Cannabis Sensitization and Allergy in Cannabis Industry Workers, Recreational Cannabis Users, and Nonusers

A Cross-sectional Study

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Objective: The aim of the study was to evaluate respiratory and allergic health symptoms and sensitization to cannabis in cannabis workers while controlling for recreational cannabis use. **Methods:** We compared allergic and respiratory symptoms, lung function, and airway inflammation among cannabis workers (n = 42) and recreational cannabis users (n = 20) and nonusers (n = 20) with no occupational exposure. **Results:** In multivariable regressions adjusted for recreational cannabis use, cannabis workers trended toward increased airway inflammation and decreased pulmonary function when compared to nonworkers. Compared to nonworkers, cannabis workers exhibited increased odds of cannabis sensitization on skin prick test (odds ratio, 9.5; 95% confidence interval, 1.38 to 193; P = 0.05) and reported a higher prevalence of allergic symptoms (odds ratio, 3.7; 95% confidence interval, 0.91, 16.9; P = 0.07). **Conclusions:** Our findings suggest that occupational exposures contribute to the respiratory and allergic effects seen in cannabis workers, regardless of recreational cannabis use.

Keywords: cannabis, occupational health, allergy, respiratory health, workplace exposure, sensitization

LEARNING OUTCOMES

- Assess respiratory and allergic health effects in cannabis industry workers through clinical measurements, surveys, and epidemiological data analyses.
- Analyze differences in health symptoms between cannabis industry workers and nonworkers who use cannabis recreationally using prevalence estimates and regression modeling.

In the United States, legal cannabis is a fast-growing, multibillion-dollar industry with more than 440,000 full-time jobs by early 2024.[1] However, few studies have investigated the cannabis industry workforce and their occupational environments, and consequently, little is known about the potential health and safety concerns associated with cannabis cultivation and processing.[2–5]

Emerging evidence suggests that during the cultivation and processing of cannabis, workers are exposed to multiple airborne contaminants that are known or suspected respiratory irritants or allergic sensitizers, including cannabis dust, mold, volatile organic compounds, dusts, pesticides, and irritant gases.[3–11] Allergic sensitization, characterized by the development of an Immunoglobulin E (IgE)-mediated response upon the ingestion, absorption, or inhalation of allergens, plays a significant role in the development of asthma and other allergic diseases.[12,13] Type I hypersensitivity responses have been reported with cannabis use, typically occur within 20 to 30 minutes of exposure, and can present with a spectrum of manifestations, ranging from conjunctival irritation to wheezing to anaphylaxis.[3,14] Multiple cannabis allergens have been sequenced and allergic sensitization to cannabis could potentially occur through contact with cannabis roots, leaves, buds, and flowers.[3,15,16] While there are no commercially available tests for cannabis sensitization in the United States, prior studies have reported that skin prick testing to a slurry of plant material has strong sensitivity and specificity in assessing cannabis allergy.[17]

In 2020, we conducted a pilot study in an indoor cannabis farm demonstrating that a high proportion of cannabis cultivation and processing workers experienced allergic symptoms related to workplace exposures. Reported symptoms included dermal, respiratory, nasal, and ocular health effects that improved during weekends and periods away from work. Targeted health testing additionally revealed a high prevalence of airway inflammation, impaired lung function, and sensitization to one or more strains of cannabis during skin prick testing.[4] Notably, these findings were confounded by a high rate (97% of study participants) of recreational cannabis use among workers, including 81% who reported smoking cannabis multiple times per day. Personal use of cannabis products, including smoking, has been linked to increased respiratory symptoms, cannabis allergy, and asthma, with evidence suggesting that micro-organisms and potentially plant allergens may remain intact after combustion or vaporization.[18–21] We were therefore limited in our ability to conclusively resolve whether the observed health effects were related to workplace exposures or recreational use of cannabis.[4]

The purpose of this study was to evaluate lung function, airway inflammation, allergic health symptoms, and sensitization to cannabis in an expanded population of cannabis cultivation and processing workers in Washington state while controlling for recreational cannabis use. In support of this aim, we compared the prevalence of allergic

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AI was not utilized in any capacity.
STROBE Guidelines for observational studies were adhered to.
Ethical Considerations and Disclosures: The study was reviewed and approved by the University of Washington Institutional Review Board and all participants provided written consent.
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health symptoms, impaired lung function, airway inflammation, and cannabis sensitization between cannabis cultivation and processing workers and a nonoccupational population of recreational cannabis users and nonusers.

