The Australian Work Exposures Study: Prevalence of occupational exposure to respirable crystalline silica

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Conflict of interest: The authors declare no conflict of interest.

Word count: 1,400

Author Contributions Statement:

SS drafted the manuscript and conducted all statistical analysis. RC extracted the data. LF directed the study and is responsible for its overall design. AR, TD, DG, GB and SP were involved in the design of this study. All authors contributed to the development and revision of the manuscript.

Abstract

Background: Respirable crystalline silica (RCS) is a biologically active dust that can accumulate in the lung and induce silicosis and lung cancer. Despite occupational exposure being the predominant source, no study has described current occupational RCS exposure on a national scale in Australia. The aim of this study is to estimate the characteristics of those exposed and the circumstances of RCS exposure in Australian workplaces.

Methods: A cross-sectional survey of the Australian working population (18–65 years old) was conducted. Information about the respondents' current job and their demographic characteristics was collected in a telephone interview. Occupational exposure to RCS was determined based on pre-programmed decision rules regarding potential levels of exposure associated with self-reported tasks.

Results: Overall, 6.4% of respondents were deemed exposed to RCS at work in 2012 (3.3% were exposed at a high level). The exposure varied with sex, state of residence and socio-economic status. Miners and construction workers were most likely to be highly exposed to RCS when performing tasks with concrete or cement or working near crushers that create RCS-containing dusts. When extrapolated to the entire Australian working population, 6.6% of Australian workers were exposed to RCS and 3.7% were highly exposed when carrying out tasks at work.

Conclusion: This is the first study investigating occupational RCS exposure in an entire national working population. The information about occupational tasks that lead to high level RCS exposure provided by this study will inform the direction of occupational interventions and policies.

Introduction

Silica is a major constituent of construction materials and is found in almost all types of rock, sand, clay, shale and gravel. Respirable crystalline silica (RCS; <10µm in diameter) is a biologically active dust that can reach the extremities of the lung where it accumulates and can induce silicosis after relatively little exposure, especially if it arises from freshly fractured silica-containing materials. (AIOH, 2009, Meldrum and Howden, 2002) RCS has been identified by the International Agency for Research on Cancer (IARC) as a Group 1 lung carcinogen. (IARC, 2012) Besides silicosis and lung cancer, cumulative low level exposure to RCS increases the risk of other non-malignant respiratory diseases including chronic obstructive pulmonary disease, bronchitis and emphysema and possibly non-malignant renal disease. (Steenland, 2005, Gallagher et al., 2015, Rushton, 2007, McDonald et al., 2005)

The main source of RCS exposure is occupational. Internationally, the established occupations with high exposure are sandblasters, miners, millers, ceramics workers, glassmakers, quarry workers, sand/stone grinding workers, and casting, shakeout or blasting workers. (Steenland and Ward, 2014) Occupational exposure standards for RCS have been introduced in most developed countries since the mid-1900s. The current Australian standard occupational exposure limit is 0.1 mg/ m^3. (Safe Work Australia, 2005)

Information regarding national prevalence and circumstances of exposure to RCS would inform policy making regarding occupational interventions. Therefore, the objective of this study is to estimate the current prevalence of Australian workers performing occupational tasks that potentially lead to RCS exposure.

Methods

This study was a part of a larger study, the Australian Work Exposures Study (AWES), which has been described previously. (Driscoll et al., 2016, Carey et al., 2014) Briefly, AWES was a national telephone survey of a sample of the Australian working population regarding occupational exposure to 38 carcinogens including RCS. The interviews were performed using a web-based platform

OccIDEAS which includes 58 job-specific modules (JSMs). Questions about occupational tasks that are likely to incur exposure to carcinogens were included in each JSM.(Fritschi et al., 2009) The probability and level of RCS exposure were assigned to individual respondents based on their self-reported tasks and related control measures at work. High exposure to RCS was assigned if the respondent undertook one or more tasks likely to result in exposure exceeding the Australian occupational exposure limit even if the job as a whole would be below the 8-hour time weighted average. (Work Safe Queensland, 2013, Parikh et al., 2009, Burstyn et al., 2000, Linch, 2002, Darby et al., 1986) Our estimated prevalence of RCS exposure was stratified by sex and occupational group and extrapolated to the entire Australian working population using data from the 2011 Australian Census. (Australian Bureau of Statistics, 2011) All analyses were performed using Stata version 14.

