An Algorithm for the Surveillance of Occupational COPD in Washington State

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Author contributions:

CRW conceived of the presented idea. BER, CRW and DT performed manual review of workers' compensation data. BER, CRW, DT and CS designed the algorithm and wrote the main body of the manuscript. MC consulted on the conceptual approach to the project and provided critical edits to the manuscript. BD and LK developed and consulted on the Job Exposure Matrix used in this report and provided critical edits to the manuscript. BER, CRW and DT contributed to data analysis and verification and development of figures and tables. All authors contributed directly to the review and writing of the manuscript.

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This article has a data supplement which is accessible at the supplements tab.

Abstract (326/350 words)

Rationale: An estimated 14% of Chronic Obstructive Pulmonary Disease (COPD) is caused by occupational exposure to vapor, gas, dust and fumes (VGDF). In collaboration with the Washington State Department of Labor and Industries' Safety and Health Assessment and Research for Prevention Program, we developed a surveillance algorithm for retrospective identification of Occupational COPD using a cohort of Washington workers. *Methods:* Potential cases were identified from workers' compensation claims filed in Washington State between 2010-2020 using keywords, disease diagnosis codes, and occupational injury and illness codes. Cases were confirmed for the presence of COPD using post-bronchodilator forced-expiratory-volume-over-1-second/forced-vital-capacity (FEV_1/FVC) <0.7. If spirometry was unavailable, alternate clinical criteria were used. In an iterative process based on review of the first 100 cases and longitudinal studies on Occupational COPD, we developed an algorithm to classify cases as *Probable, Possible, Work-Aggravated* or *Unlikely* Occupational COPD. This algorithm incorporated confirmation of COPD diagnosis, total career duration with exposure to medium or high VGDF, and smoking history. Exposure risk was estimated using a COPD-specific, occupation-based Job Exposure Matrix (JEM).

Results: Of 508 potential cases identified in the workers' compensation claims data, 494 had had a COPD diagnosis and were included in the final analysis. Of these, 132 (27%) met criteria for Occupational COPD, including 72 *Probable,* 4 *Possible,* and 56 *Work-Aggravated* cases. There were 362 (73%) cases that did not meet criteria and were classified as *Unlikely* to have Occupational COPD. Overall, 19 cases with Occupational COPD were never-smokers or had smoked <10 pack years total, including seventeen classified as *Probable* and two classified as *Work-Aggravated*. Occupations ascribed through the JEM to have medium or high exposure to VGDF included construction workers, production workers, maintenance workers and drivers, among others, and there was overlap in occupations and hazards between Occupational COPD classifications.

Conclusions: This comprehensive algorithm provides an approach for Occupational COPD surveillance that can be used to inform and prioritize prevention efforts in an effort to reduce disease burden in high-risk occupations.

Keywords: Chronic Obstructive Pulmonary Disease, job exposure matrix, vapor, gas, dust, fumes, exposure, VGDF, workers' compensation

Manuscript (3456/3500 words)

Introduction

Despite declining smoking rates, COPD is the third leading cause of death worldwide (1-3). Occupational exposures are under-recognized contributors to disease, responsible for approximately 14% of COPD cases (31% in nonsmokers) (3-8).

Occupational exposure to vapors, gases, dusts and fumes (VGDF), either self-reported or expert-assigned through job exposure matrices (JEM) (9), is causally linked to increased risk of COPD in the general population and across specific industries (4, 8, 10-13). Examples of occupational exposures that cause or aggravate COPD include respirable crystalline silica, cleaning chemicals, coal mine dust, mineral dusts, agricultural dusts, and metal fumes (6, 10, 13-19). Occupational exposure combined with smoking risk is at least additive, although the contribution of occupational exposures is underestimated in those who smoke (8, 14, 20). The appropriate attribution of risk is important for recognition and control of VGDF in the workplace, adjudication of workers' compensation claims, and in guiding policy.

Occupational COPD diagnosis is limited by many factors: First, the dose, duration, and latency of occupational VGDF exposure that causes COPD is unknown. Second, spirometry values used to define COPD vary. Historically, Global Initiative for Chronic Obstructive Lung Disease (GOLD) and American Thoracic Society (ATS)/European Respiratory Society (ERS) guidelines defined COPD as post-bronchodilator forced expiratory volume over 1 second/forced vital capacity (FEV_1/FVC) <0.7 (21-24). ATS/ERS later adopted the lower limit of normal cutoff (LLN or 5th percentile of the predicted value). However, there is no universal consensus definition, and consistent use of *any* diagnostic guidelines remains limited in both real-world practice and epidemiologic studies (25-28). Finally, Occupational COPD does not have a clinical or surveillance case definition.

In the United States (US), the National Institute for Occupational Safety and Health (NIOSH) conducts surveillance for work-related asthma and silicosis via the State-Based Occupational Safety and Health

Surveillance program (29, 30). Currently, there is no national consensus on a case definition for Occupational COPD. In collaboration with the Safety & Health Assessment & Research for Prevention (SHARP) program at the Washington State Department of Labor and Industries (L&I), we developed a novel surveillance algorithm for Occupational COPD. In an iterative process, we utilized a COPD-specific JEM developed by experts in industrial hygiene and exposure assessment (13) to estimate the risk of occupation-specific VGDF exposure on COPD development. The adoption of a standardized, JEM-based approach to medical surveillance using workers' compensation (WC) claims allows for a systematic, semi-quantitative, and scalable system of identifying workers with Occupational COPD. Post-hoc analysis of individual workers' cases can then be used to identify self-reported exposures to specific agents.

In this report, we describe the development of our novel algorithm for Occupational COPD surveillance and its application to a cohort of Washington workers who filed WC claims for respiratory related conditions between 2010 and 2020. The goal was to determine the practicality of the algorithm for public health surveillance and describe the exposure and clinical characteristics of workers who met criteria for Occupational COPD.

Methods

Data source:

Washington State employers must obtain WC insurance through L&I's State Fund program or meet requirements to self-insure, for which L&I provides oversight (31, 32). Exemptions to mandatory state coverage include self-employment and federal workers' compensation coverage (33). Our dataset includes both State Fund and Self-Insured workers' compensation claims.

Patient Population:

Potential COPD cases were identified from L&I's industrial insurance data warehouse using International Classification of Diseases (ICD) diagnosis codes for COPD, 9th and 10th revisions, Clinical Modification

(34), AND either keywords, OR Occupational Injury and Illness Classification System (OIICS, v1.01) codes (35) (**Table 1**). Case capture was not contingent on claims being filed specifically for Occupational COPD, as diagnosis was not always available at claim filing.