METHODS

Study Design and Population

We conducted a cross-sectional study to determine and compare the prevalence of cannabis-related allergic and respiratory symptoms, lung function, and airway inflammation across cannabis cultivation and processing workers, recreational cannabis users with no occupational cannabis exposure, and cannabis nonusers with no occupational cannabis exposure. Cannabis workers (n = 42) were recruited from two indoor cannabis cultivation and processing facilities in Washington State (Fig. 1). This population of workers included participants from our initial pilot study (n = 31), as previously described,[4] with an additional 11 workers recruited from a separate facility using identical study methods. Nonoccupational participants (n = 40) were recruited using a request for research participants published in digital and print formats in Seattle, Washington. Included nonoccupational participants were current recreational cannabis users (≥three times per week) (n = 20) and nonusers (within prior 30 days) (n = 20) aged 21 to 70 years living in the Puget Sound region of Washington. Nonoccupational participants were excluded if they currently used illicit inhalants (eg, cocaine, methamphetamine, volatile paints) or if they had a current or prior history of occupational cannabis exposure.

Upon study enrollment, all occupational and nonoccupational participants completed health symptom questionnaires. Additional respiratory and allergic testing was subsequently conducted for all consenting nonoccupational participants and for selected occupational participants with work-related symptoms, as described by Sack et al.[4] The study was reviewed and approved by the University of Washington Institutional Review Board, and all participants provided written consent.

Health Symptom Questionnaires

Occupational participants completed an exposure-related symptom and medical history questionnaire adapted from the European Community Respiratory Health Survey.[4] In brief, the questionnaire collected information on participants' baseline demographic information, occupational history, personal cannabis and tobacco use history, typically performed work tasks, use of personal protective equipment, and the presence of work-related health symptoms. Nonoccupational participants completed a health symptom and medical history questionnaire, also adapted from the European Community Respiratory Health Survey,[22] which collected baseline demographic information, information on respiratory, dermal, nasal, and ocular health symptoms, personal medical history, family medication history, prior medication use, and detailed information on tobacco and cannabis use.

Pulmonary Function and Inflammation Measurements

Pulmonary function was assessed prebronchodilator and postbronchodilator (albuterol by meter dose inhalation) using the NDD EasyOne Air portable spirometer (Andover, MA). Forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC) were measured in at least three trials using the American Thoracic Society (ATS) repeatability guidelines outlined by Miller et al (2005).[23] The ratio of FEV_1 over FVC was computed for the best spirometry trial and compared to the table of values based on height, age, sex, and race given by the National Health and Nutrition Examination Survey III reference equation.[24] This reference equation was selected to be comparable to current mandatory occupational standards for spirometry interpretation set by the United States Occupational Safety and Health Administration.[25]

Airway inflammation was assessed using the NIOX VERO (Morrisville, NC), a portable electrochemical analyzer, which measured fractional exhaled nitric oxide (FeNO) in each participant. Participants were instructed on the proper breathing technique by a trained physician and then encouraged to inhale through a personal mouthpiece to total

