Toenail Dust as a Potential Occupational Hazard in Podiatric Medicine

Komal Saini, BS*
Tiffany Tran, BS, BA*
Melody Khosravi, BS*
Jannani Krishnan, BS*
Dyane E. Tower, DPM, MPH, MS†
Chia-Ding Shih, DPM, MPH, MA*

Background: Debridement of toenails is a common procedure that leads to the production of nail dust aerosols in the work environment. Previous studies indicate that inhaled nail dust can cause respiratory distress and eye irritation. This comprehensive review aimed to assess the available literature on the effect of nail dust exposure and to evaluate nail dust as a potential occupational hazard for podiatric physicians.

Methods: A comprehensive literature search was conducted via PubMed, Google Scholar, CINAHL, Cochrane Library, and ClinicalTrials.gov. Risks of bias of the collected studies were evaluated using various assessment tools to match the type of study design. A qualitative analysis of the included studies was performed, from which primary and secondary outcome measures were extracted: prevalence of symptoms and specific microorganisms in nail dust.

Results: Of 403 articles screened, eight met the inclusion criteria. The primary outcome measure resulted in a pooled prevalence of eye-related symptoms being the most consistent symptom reported (41%–48%). The secondary outcome measure resulted in a pooled prevalence of *Trichophyton rubrum* (9.52%–38%) and *Aspergillus* (11.11%–35.48%) as the most common microorganisms present in nail dust.

Conclusions: From the included eight articles, we found that nail dust is a potential occupational hazard, especially for those exposed more often. *Aspergillus* and *T rubrum* are most commonly associated with nail dust leading to development of respiratory illness. It is important to take preventive measures in podiatric medical clinics by using improved and efficient personal protective equipment for workers exposed to nail dust. Detailed health safety guidelines can be developed to decrease respiratory symptoms and diseases from nail dust exposure. (J Am Podiatr Med Assoc 112(5), 2022)

The debridement of toenails is a common procedure that leads to the production of nail dust aerosols in the work environment of podiatric physicians. The use of drills and burrs for nail debridement can produce up to 3 g of nail dust per day,[1] and although larger nail dust particles settle on the floor, particles ranging from 0.5 to 5.0 μm become airborne, with the smallest nail dust particles remaining airborne for up to 10 hours.[2] Furthermore, 86% of the nail dust generated during debridement ranges from 0.8 to 1.6 μm, which can be inhaled and deposited in the fine bronchioles and alveoli, causing respiratory problems.[2] Larger nail dust particles are more likely to be inhaled through the nose and affect the upper airway region, producing symptoms in the upper respiratory tract such as sneezing, nasal blocking, and asthma.[3] Multiple studies have also observed an association between increasing years of podiatric medical practice and the development of respiratory symptoms.[2,4] In addition to the size of the nail dust particles, the fungal content of nail dust may also be contributing to the development of the respiratory symptoms. Dermatophytes and fungal

*California School of Podiatric Medicine at Samuel Merritt University, Oakland, CA.

†Clinical Affairs, American Podiatric Medical Association, Bethesda, MD.

Corresponding author: Chia-Ding Shih, DPM, MPH, MA, California School of Podiatric Medicine at Samuel Merritt University, 450 30th St, Ste 2860, Oakland, CA 94609. (E-mail: cshih@SamuelMerritt.edu)

types commonly found in fungal toenails, including *Trichophyton rubrum*, *Aspergillus* sp, and *Candida* sp, are known to cause various respiratory illnesses.[4] A laboratory study found that 63.6% of evening samples and 46% of morning samples of air and swabbed surfaces taken from a podiatric medical clinic surpassed the recommended reference limits for fungal load suggested by the World Health Organization for occupational health assessments.[1] This indicates that debridement of fungal toenails may contribute more to the level of fungal contamination in podiatric clinics than previously thought. Consequently, the fungal content of nail dust may also contribute to the pathogenesis of chronic respiratory symptoms caused by the inhalation of nail dust. Therefore, it is important to understand the implications of being exposed to nail dust aerosols and their fungal elements.

