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Predictors of psychological stress in silica-exposed workers in the artificial stone benchtop industry

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Abstract

Background and objective: Artificial stone benchtops are a popular kitchen product, but dust from their preparation and installation contains respirable crystalline silica, which causes silicosis. Silicosis is a preventable, permanent lung disease. The aim of this study was to assess mental health in workers from the artificial stone benchtop industry at risk of silicosis.

Methods: Workers from the artificial stone benchtop industry undergoing assessment for silica-associated disease were included. Information on demographics; occupational, medical and smoking history; modified Medical Research Council dyspnoea scale; Perceived Stress Scale (PSS-10) questionnaire; spirometry; and chest x-ray was collected. Univariate and multivariate regression analyses were conducted.

Results: Of the 547 participants, the majority were men, aged under 45 years, in the industry for less than 10 years. With each increase of dyspnoea score, PSS-10 scores increased. Higher PSS-10 scores were also observed in those no longer in the industry, with a history of anxiety or depression, attending assessment early in the programme and a medium exposure duration. Participants who used an interpreter reported lower stress. No difference was observed across job title, age, sex, smoking, spirometry or chest x-ray categories after multivariate analysis.

Conclusion: This study identified workers with dyspnoea as likely to report higher stress. Other factors, such as leaving the industry, early attendance and a history of anxiety or depression, are also helpful in identifying workers at risk of poorer mental health outcomes.

KEYWORDS
artificial stone benchtop industry, lung fibrosis, occupational health, quality of life, silicosis

INTRODUCTION

Artificial stone benchtops have become a popular product in many countries, including Australia.[1] These benchtops contain a high percentage of quartz, some over 90%, which is the most common form of crystalline silica. Inhaled respirable crystalline silica (RCS) causes inflammatory damage to macrophages in the lungs, leading to fibrotic damage and silicosis.[2] Freshly produced RCS is particularly cytotoxic to macrophages.[3] The forms of silicosis seen in artificial stone

SUMMARY AT A GLANCE

This study describes psychological stress scores in silica-exposed workers from the artificial stone benchtop industry and identifies predictors of elevated stress.

The findings from this study were previously presented at the 2021 Thoracic Society of Australia and New Zealand (TSANZ) and Australia and New Zealand Society of Respiratory Science (ANZSRS) Victorian Branch Annual Scientific Meeting and the 33rd International Congress on Occupational Health (ICOH; 2022 Melbourne-Rome Global Digital Congress).

benchtop workers include simple and complicated chronic, acute and accelerated, with duration between exposure and disease differentiating between the forms.[2,3] The first published cases of silicosis from workers in the industry emerged from Spain.[4–6] Subsequent reports from Israel,[7] United States[8] and Australia[9,10] soon followed.

People with silicosis may experience breathlessness and dry cough, or be asymptomatic until the disease is at an advanced stage.[2] There is no known cure for silicosis, although several classes of medication that target inflammatory and fibrotic pathways have been identified as possibilities for clinical trials.[3] Whole lung lavage showed radiological improvement in a case series of six workers,[11] and lung transplantation may be available for eligible workers with severe disease, with equivalent 1-year[7] and longer-term survival[12] compared to other lung transplant recipients. The progression of silicosis and death has been reported even after the cessation of RCS exposure in stonemasons and denim workers with RCS exposure.[13,14] When death from silicosis occurs at a young age, it is likely that there was extremely high RCS exposure.[15]

Health-related quality of life (HRQOL) is impaired in people with silicosis in a range of other industries where RCS exposure is high, such as mining,[16] denim production[17] and insulator manufacturing.[18] Respiratory symptoms and impaired lung function are known to impair HRQOL in workers undergoing assessment for silicosis from other industries.[16] A high modified Medical Research Council (mMRC) dyspnoea score was predictive of anxiety and depression in a study of patients with interstitial lung disease (ILD).[19] The impact of silicosis or silica exposure on HRQOL amongst those from the artificial stone benchtop industry has not been researched.

The aim of this study was to understand the predictors of elevated stress in silica-exposed workers from the artificial stone benchtop industry undergoing health assessment. We hypothesized that young age, leaving the industry and the existence of the symptomatic aspects of silicosis, namely breathlessness, would increase perceived stress.