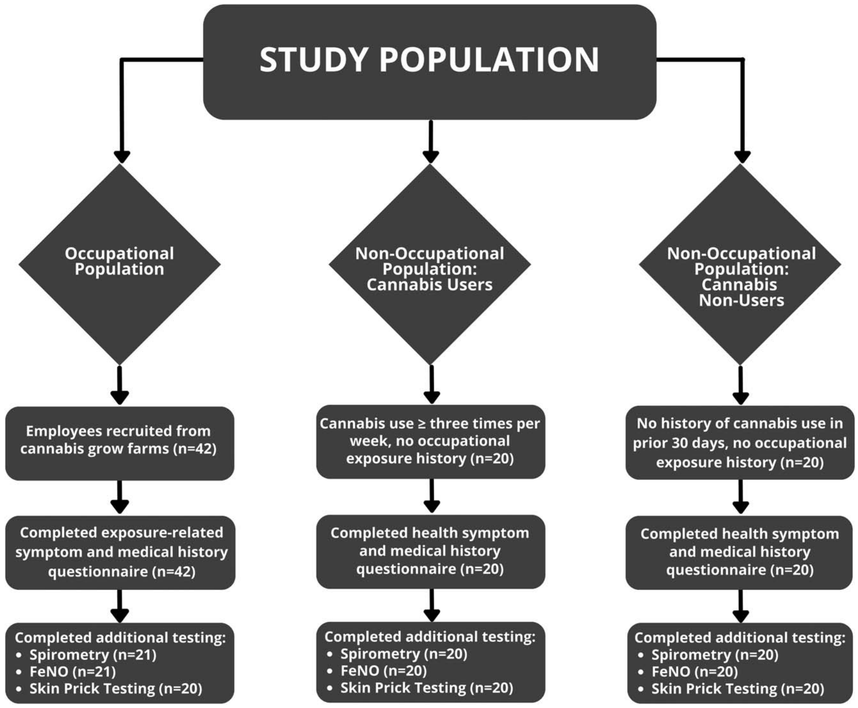

FIGURE 1. Study population ascertainment by cannabis exposure status.

lung capacity and exhale slowly with steady pressure. Quality control samples were collected using NIOSH VERO specifications. FeNO measurements were evaluated for airway inflammation in accordance with ATS guidelines.[26]

Skin Prick Sensitization Testing

A one-time skin prick test was performed on each subject for cannabis and selected allergens found in the Pacific Northwest region of the United States. Allergen extracts, purchased from ALK_Abell, Inc (Round Rock, TX), included cat dander, cockroach antigen, and dust mites. Nonoccupational participants were tested for cannabis sensitization using a hemp slurry (Preroll Mix #1; provided by LeBlanc CNE, Seattle, WA), which was made by mixing ground leaves and flowers with 1 to 2 mL of sterilized saline. Occupational participants were tested for cannabis sensitization using cannabis slurries prepared with two strains of cannabis obtained from their work facilities. A 10% histamine solution was used as a positive control and sterilized saline solution was used as a negative control. The largest wheal diameter was assessed 20 minutes after application to the forearm. A positive response was defined as a wheal diameter greater than or equal to 3 mm, erythema or pseudopodia with no reaction to the negative control, and positive reaction to histamine. Participants were excluded from skin prick testing if they reported antihistamine use in the prior 48 hours.

Statistical Analyses

Summary statistics were computed to describe the prevalence of asthma, atopy, eczema, tobacco smoking, and cannabis use across occupational and nonoccupational participants. Potential confounders were selected *a priori* based on review of the literature. Univariate and multivariate linear regression models were used to compare pulmonary function and airway inflammation between occupational and nonoccupational participants. Multivariate linear regression models for percent predicted FEV_1, FVC, and FEV_1/FVC were adjusted for recreational cannabis use and tobacco smoking. Models for FeNO were log-transformed and adjusted for recreational cannabis use, tobacco smoking, height, age, and sex. Univariate and multivariate logistic regression models were used to estimate the odds of allergic sensitization to cannabis and the odds of dermal, ocular, nasal, and respiratory symptoms when comparing occupational versus nonoccupational participants. Models for cannabis sensitization were adjusted for history of atopy and recreational cannabis use. Models for health symptoms were adjusted for recreational cannabis use, tobacco smoking, age, sex, and history of atopy. For all statistical models, the crude and adjusted regression coefficients were estimated and tested for statistical significance. All statistical tests were performed in RStudio Version 1.3.1093 (Posit Software, PBC; Boston, MA) using a two-tailed P value and an $\alpha = 0.05$ significance level.

In reporting our results, we adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Guidelines for cross-sectional studies. The STROBE checklist is included as Supplementary Digital Content (http://links.lww.com/JOM/C69).

RESULTS

Study Population

In total, 42 nonoccupational participants were recruited from the greater Seattle, Washington area, between June and August 2021. Following recruitment, one recreational cannabis user was excluded because of recent antihistamine use and one cannabis nonuser was excluded because of pregnancy. After exclusions, the final study population ($n = 82$) included 40 nonoccupational participants ($n = 20$ cannabis users and $n = 20$ cannabis nonusers) and 42 cannabis workers. All nonoccupational participants underwent additional respiratory and allergic testing to assess pulmonary function, airway inflammation, and allergic sensitization. Selected occupational participants ($n = 21$) with work-related symptoms participated in pulmonary function and airway inflammation testing. All but one of the selected occupational participants ($n = 20$) participated in skin prick testing to assess allergic sensitization to cannabis.