ICD codes were obtained from the Report of Accident form, medical or hospital billing records, or L&I's payable diagnosis codes. Keywords for COPD were gleaned from the worker, employer, and health care provider sections of the Report of Accident form. Medical, smoking and work history were determined through claim review by one of two reviewers with expertise in occupational pulmonary disease (BR) or Industrial Hygiene/respiratory disease surveillance research (CRW), while both reviewers evaluated medically complicated claims. Review was performed ≥1 year from claim filing to allow time for diagnostic workup and was independent of adjudication outcome. Duplicate claims and those with no medical record were excluded from analysis. Included claimants were over 18 years old.

Confirmation of COPD diagnosis:

Potential cases were first evaluated for clinical COPD. Obstruction was defined using GOLD criteria of post-bronchodilator FEV_1/FVC <0.7 (21, 22, 36), as this definition is independent of changing reference equations, correlates similarly to LLN for disease prognosis (25), and is more practical for workers' compensation claims in which LLN may not be reported. Cases with only pre-bronchodilator values available needed both pre-bronchodilator FEV_1/FVC <0.7 AND physician diagnosis of COPD to avoid misclassification of asthma. When spirometry was not available, alternate diagnostic criteria were used (**Table 2**).

Occupational Exposure to VGDF:

Lifetime work history was gathered from the Report of Accident, available medical notes, work history forms and employer-provided documents for each case, if available. Risk of occupational exposure to VGDF was estimated using a COPD-specific Job Exposure Matrix (JEM) developed by NIOSH (13).

Occupations were coded at L&I using Standard Occupational Classification (SOC) codes (37) cross-referenced to the U.S. Census Bureau 2002 Occupation Codes (USCB) (38) used in the JEM. The JEM identified exposure risk as low, medium, or high, representing the likelihood of the presence and severity of VGDF exposure (13). For descriptive purposes, we identified up to five specific exposures per case. Exposures were coded using the Association of Occupational and Environmental Clinics (AOEC) codes (39). Employer industry was coded using the North American Industry Classification System (NAICS) (40).

We considered only years spent in occupations with JEM-assigned medium or high VGDF exposure to contribute to Occupational COPD ("total career duration"). Occupations with low risk of exposure by JEM were considered unlikely to contribute to disease development and for analytic purposes were assigned a total career duration of zero. When lifetime work history was not available, the time spent in the job of injury was used as a surrogate for total career duration. Exception was made for work-aggravation of COPD, which allowed exposure to *any* amount of VGDF over *any* career duration, as long as diagnosis preceded exposure.

Although longitudinal exposure to VGDF is associated with an annual decline in lung function (3, 4), there is no established minimum exposure known to cause COPD. Based on expert opinion and observational studies demonstrating a dose-response relationship (5, 6, 41-44), including recommendations from the Building Trades National Medical Screening Program for former Department of Energy workers (41), we considered 5 years of JEM-assigned high, or 10 years of JEM-assigned medium, exposure to VGDF to be the lowest plausible duration to cause disease.

Accurate data on disease latency from initial exposure were not available.

Smoking history assessment:

Smoking history was determined through review of records and quantified as pack-years (packs per day multiplied by total years smoked). If smoking history varied across documentation, the highest number of pack-years was chosen. Accurate data on disease latency from smoking were not available.

Historically, ≥10-15 pack-years has been considered the minimum smoking history required to develop COPD (4, 45, 46). There is no validated combination of smoking history and occupational VGDF exposure that distinguishes between occupational vs. nonoccupational COPD. In this study, after consideration of VGDF exposure, cases were divided into two groups: Those with <10 pack-year history (including never smokers), and ever smokers with ≥10 pack-year history. Through an iterative process, we determined that in those with extensive (≥10 years high or ≥ 20 years medium) VGDF exposure, inclusion of smoking duration did not result in a change to case classification; smoking was therefore determined to be most useful in differentiating cases with moderate intensity exposure into *Probable* vs. *Possible* Occupational COPD. Cases with unknown smoking history were considered *Possible* Occupational COPD if they met adequate VGDF exposure criteria.

Algorithm for Occupational COPD Classification:

The final surveillance algorithm for Occupational COPD classification is presented in **Figure 1.**

Cases were classified as *Work-Aggravated* COPD if they met the following criteria:

1. COPD diagnosis by GOLD or alternate diagnostic criteria that *precedes* occupational exposure to VGDF, regardless of duration or intensity. Career duration and smoking history were reported but not required for classification.

Cases were classified as *Probable Occupational* COPD if they met the following criteria:

1. Career duration of ≥20 years *medium exposure* OR ≥10 years *high exposure* to VGDF (independent of smoking history) OR
2. Career duration of 10-19 years *medium exposure* OR 5-9 years *high exposure* to VGDF AND <10 pack-years smoking history (including never smokers).

Cases were classified as *Possible Occupational* COPD if they met the following criteria:

1. Career duration of 10-19 years *medium exposure* OR 5-9 years *high exposure* to VGDF AND ≥10 pack years smoking history OR smoking history is unknown.

Workers with biological exposures such as viruses, bacteria or mold were excluded from analysis as these do not constitute VGDF. Cases that lacked enough information to classify were considered "undetermined" and were excluded from the algorithm. Cases that did not meet criteria for COPD diagnosis, career duration, or VGDF exposure did not progress through the algorithm and are referred to as *Unlikely* in the tables.

Descriptive Analysis:

Available sociodemographics, including age, sex, occupation and exposure history, were described for all cases using summary statistics. Missing data were documented but not incorporated into summary statistics. Descriptive analysis was performed using statistical software R version 4.1.1 (47).

All surveillance protocols and data handling were approved by the Washington State Institutional Review Board (WSIRB).

Results:

Of the 1,632,613 workers' compensation claims filed for all causes between 2010-2020, 508 cases met our case criteria. Of these, 14 cases were excluded as duplicates or due to insufficient information, resulting in 494 cases in the final analysis (**Figure 2)**.

A total of 132 (27%) cases were classified as Occupational COPD using the algorithm: 56 (11%) *Work Aggravated* COPD, 72 (15%) *Probable* Occupational COPD, and 4 (<1%) *Possible* Occupational COPD. There were 362 (73%) *Unlikely* cases that did not meet diagnostic or exposure criteria for Occupational COPD; the majority were consistent with asthma or acute bronchitis (n=221, 61%). Data for FEV_1/FVC were missing in 302 (63%) cases overall. Among these cases, alternate clinical criteria were sufficient to confirm COPD diagnosis in 73 cases, 46 of which were classified as *Work-Aggravated,* 15 as *Probable*, and 2 as *Possible*. Most *Unlikely* cases (336, 93%) did not meet criteria using either spirometry or alternate diagnostic criteria while 26 (7%) *Unlikely* cases had confirmed COPD by spirometry but did not meet criteria for exposure duration.