METHODS

The State Occupational Health and Safety (OHS) regulator, WorkSafe Victoria (WSV), initiated a promotional campaign, incorporating media, meetings and worksite visits.[20] The campaign included resources in Chinese, Vietnamese and Italian to target workers from culturally and linguistically diverse backgrounds. Workers from the stone benchtop industry contacted WSV to book a screening assessment with an independent occupational health provider. Assessments were funded by WSV, and all workers in the artificial stone benchtop industry, including stonemasons, managers and those in sales and administration roles were eligible. Informed consent to use the data for research was obtained from participants. Data were collected and managed using REDCap (Research Electronic Data Capture) electronic data capture tools hosted at Monash University. REDCap is a secure, web-based software platform designed to support data capture for research studies.[21,22] Assessments began in June 2019, and data were extracted in July 2021.

The consultation with the occupational health provider included collection of demographic information, an occupational history related to industries with silica exposure with a focus on the artificial stone benchtop industry, a medical history and a physical examination to further assess cardiac, respiratory and autoimmune conditions. A history or current diagnosis of anxiety or depression was recorded. Smoking history was categorized by never, current and former. Early screening attendance was defined as an assessment date up to 31 December 2019, representing the first 7 months of the programme. Interpreters were provided as required.

The Perceived Stress Scale (PSS-10) is a 10-item score that measures a person's self-perceived level of stress with a recall period of 4 weeks.[23] It contains six negatively worded items, and four positively worded items that are reverse-scored, so that an overall high score indicates high level of perceived stress, with a maximum score of 40. Questions include statements such as 'In the last month, how often have you been upset because of something that happened unexpectedly?' and 'In the last month, how often have you felt confident about your ability to handle your personal problems?'. The questionnaire was provided in English, and was interpreted as needed.

Chest x-rays were reported to International Labour Organisation (ILO) standards and categorized into normal (major profusion category of 0) and abnormal (major profusion category 1 and above).

Spirometry, including diffusing capacity for carbon monoxide (D_LCO), was defined as above or below the lower limit of normal (LLN) according to the Global Lung Initiative (GLI 2012) reference values, which adjust for age, sex and race.[24]

Dyspnoea was assessed using the mMRC scale, a four-item score in which a number is allocated based on breathlessness in response to physical exertion (e.g., 'I only get breathless with strenuous exercise', 'I get short of breath when hurrying on the level or walking up a slight hill').[25]

Longest and most recent jobs were allocated to five possible categories: factory machinist, installer, factory computer numeric control (CNC) operator, other jobs with minimal (<10%) secondary exposure and other jobs with some (>10%) secondary exposure.[24] 'Other' jobs included manager, director, estimator, template maker, administration and accounts clerk. The algorithms incorporate job tasks and time spent dry cutting or spent near dry cutting.[26]

Patients were referred to respiratory physicians (RP) for secondary evaluation if they had any abnormality or high exposure identified during the assessment. A diagnosis of silica-associated disease was typically made by the RP rather than the occupational health provider, once an HRCT chest and other results were available. Further details of methodology have previously been described.[20]

Demographic, exposure and clinical variables for the eligible cohort were summarized with counts and percentages and the outcome measure of continuous PSS-10 with mean and SD. Uni- and multivariate linear regression analyses were performed to investigate the association of the demographic, exposure and clinical predictor variables with PSS. Covariates for the multivariate analysis (age, sex, smoking, interpreter use and history of anxiety or depression) were chosen a priori based on expert opinion of relevant confounders. Analyses were conducted using Stata/IC 16.0 (Stata Corp, Texas, USA) with the significance level set to 5%.

RESULTS

Our cohort included 556 participants, of whom 547 (98.4%) had a PSS-10 score with no missed items. The population had a median age of 36 years, 92.5% were men and 45.3% were never smokers (Table 1). About half of the participants

