



Social determinants of an occupational lung disease: Workers' narratives on silicosis



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ABSTRACT

Silicosis is a preventable occupational lung disease caused by inhaled silica dust. Solutions to prevent silicosis ranging from engineering controls to respirator use have been validated for nearly a century, but many workers are still at-risk of this preventable disease. We characterized how the physical, social, and institutional environments contribute to silicosis and health disparities. Using semi-structured interview responses from people living with silicosis in Wisconsin, U.S., we inductively coded participants' experiences from occupational exposure to navigating healthcare and assistance. Codes explaining the data patterns and research questions were constructed into three themes: 1) "Education and Labor Market Relationships Converge to Increase Silicosis Risk" describes how educational attainment and employment arrangements contribute to silicosis risk, 2) "On the Job" describes work-relatedness of silicosis and how organizational cultures and socialized masculine norms influence prevention, and 3) "Off the Job" illustrates how structural barriers obstruct workers' access to care and assistance when they have silicosis. Findings illustrated that institutions and sociocultural values can lead to inequitable distribution of occupational risks and mitigation resources relating to silicosis, including access to healthcare and worker's compensation, and they compound to worsen health inequity. In demonstrating how multiple socio-economic forces perpetuate and minimize silicosis risk, we show that work is a social determinant of health. We further highlight that qualitative data can enhance public health surveillance by contextualizing people's experiences of disease.

1. Introduction

Work is a major social determinant of health. The occupational health and safety field has made progress demonstrating adverse health outcomes of harmful occupational exposures such as toxins, ergonomic hazards, and psychosocial stress. Many of the published studies in the occupational health and safety literature quantitatively describe workplace exposures and disease relationships; however, for conditions such as silicosis, traditional epidemiologic analyses may not reveal the complex contributing social factors. Silicosis, a preventable and often fatal lung disease, is caused by inhaling respirable crystalline silica, a carcinogenic substance commonly produced by cutting, grinding, and sandblasting silica-containing materials including concrete, stone, and asphalt (National Toxicology Program, n. d.; Shahbazi et al., 2021). Workers handling silica materials without protection are at risk for silicosis, including approximately 2.3 million in the U.S. (Leung et al., 2012; OSHA, 2016). The hazards associated with silica exposure have been

known for about a century, notably since Dr. Alice Hamilton, a pioneering occupational medicine physician, documented silicosis among stone workers (Derickson, 1988; Greenberg et al., 2007; Hamilton, 1943; Shahbazi et al., 2021), yet silicosis remains a public health concern.

Public health surveillance of occupational diseases often relies on administrative datasets (e.g., census data, hospital records, vital statistics) that describe risk and disease burden through quantitative measures (e.g., prevalence, rates). However, this approach has two inherent limitations. First, administrative datasets are generated by institutions whose resources and services are not inclusive of all populations. For example, immigrant workers are overrepresented in occupations with high rates of disease and injury (Fan & Qian, 2017; Grzywacz et al., 2012; Torres et al., 2013) but are underserved in social programs and healthcare (Hacker et al., 2015; Nakphong et al., 2022). Second, administrative data seldom include social conditions that influence the distribution of health risks and outcomes. Thus, current epidemiological approaches may not fully account for all populations at risk and key factors contributing to those

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risks. Thus, there is a need to incorporate qualitative data into studies of occupational diseases to contextualize multilevel contributing factors. This aligns with the recent call-for-action by the National Institute for Occupational Safety and Health (NIOSH), a U.S. federal agency tasked to protect workers, which recommends a paradigm shift to inclusively examine work-related disease and injury by adding a social science lens into epidemiological studies (Flynn et al., 2022).

In this paper, we use qualitative data to situate workers' experiences of silicosis within the macro, mezzo, and micro (community/government, group, individual level, respectively) social forces affecting worker health. Using semi-structured interview responses from retired workers living with silicosis, we provide examples of how social forces shape workers' risks across all stages of their working life. Our study aims to fulfill two objectives. First, we seek to shed light on confluent forces that perpetuate this well-understood, preventable occupational disease. Second, we offer this specific example of silicosis as a general illustration of how the physical, social, and institutional environments of work intersect to make work a social determinant of health and a significant driver of health disparities.

1.1. Silicosis

Two million out of the 2.3 million U.S. workers at risk of silicosis work in construction (Center for Construction Research and Training, 2018). Historically, workers in the building and manufacturing industries such as construction, foundry, and mining are at high risk for developing chronic silicosis (Greenberg et al., 2007; Leung et al., 2012). Chronic silicosis has a latency of 10 or more years after prolonged exposure to relatively low levels of silica. In addition, epidemiological studies have reported that workers exposed to very high levels of silica can suffer accelerated or acute silicosis within 5–10 years after initial exposure (OSHA, 2016). Recently, accelerated silicosis has been reported among workers cutting, finishing, and installing engineered stone countertops (Heinzerling et al., 2021; Rose et al., 2019). Engineered stones are produced by mixing quartz, polyester resins, and pigments, and they are composed of more than 90% silica compared to 10–45% in natural granite, and 3% in marble (Leso et al., 2019; OSHA & NIOSH, 2015). While emerging accelerated silicosis is concerning, workers of the traditional building trades remain at risk for chronic silicosis compared to all industries.

