputum median (25th–75th percentiles) • Hairdressers 376 (183–980) • Controls 182 (96–358) • Hairdressers also had significantly elevated eNO and CRP levels compared to the control subjects, after adjusting for age and BMI. Exposure measurements indicated that the hairdressers in salons with inadequate ventilation were exposed to ammonia concentrations ranging from 3 to 61 mg/m3. *Main confounders considered:* Age, height, and BMI
Diab et al. 2014 [48]	*N*= 46, female hairdressers in Lund, Sweden: Symptomatic (n = 17) Asymptomatic (n = 19) Pollen-allergic (n = 10)	Symptomatic 39 ± 11 years Asymptomatic 37 ± 12 years Pollen-allergic 34 ± 15 years	4 weeks of exposure after 2 weeks off work (year study was conducted was not specified)	Short-term prospective	Exposure was based on job title.	Diary: Airway symptoms and occupational exposure based on job tasks (e.g., hair treatment; bleaching; hair coloring, etc.) Inflammatory markers in nasal lavage: Eosinophil cationic protein (ECP) Tryptase Albumin Substance P Nasal Provocation Test: Nasal symptom score Acoustic rhinometry Quality of Life questionnaires: Summary indexes Physical and mental domains	Skin prick tests to persulfate performed in the hairdressers were negative. A steady increase in nasal symptoms, mainly blockage, and in the ECP was noticed in the symptomatic hairdressers. The health-related quality of life deteriorated in the symptomatic hairdressers, indicating an effect on their work and daily life. Atopic hairdressers had more varying symptoms (itching, sneezing and secretion) compared to non-atopic hairdressers. *Main confounders considered:* None mentioned.
Hansell et al. 2014 [47]	*N*= 1017 individuals with completed questionnaires in Wellington, New Zealand: Female n = 502	25–74 years	2003–2004	Cross-sectional	Exposure was based on job title.	Chronic obstructive pulmonary disease Chronic bronchitis symptoms Self-reported doctor diagnosis of COPD,	Chronic bronchitis symptoms were associated with self-reported exposure to hairdressing based on a job exposure matrix. The strongest association with chronic bronchitis symptoms among all work groups

Table 2 (continued)

Author and year	Study population	Age range or mean ± SD	Years during which the study was conducted	Study design	Exposure assessment	Outcomes evaluated	Main findings
	Females ever worked in hair dressing (n = 17) Male n = 512 Males ever worked in hair dressing (n=2)					chronic bronchitis, or emphysema Predicted FEV1 percentage from tests of asymptomatic non-smokers in the NHANES III study	assessed was for hairdressers (OR, 6.91; 95% CI, 2.02–23.70). Cumulative exposure to mineral dust and gases/fumes was associated with higher FEV1% predicted. *Main confounders considered:* Sex, age, height, age height, age squared, smoking (pack-years), ethnicity, and deprivation
Lysdal et al. 2014 [46]	N= 5239: hairdressing vocational graduates/-questionnaire respondents in Denmark: Female (n = 5014) Male (n = 225)	22–65 years	Study population received a mail-in questionnaire in May 2009	Register-based questionnaire	Exposure was based on job title.	Self-reported asthma Airway symptoms (e.g., cough, nasal congestion, rhinitis, rhinorrhea, shortness of breath)	Hairdressers reported asthma (11.2%), cough (25.3%), nasal congestion (24.0%), and rhinitis (18.2%). 27.1% of all trained hairdressers reported difficulty breathing or shortness of breath after contact with bleaching products. Less than 1/3 of all hairdressers with suspected occupational asthma reported their asthma as an occupational disease to the authorities. In total, 27.3% of participants were daily smokers; the smoking pattern was similar between hairdressers with and without asthma. *Main confounders considered:* None mentioned.
Toru et al. 2014 [50]	N= 225, employees working in small and medium enterprise from Düzce, Turkey: Hairdressers (n = 75) Auto painters (n = 75) Carpenters (n = 75)	Hairdressers 27.2 ± 9.2 years Auto painters 36.9 ± 10.3 years Carpenters 32.4 ± 9.7 years	April–July 2009	Cross-sectional	Urine samples obtained within working hours to measure cotinine levels	Respiratory complaints, (e.g., cough, phlegm, and chest tightness, dyspnea, rhinitis, FVC, FEV1, FEV1/FVC, MMFR) Pulmonary function tests (PFTs) Cotinine measurements in urine	FEV1 and MMFR were found to be significantly lower in hairdressers compared to other work groups (p = 0.005, p = 0.001, respectively). Hairdressers with cotinine levels > 500 ng/mL reported more respiratory complaints and rhinitis history; for this group both occupational and smoking status had an additive effect on respiratory symptoms. *Main confounders considered:* None mentioned.