Although exposure to nail dust has not been officially recognized as an occupational hazard for podiatric physicians, inhalation of nail dust is acknowledged as a health concern for nail salon technicians requiring safety guidelines. Nail salon technicians provide nail services ranging from filing, buffing, and cutting nails on the hands and feet. Therefore, nail salon technicians are exposed to nail dust aerosols in a similar manner as podiatrists. A study of work-related symptoms in nail salon technicians reported eye irritation and symptoms of respiratory distress, such as wheezing, chest tightness, and coughing.[5] According to Occupational Safety and Health Administration guidelines, it is recommended that nail salon technicians use National Institute for Occupational Safety and Health–approved filtering facepiece respirators (ie, N95 masks, which prevent particles measuring 0.1–0.3 μm) to reduce the risk of developing respiratory illnesses.[6] A proper ventilation system is also recommended in nail salons to clear the air of nail dust and other hazardous particles.[7] However, there are no set guidelines for podiatric medical clinics regarding exposure to nail dust aerosols. In this comprehensive review, we aimed to assess the available literature on the effect of nail dust exposure and to evaluate nail dust exposure as a potential occupational hazard for podiatric physicians.

Methods

Search Strategy

Scholarly (peer-reviewed) journal articles pertaining to the hazards related to nail dust exposure were reviewed to perform a systematic review. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for the conduct of systematic studies was followed for the search process and is presented in the PRISMA flowchart (Fig. 1). The databases searched included PubMed, Google Scholar, CINAHL, Cochrane Library, and ClinicalTrials.gov. The search was conducted in December 2019; therefore, literature published after December 2019 and during the COVID-19 pandemic are not included in this review.

Outcome Measures and Search Criteria

The purpose of this comprehensive literature review is to further explore the occupational hazard of nail dust, how it affects the respiratory system, and how to prevent or reduce the risk of respiratory symptoms caused specifically by fungal nail dust. The goal is to understand the relationship between the fungal elements and the potential development and pathophysiology of respiratory symptoms due to nail dust exposure. To fulfil this goal, selection criteria were decided on to obtain peer-reviewed journal articles for a comprehensive review. Keywords or Medical Subject Heading terms, including *nail dust* or *fungal nail*, an illness (eg, *respiratory disease*, *asthma*, or *trachea*), *podiatric treatment* or *salon*, and a debridement method (ie, *trim*, *file*, or *cut*), were used to perform a systematic search. The detailed search method is listed in Appendix 1. Four of us (K.S., M.K., J.K., and T.T.) performed three rounds of database searches, followed by title and abstract screening.

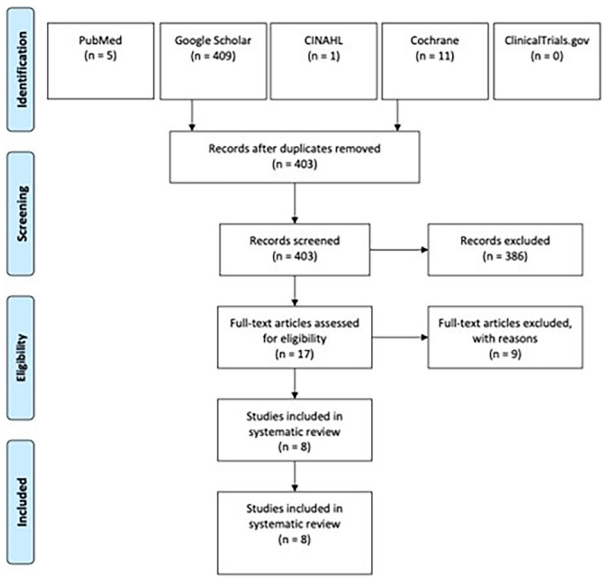


Figure 1. PRISMA Flowchart demonstrates the search process.

Articles were eliminated and narrowed based on search criteria, relevance, and de-duplication, which resulted in a final number of articles for qualitative analysis (Table 1). Due to the limited number of studies performed and the inclusion criteria being lax, the review became a comprehensive literature review rather than a systematic review. Although a systematic approach was initially used for this review, we concluded it to be a comprehensive literature review due to the collected articles being of a wide range of study types.

Study Eligibility Criteria

Owing to the small number of published papers on the topic, a limitation was not set on the study type or year published to capture all of the pertinent articles. To determine the eligibility criteria for articles that best fit the search methods, articles that matched the search terms and were published in the English language were included. Therefore, review articles were included in the inclusion criteria.