1.2. Prevention strategies

Silicosis has been recognized as an occupational disease in the U.S. since the 1920s (Center for Construction Research and Training, n. d.). Much of the evidence-based dust mitigation measures identified during the early 1900s are relevant today (Flanagan et al., 2003; Meeker et al., 2009; NIOSH, 1997, 2019). These approaches include: 1) eliminating silica materials; 2) removing silica dust through engineering designs (e.g., closed workstations, dust collection systems); 3) monitoring the work environment and worker health by implementing administrative controls (e.g., air sampling, job reassignment, medical surveillance); and 4) maintaining a written respiratory program to further reduce dust exposure (e.g., training, fit test, providing respirators). In addition to workplace interventions, Occupational Safety and Health Administration (OSHA) reduced the permissible exposure limit of silica dust to 0.05 mg/m³ for an 8-h time weighted average workday (OSHA, 2016). The revised OSHA standard also requires employers to medically monitor exposed workers' pulmonary health.

1.3. Theoretical framework and analysis approach

While advancements have been made to identify exposure pathways and develop prevention strategies, many workers remain at risk of silicosis and further efforts are needed to address the contributing social conditions. Several authors have recently noted that the “traditional

disease-exposure approach” that dominates occupational health research is “not equipped to address the social contexts in which work is embedded” (Flynn et al., 2022; Fujishiro et al., 2021). Both Fujishiro et al. (2021) and Flynn et al. (2022) note that greater understanding of the social context of work is imperative for understanding, and ultimately alleviating, health disparities and inequities. At a macro level, Fujishiro et al. (2021) call for a political economy approach which highlights the sorting of populations of workers into different risk environments, as well as the resources and constraints they face within those environments. Closer to the micro level, Flynn et al. (2022) propose wider use of a “biopsychosocial paradigm” of the “social arrangements” of work to better understand how those social arrangements on worksites can contribute to risk.

We draw from both approaches to examine workers' occupational experiences. Specifically, we applied these frameworks to explain the meanings and relationships among inductively constructed codes. The theme, “Education and Labor Market Relationships Converge to Increase Silicosis Risk”, highlights political economy relating to labor force stratification and market differentiation that likely assign certain demographic groups jobs with high silica exposure but low levels of protection. “On the Job” examines workers' silica exposure and how workplace cultures, such as lack of organizational controls and socialized masculine norms, propagate inadequate protection. This section elucidates how health and safety regulations are variously applied across work environments and how that is reflected in workplace cultures and narratives. Our final theme, “Off the Job”, explores how structural barriers obstruct workers' access to healthcare and worker's compensation when they have silicosis.

2. Methods

We used a validated approach of reviewing hospital discharge and emergency room visit records during 2019–2021 to identify silicosis patients (Rosenman et al., 2001). Medical records from Wisconsin rural and metropolitan hospitals ranging from 25 to 900 beds were abstracted to verify silicosis diagnosis, work history, and other information relevant to this study. Patients diagnosed with silicosis who were under 75 years of age were interviewed by phone to characterize silica exposure, prevention measures, and access to healthcare and worker's compensation. This inclusion criteria allowed the identification of accelerated and chronic silicosis patients. Four call attempts were made to follow up with patients. This study was part of Wisconsin Department of Health Services' public health surveillance on reportable occupational lung diseases that has received approval from the Institutional Review Board at the University of Wisconsin – Madison. The first author explained the study objectives to and obtained verbal informed consent from interviewed patients (hereinafter participants) prior to conducting each interview.

Participants were asked open-ended questions about their occupational history, silica prevention (e.g., engineering controls, administrative controls, personal protective equipment (PPE) utilization), and access to social services and assistance programs. They were also asked closed-ended questions about silicosis diagnosis, respiratory symptoms, worker's compensation claims, educational attainment, and cigarette smoking history. Phone interviews were not recorded to minimize participants' discomfort relating to having their discussions about health recorded. The first author transcribed each interview live with as much verbatim text as possible, except for filtered words (e.g., ah, hmm), pauses, and descriptions of specific medical procedures since the study focused on characterizing occupational experiences. We summarized close-ended responses using descriptive statistics and thematically analyzed open ended responses.

We used an inductive approach to stay close to participants' interpretations of their experiences of occupational exposure and navigating healthcare and financial assistance systems (Braun & Clarke, 2006, 2012). The first author was closely involved in collecting and coding the data. The research team reviewed the codes and themes.