Nonoccupational participants were generally similar to cannabis workers across baseline demographic variables, with some variability noted in sex, cannabis use frequency, and tobacco smoking status (Table 1). Participants predominantly identified as non-Hispanic White in both the occupational ($n = 33$, 81%) and nonoccupational

TABLE 1. Baseline Characteristics of Participants in Nonoccupationally Exposed and Occupationally Exposed Groups

	Nonoccupational Participants		Cannabis Workers	
	Cannabis Nonusers ($n = 20$)	Cannabis Users ($n = 20$)	Cannabis Workers ($n = 42$)	Selected Workers With Work-Related Symptoms ($n = 21$)
Male, n (%)	5 (25.0)	8 (40.0)	23 (54.8)	11 (52.4)
Mean age (years) (SD)	37 (17)	35 (12)	32 (8)	32 (11)
Non-Hispanic White, n (%)	14 (70.0)	12 (60.0)	33 (80.5)	16 (80.0)
Education level, n (%)				
≤High school	0 (0.0)	3 (15.0)	10 (23.8)	4 (9.0)
Some college	3 (15.0)	3 (15.0)	13 (31.0)	6 (28.6)
≥Bachelor's degree	17 (85.0)	14 (70.0)	19 (45.2)	11 (52.4)
Atopy, n (%)				
Asthma	2 (10.0)	6 (30.0)	9 (21.4)	4 (19.0)
Hay fever	2 (10.0)	4 (20.0)	11 (26.2)	9 (42.9)
Eczema	3 (16.7)	3 (15.8)	10 (23.8)	4 (19.0)
Tobacco smoking, n (%)				
Current	0 (0.0)	2 (10.0)	17 (40.5)	10 (47.6)
Past	3 (15.0)	6 (30.0)	12 (28.6)	3 (14.3)
Never	17 (85.0)	12 (60.0)	13 (31.0)	8 (38.1)
Cannabis use, n (%)				
Current	0 (0.0)	20 (100.0)	41 (97.6)	0 (0.0)
≥Daily	0 (0.0)	13 (65.0)	34 (81.0)	17 (81.0)
Weekly	0 (0.0)	7 (35.0)	4 (9.5)	2 (9.5)
≤Monthly	0 (0.0)	0 (0.0)	3 (7.1)	2 (9.5)

Baseline characteristics of the study population according to cannabis exposure status.
SD, standard deviation.

TABLE 2. Health Measurements in Nonoccupationally Exposed and Occupationally Exposed Participants

	Nonoccupational Participants		Cannabis Workers
Health Measurements*	**Cannabis Nonusers (n = 20)**	**Cannabis Users (n = 20)**	**Selected Workers With Work-Related Symptoms (n = 21)**
Mean FeNO (ppb) (SD)	15.7 (7.3)	15.6 (13.3)	24.4 (19.7)
Mean FVC% (%) (SD)	99.3 (15.4)	104.0 (17.5)	95.9 (10.0)
Mean FEV_1% (%) (SD)	96.0 (15.1)	97.6 (15.8)	90.6 (11.6)
Mean FEV_1/FVC% (%) (SD)	96.4 (7.3)	94.0 (8.3)	94.4 (8.3)
Cannabis sensitization, n (%)	0 (0.0)	1 (5.0)	7 (35)

Pulmonary function, airway inflammation, and cannabis sensitization measurements according to cannabis exposure status.
*Pulmonary function measurements reflect the measured percent of the predicted pulmonary function based on participant age, sex, race, and height.
FENO, fractional exhaled nitric oxide; FEV1, forced expiratory volume in 1 second; FVC, forced vital capacity.