Characteristics of confirmed COPD cases by Occupational COPD classification are reported in **Table 3**. Case counts for the different clinical pathways are available by COPD classification in **Supplement Table 1 (S-Table 1**).

Figure 3 shows WC claim filing trends between 2010 and 2020 for the 494 potential cases by case classification. The annual total of potential COPD claims declined over the study period, from 54 in 2010 to 18 in 2020. For context, total claims filed due to all causes rose 7% between 2010 and 2019, then declined by 19% in 2020. This decline was likely due to the COVID-19 pandemic based on a similar 20% reduction in claim filing for injuries other than COVID-19 between 2019 and 2020.

There were significant demographic differences between cases classified as Occupational COPD versus *Unlikely* (**Table 3**). Those with *Probable* Occupational COPD were older with a higher proportion of males than those classified as *Work Aggravated* or *Unlikely* (median age 62.1, 58.0 and 46.5 years, respectively; 89%, 61%, and 65% male respectively; Kruskal-Wallis chi-squared and Pairwise Wilcoxon p-values < 0.0001).

The median career exposure duration to medium and/or high VGDF was 0.92 years for cases classified as *Work Aggravated* (IQR 3.96), 30 years for *Probable* (IQR 13.5), 15 years for *Possible* (IQR 4.69), and 1.5

years for *Unlikely* Occupational COPD (IQR 9.98). Total career duration was missing for 251 cases (51%), for which duration in the job of injury was used as a surrogate. Many cases classified as *Probable* had worked in a single occupation their entire career.

Cases with Occupational COPD had a heavier smoking history compared to *Unlikely* cases. Nineteen cases classified as Occupational COPD smoked <10 pack years, including 2 *Work Aggravated* and 17 *Probable* cases (n=7 never smoked). Pack-year history was missing for 20 *Work Aggravated* cases and 1 *Probable* case. Occupations and exposures for those who smoked <10 pack years (including never smokers) are listed in **Table 4.**

Commonly reported occupations organized by COPD classification are presented in **Table 5**. Occupations with high exposure to VGDF included welders, brazers, solderers, truck drivers, construction workers, painters and general production workers. Cases classified as *Probable* or *Possible* worked in production, construction/extraction, installation, maintenance/repair, and transportation/material moving. *Work Aggravated* cases had similar occupations to *Probable/Possible* cases, with building & grounds cleaning/ maintenance, office/administrative support, and food prep/service-related occupations also represented.

Commonly reported industries organized by Occupational COPD classification are listed in Supplement **Table 2 (S-Table 2).** Manufacturing and Construction were heavily represented across the groups.

Those classified as Occupational COPD reported multiple VGDF exposures (**Table 6**, Supplement **(S-Table 3)**). Commonly reported exposures included mineral/inorganic dusts (asbestos, cement dust, silica, fiberglass), metal/metalloid fumes/dust, solvents, cleaning materials, combustion products, welding exposures, plant material/organic dust, and nonspecific dust, chemical or fume exposures. *Probable* or *Possible* cases most frequently reported exposure to fibrogenic/nonspecific dusts and metals/metalloid fumes. *Work Aggravated* cases most frequently reported exposure to cleaning chemicals**.**

Discussion:

We present a novel algorithm for surveillance of Occupational COPD in Washington workers. This algorithm will be adopted by Washington State's Occupational Respiratory Disease Surveillance System to guide prevention resources for occupations and industries with high prevalence of Occupational COPD.

Despite robust evidence, occupational exposures remain under-recognized contributors to COPD development (3, 4, 6, 7, 10, 13, 17). Accurate diagnosis, surveillance and causal attribution are required for workplace prevention efforts, receipt of appropriate healthcare resources, workers' compensation benefits, and health and public policy (48, 49).

As expected, those classified as *Probable* and *Possible* Occupational COPD worked in occupations associated with dusty exposures (e.g. welding, construction, production). Those with *Work Aggravated* Occupational COPD had more irritant exposures (e.g. cleaning chemicals), although there was overlap between groups.

In this study, only 27% of claims initially assessed met our criteria for Occupational COPD. This may seem low for workers' compensation data. However, larger population studies show only 4% of the general working population are considered to have Occupational COPD with a population attributable fraction of occupational exposures to COPD of ~14% - 31% (3, 6, 50). A major reason potential claims did not meet criteria was the broad range of respiratory-related diagnosis codes used to pull potential cases. These codes were designed to maximize sensitivity, thereby capturing some claims with alternative diagnoses. For example, the ICD-9 code for "bronchitis not specified as acute or chronic" identified many claims with acute bronchitis without COPD. Additionally, some claims with COPD-related diagnostic codes failed to meet spirometry criteria upon workup and were more consistent with asthma. Finally, several potential cases had only a singular emergency room encounter for review, while a small number were rejected for administrative reasons; all of these did not meet criteria, potentially due to incomplete diagnostic workup.

Very few cases with Occupational COPD were light or never smokers; 14% of confirmed cases smoked <10 pack years and <5% were never smokers. Smoking and occupational exposures often overlap in the working population (3, 4, 6, 7, 13), although bias towards attributing causation to smoking, rather than occupational exposures (20), may influence claim filing. Through many iterations of this algorithm, smoking history was found to be most useful in distinguishing between *possible* vs *probable* Occupational COPD in those with moderate intensity VGDF exposure. Smoking history was found not to be a sufficient reason to exclude cases from consideration for Occupational COPD where work history was consistent with a heavy cumulative VGDF exposure (≥20 years medium, ≥10 years high).

Although occupational COPD cases in our study tended to be younger and male, we found a relatively high proportion of female cases (32% overall; 39% of *Work-aggravated* cases) compared to the general population (51-53). In the US, women have a higher prevalence of COPD than men (6-7% vs. 5-6%, respectively), especially in nonsmokers (51-53), with increased risk of delayed diagnosis and severe outcomes (54). Globally, men are more likely than women to have COPD (13.4% vs 8.5%) (55), although prevalence is projected to increase disproportionately in women (55-57), potentially due to genetic or hormonal risk modifiers (58). As more women enter the workforce into high-risk or male-dominated industries, attention should be paid to avoid under-recognition of disease in this group.

Limitations and Strengths

There are a number of limitations to this study. Workers' compensation data underestimate the true burden of disease (48, 49) while workers/providers may undervalue the contribution of workplace VGDF to COPD, especially in heavy smokers (20). Although COPD is more likely in individuals > 65 years (59), older workers may have less incentive to file a claim, especially in cases of retirement, comorbidities, or concurrent smoking. Regardless of age, those who file claims may be biased toward known high-risk exposures and longer career duration than those with "lower risk" occupations.