Codes indicated meaningful data patterns were condensed into categories. Categories reflected thematic relationships and answering the research questions were developed into themes. The first theme encompasses codes relating to participants' educational attainment (e.g., some high school training, high school graduate), employment arrangement (e.g., small/rural companies, big/urban companies, self-employed), and citizenship (e.g., immigrants). The second theme contains codes relating to work environments (e.g., foundry, construction), tasks performed (e.g., sandblasting, cutting cement blocks), unavailability/availability of silica dust prevention (e.g., "no protection", ventilation systems, respirators), attitudes toward prevention (e.g., refusing/wearing respirators), and organizational influences on prevention (e.g., safety meetings, safety incentives). The third theme includes codes about healthcare and worker's compensation (e.g., clinicians' lack of awareness about silicosis, burden to prove work relatedness).

Approaches employed to achieve analytic reliability included verifying consistency in code development by recoding a sample of transcripts (Elliott, 2018), reviewing codes within text units, refining codes, and documenting analytical reflections (Blair, 2015). Reflections included self-reminder of holding preconceptions and anticipating seeing expected and unexpected findings during coding. Our methods were intended to understand structural contributors of silicosis, and our success in identifying multilevel factors from the data led us to believe that our analytical processes were valid.

3. Results

Among the 56 patients that met the inclusion criteria, 46 cases (82%) were classified as White, five (9%) as Black, and five (9%) as Hispanic. Fifteen (27%) of the 56 patients participated in an unpaid phone interview lasting 20–60 min during April–May 2022. The remaining patients were either unreachable due to missing contact information (46%), unresponsive to phone calls (16%), deceased (7%), or declined an interview (4%). Many participants had worked in construction (40%) and foundries (33%), and one participant (7%) each had employed in sand mining, automotive maintenance, transportation, and food-manufacturing. Participant median age was 64 years old, and they were all male, with racial/ethnic distribution as follows: ten (67%) White, three (20%) Black, and two (13%) Hispanic/Latino. Of the five silicosis patients classified as Hispanic in the hospital data, one self-identified as an immigrant and was interviewed in Spanish, one was lost to follow-up after briefly mentioning during an initial call that he was a foundry worker and was experiencing lung problems, and three were unable to reach. Thirteen (87%) participants primarily spoke English and two (13%) participants spoke Spanish and limited English. Eleven (73%) participants completed high school and four (27%) didn't provide information on schooling. Thirteen (87%) participants confirmed living with silicosis while two (13%) participants stated having chronic obstructive pulmonary disease despite their medical records documenting silicosis as one of the health conditions. Seven (47%) participants filed and received worker's compensation, six (40%) didn't file a claim for this support, and two (13%) didn't provide information on claims filed.

3.1. Education and Labor Market Relationships Converge to Increase Silicosis Risk

Because chronic silicosis generally manifests after decades of exposure, participants were asked to reflect on their work histories, including various work assignments involving dust throughout their careers. Thirteen (87%) of the 15 participants conveyed that they started working in the construction and foundry industries either during or after high school while the other two (13%) entered these trades after military service. All participants remained in the building trades throughout their careers and were exposed to multiple hazards including silica, asbestos, and chemicals. Nonetheless, participants felt sense of pride to have had started working early: "I had been doing masonry work since I was 14

years old ... I was a journeyman for 20 years. I got my union card at 20 years old" (Participant 9 – Mason). He went on to describe being exposed to silica across jobs (e.g., cutting and installing different types of stones and cement blocks) and reiterated the prevalence of silicosis: "Again, most people that worked in the same trade of the bricklayers and the union that I worked in ..., and most [of them] have some forms of silicosis."

Participants also highlighted the types of firms they worked for, in relation to risk of exposure. Labor market relationships identified from the interviews are employment status (i.e., self-employed versus employed), operation size, and job location. Participants discussed being exposed in various occupational settings, including when working for large operations. However, self-employment and work with smaller and more rural firms were repeatedly highlighted as involving greater risk. One participant who was a self-employed sandblaster disclosed that he had worked with his father in sandblasting: "We didn't have insurance, didn't have masks. [Company A] has brochures about dust risks. They have a lot of workers Big companies have information like that" (Participant 7 – Sandblaster). He further stated that his father died of silicosis, and he is fighting the same disease.

Similarly, a participant of the construction trade characterized the complex interplay between working in rural versus urban areas and large versus small companies: "I live in a small town. The companies out here are small companies. The large companies have more standards as they're keeping up with the OSHA standards" (Participant 2 – Construction Worker). He perceived that large companies under OSHA jurisdiction are incentivized to provide workers safety resources including PPE to reduce occupational risks. In contrast, many businesses in rural communities tend to employ less than 10 workers and are exempt from reporting work-related injuries and illnesses to OSHA. Participants felt that the intricate dynamics between work location, employment size, and regulatory system shape the extent to which their work is legally protected.

The inequitable distribution of high-risk jobs by race, ethnicity, and citizenship status could not be pinned down in our data, given that participants were overwhelmingly White non-Hispanic, and we did not ask about citizenship or immigration status. The one Spanish worker interviewed stated that he had worked in construction and sandblasting. In addition to silicosis, he is having trouble accessing affordable health care for other health problems.