(n = 26, 65%) groups. Across the study population, 84% (n = 69) of participants reported completing at least some college, including 76% (n = 32) of occupational participants and 93% (n = 37) of nonoccupational participants. The mean ages of cannabis workers and nonoccupational participants were 32 years (SD 8) and 36 years (SD 14), respectively. Cannabis workers were predominantly male (n = 23, 55%), whereas most nonworkers were female (n = 27, 68%). Eleven nonoccupational participants (28%) reported current (n = 2) or prior (n = 9) tobacco smoking, compared to 29 (69%) occupational participants who reported current (n = 17, 41%) or prior (n = 12, 29%) tobacco smoking. Most cannabis workers (n = 41, 98%) were current recreational cannabis users, including 34 participants (81%) who reported using cannabis at least once per day. Among cannabis users in the nonoccupational group, 13 (65%) reported using cannabis at least once daily and 7 (35%) reported weekly use.

Pulmonary Testing

Within the nonoccupational group, the mean FeNO levels measured were similar across cannabis users (15.7 ppb; SD, 7.3 ppb) and cannabis nonusers (15.6 ppb; SD, 13.3 ppb) (Table 2). On average, cannabis workers had higher FeNO compared to nonoccupational participants (24.4 ppb; SD, 19.7 ppb). After adjusting for recreational cannabis use, tobacco smoking, height, sex, and age, the geometric mean FeNO levels measured in cannabis workers were 40% higher (95% confidence interval [CI], −10 to 120%; P = 0.13) than those measured in nonoccupational participants (Table 3).

Pulmonary function measurements, including percent predicted FVC, FEV_1, and FEV_1/FVC, were comparable across nonoccupational cannabis users and nonusers but lower in the cannabis workers. After adjusting for recreational cannabis use and tobacco smoking, the mean percent predicted FEV_1 and FVC were 6.2% lower (95% CI, −2.4 to 14.7%; P = 0.15) and 7.8% lower (95% CI, −1.6 to 17.1%; P = 0.10), respectively, in cannabis workers compared to nonoccupational participants.

Allergic Sensitization

In the nonoccupational group, one participant (3%) demonstrated sensitization to cannabis during skin prick testing. The single participant exhibiting cannabis sensitization was a recreational cannabis user. Of the 20 cannabis workers who underwent skin prick testing, seven (35%) demonstrated sensitization to cannabis. The odds of cannabis sensitization were 9.5 (95% CI, 1.4, 193.2; P = 0.05) times greater among cannabis workers than among nonoccupational participants after adjusting for recreational cannabis use and history of atopy.

Prevalence of Health Symptoms

Cannabis workers reported a higher prevalence of respiratory (n = 29), dermal (n = 10), ocular (n = 16), and nasal (n = 16) symptoms than nonoccupational participants (Fig. 2). Nearly 70% (n = 29) of cannabis workers reported that they experienced at least one respiratory symptom at work, including chest tightness or shortness of breath (n = 12), cough (n = 19), sputum (n = 9), wheeze (n = 7), or sore throat (n = 10). After adjusting for recreational cannabis use, tobacco smoking, age, sex, and history of atopy, cannabis workers were 2.5 (95% CI, 0.72, 9.3; P = 0.15) times more likely to experience respiratory symptoms than nonoccupational participants (Table 4). The adjusted models for dermal, nasal, and ocular symptoms also trended toward increased odds of reported allergic symptoms. Compared to nonoccupational participants, cannabis workers were 13.5 (95% CI, 1.3, 332.6; P = 0.05) times more likely to experience dermal symptoms, 2.0 (95% CI, 0.53, 8.2; P = 0.32) times more likely to experience nasal symptoms, and 1.3 (95% CI, 0.36, 4.6; P = 0.73) times more likely to experience ocular symptoms. Together, the odds of experiencing any allergic (ie, dermal, nasal, ocular, or respiratory) symptom were 3.7 (95% CI, 0.91, 16.9; P = 0.07) times higher among cannabis workers than in nonoccupational participants.