Data Extraction

Data were extracted from each article by four of us (K.S., M.K., J.K., and T.T.) by annotating and noting relevant data in a summary table (Table 1). Relevant data were extracted from each article, including the characteristics of the samples used, study design and methods, purpose, procedures used, and outcomes. Furthermore, primary and secondary outcome measures were set to extract relative data from the articles. The primary outcome measure extracted from the studies included the prevalence of specific self-recorded symptoms that appeared due to exposure to nail dust (Table 2). The secondary outcome measure that was extracted from the studies included the various microorganisms that were found in nail dust particles (Table 3). The pooled prevalence was compiled from numbers reported in questionnaires. Both primary and secondary outcome measures were input into tables with respective pooled prevalence across the studies.

Assessment of Study Quality

After accessing the final articles, risk of bias was assessed by four of us (K.S., M.K., J.K., and T.T.) using various risk assessment tools appropriate for each type of study. Each article was assigned a test to assess the risk of bias (Appendix 2), except the laboratory studies[1,2] and the topical review article.[3] The two laboratory studies were not assessed in this general assessment table due to having human samples. Each paper was evaluated twice by two of us (K.S. and T.T.) that is, a total of four times. Studies that used laboratory methods in a cross-sectional study and qualitative analysis[9,11] were to be assessed using the Critical Appraisal Skills Programme Qualitative Checklist. Five articles[4,8-11] used a single, standard general risk assessment analysis for risk of bias comparison with one another (Table 4). This general bias assessment matrix was adapted from the recommendation of the Cochrane RoB 2 risk of bias tool for cross-sectional studies. Four of us (K.S., M.K., J.K., and T.T.) assessed each article together to determine the level of bias in the five general categories (selection bias, performance bias, detection bias, attrition bias, and reporting bias). The overall qualitative assessment is presented in Table 4.

Results

Eligible Studies and Risk of Bias Assessments

The preliminary search of all of the databases revealed 426 related articles; after eliminating 23 duplicates, 403 articles remained for title screening. Of those articles, 17 fulfilled the inclusion criteria based on title and abstract screening (Fig. 1). These articles were selected for full-text screening. After full-text evaluation by all of us, eight articles were selected to be included in the analysis. (The other articles were not included for final assessment due to irrelevance to this study.) These eight articles, with publication dates ranging from 1984 to 2018, included one topical review, three cross-sectional studies, two laboratory methods in a cross-sectional study, and two laboratory studies. The topical review by Ward[3] was kept due to having provided vital information and support; however, it was not included in the summary table due to being a review article. All of the relevant data, risk assessment tools, and results of each of the seven articles were captured in a summary table (Table 1). Four articles were found to have low bias, one moderate bias, and one high bias; two articles could not be assessed for bias because there was no appropriate risk of bias tool, which created limitations. A meta-analysis or quantitative analysis could not be performed due to limited data and variability across study design.

Table 1. Summary Table

Study, Year	Sample Characteristics	Study Design	Purpose	Procedures	Outcome Measures	Conclusions
Abramson and Wilton,[8] 1985	Precipitin antibodies to *Trichophyton rubrum*: 96 student controls; 84 podiatrists with 0–15 y in practice; 95 podiatrists with ≥16 y in practice. IgE titers: 98 student controls; 218 podiatrists.	Cross-sectional study	To evaluate podiatrists' respiratory symptoms and measure their exposure to fungus *T rubrum* in nail dust.	A questionnaire was mailed to podiatrists to assess respiratory symptoms and their exposure to nail dust aerosols. Blood samples were collected for IgE titers and detection of precipitin antibodies to fungal types found in nail dust.	Incidence of precipitin antibodies to *T rubrum* was 23% for podiatrists in practice for 0–15 y and 29% for those in practice for ≥16 y. 31% of podiatrists had IgE levels above the normal range.	Podiatrists who had long-term exposure to nail dust aerosols presented with symptoms including rhinitis, asthma, conjunctivitis, hypersensitivity, and impaired lung function. Podiatrists had statistically significantly increased IgE levels and incidence of precipitin antibodies to *T rubrum* compared with controls.
Abramson and Wilton,[2] 1992	NA	Laboratory study	To analyze and identify shape, range of particle sizes, and fungal types in nail dust.	Scanning electron microscopy and an Elzone[a] analyzer were used to analyze shape, particle size, and frequency of files generated by grinding hyperkeratotic fungal-infected nails. Nail dust was cultured on Sabouraud dextrose agar, blood agar, and MacConkey agar to isolate and analyze microflora.	80% of nail dust is 0.8–1.6 μm, which can reach alveoli and fine bronchioles. In a single breath, ~31% of a cloud of nail dust is capable of being inhaled and deposited in the fine bronchioles and alveoli. *T rubrum* composed most of the fungal content in nail dust. Fungal spores ranging from 0.65 to 7.0 μm can enter and lodge in any region of the respiratory tree.	Nail dust functions as an irritant due to its jagged shape. Most nail dust falls within the range of particle sizes that can be inhaled, deposited in alveoli and fine bronchioles, and cause various respiratory symptoms and illnesses.
Coggins et al,[9] 2012	101 podiatrists were surveyed in Ireland. Microbial hazards were measured in 15 podiatric medical clinics.	Laboratory methods used in a cross-sectional study	To assess PPE use in podiatric medical clinics, the prevalence of respiratory illnesses among podiatrists, and the level of microbial hazards in the breathing zone of podiatrists.	Podiatrists voluntarily filled out a survey inquiring about experiencing respiratory symptoms due to nail dust and PPE use in podiatric medical practice. A six-stage viable microbial cascade impactor was used to sample airborne microorganisms in the breathing zone of podiatrists while using a toenail drill.	32 of the 101 podiatrists reported having a work-related respiratory illness diagnosed by their doctor. 42 podiatrists reported that they used masks 34.6% of the time during podiatric medical treatment, and 47% of the respondents reported using nail drills with dust extractors. 65% of the bioaerosols in the breathing zone of the podiatrist was capable of being inhaled.	Proper PPE use in podiatry clinics can be improved. Given the high amount of bioaerosols that can be inhaled during the use of a nail drill, proper PPE use is imperative to minimize exposure to nail dust.