Nonetheless, the possibility of stratifying risks by race/ethnicity was noted by a White-male foundry participant. He related:

"The foundry job is a job not many will take. I worked with many Mexicans ... They'd do any job. ..., White guys don't want to do some of the jobs. It's so hot, over 100° inside the foundry. But, with proper PPE, Mexicans will work in hot and cold conditions." (Participant 11 – Foundry Worker).

Participant 11's comments are limited in that they are a generalization made by an outside observer. It is unlikely that all the presumably Hispanic co-workers he described were from Mexico (our single Spanish language participant was not), that they would say they're willing to "do any job" or that they took the foundry job primarily because they "want to." Despite these important limitations, his comments highlight the plausible stratification of risks by race/ethnicity in the workplace.

3.2. On the job: the organizational context for silica exposure

Participants described working in various environments where silica dust prevention was either nonexistent or insufficient. Jobs involving silica dust included sandblasting, cleaning up around metal melting docks and furnaces in foundries, cutting concrete blocks and stones in construction projects, and operating drills in sand mines. Other jobs with possible silica exposure included cleaning up painting sites in an automotive body shop, cleaning grain bin storage in a brewery, and dumping rocks onto railroad tracks from carts. Sandblasting was one of the

common exposure pathways our participants reported, and it occurred in many settings, for example: “I sandblasted blocks, brick buildings, concrete buildings, houses having asbestos, and water towers” (Participant 7 – Sandblaster).

Across silica-prone industries, exposure was prevalent and severe in the building and manufacturing trades. Participants who used to work in construction stated that they were exposed to “a lot of concrete dust” (Participant 4 – Construction Worker), especially early in their careers when few protection measures were implemented. Furthermore, the severity of exposure heightened when they were assigned to work in poorly ventilated settings without any dust containment:

“The underground parking project, that was the worst. No ventilation. I couldn’t even see the guys next to me. That was about two years. I set up about 1000 door frames in the building. They were grinding concrete down there. There was all the dust.” (Participant 4 – Construction Worker).

“I mixed sand, shoveled sand, shoveled dirt, and shoveled metal. I was on a cleanup crew for about 15 years. That was working in extreme conditions. Sometimes [I] was even working when the motors were running; it was so black in the basement. You hardly can see 3 feet away. I wore a paper respirator.” (Participant 8 – Foundry Worker).

Inadequate protection coupled with excessive exposure duration can magnify silicosis risk. For example, a sandblaster participant described that engineering controls and PPE failed to fully protect him when working long shifts: “Sometimes I could have a full day of sandblasting. I got a [protective] hood. But the microscopic dust still is going to come through the hood or the PPE, so you don’t really get 100% protection” (Participant 2 – Construction Worker).

Participants stated that workers are reluctant to voice concerns of unsafe working conditions for fear of losing their jobs. As one of the construction participants explained: “My line of work involved concrete dust all the time. No protection was in place Employees don’t want to report because they don’t want to get fired ... I wanted to be a good employee; the boss wanted me to do something, no questions asked, I just did it. That’s why they kept me.” (Participant 6 – Construction Worker).

Among employers that implemented dust controls, their interventions may have been too late or inadequate to protect some workers. One participant who did sandblasting shared that “Just before I left, they started a makeshift doing the stuff [to reduce dust]. When I first got there, there were no dust controls” (Participant 3 – Malted Grain Worker).

Among industries represented in this study, large foundries were reported by workers to have implemented some elements of engineering and administrative controls during their time on the job, but those measures were delayed and inadequate. Two retired foundry workers stated that in recent years their employers utilized enclosure and exhaust systems to contain airborne dust, replaced silica sand with less hazardous materials, and reassigned exposed workers to low-exposure positions (Participants 1 & 11 – Foundry). However, workers still reported exposure under these improved conditions: “They transferred me to the lab testing metals and sand, but I was still exposed ...” (Participant 5 – Foundry Worker). In addition, poorly designed controls (i.e., ineffective ventilation systems) can intensify exposure by generating airborne silica dust, as participant 11 stated: “As fans were turned on, they stirred up dust, and you breathe in dust again” (Participants 11 – Foundry Workers).

Lack of organizational commitment in applying engineering and administrative controls to mitigate silica dust was further revealed in the exclusion of silicosis risk from a workplace culture of health and safety. When asked directly how employers responded to silica dust, participants reported that they either downplayed or excluded it from discussions of safety culture and practices. For example, one participant with a foundry work history recalled that “Nobody mentioned it [silica dust] in the safety meeting” (Participant 8 – Foundry Worker). Instead, employers prioritize reducing acute safety hazards that directly impact production,

for example, another foundry participant stated that “The years I spent there; we’d be rewarded for being safe; we set goals for not losing manpower and had safety awards” (Participant 11 – Foundry Worker).

In some cases, workplace safety culture was not merely selective, but actively subverted or rejected. For instance, a participant of the construction trade reported that they were given bonuses for completing projects early, discouraging workers to spend time on implementing safety practices. Participants also pointed to the ways that industry safety culture is organizationally eschewed in smaller, lower resource operations, often by employing anti-safety masculinity norms.