DISCUSSION

This cross-sectional study of cannabis workers, recreational cannabis users, and nonusers demonstrated that occupational exposure to cannabis cultivation and processing was associated with a trend toward increased self-reported allergic symptoms, reduced pulmonary

TABLE 3. Change in Lung Function and FeNO With Occupational Exposure

	Change in Percent Predicted Lung Function Parameter*†	P
FEV_1% predicted		
Unadjusted	−6.02 (−13.2, 0.79)	0.08
Adjusted	−6.16 (−14.72, 2.40)	0.15
FVC % predicted		
Unadjusted	−5.70 (−12.49, 1.10)	0.10
Adjusted	−7.75 (−17.12, 1.61)	0.10
FEV_1/FVC % predicted		
Unadjusted	−0.79 (−5.15, 3.56)	0.72
Adjusted	0.90 (−4.90, 6.70)	0.76
FeNO % change	*Percent change in FeNO ‡*	*P*
Unadjusted	38 (−5, 99)	0.09
Adjusted	40 (−10, 120)	0.13

*Regression coefficients represent the n-fold change in the percent predicted lung function parameter.
†Lung function models were adjusted for recreational cannabis use and tobacco smoking. The FeNO model was adjusted for recreational cannabis use, tobacco smoking, height, sex, and age.
‡Regression coefficients represent the percent change in FeNO.
FENO, fractional exhaled nitric oxide; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity.

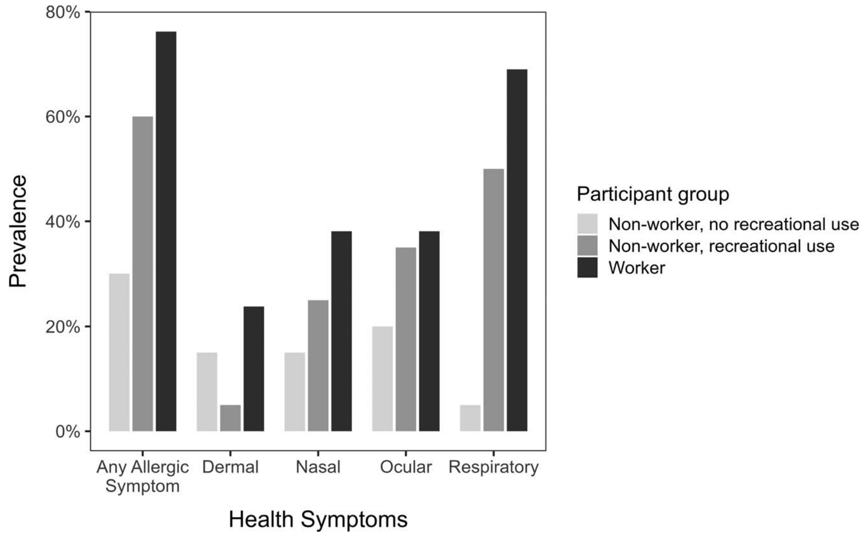

FIGURE 2. Prevalence of health symptoms reported by participants according to cannabis exposure status. Allergic symptoms were categorized by whether they were dermal, nasal, ocular, or respiratory in nature based on responses to health questionnaires.

function, increased airway inflammation, and a higher odds of sensitization to cannabis on skin prick testing. Although the small study population—which included just 21 workers undergoing health testing—hindered our ability to detect statistically significant effects for some measurements, the consistent pattern in symptoms and health measurements provides compelling preliminary evidence that occupational exposures during cannabis cultivation and processing may be a risk factor for allergic and respiratory diseases.

Our results are consistent with a growing body of evidence that suggests that cannabis workers experience allergic and respiratory symptoms due to workplace exposures during cultivation and processing activities.[4,11,27,28] Walters et al (2018) reported that 17.6% and 7.0% of Colorado cannabis workers surveyed experienced skin irritation or difficulty breathing, respectively, after handling pesticides during cannabis grow operations.[27] In a qualitative analysis investigating exposure and health concerns in the California cannabis industry, Beckman et al (2022) found that respiratory and dermal exposures were a key concern among workers, who reported symptoms including cough, shortness of breath, rashes, or skin problems after handling cannabis plant materials. At least one worker in this study noted that they developed a newly onset cannabis allergy due to their handling of cannabis in the workplace.[11] In a subsequent pilot study at a separate facility, Beckman et al (2023) found that nearly 40% of California cannabis cultivation workers experienced work-related allergic symptoms, including 24% who reported respiratory symptoms and 31% who reported nasal symptoms.[28]