TABLE 1 Participant demographics

	N (%)	PSS-10 score mean (SD)	Univariate coefficient (95% CI)	Multivariate[a] coefficient (95% CI)
N	547			
Sex				
Male	506 (92.5)	13.0 (7.0)	Ref	Ref
Female	41 (7.5)	12.4 (6.3)	−0.62 (−2.85, 1.61)	−0.49 (−2.68, 1.70)
Age (years)				
<25	75 (13.7)	12.2 (6.7)	Ref	Ref
25–34	191 (34.9)	13.5 (7.0)	1.32 (−0.55, 3.19)	1.07 (−0.73, 2.86)
35–44	141 (25.8)	13.0 (7.3)	0.79 (−1.17, 2.76)	0.72 (−1.17, 2.62)
45–54	98 (17.9)	12.6 (6.5)	0.37 (−1.74, 2.48)	0.61 (−1.43, 2.64)
≥55	42 (7.7)	12.3 (7.6)	0.06 (−2.58, 2.71)	0.15 (−2.40, 2.70)
Smoking history				
Never smoked	248 (45.3)	12.2 (6.7)	Ref	Ref
Former smoker	107 (19.6)	13.5 (7.0)	1.25 (−0.33, 2.84)	0.94 (−0.64, 2.51)
Current smoker	187 (34.2)	13.6 (7.3)	**1.40 (0.08, 2.73)**	1.10 (−0.21, 2.40)
Unknown	5 (0.9)	12.0 (6.7)	−0.21 (−6.40, 5.97)	−1.20 (−7.17, 4.77)
Anxiety/depression				
No	440 (80.4)	12.0 (6.5)	Ref	Ref
Yes	99 (18.1)	17.0 (7.1)	**5.06 (3.59, 6.52)**	**4.61 (3.14, 6.09)**
Unknown	8 (1.5)	16.0 (10.7)	4.04 (−0.66, 8.74)	4.22 (−0.48, 8.92)
Born in Australia				
Yes	272 (49.7)	13.5 (6.9)	Ref	Ref
No	274 (50.1)	12.3 (7.0)	**−1.20 (−2.38, −0.03)**	0.01 (−1.21, 1.23)
Unknown	1 (0.2)	21.0 (−)	7.47 (−6.23, 21.17)	3.61 (−9.58, 16.80)
Interpreter used for assessment				
No	405 (74.0)	13.2 (7.0)	Ref	Ref
Yes	58 (10.6)	9.4 (6.3)	**−3.76 (−5.66, −1.86)**	**−3.24 (−5.11, −1.37)**
Unknown	84 (15.4)	14.0 (6.8)	0.81 (−0.81, 2.44)	0.76 (−0.82, 2.33)
Early screening attendance[b]				
No	379 (69.3)	12.1 (6.8)	Ref	Ref
Yes	168 (30.7)	14.8 (7.0)	**2.73 (1.48, 3.98)**	**2.29 (0.99, 3.59)**
Referred for respiratory physician assessment				
No	75 (13.7)	11.6 (6.1)	Ref	Ref
Yes	345 (63.1)	13.6 (7.2)	**1.98 (0.24, 3.72)**	1.61 (−0.14, 3.36)
Unknown	127 (23.2)	12.0 (6.6)	0.38 (−1.61, 2.36)	0.53 (−1.41, 2.47)

Abbreviation: PSS-10, Perceived Stress Scale.
[a]Adjusted for age, sex, smoking, depression/anxiety and interpreter use.
[b]Attendance within the first 7 months of the programme.

TABLE 2 Clinical markers

	N (%)	PSS-10 score mean (SD)	Univariate coefficient (95% CI)	Multivariate[a] coefficient (95% CI)
mMRC dyspnoea score				
0	411 (75.1)	11.9 (6.4)	Ref	Ref
1	90 (16.5)	15.0 (7.0)	**3.04 (1.50, 4.58)**	**2.81 (1.30, 4.31)**
2	27 (4.9)	17.9 (7.9)	**5.94 (3.31, 8.56)**	**5.42 (2.87, 7.96)**
3	19 (3.5)	18.5 (10.7)	**6.56 (3.46, 9.66)**	**6.24 (3.22, 9.26)**
ILO chest x-ray				
Normal (ILO = 0)	423 (77.3)	12.9 (6.8)	Ref	Ref
Abnormal (ILO ≥ 1)	107 (19.6)	13.1 (7.4)	0.17 (−1.31, 1.66)	0.15 (−1.34, 1.64)
Unknown	17 (3.1)	13.5 (9.5)	0.65 (−2.75, 4.05)	0.01 (−3.30, 3.32)
FEV_1				
≥LLN	369 (67.5)	13.2 (6.9)	Ref	Ref
<LLN	30 (5.5)	13.4 (6.7)	0.25 (−2.35, 2.86)	0.61 (−1.89, 3.12)
Unknown	148 (27.1)	12.2 (7.3)	−0.96 (−2.29, 0.38)	−0.68 (−1.97, 0.60)
FVC				
≥LLN	378 (69.1)	13.3 (6.8)	Ref	Ref
<LLN	20 (3.7)	11.7 (7.4)	−1.61 (−4.76, 1.53)	−0.98 (−4.00, 2.03)
Unknown	149 (27.2)	12.3 (7.3)	−0.99 (−2.32, 0.34)	−0.72 (−2.00, 0.56)
FEV_1/FVC				
≥LLN	343 (62.7)	13.0 (6.8)	Ref	Ref
<LLN	55 (10.1)	14.1 (7.0)	1.01 (−0.98, 3.00)	0.26 (−1.65, 2.18)
Unknown	149 (27.2)	12.3 (7.3)	−0.77 (−2.11, 0.58)	−0.63 (−1.92, 0.67)
D_LCO				
≥LLN	373 (68.2)	13.2 (6.7)	Ref	Ref
<LLN	26 (4.8)	13.9 (8.5)	0.73 (−2.05, 3.51)	0.59 (−2.09, 3.26)
Unknown	148 (27.1)	12.2 (7.3)	−0.93 (−2.26, 0.40)	−0.69 (−1.97, 0.59)