Table 1. continued

Study, Year	Sample Characteristics	Study Design	Purpose	Procedures	Outcome Measures	Conclusions
Davies,[10] 1984	635 chiropodists and 20 students were surveyed. Mean age of those adversely affected by nail dust: 40 y.	Cross-sectional study	To evaluate the immunologic effects of nail dust on chiropodists.	A questionnaire was administered to assess whether nail dust affected a population of chiropodists and final-year students. Participants were asked to volunteer a blood sample to be analyzed for precipitation of antibodies to *T rubrum*. Respiratory function was also assessed using a Vitalograph[b] spirometer.	49% of the 635 chiropodists and 20 students responded that they were affected by nail dust, reporting symptoms affecting the eyes, nose, throat, and chest. 577 chiropodists gave 10-mL blood samples, and 14% of the blood samples contained antibodies to *T rubrum*. The respiratory function of 398 chiropodists was assessed, and 49 of them were determined to have a defect in ventilatory function.	After being inhaled, human nail dust activates the complementary system of the blood via alternative pathways. This results in precipitin of antibodies to *T rubrum*, a fungus commonly found in onychomycotic toenails, and the development of symptoms affecting the eyes, nose, throat, and chest.
Nowicka et al,[11] 2016	77 salon clients: 69 women and 8 men.	Laboratory methods used in a cross-sectional study	To measure the amount of pathogenic fungi in nail and skin dust samples produced during nail salon treatment and to assess the hazardous effect of nail dust on podiatrists and similar professions working with toenails.	Direct fluorescence light microscopy used and fungal samples digested in 10% potassium hydroxide and stained with Calcofluor white. Cultures were performed on DERM(R) (dermatophyte test medium selective for dermatophytes) as well as Sabouraud agars.	More than half of the participants had positive fungal results from their nail and dust samples.	It was concluded that salons are frequently infected with fungal particles. Personal protection is needed for podiatrists and nail salon workers to protect them from these hazardous pathogens.
Tinley et al,[4] 2014	50 podiatrists vs 45 nonpodiatrist occupational therapy students (control group) (note: Tinley et al[4] used a variation of dextrose agar to inhibit the growth of molds and bacteria and to stimulate the growth of dermatophytes).	Cross-sectional study	To see whether podiatrists are at higher risk for developing a respiratory illness due to higher exposure to nail dust.	Self-administered nasal swabs of podiatrists and a control group (nonpodiatrists in occupational therapy). Five-point questionnaires about mask type and years in practice were completed by each participant.	The podiatrists' culture results identified 44% as having *Aspergillus fumigatus* in their noses compared with only 9% in the control group. The control group had 44% of unidentified yeasts cultured from their nasal swabs compared with only 6% of the podiatrists.	Podiatrists (compared with a control group) have more types of microbes present in their noses with common and serious pathogens, such as *A fumigatus,* found to be more prevalent in the podiatric group.