IgE-mediated sensitization plays an important role in the development of asthma and other allergic diseases[12,13]; therefore, it is critical to understand and control exposure to sensitizing agents in the workplace. In the present analysis, we found that 35% of tested workers demonstrated sensitization to cannabis during skin prick testing and that cannabis workers were 9.5 times (95% CI, 1.4, 193.2; $P = 0.05$) more likely to be sensitized than nonoccupational participants, despite controlling for recreational cannabis use. These data imply that occupational exposure to cannabis plant material may play an important role in the development of work-related health symptoms and disease. This finding is particularly important given recent case reports of work-related asthma, including a fatal asthma exacerbation, in cannabis workers engaged in the trimming, grinding, chopping, processing, growing, or packaging of cannabis.[29–31]

While our findings highlight the potential allergenicity of the cannabis plant to workers, it is important to note that workers are exposed to a number of other respiratory hazards during their normal job duties.[3,10,15,32–35] Health Hazard Evaluations conducted by the National Institute of Occupational Safety and Health (NIOSH) in cannabis cultivation and grow facilities have found elevated airborne levels of endotoxins, VOCs, and mold, many of which can act as either respiratory irritants or sensitizers.[10,15,36] In these Health Hazard Evaluations, NIOSH reported elevated VOC levels during grinding activities and microbiological hazards during harvesting, bud stripping, and hand trimming activities.[10,15,36,37] NIOSH investigators additionally reported elevated exposure to endotoxin in personal air samples during harvesting and grinding activities.[10,15,37] Although there is currently no occupational exposure limit for endotoxin in the United States, 40% of the personal air samples collected at one indoor cultivation and processing facility showed that workers were exposed to airborne endotoxin levels exceeding the occupational exposure limit set by the

TABLE 4. Odds of Health Symptoms (Last 12 Months) With Occupational Exposure

Health Symptoms*	Odds Ratio (95% CI)	P
Dermal symptoms		
Unadjusted	2.81 (0.85, 11.07)	0.11
Adjusted	13.49 (1.33, 332.58)	0.05
Nasal symptoms		
Unadjusted	2.46 (0.93, 6.92)	0.08
Adjusted	1.99 (0.53, 8.18)	0.32
Ocular symptoms		
Unadjusted	1.62 (0.64, 4.20)	0.31
Adjusted	1.25 (0.36, 4.55)	0.73
Respiratory symptoms		
Unadjusted	5.88 (2.33, 15.84)	0.0002
Adjusted	2.53 (0.72, 9.26)	0.15
Any allergic symptom		
Unadjusted	3.91 (1.56, 10.40)	0.005
Adjusted	3.73 (0.91, 16.85)	0.07
Cannabis sensitization		
Unadjusted	21.01 (3.31, 412.5)	0.006
Adjusted	9.50 (1.38, 193.24)	0.05

*Models for dermal, nasal, ocular, respiratory, and any allergic symptoms were adjusted for recreational cannabis use, tobacco smoking, age, sex, and history of atopy. Models for cannabis sensitization were adjusted for recreational cannabis use and history of atopy.

Dutch Expert Committee on Occupational Safety (90 endotoxin units per m^3 as an 8-hour time-weighted average).[10,38] Other published studies have reported concern among cannabis cultivation and processing workers related to mold and pesticide exposures during their work activities.[11,27] The high watering requirements of cannabis can promote the growth of molds, such as *Golovinomyces cichoracearum* and *Botrytis cinerea*, and prior studies have identified over 200 fungal species in indoor grow facilities.[34,39–41] Many of these species have been linked to disease in agricultural workers and can cause fungal sensitization.[42–45] In a qualitative assessment of health concerns among cannabis cultivation and processing workers, all or most participants reported exposure to mold and noted it to be a primary health and safety concern.[11] Recent studies have also measured mycotoxins, including those produced by *Fusarium* and *Aspergillus*, in cannabis and at cannabis grow farms.[46–48] Currently, it is unknown how these agents might contribute to the respiratory and allergic symptoms observed in cannabis workers and further research is needed.