“The small companies with 2, 5, or 8 guys, they are “old school”, have their macho, and think [wearing PPE] is weak. The big ones do the PPE. The smaller guys, they think that they’re tough guys and don’t need [protective] equipment. But they still breathed in dust, even working outside.” (Participant 2 – Construction Worker).

In addition, participants suggested that in male-dominant industries such as construction and foundry work the culture is closely intertwined with masculine identities of independence and strength that influence compliance with occupational health and safety practices. Multiple participants highlighted that wearing a mask is stigmatized and perceived as a threat to one’s identity as a man, for example, “Real men don’t wear that [respirators] I see guys cutting concrete now not wearing any respirators” (Participant 4 – Construction Worker).

While the language of “tough guys” and “real men” implies that workers were fully aware of risks and chose to accept them, participant accounts instead point to the absence of silicosis risk information and signaling on the job. Whether their organization had an injury-centered safety culture that was silent on silicosis risk, or a culture that stigmatized safety concerns altogether as “unmanly”, workers operated under conditions that normalized silica exposure and problematized individual efforts of taking preventative measures.

3.3. Off the job: structural barriers impede access to treatment and compensation

The dynamics noted thus far fused to make it particularly difficult for workers with silicosis to effectively access treatment and financial support for their occupational injuries. Institutional minimization of chronic conditions was reflected in medical providers’ ignorance of silicosis. Several participants stated that they had visited multiple physicians before finding one that was aware of silicosis. They described the unfamiliarity as “it wasn’t talked about as much” and felt that many physicians “didn’t know it” (Participant 2 – Construction Worker).

In some instances, workers felt that the medical and insurance establishment shared industry’s active denial of silicosis risk. For example, one participant who used to sandblast grain storage and shipping containers in a brewery believed that a worker’s compensation specialist intentionally misdiagnosed him as not having silicosis. He stated that, “My doctor [worker’s compensation specialist] said I had emphysema, but my biopsy report and my main doctor told me I have silicosis. I knew I have silicosis, they never mentioned silicosis. I read the biopsy report; I asked them to read the report; they wouldn’t say the word *silicosis*” (Participant 12 – Sandblaster). These statements indicate that workers are burdened by institutional bureaucracy to demonstrate work-relatedness of silicosis while it has long been recognized as an occupational disease. The same frustration was experienced by multiple participants who viewed this responsibility as questioning their honesty. For example, “I ended up hiring a worker’s compensation lawyer and had to prove that it was work-related” (Participant 10 – Sand Mine Drill Operator). Another participant narrated:

“There’re a lot of people with lung problems related to work. I never smoke, never done nothing. This is definitely work-related.... I wish I wouldn’t have to work so hard to prove this. It’s not rare. I go to the

gym, I run, I don't even take an aspirin. My lung doctor said this is not work-related." (Participant 6 – Construction Worker).

Among participants claiming worker's compensation, all stated that they worked with attorneys on their requests, and almost all their first claims were dismissed because of the lack of occupational histories in their medical records. Some foundry participants recounted that their employers arranged annual lung exams, and several were diagnosed with silicosis by their employers' occupational medicine physicians, however they too had to hire an attorney seeking worker's compensation. The difficulties in securing this assistance compelled one participant to reemphasize: "You got to tell them [doctors] it is work-related. He [the doctor] is document[ing] the stuff, when you go in, tell them it came from the job. That's where a lot of people make mistakes" (Participant 12 – Sandblaster).

Physicians' failure to medically validate the work-relatedness of silicosis has financial implications for workers: "Previous doctors denied I have silicosis, caused me not getting worker's compensation" (Participant 1 – Foundry Worker). When asked if they are seeking treatments for silicosis, one participant replied: "I don't have money to travel down to [city name] to get treatment. I only get \$600 a month" (Participant 4 – Construction Worker). Another participant stated: "I lost everything, all the earnings that I lost [I] have nothing coming in" (Participant 6 – Construction Worker). This participant further shared that he is facing food insecurity. In addition, many participants developed silicosis at their prime working age (i.e., 30–50 s years old) and are suffering from reduced quality of life and wellbeing as symptoms worsen. As one participant who was diagnosed with silicosis at age 34 described: "I am on 4 L of oxygen. In the early 2000s, I wasn't feeling very sick, and I got worse since 2017" (Participant 10 – Sand Mine Drill Operator). He has been waiting for a lung transplant.

Within the social institution of medical services and public resources for silicosis patients, there is variability in who can obtain assistance. In contrast to the participants who couldn't afford respiratory treatments; one participant who is a union member responded: "I am taking medication for it [breathing problem]. It is very expensive. I have insurance for it" (Participant 9 – Mason). He went on to describe how current inflation exacerbates financial difficulties for people on a limited income and acknowledged his relatively secure financial position:

"There's a lot of people right now on social security, they have to decide whether they are going to eat or buy medication ... It is a damned shame But I get [a] pension, get an annuity. I know people who don't have that, they have hard time to fill up gas, go to grocery stores. We are the forgotten generation." (Participant 9 – Mason).