Results

Overall, 72% cooperation rate was achieved in this survey with 4993 respondents (55.4% males and 44.6% females) completed the occupational survey. Among them, 317 (6.4%) were exposed to RCS at work, and 165 (3.3%) were assigned high RCS exposure (Table 1). Exposure occurred predominantly in male workers (10.5% any exposure to RCS versus 1.2% in female workers) and was higher in workers residing in remote and low socio-economic areas (see supplementary Table 1 in online edition).

Compared to other occupations, miners and construction workers were most likely to carry out tasks that lead to high level RCS exposure, with more than 60% of the workers in those groups deemed highly exposed (Table 1). Additionally, around one-third of plumbers and handy persons were deemed highly exposed to RCS.

Table 1: Occupations with the highest proportion of exposure to RCS

The most frequently reported occupational tasks that led to high level RCS exposure in Australia included cutting, grinding, or sanding concrete (49%) and mixing concrete or cement (44%) among labourers working on construction sites (Table 2). On mining sites, working in dusty areas near crushers was the most common circumstance leading to high RCS exposure, followed by working at

the mine face, in passageways used to transport ore, and in the mine shaft. Other tasks that led to high RCS exposures included ploughing or harrowing soils, road paving or sealing, road sweeping, floor screeding, asphalt milling and applying grout to floors. It is worth noting that 85% (33/39) of workers who were assigned to the farmer JSM in our survey self-reported ploughing and harrowing within an enclosed cab, which to a large extent reduced the probability of high RCS exposure among workers while doing these tasks (low RCS exposure were assigned) .

Table 2: The major tasks resulting in high level exposure to RCS; the number of workers who undertook each task and the proportion of the 165 highly exposed workers who performed each task

When extrapolated to the 2011 Australian working population, 6.6% (95% CI: 4.1%, 9.5%) were exposed to RCS at any level with exposure for males more common than for females (Table 3). This is equivalent to around 329,000 Australian workers. Approximately 3.7% (95% CI: 2.0%, 5.4%) of the Australian working population reported undertaking at least one high exposure task.

Table 3: Proportion of the Australian working population estimated to be exposed to RCS in the workplace

Discussion

We estimated that 6.6% of the Australian working population were exposed to RCS in 2012 and 3.7% were potentially highly exposed by performing at least one high exposure task. Miners and construction workers were most often subject to high RCS exposure when working with concrete or cement or working near crushers that create RCS-containing dusts.

Because no compensation claim for silicosis has been successfully made in Western Australia since the introduction of the industrial RCS exposure standard in 1974, there have been suggestions that occupational exposure to RCS no longer poses a health hazard for Australian workers. (Wan and Lee, 1999, de Klerk et al., 2002) However, the pattern of occupational compensation claims may not truly reflect the incidence of all silicosis, but rather only of severe cases. Evidence indicates that silicosis compensation payments were more likely to be made to workers with co-existing respiratory disease or who are symptomatic. (de Klerk and Musk, 1998) It is highly likely that silicosis remains undiagnosed and uncompensated among workers exposed to RCS due to a lack of sufficient disability

to get compensation. (Safe Work Australia, 2005, de Klerk et al., 2002) Pooled data from ten international cohort studies demonstrated that continuous exposure to RCS at a level of 0.1 mg/m^3 over 45 years was associated with 1.1-1.7% increased lifetime risk of silicosis. (Steenland et al., 2001) Furthermore, cumulative low level RCS exposure is a risk factor for other respiratory diseases. (Park et al., 2002)

The majority of studies in the literature have estimated the prevalence of occupational RCS exposure by collecting samples from high risk industries such as construction, mining iron and steel foundries and metal work. (Yassin et al., 2005, Parikh et al., 2009, Hedges et al., 2009, Burstyn et al., 2000, Linch, 2002) American studies reported a downward trend in both the concentration and prevalence of RCS exposure between 1988 and 2003, and overall 3.6% of sampled workers were exposed to RCS above 0.1 mg/m^3 in 2003. (Yassin et al., 2005) The Carcinogen Exposure (CAREX) study for the European Union in the 1990s assessed prevalence of occupational exposure to RCS by industry and occupation using a job exposure matrix approach. (Finnish Institute of Occupational Health, 1998, Kauppinen et al., 2000) The more recent Canadian CAREX updated the results of the European CAREX database, and reported an overall 2.3% occupational exposure to RCS in the Canadian working population, which is lower than our estimate.(Peters et al., 2015) It is possible that Australian workers were generally subject to higher occupational exposure to RCS; on the other hand, it could be due to different methods adopted by the two studies. While the CAREX study estimate was based on quantitative measurements of RCS of known high risk occupations, AWES provides cross-sectional qualitative estimates of occupational exposure to RCS. Occupation-wise, the Canadian CAREX study found the highest prevalence of occupational RCS exposure in construction, mining, manufacturing and agriculture; and the relevant occupational tasks to be grinding, sandblasting, crushing, chipping and mixing concrete and ploughing, (Peters et al., 2015) which is consistent with our findings. The major limitation of our study is that we did not ask about the duration of the task, so we cannot relate our findings to the occupational standard which is an average of RCS exposure over an eight hour shift. Like all cross-sectional studies, the accuracy of our estimate is subject to the study sample size and cooperation rates, as well as the demographic and occupational representativeness of the sample.