The present analysis extends on prior findings by incorporating objective health measurements and by including a control population. The pulmonary testing used in this study facilitated comparisons with the clinical benchmarks used to diagnose lung diseases, including Chronic Obstructive Pulmonary Disease and asthma, thereby providing important context on the impact of workplace exposures on respiratory health. Our assessment of cannabis sensitization through skin prick testing informed on the potential etiology of the allergic effects and allergic-mediated diseases observed in cannabis workers. The inclusion of a control population without occupational exposure to cannabis allowed us to adjust analyses for recreational cannabis use, an important potential confounder—particularly as a high proportion of workers report personal use of cannabis products at least once daily.[4,27,28] To our knowledge, this is the first study to assess the impact of cannabis cultivation and processing exposures while controlling for recreational cannabis use.

Despite these strengths, our findings must be interpreted in the context of several important limitations. As with all cross-sectional studies, we were unable to determine causation and estimated prevalence, rather than incidence, of allergic and respiratory health impacts. Our study was small and included workers from only two indoor cannabis grow facilities in Washington State, which limited our power and reduced the generalizability of our findings. Furthermore, at one of the cannabis facilities, we selected employees who complained of work-related symptoms to perform health measurements, which may have biased our results. Differences in the baseline demographics and frequency of substance use between our occupational and nonoccupational populations may have also biased our findings. In general, the nonoccupational participants included a higher proportion of females, higher educational attainment, and lower current or former tobacco smoking. Additionally, there were important differences in the frequency of cannabis use: 81% of occupational participants reported using cannabis at least once daily, whereas only 65% of recreational cannabis users in the nonoccupational population reported using cannabis at least once daily. While analyses adjusted for these covariates, residual confounding—particularly from cannabis use frequency—may have influenced our results.

There were also significant limitations in our method of determining cannabis sensitization. While skin prick testing has a high sensitivity, there can be false positives and negatives, particularly for noncommercial extracts prepared from a slurry of plant material. Plant material may have been contaminated by molds, pests or other high molecular weight antigens that contributed to the allergic reaction observed. Additionally, we were unable to identify specific allergens, such as Can s3, within plant material that may have been responsible for the hypersensitivity reaction. Future studies should explore the use of emerging ImmunoCap assays to various cannabis and hemp proteins to identify specific-IgE from workers' serum.

Additionally, there were important differences in the allergen extracts that we used to determine cannabis sensitization in the worker versus control populations. In the cannabis workers, we used a slurry of ground cannabis dust created from several strains of cannabis at the worksite. For the control population of recreational cannabis users and nonusers, we were only permitted to use a slurry of cannabis dust that was composed of hemp, with <0.3% of the psychoactive cannabinoid tetrahydrocannabinol.[49] Prior studies have demonstrated high allergenic cross-reactivity between strains of Cannabaceae with < and >0.3% tetrahydrocannabinol, with recent detailed proteomic analyses showing high expression of Can s2, Can s3, and Can s5 in both hemp and cannabis extracts.[50,51] While these studies support the comparability of our skin prick testing in the worker and control populations, it is possible that the use of different extracts may have biased our findings.

Finally, our analyses aggregated all forms of recreational cannabis use—including smoking, dabbing, vaping, and edible use of cannabis products—into a single category when controlling for recreational cannabis use. Although all routes of exposure could be relevant when assessing cannabis sensitization, cannabis smoking is the most relevant route of exposure when evaluating respiratory outcomes. Notably, if any effect from misclassification is present, we expect it to nondifferentially impact occupational and nonoccupational participants, as we presently have no data suggesting that forms of recreational cannabis use differ according to occupational status.

Even with the noted limitations, our study provides compelling evidence that workplace exposure to cannabis contributes to the respiratory and allergic effects seen in cultivation and processing workers, even after adjusting for recreational cannabis use. Understanding the prevalence and etiology of the respiratory and allergic outcomes in cannabis workers is the critical first step to implementing targeted work controls that can reduce exposure. We recommend that further research examines the relationship between sensitizing and irritating agents and allergic or respiratory health outcomes during cannabis cultivation and processing activities.

CONCLUSIONS

We found that, on average, cannabis workers trended toward increased airway inflammation and decreased pulmonary function when compared to nonworkers. Additionally, cannabis workers exhibited increased odds of cannabis sensitization and reported a higher prevalence of allergic symptoms when compared to nonworkers. Our findings suggest that workplace exposures contribute to the respiratory and allergic effects seen in cannabis workers, regardless of recreational cannabis use.

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