4. Discussion

This analysis uses narratives from workers with silicosis to examine how work operates as a social determinant of health throughout one's working years. Our three main themes broadly illustrate many of the factors highlighted by Fujishiro et al.'s (2021) sociopolitical value and social institution framework.

The first theme, "Education and Labor Market Relationships Converge to Increase Silicosis Risk" illustrates education and labor market's influences on health. In our example, low educational attainment increases workers' silicosis risk by leading them into employment with silica exposure at a young age and subsequently restricting their opportunities to exit those hazardous occupations. Participants' reluctance to report workplace hazards for fear of jeopardizing job security and their decision to stay in the building trades despite known risks suggests that they have limited career mobility; an effect that has been well-documented for workers without a college degree (Bair et al., 2021, p. 28991). Participants' silicosis narratives also revealed how the labor market's "inequitable sorting systems" (Fujishiro et al., 2021) assigns low-socioeconomic status workers into work-related risk trajectories that

start at a young age and continue across their careers (Bhatia et al., 2013), resulting in "cumulative precarity" (Flynn et al., 2022). With the exception of sand mining, all participants reported working in occupations that earn less than the mean annual salary for Wisconsin (U.S. Bureau of Labor Statistics, 2021).

Even within high-risk industries or occupations, the labor market's "inequitable sorting systems" further differentiate health risk by the type of organization. Our participants noted the higher risks of exposure in smaller, rural companies. Indeed, the generally higher incidence of illnesses and injuries at small companies and the difficulties of effectively engaging them in risk-reductions (Fabiano et al., 2004; Holte et al., 2015; Masi & Cagno, 2015), are central themes in the occupational health and safety literature.

Among the many identified contributing factors to high occupational risks in small companies (Cunningham & Sinclair, 2015; Mellor et al., 2011), most are related to their marginal positions in both the economy and the occupational health and safety regulatory world (Masi & Cagno, 2015). For example, businesses employing fewer than 10 workers are classified as partially exempt industries that are not required to notify OSHA of injuries and illnesses that do not involve fatalities, hospitalization, amputation, or loss of an eye (OSHA, n. d.-c).

These small, higher-risk companies tend to overrepresent immigrant workers and workers of color (Flynn et al., 2013), who are less likely to be protected compared to workers at large companies who may have labor law enforcement and unionization. This structural disparity contributes to the disproportionate rates of immigrant workers in occupational diseases and injuries (Fan & Qian, 2017; Grzywacz et al., 2012; Torres et al., 2013). The greater percentage of works of color among our participants (20% Black, 13% Hispanic/Latino) compared to Wisconsin's population (6.8% and 7.5%, respectively), illustrates this structural disparity (U.S. Census, 2021). Even so, it is possible that our participant pool still under-represents immigrant workers relative to their silicosis risk. Institutional services' ongoing exclusion of these workers through practices including the unavailability and unaffordability of healthcare, worsens their "structural invisibility" (Flynn et al., 2022; Lever & Milbourne, 2017), as their disease burdens were excluded from public health surveillance.

Even among workers at larger, more rigorously monitored firms, weak enforcement of OSHA standards could intensify silicosis risk. This was amplified by our participants' experiences working in large foundries, settings which were noted as having low implementation of silica dust controls (Greenberg et al., 2007; Oudiz et al., 1983). OSHA's shortage of field inspectors (i.e., one inspector per 70,000 workers (OSHA, n. d.-a)) contributes to incomplete enforcement of occupational health and safety standards even in larger enterprises (Bhatia et al., 2013), and potentially reduces inspections including workplaces with imminent danger and severe hazards (OSHA, n. d.-b). This, in turn, reflects a broader set of "sociopolitical values" that limit OSHA's capacity to protect workers.

Together, educational attainment and labor market relationship are socioeconomic and political context that generate and reinforce mechanisms affecting health through stratifying and dividing populations into different risk-environments based on socioeconomic positions (Solar & Irwin, 2010). In our study, these mechanisms include career opportunities and access to workplace protection, healthcare, and worker's compensation.

The second theme, "On the Job", shows how silicosis exposures are perpetuated at the worksite, with a focus on how organizational practices put workers at risk while organizational cultures minimized workers' perceptions of risk. Workers described a variety of silicosis risk situations, with prevention measures ranging from non-existent to partially effective. Such failures have been widely documented across occupational health hazards and are enabled by the relative weaknesses of an under-resourced regulatory regime and a structurally vulnerable workforce that is unlikely to report safety violations (Centro de los Derechos del Migrante, 2020; McCallum et al., 2022). This in turn impacts workplace