Table 1. continued

Study, Year	Sample Characteristics	Study Design	Purpose	Procedures	Outcome Measures	Conclusions
Viegas et al,[1] 2018	Conventional: 11-d samples were collected. Airborne fungi were collected using an SAS Super 100[c] air sampler (flow rate, 100 L/min).	Laboratory study	To characterize fungal levels in podiatric medical clinics.	14 air samples were collected for direct detection of fungal DNA using impinger sampling (flow rate, 2.2 L/h), and surface samples were collected via cotton swab. Fungal DNA was analyzed using quantitative PCR and PCR and 2% agarose gel for gel electrophoresis.	63.6% of evening samples and 46% of morning samples surpassed fungal load thresholds. Fungal DNA analysis showed that *T rubrum* was positive on days 6–9 of the experiment.	To reduce fungal load in podiatric medical clinics, it is recommended to keep windows closed to avoid more contaminants during treatment. It is also highly recommended to wear gloves and a mask and to have an air cleaning and ventilation system.

Abbreviations: NA, not applicable; PCR, polymerase chain reaction; PPE, personal protective equipment.
[a]Micromeritics Instrument Corp, Norcross, Georgia.
[b]Vitalograph Inc, Lenexa, Kansas.
[c]Cherwell Laboratories Ltd, Bicester, England.

Table 2. Pooled Prevalence of Symptoms Due to Nail Dust Exposure

Symptom	Pooled Prevalence (%)
Nose related	12.5–75.0
Eye related	41–48
Chest related	19–25
Asthma	25–31
Throat related	16–36
Sinus	22
Bronchitis	6

Table 3. Prevalence of Various Microorganisms Found in Nail Dust Particles

Microorganism	Pooled Prevalence (%)
Other nondermatophytes	2–90
Dermatophytes (others)	0–57
Saprophytes	0–41
Trichophyton rubrum	9.52–38
Aspergillus sp	11.11–35.48
Trichophyton mentagrophytes	3.17–12.0
Unidentified	0–4.84
Yeast	3–4.76
Bacteria	0–3.23

Prevalence of Symptoms Due to Long-term Nail Dust Exposure

The pooled prevalence of the symptoms was calculated using questionnaire data from studies[8–10] in which podiatric physicians self-reported the symptoms they experienced resulting from exposure to nail dust aerosols (Table 2). Eye-related symptoms had the most narrowed and high prevalence (41% to 48%) followed by other airway-related symptoms among all reported symptoms. Nail dust particles can affect the eye conjunctiva, giving rise to conjunctivitis, pruritus on the eyelids, and watering and burning of the eyes.[10] Other results revealed chest-related symptoms such as chest infections arising from microbes[9] and throat-related symptoms such as severe persistent cough.[9,11] The least prevalent symptom was bronchitis, with a pooled prevalence of 6% across the studies.

Prevalence of Microorganisms in Nail Dust

A percentile range was also composed for different dermatophytes, nondermatophytes, yeasts, and bacteria found in the various samples from studies[1,2,4,11] that used laboratory methods to assess the microbial composition of nail dust (Table 3). The most common type of dermatophyte found in nail

Table 4. Risk of Bias Assessment Matrix

Study, Year	Selection Bias	Performance Bias	Detection Bias	Attrition Bias	Reporting Bias
Abramson and Wilton,[8] 1985 (QUIPS)	+	+	+	+	+
Abramson and Wilton,[2] 1992[a]	NA	NA	NA	NA	NA
Coggins et al,[9] 2012 (CASP)	?	+	+	+	+
Davies,[10] 1984 (QUIPS)	+	+	+	+	+
Nowicka et al,[11] 2016 (CASP)	–	+	+	+	+
Tinley et al,[4] 2014 (QUIPS)	–	+	+	+	+
Viegas et al,[1] 2018[a]	NA	NA	NA	NA	NA
Ward,[3] 1995[b]	NA	NA	NA	NA	NA

Abbreviations: CASP, Critical Appraisal Skills Programme Qualitative Checklist; NA, not available; QUIPS, Quality in Progress Studies.

[a]Laboratory studies.

[b]Topical review article.

dust samples was *T rubrum*, with a pooled prevalence ranging from 9.52% to 38% across the studies.