Forced vital capacity (FVC), predicted value (PV), forced expiratory volume in 1 s (FEV1), Tiffeneau index (FEV1/FVC), maximum mid-expiratory flow rate (MMFR). *IRR* incidence rate ratio; *OR* odds ratio; *95%CI 95%* confidence interval

[a] While other outcomes were assessed in the study, data presented in the table is limited to respiratory outcomes.

27, 43, 45–47, 50], sole reliance on questionnaires to ascertain respiratory outcomes [43–46], lack of biomonitoring to ascertain exposures and related health outcomes to specific contaminants [27, 43, 45, 47, 48, 50], lack of adjustment for critical confounders [44], small samples sizes [27, 47, 48], and potential bias arising from the healthy worker effect [27, 43–47, 49, 50]. Despite these limitations, studies generally arrived at similar conclusions.

Nail Salon Workers

Five articles [34, 51–54] assessed respiratory outcomes among nail salon workers (Table 3). One US study [54] surveyed 61 female Southeast Asian immigrant nail salon workers in Oregon. Allergies were among the most commonly reported problems, although a definition of allergies was not provided. Another cross-sectional study [51] of 68 workers from 40 nail salons in New Jersey reported frequent lung and throat irritation. Similarly, another study among 159 Korean nail salon technicians (98% female) from 120 salons reported frequent respiratory-related symptoms, including nose (odds ratio, OR 54.0; 95% confidence interval, CI 21.6 to 134.8) and throat irritation (OR 4.3; CI, 2.2 to 8.5) compared to controls (non-exposed office workers), after adjusting for relevant confounders [34]. Kiec-Swierczynska et al. [52] captured information on respiratory symptoms (defined as wheezing and rales, chronic non-infection related cough, dyspnea) and other outcomes (ocular, nasal) during medical interviews among 93 Polish nail salon workers. Nail salon workers attributed several respiratory symptoms with exposure to nail dust, acrylic products, polish removers, disinfectants, and nail glues. The authors conducted a questionnaire among a larger sample of 145 nail salon workers, and, among these, 42% reported respiratory symptoms. Another Polish study [53] examined self-reported health status and work-related symptoms among 145 female nail salon workers occupationally exposed to VOCs with 152 population-based female controls. Nail salon workers experienced dyspnea, difficulty breathing, and regular/chronic coughing. Combined exposure to a VOC mixture did not modulate the hazard of occurrence of any symptoms assessed. The majority of recent studies in nail salons included in this scoping review were cross-sectional and respiratory symptoms were not always well defined. Additionally, some studies did not account for key confounders, including smoking [52, 54].

Endocrine-Related Outcomes

No articles on endocrine-related outcomes among hair or nail salon workers (e.g., thyroid, metabolic disease, diabetes) published in the last 5 years were identified. This reflects a critical data gap as chemicals in hair and nail care products include endocrine disrupting compounds (e.g., phthalates, placenta, parabens). Future studies should evaluate endocrine-related conditions and diseases among hair and nail salon workers in relation to EDC exposures.