Cases missing at least one major input (e.g. spirometry, lifetime work history, smoking history) could be misidentified by the algorithm. Missing data among *Unlikely* and *Undetermined* cases could result in an underestimation of the burden of disease. In *Work Aggravated* cases, it may lead to misclassification as a large number lacked spirometry or in-depth history (e.g. two workers diagnosed with *Work-Aggravated* COPD by alternate criteria had smoked <10 years). While *Unlikely* cases caused by asthma or acute bronchitis did not meet criteria, those with mixed asthma/COPD or severe asthma with chronic, fixed obstruction (e.g. western red cedar exposures (60)) would progress through the algorithm. Complicated cases such as fibrosis/COPD overlap may result in normalization of the FEV_1/FVC ratio, leading to misclassification through the algorithm. However, these affected very few cases in our cohort and were considered an acceptable limitation.

JEMs and occupation codes may misrepresent an individual's true exposure as they do not consider exposure controls (e.g. ventilation, personal protective equipment). Similarly, this surveillance system is not designed to recognize novel exposures that may occur in "low risk" occupations, nor is it designed to longitudinally follow individual cases "at risk" of developing COPD (e.g. impaired FEV_1 or FVC with a normal ratio). However, as all cases are manually reviewed in this particular system, claim clusters from traditionally low-risk or novel occupations would likely trigger prevention activities.

Latency from exposure to disease development was not available. Most workers classified as *Probable* Occupational COPD spent decades in high-risk jobs prior to claim filing, suggesting latency is built into the bias of claim filing.

Finally, our analysis does not account for environmental or genetic contributions to COPD, such as air pollution or alpha-1-antitrypsin deficiency. This is particularly important for the two cases classified as *Work Aggravated* COPD but with low smoking history. This group has limited information to differentiate diagnostic bias from alternative environmental or genetic contributors.

This study has many strengths.

As a data source, workers' compensation is beneficial for longitudinal and systemic data acquisition, detailed case-level review of submitted medical records, exposure assessments and safety data sheets, and the administrative coding of injury, occupation and industry.

Our semi-quantitative approach to VGDF exposure classification uses both self-reported exposures and a well-established COPD-specific JEM to aid attribution of risk. One of the hallmarks of a surveillance program is systematic protocols, and the COPD-specific JEM allows consistent decision making regarding VGDF exposure by occupation. Our algorithm is easy to use and implement despite the limitation of workers' compensation data and could be adapted to other state or national surveillance programs. It also allows for a robust apportionment of risk based on smoking and VGDF exposures beyond expert opinion alone.

By emphasizing objective diagnostic testing and detailed categorization of VGDF exposures, our algorithm could help practicing physicians conceptualize how to identify and advocate for workers who wish to file workers' compensation claims for Occupational COPD.

Conclusion and Future Directions

This occupational COPD surveillance algorithm provides an opportunity to systematically identify an under-recognized disease in high-risk populations. Implementation by Washington State's Occupational Respiratory Disease Surveillance System will help clinicians and safety experts more accurately identify populations at risk of disease and guide prevention activities.

In the future, this algorithm could be used as a conceptual framework to inspire medical societies to formulate a clinical definition for occupational COPD to be used at the provider level, where consideration of individual protective factors (e.g. ventilation, personal protective equipment) can be included in decision making.

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Data availability

A de-identified dataset that supports the findings of this study are available from author CRW upon reasonable request.

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Figure Legends

Figure 1: Surveillance Algorithm for Occupational COPD

1. COPD = Chronic obstructive pulmonary disease
2. Alternate criteria: Physician diagnosis of COPD plus classic symptoms; or statement by a specialist that spirometry is consistent with COPD; or imaging reports consistent with emphysema.
3. POST-BD = Post-bronchodilator
4. PRE-BD = Pre-bronchodilator; FEV1 = forced expiratory volume over 1 second; FVC = forced vital capacity; Dx = diagnosis
5. GOLD = Global Initiative for Obstructive Lung Disease. GOLD criteria = post-bronchodilator FEV1/FVC < 0.7.
6. VGDF = Vapors, gases, dusts and fumes
7. Cases with medium exposure history where smoking history was ≥10 pack years or unknown were classified as possible occupational COPD in this surveillance system.

Figure 2: Analysis profile with reasons for exclusion.

[No legend]

Figure 3: Occupational COPD and Unlikely Occupational COPD case counts by claim established year:

COPD = Chronic obstructive pulmonary disease

Figure 3: Occupational COPD and Unlikely Occupational COPD case counts by claim established year