Discussion

Overall, this comprehensive review revealed a wide range of study types that were pertinent to the research question. The quality of the collected studies also varied, ranging from low to high risk of bias. Nonetheless, we extrapolated the prevalence of reported symptoms related to nail dust exposure as the primary outcome. There was a considerably high prevalence of eye-related symptoms (41%–48%) and respiratory symptoms such as asthma (25–31%) and bronchitis (6%) (Table 2). The secondary outcome also suggested that the most common type of dermatophyte found in the collected air samples was *T rubrum*, with a pooled prevalence of 9.52% to 38%.

Although we were not able to establish a cause-effect relationship between the symptoms and the contaminated nail dust, there was compelling evidence to discern an association between presented symptoms and nail dust exposure and to make an inference that such exposure would be considered an occupational hazard.

Several studies have shown potential risks of developing adverse respiratory conditions after being exposed to nail dust that contains fungal elements.[8,10,11] Debridement of onychomycotic nails can result in airborne fungal debris, which can cause inflammation in the respiratory tract due to stimulating release of interleukin-8 from epithelial cells.[12] However, debridement of nails that appear asymptomatic of onychomycosis may also be a source of fungal content. A recent study also found that 46% of skin and nail samples taken from individuals asymptomatic for onychomycosis were positive for fungal content, with 10% of the total samples being positive for *T rubrum*.[11] In addition, the positive correlation between the number of years in practice and high levels of IgG against *T rubrum* found in blood samples implies that there is a higher risk of respiratory, allergic, and asthmatic reactions the longer someone has been in practice.[10] *T rubrum* is the most prevalent type of dermatophyte found in nail dust aerosols, and the second-most prevalent is *Aspergillus* sp (Table 3). Fungal types such as *T rubrum*, *Candida* sp, and *Aspergillus* sp are associated with onychomycosis and are known to cause respiratory illnesses.[4,10,11] In particular, *Aspergillus fumigatus* tends to colonize in the lower respiratory tract of individuals with asthma or structural lung damage and cause further respiratory symptoms.[8] Therefore, podiatric physicians who have asthma or other respiratory conditions may be inherently more hypersensitive to fungi and microbes and be more likely to develop respiratory illnesses during their career. Tinley et al[4] reported that 44% of podiatrists had *A fumigatus* isolated from their nasal cavities compared with only 9% of the control group. An analysis of fungal contamination in a podiatric medical clinic also showed that *Aspergillus* sp and *T rubrum* were present in air samples taken before the clinic opened in the mornings and after the clinic closed in the evenings.[1] This information suggests that the debridement of fungal toenails can leave fungal spores lingering in the air for a substantial amount of time after the debridement was performed, increasing the possibility of exposure to fungal spores that can cause respiratory issues. As a result of exposure to nail dust, podiatric physicians were found to have elevated plasma IgG and IgE antibody levels, which are indicative of hypersensitivity pneumonitis and allergic hypersensitivity, respectively, as

well as increased microbe prevalence in their nasal cavities.[2,10] The elevated levels of specific antibodies in reaction to harmful pathogens and increased quantity of microbes in podiatric physicians' nasal cavities serves as evidence that exposure to nail dust and its fungal components is linked to the pathogenesis of respiratory illnesses in podiatrists. Therefore, the prolonged presence of fungal spores in the air after debridement increases the likelihood of inhaling fungal spores that are associated with the development of respiratory problems.

Reducing Nail Dust Exposure in Podiatric Medical Clinics

During patient treatment, respiratory protective equipment serves as a vital physical barrier that will prevent the spread and inhalation of microbes contained in nail dust. However, general personal protective equipment (PPE) use may be lacking in podiatric medical clinics. In a questionnaire, 81% of podiatrists who used drills reported using some form of a mask while working with nails in a podiatric medical setting, and 17% said that they used no mask at all.[4] Nowicka et al[11] reported that only 73.3% of podiatric physicians used PPE such as gloves while treating patients. Furthermore, the results of another questionnaire regarding PPE in podiatric medical clinics showed that the participating podiatrists used masks and other forms of respiratory equipment only 34.6% of the time during patient treatments.[9] Therefore, the use of PPE can be improved in podiatric medical clinics and should be further reinforced to minimize exposure to nail dust.