Current Gaps and Future Research Needs

Most studies identified among hairdressers focused on Caucasian populations and a few on Middle Eastern and Asian hairdressers/salons. However, no published studies to date have assessed indoor environmental exposures and/or conducted biomonitoring among hairdressers who serve a predominantly Black clientele (i.e., African American, African, Afro Caribbean, Afro Latinas). A recent study [8••] detected 45 EDCs in 18 products used by Black women (e.g., hot oil treatments, root stimulators, hair lotions, and hair relaxers). Products tested contained between four and 30 of the EDCs measured; 11 of the products contained seven chemicals that are either prohibited for use in Europe or regulated under California Proposition 65 which requires businesses to provide warnings to Californians about significant exposures to chemicals that cause cancer, birth defects, or other reproductive harm [56]. Notably, 84% of the chemicals detected were not listed as ingredients. This evidence supports growing concerns that hairdressers using such products for personal use and/or on their clients may experience elevated exposures to VOCs, phthalates, and other chemicals that have been linked to adverse health effects. In addition to EDCs, some hair relaxers contain highly corrosive ingredients (e.g., lye) and other products may contain toxic solvents and adhesives. Hair loss, scalp lesions, and burns have been reported among hair relaxer users, which facilitate dermal chemical exposure [57]. Limited studies report associations between placenta-containing hair oils and other products with earlier age of menarche among African American adolescents and increased risk of uterine fibroids [57]. To our knowledge, no exposure or epidemiologic studies have been conducted among hairdressers predominantly serving a Black/ethnic clientele, highlighting the need for further research, particularly among hairdressers who may also use these products on themselves and experience an increased exposure burden. A combination of biomonitoring, exposure, and epidemiologic studies are urgently needed in this population, as disparate exposures are plausible. Research is also needed on ingredients in salon products to better understand their potential health impacts and to design culturally appropriate measures to reduce exposures and minimize health risks in this population. Additionally, while this review focused on select health endpoints, other health risks may be prevalent as a result of chemical exposures encountered in hair and nail salons, including cancer, skin conditions, neurotoxic effects, and immune disorders.

Table 3 Summary of studies examining associations between occupational exposures among nail salon workers and respiratory outcomes

Author and year	Study population	Age range or mean ± SD	Years during which the study was conducted	Study design	Exposure assessment	Outcomes evaluated	Main findings
Shendell et al. 2018 [51]	*N*= 68, nail salon technicians in New Jersey salons: Females (*n* = 51) Male (*n* = 17)	20–34 years (*n* = 20) 35–40 years (*n* = 22) 41–56 years (*n* = 26)	2016	Pilot cross--sectional study	Exposure was based on job title.	Acute symptoms (e.g., irritation, defined as eye, nose, throat, lung, and skin irritation; headaches; lightheadedness; coughing)	Of the 68 respondents from 40 participating salons, most were Asian females with a self-reported history of work-associated eye, nose, throat, and skin symptoms. Few workers used personal protective equipment. Most workers had not received training in their primary language. *Main confounders considered:* None mentioned.
Kiec-Swierczynska et al. 2017 [52]	*N*= 145, female manicurists in Łódź, Poland *N*= 77, control group, female office workers or students	Manicurists: 21–64 years Control group: 18–59 years	Not provided	Cross-sectional	Exposure was based on job title.	Nasal and respiratory problems	High frequency of self-reported symptoms based on a questionnaire, in particular nasal symptoms (70%) and respiratory symptoms (42%) among manicurists. Lower frequency of health symptoms reported during a medical examination among manicurists: nasal symptoms 41%; cough − 18%. Manicurists reported more frequent coughing compared to controls ($p < 0.01$). Manicurists ($n = 3$) had positive reactions to methacrylates noted on patch tests, but only clinically relevant for 1 person. The frequency of atopic diseases was similar among cases and controls. Irritant nasal and respiratory reactions were significantly more prevalent among manicurists compared to controls (nasal, 18 vs. 2%, $p < 0.01$; respiratory 18 vs. 1%, $p < 0.001$). Work-related nasal irritant reactions were diagnosed for 19%; respiratory 18% among manicurists. *Main confounders considered:* None mentioned.
Gresner et al. 2016 [53]	*N*= 145, female nail technicians in Łódź, Poland *N*= 152, female controls	Nail technicians 21–64 years Controls 19–59 years	Not provided	Case-control	Exposure was based on job title.	Subjective assessment of an individual's health status and incidence of adverse health effects due to occupational exposure to VOCs.	61% of nail technicians confirmed having experienced at least one symptom among all symptoms considered in the study since the commencement of the job; the odds of manicurists reporting at least one symptom was significantly greater than controls (OR, 2.8; 95%CI, 2.1–3.7; $p < 0.0001$). Estimated duration of employment period free of respiratory-related and other symptoms was significantly shorter among nail technicians vs.