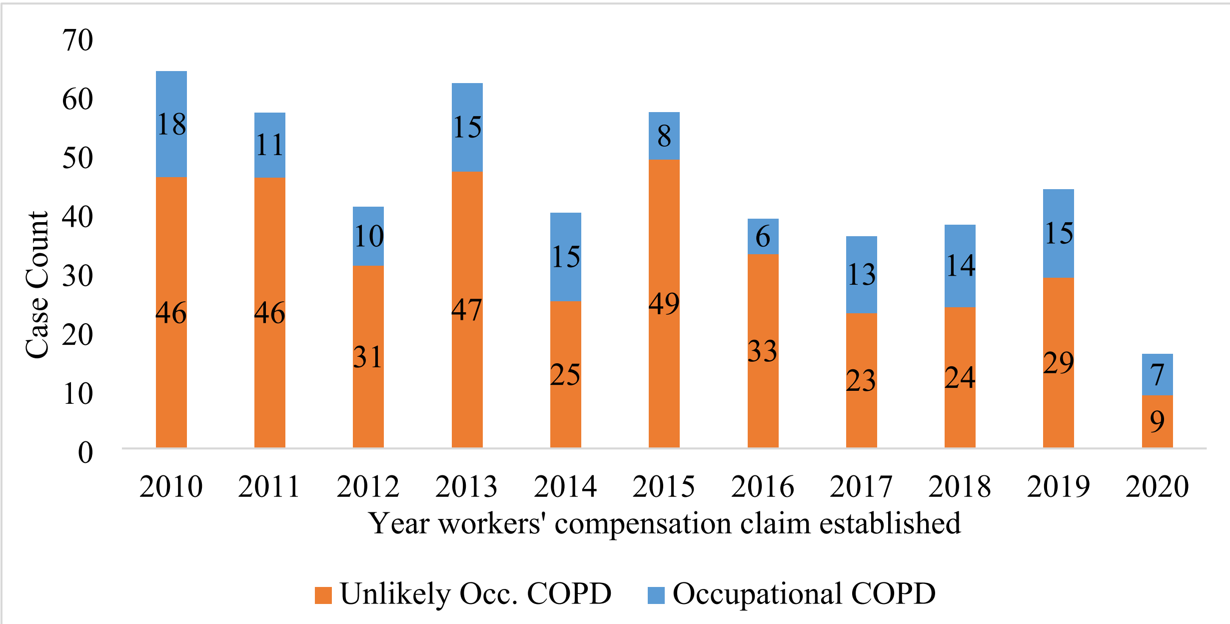

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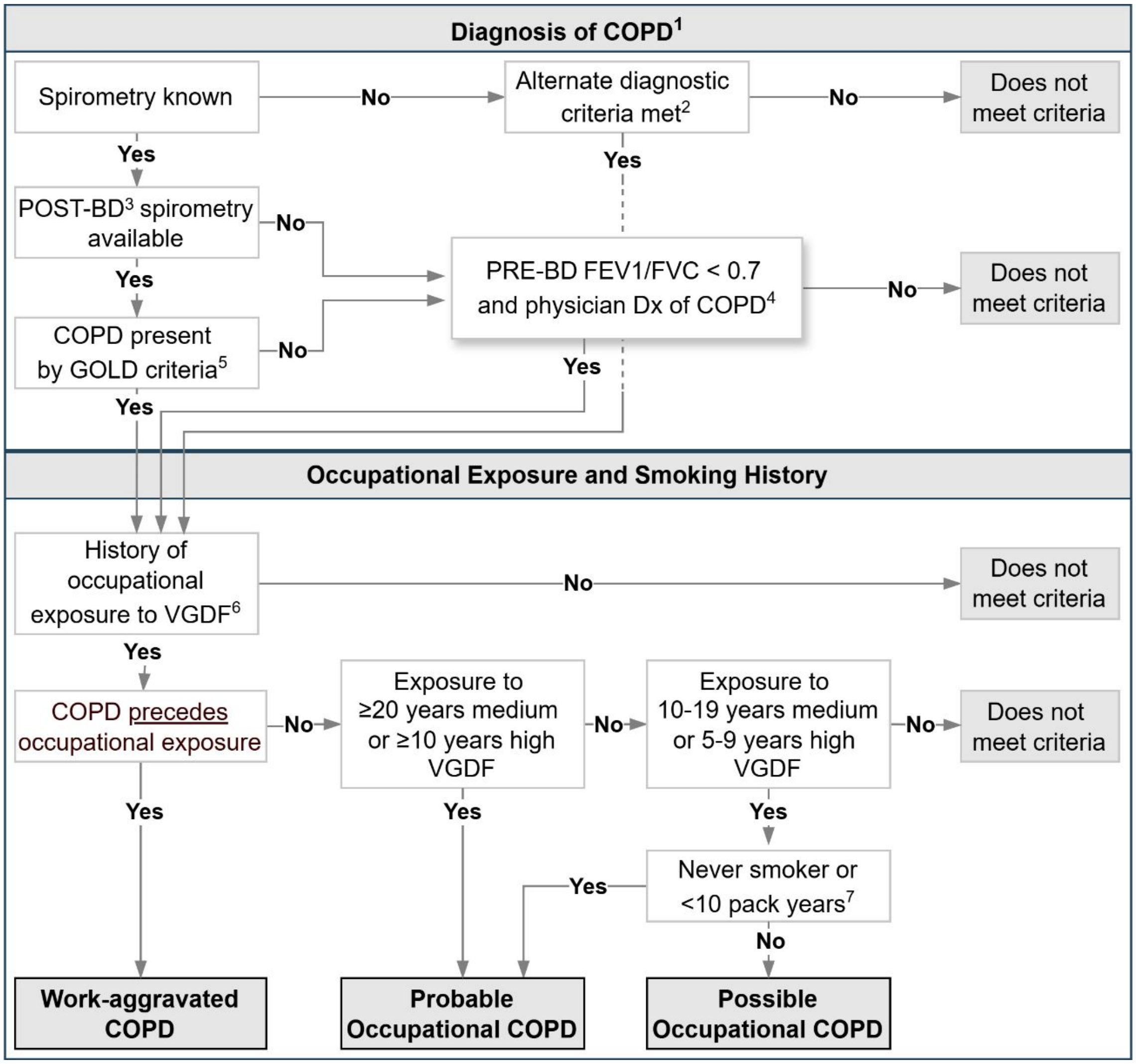
Figure 1: Surveillance Algorithm for Occupational COPD



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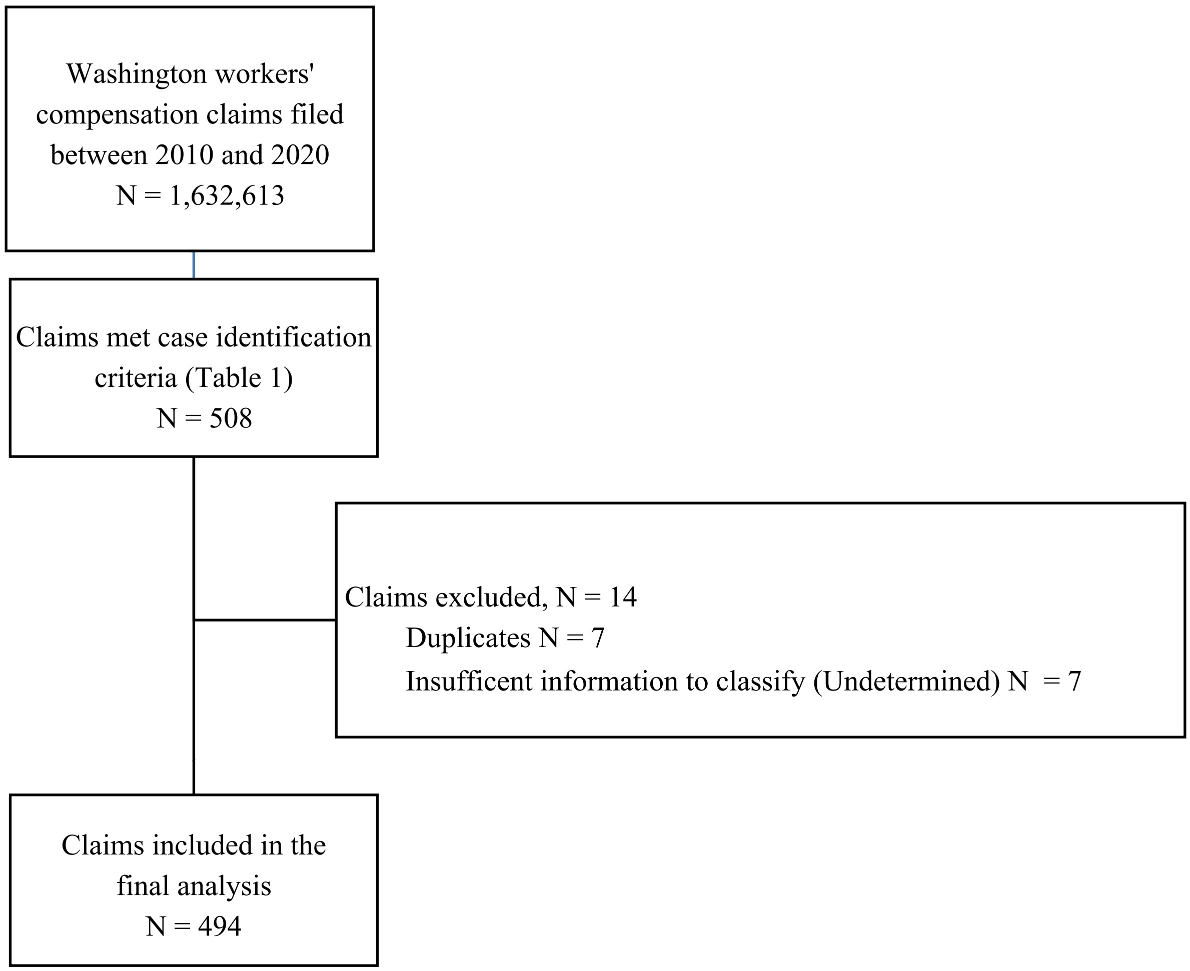