However, the use of masks alone might not be enough to protect against nail dust aerosols. A previous study also found that the masks being used were unable to filter out particles smaller than 0.8 μm, although 70% of nail dust particles fall within that range.[2,13] Although the fungal content of nail dust ranging from 0.65 to 7.0 μm can be inhaled and lodged into the respiratory tree, fungal spores measuring 0.5 μm or less can easily enter the respiratory tree even if the individual is wearing a face mask for protection.[2,4] Therefore, the use of nail dust extractors and central vacuum systems may further reduce the hazard of inhaling nail dust particles that cannot be filtered by masks. Most nail drills come with nail dust extractors built in for reduction of nail dust aerosols, and nail dust extractors are assessed to be 25% to 92% effective in reducing the amount of airborne nail dust.[3,10] Keeping windows and doors closed during nail debridement is also highly recommended combined with air filtration systems in rooms to maintain good hygiene and limit the spread of microbes contained in nail dust.[1] However, 70% of podiatric physicians reported not having mechanical ventilation systems in their clinic.[9] Although there are no official podiatric medicine safety recommendations for exposure to nail dust aerosols in the United States, protective measures must be taken and regulated to ensure the safety of those who are frequently exposed to nail dust. Given the results of these various studies and questionnaires, it is imperative that we take preventive action through proper use of PPE, dust extractors, and air ventilation systems in the podiatric medical clinic.

Limitations

There were multiple limitations in this comprehensive literature review. One limitation was that we did not have institutional access to EMBASE, which is a larger online database with academic publications. Thus, additional relevant papers may not be included in this review; however, we systematically searched PubMed, Google Scholar, CINAHL, Cochrane Library, and ClinicalTrials.gov.

Another limitation was that the term *chiropodist* was not included in the search method. *Chiropodist* is an older term for *podiatrist* that became defunct in the United States in 1993 and a synonym for *podiatrist* in the United Kingdom.[14] Therefore, including *chiropodist* in the search method might have yielded more eligible studies for this comprehensive literature review. However, excluding the term *chiropodist* may have excluded papers that used dated technology and techniques not reflective of current practices in medicine. Consequently, exclusively using the term *podiatrist* may have made the comprehensive literature review more relevant to modern podiatric medicine in the United States.

To compare bias across the studies, we used a general bias assessment tool adapted from the Cochrane RoB 2 risk of bias tool that is more applicable across different study designs. However, this bias assessment tool is applicable only to clinical studies and, therefore, is not appropriate for the topical review and laboratory studies included in the study. In addition, there are no standard or recommended bias assessment tools for topical reviews and laboratory studies not involving animals as the test subjects. Therefore, it is a limitation that we were unable to assess the bias for three of the papers included in this comprehensive literature review, as indicated in Table 4.

An additional limitation was the variability in study designs across the studies included in the comprehensive literature review. Although these studies had similar goals of analyzing the microbes contained in nail dust and evaluating how nail dust exposure manifests in the human body, each paper developed a distinct method for assessment. For example, Tinley et al[4] specifically used agars that inhibited the growth of bacteria and enhanced the growth of fungi and yeast, and others used an agar favorable to the growth of all types to assess the variety of microbes in nail dust.[1,2,4,9,11] The microbes were also sampled from various sources, including nail dust vacuum bags, nail and skin shavings, air samples, surface swabs, and the nasal cavities of podiatric physicians.

Another limitation across the papers included not having a time frame or definition of long-term nail dust exposure. The presence of antibodies was used to determine long-term exposure[4]; however, there was absence of a constant period in practice. Given this variability, it was difficult to compile all the evidence into a chart for comparison and further understanding. Considering this, an overall qualitative analysis of the papers was preferred over a quantitative analysis.

Conclusions

After performing this comprehensive literature review, we can discern that exposure to nail dust is an occupational hazard that can lead to the development of respiratory dysfunction. Inhalation of nail dust and its fungal components, including *T rubrum* and *Aspergillus* sp, can lead to respiratory illnesses, including rhinitis, asthma, hypersensitivity, and impaired lung function. In addition, eye irritation such as conjunctivitis was also noted. Those who are at high risk for developing respiratory illnesses due to nail dust exposure include podiatric physicians, nail salon workers, and any individual who works with fingernails and toenails on a regular basis. To understand the cause-effect relationship between nail dust and respiratory illness better, future studies can quantitatively investigate the correlation between respiratory symptoms reported by podiatric physicians and the amount of exposure to nail dust. Given the risk of respiratory dysfunction, the proper use of PPE is a crucial preventive measure. Although the use of PPE tends to vary across podiatric medical clinics, the overall use of PPE remains insufficient. Future studies should investigate how well recommendations for PPE, dust extractors, and air ventilation systems can protect us from nail dust exposure and how those can be improved to make future guidelines. Such guidelines will rely on further studies to establish the direct association between nail dust exposure and respiratory symptom or illness severity, as well as to determine which PPE could best shield workers with nail dust exposure. The results of these future studies will aid in ensuring that we have guidelines that maximize protection against nail dust exposure.