Table 3 (continued)

Author and year	Study population	Age range or mean ± SD	Years during which the study was conducted	Study design	Exposure assessment	Outcomes evaluated	Main findings
							controls (12 years vs. 33 years, $p < 0.0001$), consistent with almost 4-times increased hazard of the occurrence of such symptoms among the nail technicians (hazard ratio (HR), 3.9; 95% CI, 2.7–5.7; $p < 0.0001$). Cox proportional hazard regression modeling showed increased hazard of any symptoms among nail technicians exposed to higher levels of VOCs versus those exposed to lower levels. *Main confounders considered:* Age, current tobacco load (expressed in pack-years), and estimated weekly ethanol ingestion
White et al. 2015 [54]	*N*= 65, nail salon immigrant workers from Southeast Asia in Portland, Oregon: Female (n = 61) Male (n = 4)	Not specified	Not provided	Cross-sectional	Exposure was based on job title.	Self-reported health issues (e.g., nose irritation, allergies, coughing)[a]	> 20% of the participants reported nose irritation and allergies as the most common health problems. *Main confounders considered:* None mentioned.
Park et al. 2014 [34]	*N*= 159, nail salon technicians in Daegu City, Korea: Female, n = 155 Male, n=4 *N*= 105, control group	Nail salon workers 31.3 ± 7.1 years Office-based controls 34.4 ± 8.5 years	Not provided	Cross-sectional	Personal exposure levels of airborne VOCs using passive samplers.	Respiratory symptoms (e.g., nose irritation, throat irritation, wheeze, cough, sputum, chest tightness) Volatile organic compounds in nail salons	Most frequently reported respiratory symptoms by nail shop technicians: • Nose irritation (OR, 54.0; 95% CI, 21.6–134.8) • Throat irritation (OR, 4.3; 95% CI, 2.2–8.5) VOC measures in salons: From personal measurements, the proportion exceeding the Korean Occupational Exposure Limit, was the highest for acetone with 64%, followed by toluene (50%), butyl acetate (46%), and methyl methacrylate (12%). *Main confounders considered:* Age, smoking, alcohol drinking status, exercise, marital status, average working hours a week and duration of employment

EDCs endocrine-disrupting compounds, *VOCs* volatile organic compounds. *OR* odds ratio, *95%CI 95%* confidence interval

[a] While other outcomes were assessed in the study, data presented in the table is limited to respiratory outcomes

Currently, owners and workers in hair and nail salons have limited options for safer products and current regulations do not ensure worker health and safety. Guidelines and occupational standards are non-existent, outdated, or do not protect women of reproductive age. Recommendations to advance research on occupational health and workplace exposures among hair and nail salon workers include:

- Research on safe work practices and low to no-cost solutions to decrease chemical exposures in these settings
- Research on safer alternative products
- Characterization of exposures to chemicals via environmental and biological monitoring
- Non-targeted analysis to screen chemicals of potential concern and inform future epidemiologic studies
- Research on potential additive and synergistic effects of chemical exposures
- Epidemiologic studies to assess potential health effects of specific chemicals and mixtures of concern, including among hairdressers predominantly serving a Black clientele
- Research on the interplay between social factors and chemical exposures

In the U.S., labeling requirements for cosmetics and personal care products are limited because they are regulated as over-the-counter drugs by the Food and Drug Administration (FDA). The FDA requires ingredients to be listed proportionally to their content in the product but allows incidental ingredients and components in fragrances to be excluded from product ingredient lists (Fair Packaging and Labeling Act 1967; Federal Food, Drug, and Cosmetic Act 1938). This lack of transparency in labeling prevents workers and consumers from determining what chemicals they may be exposed to and what risks such exposures could pose. Moreover, while US federal occupational safety regulations and guidelines exist for some chemicals, these are outdated and may not be protective of this population. Occupational safety regulations in these settings are often promulgated by state cosmetology boards, which can vary by state, lack enforcement capacity, and fail to adequately address toxic chemical exposures.

Conclusions

Hair and nail salon workers are exposed to many chemicals linked to adverse effects. While more research is needed in these settings, safe work practices such as the use of PPE, proper ventilation, and using less harmful alternatives, if available, could help ameliorate exposures and lessen the risk of long-term health effects. Reducing salon exposures will require stakeholder involvement, including product manufacturers and government agencies, as the sole burden of safety should not fall on workers. Limited multipronged approaches to develop safer salons have achieved promising results [58, 59], and consumer demand for less-toxic beauty products has shown that such reformulations are marketable. While additional exposure and epidemiologic studies are warranted, improving air quality in salons and development of safer products is paramount to strengthen occupational health and safety among hair and nail salon workers.

Authors' Contributions LQA and AP conceived and designed the study. NT conducted the literature search with input from primary authors regarding initial key terms. MD generated the summary tables. LKK helped identify articles for inclusion in the manuscript. The manuscript was written with input from all the authors.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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