Tables

Table 1. Case identification criteria for potential COPD cases

Criteria	Description
ICD-10-CM [a]	
J40	Bronchitis not specified as acute or chronic
J41	Simple and mucopurulent Chronic Bronchitis
J42	Unspecified Chronic Bronchitis
J43	Emphysema
J44	Other Chronic Obstructive Pulmonary Disease
ICD-9-CM	
490	Bronchitis not specified as acute or chronic
491	Chronic Bronchitis
492	Emphysema
496	Chronic Airway Obstruction NEC
AND	
Keywords [b]	
COPD	Chronic obstructive pulmonary disease
Bronchitis	Includes acute, chronic or unspecified
Emphysema	n/a
OR	
OIICS code [c]	
340 (accident)	Exposure to caustic, noxious, or allergenic substances, unspecified
341 (accident)	Inhalation of substance
1440 (nature)	Chronic obstructive pulmonary disease and allied conditions, unspecified
1449 (nature)	Chronic obstructive pulmonary diseases and allied conditions, n.e.c.

[a] International Classification of Diseases, Clinical Modification. Version 9 applies to claims submitted prior to 2015, Version 10 applies to claims beginning in 2015. Sub codes are included.
[b] Includes misspellings
[c] Occupational Injury and Illness Classification System codes, sub codes are included.

Table 2. Alternate Diagnostic Criteria for COPD Diagnosis

COPD CONFIRMED IF ANY OF THE THREE CRITERIA ARE MET
Physician diagnosis of COPD plus classic symptoms (cough, dyspnea, wheeze, bronchitis, or exacerbations)
If spirometry report was not available to reviewers, a statement by a specialist that spirometry is consistent with COPD
Imaging reports consistent with emphysema

Table 3: Characteristics of confirmed COPD cases by occupational COPD classification

Characteristic	**Total (N = 494)**	**Work-Aggravated COPD (N = 56)**	**Probable Occ. COPD (N = 72)**	**Possible Occ. COPD (N = 4)**	**Unlikely Occ. COPD[a] (N=362)**
Age Group[years] [mean (SD)]	50.18 (14.13)	57.96 (7.83)	62.11 (10.24)	60.5 (3)	46.48 (13.79)
Age missing (n)	1	0	0	0	1
Male n(%)[b]	337 (68%)	34 (61%)	64 (89%)	3 (75%)	236 (65%)
Spirometry [mean (SD)]					
FEV1/FVC	0.68 (0.14)	0.5 (0.08)	0.54 (0.12)	0.52 (NA[c])	0.75 (0.09)
Ratio data missing n(%)	310 (63%)	47 (84%)	18 (25%)	3 (75%)	242 (67%)
FEV1 [L]	2.45 (0.89)	1.81 (0.66)	1.92 (0.68)	1.3 (NA[c])	2.75 (0.85)
FEV1 data missing n(%)	321 (65%)	47 (84%)	22 (31%)	3 (75%)	249 (69%)
FVC [L]	3.63 (1.05)	3.35 (0.97)	3.58 (1)	2.52 (NA[c])	3.68 (1.07)
FVC data missing n(%)	325 (66%)	48 (86%)	22 (31%)	3 (75%)	252 (70%)
Smoking Status [n (%)]					
Never Smoker or <10years	124 (25%)	2 (4%)	17 (24%)	0 (0%)	105 (29%)
Current or Former Smoker (≥10 years)	141 (29%)	34 (61%)	54 (75%)	4 (100%)	49 (14%)
Smoking Pack Years [Median (IQR)]	10 (30)	30 (21.25)	23 (30)	35 (14.75)	1 (15.75)
Smoking Status or Pack Years Missing	229 (46%)	20 (36%)	1 (1%)[f]	0 (0%)	208 (57%)
Median Career Exposure to Med and/or High VGDF [years (IQR)][d]	3 (17.88)	0.92 (3.96)	30 (13.5)	15 (4.69)	1.5 (9.98)
Job of Injury used as a surrogate for Career Exposure Duration n(%)[e]	251 (51%)	30 (54%)	15 (21%)	2 (50%)	204 (56%)
Both career and job of injury tenure missing n(%)[e]	15 (3%)	2 (4%)	0 (0%)	0 (0%)	13 (4%)

COPD = Chronic Obstructive Pulmonary Disease, FEV1 = forced expiratory volume over 1 second; FVC = forced vital capacity, VGDF = vapor, gas, dust or fume exposure

[a]"Unlikely" cases do not meet criteria for COPD diagnosis or exposure history

[b]No data missing

[c]NA indicates not enough data available for calculations

[d]Defined as duration spent in an occupation with medium or high exposure to VGDF

[e]Includes cases missing work history in an occupation with medium or high exposure to VGDF beyond the job of injury or cases whose full career in a medium or high exposure occupation was spent at the job of injury. For cases with no time spent in an occupation with medium or high exposure, career duration was considered zero.

[f]Career duration in an occupation with medium VGDF exposure was 20 years, which qualifies for Probable COPD regardless of smoking history.