Financial Disclosure: None reported.
Conflict of Interest: None reported.

References

1. Viegas C, Coggins AM, Faria T, et al: Fungal burden exposure assessment in podiatry clinics from Ireland. Int J Environ Health Res **28:** 167, 2018.
2. Abramson C, Wilton J: Nail dust aerosols from onychomycotic toenails: part I. Characterization of particles. JAPMA **82:** 116, 1992.
3. Ward PE: Atopy and reaction to nail dust inhalation. Clin Podiatr Med Surg **12:** 275, 1995.
4. Tinley PD, Eddy K, Collier P: Contaminants in human nail dust: an occupational hazard in podiatry? J Foot Ankle Res **7:** 15, 2014.
5. Harris-Roberts J, Bowen J, Sumner J, et al: Work-related symptoms in nail salon technicians. Occup Med **61:** 335, 2011.
6. Occupational Safety and Health Administration: *Stay Healthy and Safe While Giving Manicures and Pedicures: A guide for Nail Salon Workers*, *US Department of Labor*, Washington DC, 2012.
7. Park SA, Gwak S, Choi S: Assessment of occupational symptoms and chemical exposures for nail salon technicians in Daegu City, Korea. J Prev Med Public Health **47:** 169, 2014.
8. Abramson C, Wilton J: Nail dust aerosols from onychomycotic toenails: part II. Clinical and serologic aspects. JAPMA **75:** 631, 1985.
9. Coggins MA, Hogan VJ, Kelly M, et al: Workplace exposure to bioaerosols in podiatry clinics. Ann Occup Hyg **56:** 746, 2012.
10. Davies RR: Human nail dust in chiropodial practice: irritant, allergen and source of antibodies to *Trichophyton rubrum*. J R Soc Health **104:** 1, 1984.
11. Nowicka D, Nawrot U, Wlodarczyk K, et al: Detection of dermatophytes in human nail and skin dust produced during podiatric treatments in people without typical clinical signs of mycoses. Mycoses **59:** 379, 2016.
12. Donaldson CL, Carline T, Brown DM, et al: Toenail dust particles: a potential inhalation hazard to podiatrists? Ann Occup Hygiene **46** (suppl): 365, 2002.

13. Purkiss R: An assessment of the airborne dust in podiatric treatment areas, and its relevance to the use of respiratory protective equipment. J Br Podiatr Med **52:** 129, 1997.

14. Ackroyd R: What's the difference between a chiropodist and a podiatrist? Available at: https://21stcenturyclinic.co.uk/whats-difference-chiropodist-podiatrist/. Published March 3, 2015. Accessed March 13, 2020.

Appendix 1. Search Method

1	Nail dust
2	Nail
3	Fungal OR Fungi OR Fungus OR Onychomycosis
4	Podiatric treatment
5	Nail technician OR pedicure OR salon
6	Trim OR file OR cut OR debridement
7	Respiratory disease
8	Bronchitis
9	Asthma
10	Trachea
11	Nasal cavity
12	2 AND 3
13	1 OR 12
14	4 OR 5 OR 6
15	7 OR 8 OR 9 OR 10 OR 11
16	14 AND 15
17	13 AND 16

Appendix 2. Bias Assessment Tools

Study	1. Was there a clear statement of the aims of the research?	2. Is a qualitative method appropriate?	3. Was the research design appropriate to address the aims of the research?	4. Was the recruitment strategy appropriate to the aims of the research?	5. Was the data collected in a way that addressed the research issue?	6. Has the relationship between researcher and participants been adequately considered?	7. Have ethical issues been taken into consideration?	8. Was the data analysis sufficiently rigorous?	9. Is there a clear statement of findings?	Total
Nowicka et al,11 2016	Yes	Yes	Yes	Yes	Yes	Not clear	Yes	Yes	Yes	8/9
Coggins et al,9 2012	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9/9