cultures around occupational risk. For instance, regulators and industry compromise by focusing occupational safety and health on a narrow range of the most visible issues—acute injuries—to the detriment of silicosis and other chronic occupational diseases. Many of our participants reported that silicosis risk was absent from workplace safety discussions. At the margins of industry—e.g., small, rural, subcontracted firms, which often rely heavily on immigrant and non-unionized labor—workplace cultures can go as far as to normalize risk-taking and stigmatize health and safety behaviors, such as PPE use, as “unmanly”. The pervasiveness of such “restrictive gender norms” (Heise et al., 2019), particularly in smaller companies, was remarked on by several participants and has been noted by scholars (Forssberg et al., 2022). As Stergiou-Kita and colleagues note (2015), the combination of high-risk work itself and productivity pressures (such as those found in smaller companies and by self-employed workers) “may reinforce and institutionalize ‘masculinized’ values that discipline workers to perform at maximum physical capacity, tolerate adverse work conditions and sacrifice their bodies, their health and their safety to ‘get the job done’” (p. 218). For our participants, both the dust exposure conditions themselves and the organizational narratives around risk and protection, combined with socialized masculine values to put them in danger. These same dynamics play out for other male-dominated occupational diseases and injuries, and escalate health disparities among at-risk workers (Haji et al., 2021).

The third theme, “Off the Job”, summarizes how structural barriers impede silicosis workers' access to treatment and compensation. Silicosis is expensive both because it eventually prevents people from working and because chronic silicosis requires ongoing care. Worker's compensation is one of the few programs designed to alleviate financial burden (e.g., medical treatment, rehabilitation, disability benefits) resulting from occupational diseases and injuries. Almost all workers are eligible to file for worker's compensation in Wisconsin (Wisconsin Department of Workforce Development, 2022). However, most of our participants have experienced difficulties accessing this critical assistance and are frustrated by having to prove the work-relatedness of silicosis—a condition which seldom is acquired outside of work. Among those requesting worker's compensation, their first claim was denied, and they had to hire an attorney to undergo an intensive dispute process involving court hearings to secure benefits. One of the common rejection reasons noted by the Wisconsin worker's compensation administrator is insufficient medical evidence validating occupational diseases and injuries (Wisconsin Department of Workforce Development, 2022). This required evidence is in the form of certified clinician reports.

Obtaining medical validation is systematically challenging, especially when the burden falls largely to workers. Collecting patients' occupational history is not a routine practice for most clinicians except occupational medicine nurses and physicians. Equally important is that workers may be unaware of the need to inform providers of their work history, as pointed out by one of our participants. For diseases with more than 10 years of latency such as chronic silicosis, it is difficult to recall cumulative exposure occurring decades ago. In addition, the system scrutinizes individual behavior and “lifestyle choices over structural sources of harm” (Zoller, 2009), forcing exposed workers to defend their health behaviors, as expressed by our participant who noted that he went to the gym and did not smoke.

The fact that the U.S. system “require[s] that workers become ill and establish causation before measures are taken” (Zoller, 2009) suggests that clinicians treating sick workers become deeply enmeshed in establishing such causation. This creates a disincentive to the integration of occupational health principles into the broader medical community (ibid) and results in a dearth of clinical experts who can make and defend precise occupational illness diagnoses. For instance, silicosis may be misdiagnosed because it shares similar clinical symptoms with other interstitial lung diseases (e.g., sarcoidosis, asbestosis, other pneumoconiosis) particularly if clinicians are unfamiliar with reading chest radiographs associated with dust inhalation. Finally, there are few

occupational medicine clinicians whom workers can request for a timely and correct diagnosis. Similarly, there is a shortage of physicians participating in worker's compensation program for reasons including tedious paperwork, low reimbursement fees, and clinicians' frustrations with worker's compensation administrators overturning their medical judgements (Kilgour et al., 2015). This structural shortage of occupational medicine physician highlights the “intermediary determinant” (Solar & Irwin, 2010) role of health system in shaping differential outcomes through mediating access to care. While the lack of willing and informed physicians hinders workers' ability to obtain medical validation, even workers who obtain medical validation often need representation. However, because workers' compensation attorneys charge clients based on settlement awards, the field offers few incentives to take cases that are unlikely to win (e.g., chronic occupational diseases as opposed to acute injuries).

Such institutional hurdles present significant barriers to ill workers, often making this critical assistance effectively unobtainable to workers with limited resources (Azaroff et al., 2013). This “feedback effect of health on socioeconomic position” (Solar & Irwin, 2010) was evident among our participants experiencing financial difficulties (i.e., unaffordable treatment, food insecurity). On a larger scale, the absence of low-resource workers in worker's compensation and medical data systems perpetuates their structural invisibility, which in turn keeps them at risk. These issues are both long-standing and extremely relevant for today's efforts to alleviate health disparities. Precisely, the very low number of silicosis claims in the first few years of it being a compensable condition (1936–1940) inaccurately led to silicosis being considered “a disease of the past” only a few years later (Thomas & Kelley, 2010).

4.1. Implications

While this study elucidates the experiences of some workers with silicosis, in many ways it represents the best-case scenario for workers facing this deadly disease. Our participants were older, predominantly white, native-born men whose exposure occurred over decades and many were diagnosed in their 40s–60s. Yet, even they struggled to obtain a diagnosis, care, and treatment. Younger, immigrant, and other racial/ethnic minority workers are presumed to be at greatest risk of acute and accelerated silicosis (Rose et al., 2019). The barriers immigrants face in accessing healthcare and social services (Hacker et al., 2015; Nakphong et al., 2022) have been well documented. More qualitative research is needed to center the experiences of immigrant workers and others who seldom interact with formal institutions (Abrams, 2010) to enhance public health practice.