The representativeness of the study sample was discussed in previous AWES papers.(Carey et al., 2014) Also, the study relies on respondents' self-report information on occupational task.

Occupational interventions to reduce RCS exposure should be prioritized on high exposure tasks with high prevalence in Australia. According to our study, the major occupational tasks that lead to RCS exposure in Australia were cutting, grinding, sanding or mixing concrete or working in dusty areas near crushers. Levels above the occupational exposure limits have been recorded in these industries in Australia. (Work Safe Queensland, 2013, Parikh et al., 2009, Burstyn et al., 2000, Linch, 2002, Darby et al., 1986, Easterbrook and Brough, 2009) Relevant interventions including source control (e.g. process or equipment modification, wet methods); containment of dust transmission (e.g. enclosed cabs, local exhaust ventilation or water spray) or use of personal protective equipment should be implemented to further reduce occupational exposure to RCS in Australia. (Steenland and Ward, 2014)

This is the first study investigating occupational RCS exposure in an entire national working population. Overall, we estimated 6.6% of the Australian working population were exposed to RCS at work in 2012, and 3.7% were likely to be highly exposed by performing at least one high exposure task at work. The information about the occupational groups and tasks of exposed workers provided by this study will inform the direction of occupational interventions and policies.

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Acknowledgements

The authors wish to acknowledge Renae Fernandez for her role in preparing the questionnaires for this study and Troy Sadkowsky for his technical assistance. The authors also thank Vicki Graham and Theresa Wilkes at the Survey Research Centre, Edith Cowan University, Western Australia for their assistance in the data collection.

Disclosure of potential conflict of interest

Funding for this project was provided by NHMRC ; Cancer Council Western Australia and SafeWork Australia. The authors declare no conflict of interest relating to the material presented in this Article. Its contents, including any opinions and/or conclusions expressed, are solely those of the authors.

Ethics Approval

The study was approved by the University of Western Australia human research ethics committee

Table 4: Occupations with the highest proportion of exposure to RCS

Occupational groups	N	Any Exposure to RCS		High Exposure to RCS	
		N	Mean (95%CI) %	N	Mean (95%CI) %
Total in AWES survey	4993	317	6.4 (5.7, 7.0)	165	3.3 (2.8, 3.8)
Miner	24	22	91.7 (79.7, 100)	15	62.5 (41.6, 83.4)
Construction worker	55	44	80.0 (69.1, 90.9)	34	61.8 (48.6, 75.1)
Engineer	91	40	44.0 (33.6, 54.3)	25	27.5 (18.1, 36.8)
Plumber	69	28	40.6 (28.7, 52.5)	26	37.7 (26.0, 49.4)
Handyperson	38	15	39.5 (23.2, 55.8)	13	34.2 (18.4, 50.0)
Heavy Vehicle driver	149	49	32.9 (25.3, 40.5)	8	5.4 (1.7, 9.0)
Farmer	120	31	25.8 (17.9, 33.8)	3	2.5 (0, 5.3)
Machine operator	69	9	13.0 (4.9, 21.2)	4	5.8 (0.1, 11.5)
Animal & Horticultural worker	92	10	10.9 (4.4, 17.4)	3	3.3 (0, 7.0)
Scientist	79	7	8.9 (2.5, 15.3)	3	3.8 (0, 8.1)
Metal Worker	103	8	7.8 (2.5, 13.0)	6	5.8 (1.2, 10.4)
Electrical Worker	117	6	5.1 (1.1, 9.2)	5	4.3 (0.6, 8.0)

Table 5: The major tasks resulting in high level exposure to RCS; the number of workers who undertook each task and the proportion of the 165 highly exposed workers who performed each task