Table 4. Exposures and Occupations of COPD cases with a < 10 pack-year smoking history

USCB Occupation	**Common Exposures** [a]
Probable Occupational COPD with < 10 pack-year smoking history (n=17[b])	
Welding, Soldering, and Brazing Workers (n=4)	Welding Fume; Dust; Fiberglass; Cutting Oils; Metal Dust; Welding
Painters, Construction and Maintenance (n=2)	Dust; Asbestos; Crystalline Silica; Drywall Mud; Epoxy Paint; Zinc Compounds
Production Workers, All Other (n=2)	Fiberglass; Crystalline Silica; Quartz Dust; Rock; Metal Dust; Welding Fume; Glues; Wood Dust; Asphalt
Automotive Service Technicians and Mechanics (n=1)	Dust; Solvents; Diesel Exhaust; Mold; Antifreeze
Dental Assistants (n=1)	Dust; Epoxy Resins; Polymers; Glues; Disinfectants
Fire Fighters (n=1)	Dust; Smoke
Grounds Maintenance Workers (n=1)	Heavy metals; Welding fume; Diesel fuel
Industrial Truck and Tractor Operators (n=1)	Silica Crystalline
Industrial and Refractory Machinery Mechanics (n=1)	Ammonia
Logging Workers (n=1)	Crystalline Silica; Ash
Millwrights (n=1)	Asbestos; Copper; Metal Dust; Paper Dust
Operating Engineers and Other Construction Equipment Operators (n=1)	Asbestos; Cement Dust; Smoke; Diesel Exhaust; Diesel Fuel
Work aggravated COPD with < 10 pack-year smoking history (n=2)	
Dishwashers (n=1)	Cleaners Detergent; Smoke; Carbon Monoxide
Production Workers, All Other (n=1)	Dust; Paint

COPD = Chronic Obstructive Pulmonary Disease, USCB = United States Census Bureau

[a] Exposures were coded using the Association for Occupational & Environmental Clinics (AOEC) system.

[b] N=7 had 0 pack years. No cases of Possible Occupational COPD had known smoking history < 10 pack-years.

Table 5. Common occupations, JEM classification, and Job-of-injury duration in cases with medium or high exposure to VGDF, by study group

USCB Occupation Code (grouped)	N	High VGDF Exposure	Medium VGDF Exposure	Low VGDF Exposure	Job-of-injury duration, n[a] (Med)[IQR]
Probable Occupational COPD	72	46	26	0[b]	71(14)[15.86]
Production	28	17	11	0	27(15)[9.06]
Construction & extraction	17	16	1	0	17(10)[13]
Installation, maintenance, & repair	10	6	4	0	10(18.09)[14.23]
Transportation & material moving	7	0	7	0	7(4.83)[24.91]
Protective service	2	2	0	0	2(30.46)[0.54]
Architecture & engineering	1	0	1	0	1(1.08)[0]
Building & grounds cleaning & main tenance	1	1	0	0	1(30)[0]
Community & social service	1	1	0	0	1(29)[0]
Farming, fishing, & forestry	1	1	0	0	1(7)[0]
Food preparation & serving related	1	0	1	0	1(13)[0]
Healthcare support	1	0	1	0	1(22)[0]
Legal	1	1	0	0	1(2)[0]
Personal care & service	1	1	0	0	1(25)[0]
Possible Occupational COPD	4	0	4	0[a]	4(10.12)[2.17]
Transportation & material moving	3	0	3	0	3(10.23)[4]
Production	1	0	1	0	1(10)[0]
Work-aggravated COPD	56	17	21	18	54(2.71)[9.04]
Production	10	4	6	0	10(2.12)[11.75]
Transportation & material moving	10	2	8	0	10(2.79)[2.69]
Office & administrative support	8	0	0	8	8(7.79)[9.69]
Building & grounds cleaning & maintenance	6	6	0	0	6(2.04)[2.61]
Food preparation & serving related	6	1	5	0	5(1.92)[3.5]
Construction & extraction	4	3	0	1	4(5.29)[11.21]
Installation, maintenance, & repair	3	1	2	0	3(2)[6.66]
Sales & related	3	0	0	3	2(9.34)[2.67]
Healthcare support	2	0	0	2	2(13)[10.33]
Community & social service	1	0	0	1	1(3)[0]
Healthcare practitioners & technical	1	0	0	1	1(0.42)[0]
Life, physical, & social science	1	0	0	1	1(5.92)[0]
Personal care & service	1	0	0	1	1(2.03)[0]
Unlikely Occupational COPD[c]	362	169	112	80	345(2.67)[7.4]
Total	494	232	163	98	474(3)[11.17]

JEM = Job Exposure Matrix, VGDF = vapors, gases, dusts and fumes, USCB = United States Census Bureau, COPD = Chronic Obstructive Pulmonary Disease

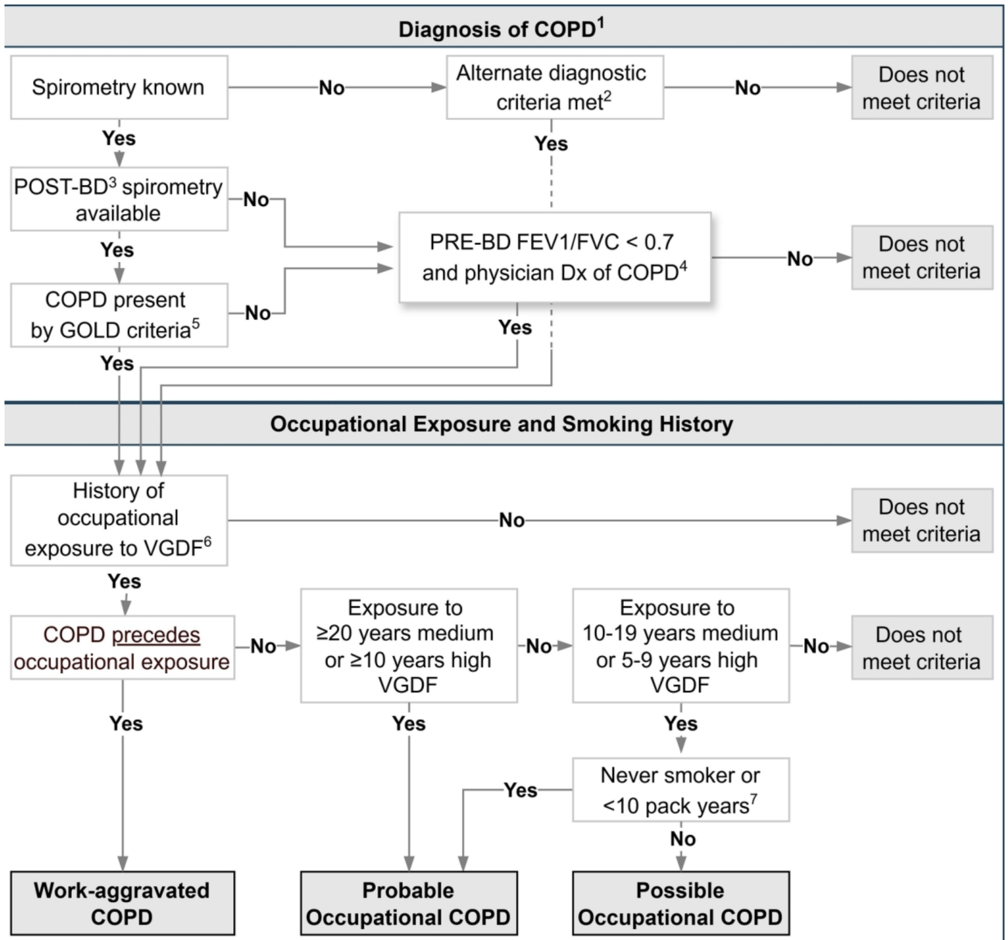
[a]Job of injury duration was missing for 1 probable, 2 work aggravated, and 17 unlikely cases.
[b]As defined in the algorithm, cases of Possible COPD or Probable COPD are defined based on time in an occupation with medium or high exposure to VGDF.