This study highlights several intervention opportunities for medicine and public health. Routine collection of employment information, as is being promoted through the Occupational Data for Health initiative (Wallace et al., 2021), would normalize provider/patient discussions of workplace risks (Bhatia et al., 2013). This can increase the prospects for diagnosing and treating occupational diseases while helping to change the professional risk structure that currently makes individual clinicians hesitant to engage in anything that could embroil them in worker's compensation. A greater clinician emphasis on occupational or environmental risks could also temper clinicians' emphasis on individual risk behaviors (e.g., smoking, going to the gym, using PPE were all mentioned by our participants) which so often shame patients, misattribute causation, and jeopardize access to treatment and compensation.

Our participants also suggested that clinicians need more education around silicosis and other occupational diseases. Both medical institutions and public health practitioners could help educate physicians about the exposure-outcome relationships between work environments and diseases and injuries and by training healthcare support staff on collecting occupational histories when scheduling/registering patients.

This study also underlines a role for public health practitioners to communicate occupational risks and mitigation strategies to at-risk communities. Risk communication efforts could focus on small-scale

and rural companies and workers with the most limited access to risk information and organizational protections. Health education materials which acknowledge the persistence of masculinity norms on such worksites (Stergiou-Kita et al., 2015), and which are otherwise culturally relevant (see e.g., Flynn et al., 2013; Flynn et al., 2022), are likely to have a greater effect.

4.2. Strengths and limitations

This study uses qualitative data to demonstrate the various institutional and organizational mechanisms through which work operates as a social determinant of health. While focusing on silicosis as a particular disease, it highlights institutional and organizational dynamics that can similarly impact a variety of health outcomes for workers in the trades. More broadly, this study provides support for the value of qualitative studies in understanding multilevel factors that hinder and/or promote occupational health and safety. Our study, which identified participants through medical record review, displays the rich narratives that can emerge from traditional case interviews and case identification methods. Our participants' narratives consistently underscore factors reported in the literature as consequential for occupational health and safety (e.g., firm size, organizational commitment to risk controls, socialized masculinity norms' influences on occupational exposures, barriers to healthcare and worker's compensation) which lends credibility to our findings.

Our selection of silicosis as a focus necessarily makes this study most applicable to work as a social determinant of health for males involved in certain types of manual labor. Since "gendered pathways to health" affect everything from occupational exposures to access to care (see e.g., Heise et al., 2019), it's important to note the limitations of silicosis as a lens for examining work as a social determinant of health more broadly. As a small qualitative study, this piece should not be interpreted as a complete and representative description of silicosis risk within the trades. Rather, it is helpful for illuminating the dynamics behind quantitatively documented phenomena and helping to elucidate gaps in quantitative studies. The relatively small number and homogenous composition of our participants and a sample selection based on silicosis diagnosis, highlight a particular worker experience rather than a representative array of experiences. Furthermore, our participants were mostly reflecting on past exposures, limiting our ability to extrapolate findings to current workplace conditions. Our sample did not include any workers handling manufactured stones, which is currently presumed to be the most dangerous setting for acute silicosis.

5. Conclusions

Silicosis is an irreversible disease whose causes are well-established and prevention methods are well-known and federally required in the U.S. Nonetheless, workers today continue to be at-risk, with some indications of a resurgence in this "ancient" disease. How can this be? Using case interviews from workers with silicosis, we take up Fujishiro et al.'s (2021) recent challenge to highlight how various social forces converge to perpetuate occupational disease. Our study thus illustrates how certain types of work can function as a social determinant of health across all stages of a person's working life: from the initial stratification of occupational risks that funnels people into different, decades-long exposure pathways; through the organizational perpetuation of harmful exposures and the downplaying of chronic conditions in safety cultures; to the structural barriers that impede access to care and compensation even after work is no longer feasible.

Our participants' exposure to silica dates back years or even decades. By their own account, conditions at many of their workplaces improved over time. Yet the broader context behind their exposures—such as the need to work high-risk jobs at the margins of the labor market; the limitations of an under-resourced OSHA; and the hurdles to access the worker's compensation system—remain just as relevant today. Moreover,

the experiences of our participants—who were older, whiter, and more likely to be native-born than those presumed to be at risk in the current workforce—casts the risks to most at-risk workers in relief. The numerous difficulties that these white, U.S.-born workers faced in getting basic information, protection, treatment, and compensation provide a lens for understanding how difficult this is for workers with even fewer advantages, and why those workers are more likely to remain "structurally invisible" (Flynn et al., 2022) to regulatory, public health and medical systems tasked to assess and address disease burden. By directly presenting the multitude of health risks faced by some workers, and indirectly pointing to the even more disadvantaged context faced by others, we hope to contribute to ongoing shifts within medicine and public health generally towards approaching work as a social determinant of health.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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