Tasks	No. of workers	Proportion of high level RCS exposed subjects doing this task		
		%^	Lower limit of 95% CI	Upper limit of 95% CI
No. of workers exposed to high level RCS	165			
Construction JSM/Labourer JSM				
Cutting, grinding or sanding concrete	80	48.5	40.8	56.2
Mixing concrete or cement	73	44.2	36.6	51.9
Stonemasonry/stone cutting	5	3.0	0.4	5.7
Mining JSM				
Working in dusty area from crusher	27	16.3	10.7	22.1
Working at mine face	11	6.7	2.8	10.5
Working in passageways used to transport ore	6	3.6	0.8	6.5
Working in mine shaft	4	2.4	0.1	4.8
Road construction JSM				
Road paving/sealing	5	3.0	0.4	5.7
Road sweeping	5	3.0	0.4	5.7
Asphalt milling	2	1.2	0.0	2.9
Farmer JSM				
Ploughing, harrowing or disturbing soil		-	-	-
• Using enclosed cab*	33	-	-	-
• Without using enclosed cab	6	3.6	0.8	6.5
Floor laying JSM				
Screeding floors	3	1.8	0.0	3.9
Applying grout to floors	1	0.6	0.0	1.8

^The % do not add up to 100% because workers may have partaken in multiple tasks that lead to high level exposure to RCS.

*If using enclosed cab, medium RCS exposure was assigned; otherwise, high RCS exposure was assigned.

Note: Although JSMs are good indicators of occupation groups, they are not equivalent. For example, not all respondents who got the farmer JSM were farmers; JSM: job-specific module

Table 6: Proportion of the Australian working population estimated to be exposed to RCS in the workplace

	Population projection			Population Prevalence		
	N (*1000)	LL of 95% CI	UL of 95% CI	Mean (%)	LL of 95% CI (%)	UL of 95% CI (%)
Total working population						
Any Exposure	592	370	847	6.6	4.1	9.5
High Exposure	329	183	484	3.7	2.0	5.4
Males						
Any Exposure	546	360	745	11.6	7.7	15.8
High Exposure	321	180	464	6.8	3.8	9.9
Females						
Any Exposure	46	11	102	1.1	0.2	2.4
High Exposure	8	3	20	0.2	0.1	0.5

LL-lower limit; UL-upper limit

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Supplementary Table 1: Demographic characteristics and occupational exposure to RCS in the Australian Workplace Exposures Study (AWES), a national survey of Australian workers (2012)

Demographic characteristics	Exposure to RCS				
	Study samples	Any exposure		High exposure*	
	N	N	%	N	%
Total	4993	317	6.4	165	3.3
Sex					
Male	2766	***290***	***10.5***	162	5.9
Female	2227	***27***	***1.2***	3	0.1
Age					
18-34 years	747	51	6.8	24	3.2
35-54 years	2988	186	6.2	95	3.2
55-65 years	1216	79	6.5	46	3.8
Education level					
High school or less	1843	***145***	***7.9***	67	3.6
Trade certificate/diploma	1392	***119***	***8.6***	77	5.5
Bachelor degree or higher	1743	***53***	***3.0***	21	1.2
State of Residence					
New South Wales	1723	***102***	***5.9***	58	3.4
Victoria	1228	***69***	***5.6***	26	2.1
Queensland	907	***74***	***8.2***	40	4.4
Western Australia	566	***49***	***8.7***	29	5.1
South Australia	306	***13***	***4.3***	6	2.0
Australian Capital Territory	109	***3***	***2.8***	3	2.8
Tasmania	99	***6***	***6.1***	3	3.0
Northern Territory	55	***1***	***1.8***	0	0
Remoteness					
Major city	3028	***130***	***4.3***	87	2.9
Inner regional	1359	***101***	***7.4***	43	3.2
Outer regional	517	***67***	***13.0***	27	5.2
Remote	89	***19***	***21.4***	8	9.0
Socio-economic status					
1	497	***46***	***9.3***	18	3.6
2	863	***71***	***8.2***	35	4.1
3	1019	***65***	***6.4***	30	2.9
4	1248	***79***	***6.3***	47	3.8
5	1366	***56***	***4.1***	35	2.6

**Potential RCS exposure at levels above national industry standard of 0.1mg/m^3;*
*Chi square tests were conducted, results with significant differences ($p<0.05$) were highlighted in **bold and italic** fond*