[c] One claim in the 'Unlikely COPD' study group had no occupational information available and is therefore missing a JEM value

Table 6. Commonly reported exposures grouped by COPD classification

Exposure Category[a]	Work-aggravated COPD (56 cases)	Probable/Possible Occ. COPD (76 cases)	Unlikely Occ. COPD[c] (362 cases)	Total (494 cases)
Mineral and inorganic dust, other	11 (20%)	63 (83%)	21 (6%)	95 (19%)
Miscellaneous chemicals	11 (20%)	13 (17%)	12 (3%)	36 (7%)
Metals and metalloids, other	2 (4%)	30 (39%)	2 (1%)	34 (7%)
Solvents, NOS	6 (11%)	21 (28%)	7 (2%)	34 (7%)
All other chemicals	14 (25%)	11 (14%)	6 (2%)	31 (6%)
Plant material	3 (5%)	11 (14%)	13 (4%)	27 (5%)
Cleaning materials	15 (27%)	3 (4%)	5 (1%)	23 (5%)
Exhaust and pyrolysis, other than diesel	7 (13%)	8 (11%)	8 (2%)	23 (5%)
Welding exposures	0 (0%)	15 (20%)	7 (2%)	22 (4%)
Silica, crystalline	1 (2%)	15 (20%)	1 (0%)	17 (3%)
Animal material and microorganisms	5 (9%)	4 (5%)	7 (2%)	16 (3%)
Diesel exhaust	3 (5%)	9 (12%)	1 (0%)	13 (3%)
Petroleum derivatives, other	0 (0%)	9 (12%)	1 (0%)	10 (2%)
Acids, bases and oxidizing agents	1 (2%)	4 (5%)	3 (1%)	8 (2%)
Hydrocarbons, other	2 (4%)	5 (7%)	0 (0%)	7 (1%)
Gases	3 (5%)	3 (4%)	0 (0%)	6 (1%)
Total Exposures [b]	84	224	94	402

[a] Exposures were coded using the Association for Occupational & Environmental Clinics (AOEC) system.
[b] Cases can have up to five coded exposures, therefore total exposures will exceed the number of cases.
[c] Due to missing information, exposure was coded for 26% of Unlikely cases



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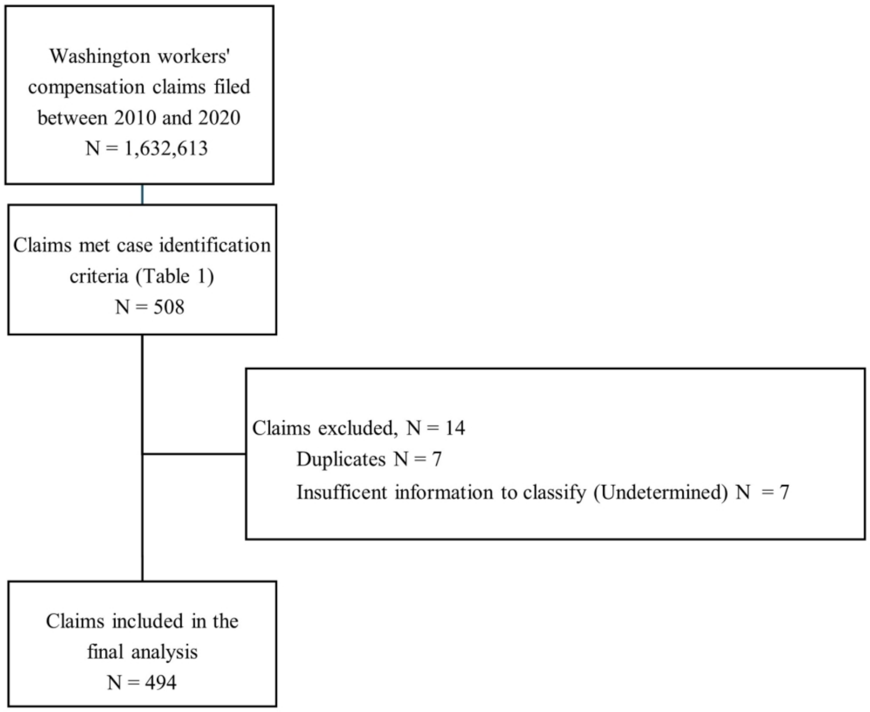

Figure 2: Analysis profile with reasons for exclusion.

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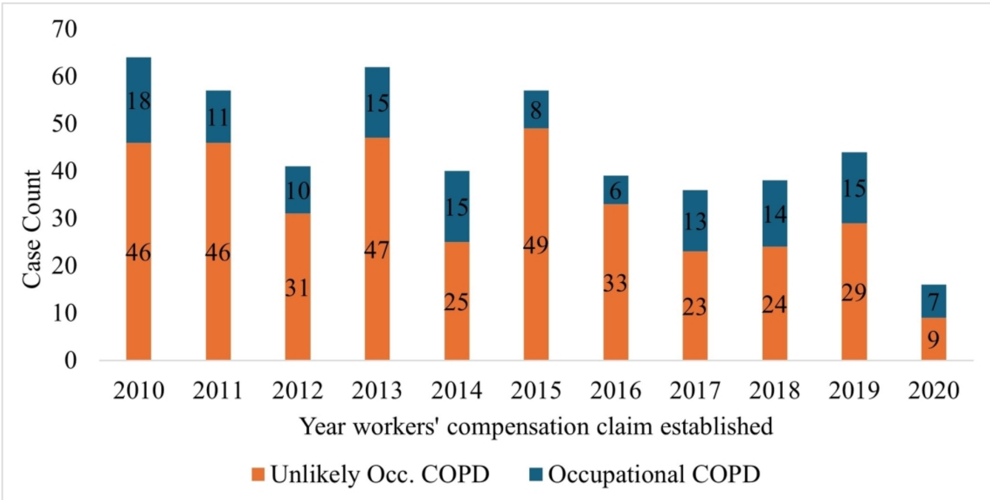

Figure 3: Occupational COPD and Unlikely Occupational COPD case counts by claim established year
COPD = Chronic obstructive pulmonary disease

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