Abbreviations: D_LCO, diffusing capacity for carbon monoxide; FEV_1, forced expiratory volume in 1 s; FEV_1/FVC, ratio of FEV_1 to FVC; FVC, forced vital capacity; ILO, International Labour Organisation; LLN, lower limit of normal (Global Lung Initiative 2012 reference values); mMRC, modified Medical Research Council; PSS-10, Perceived Stress Scale.

[a]Adjusted for age, sex, smoking, history of depression/anxiety and interpreter use. Spirometry (FEV_1, FVC, FEV_1/FVC and D_LCO) was adjusted for smoking, history of depression/anxiety and interpreter use only, as the LLN calculations already take age and sex into account.

were born outside Australia, in 52 different countries. Vietnam, India, China, Italy and the United Kingdom were the most frequently reported countries. An interpreter was used for 58 (10.6%) assessments.

Clinical markers, including ILO chest x-ray, were within normal limits for the majority of participants (Table 2). No dyspnoea was reported in 75.1% of participants. For both longest and the most recent job, the majority of participants were allocated to the factory machinist categories, with smaller numbers of people allocated to the specified roles of installer, factory CNC and the two 'other' categories (Table 3).

Significantly higher scores of PSS-10 were observed in those who attended screening early compared to those who attended later in the programme, were referred for follow-up, were current smokers, had left the artificial stone benchtop industry, had an mMRC score above zero compared to those with a score of zero, a past or present diagnosis of anxiety or depression and exposure in the industry from 5 to 14 years compared to those with 0–4 years. Significantly lower PSS-10 scores were observed in those born outside of Australia, had used an interpreter for the assessment or reported factory CNC as their longest job. After adjusting for age, sex, smoking status, anxiety and depression history, and interpreter use, the association between PSS score and the variables of referral for follow-up, current smoker, factory CNC as the longest job and born in Australia were no longer significant.

DISCUSSION

This study identified several factors that were associated with increased stress in workers in the artificial stone benchtop industry who were undertaking a screening programme to identify silica-associated health effects. The strongest associations were dyspnoea, leaving the stone benchtop industry and a past or current diagnosis of anxiety or

TABLE 3 Occupational exposures in the stone benchtop industry

	N (%)	PSS-10 score mean (SD)	Univariate coefficient (95% CI)	Multivariate[a] coefficient (95% CI)
Still in stone benchtop industry				
Yes	498 (91.0)	12.5 (6.8)	Ref	Ref
No	49 (9.0)	17.5 (7.4)	**5.00 (2.99, 7.01)**	**4.39 (2.44, 6.33)**
Exposure duration in stone benchtop industry (years)				
0–4	207 (37.8)	11.9 (6.6)	Ref	Ref
5–9	127 (23.2)	13.6 (7.4)	**1.71 (0.17, 3.24)**	**1.67 (0.16, 3.19)**
10–14	104 (19.0)	14.1 (7.1)	**2.28 (0.64, 3.92)**	**1.86 (0.15, 3.57)**
15–19	46 (8.4)	12.4 (6.6)	0.51 (−1.71, 2.73)	0.51 (−1.85, 2.88)
≥20	63 (11.5)	13.6 (7.1)	1.76 (−0.20, 3.72)	1.54 (−0.74, 3.81)
Most recent job in stone benchtop industry				
Factory machinist	286 (52.3)	12.9 (7.2)	Ref	Ref
Installer	110 (20.1)	14.3 (7.1)	1.40 (−0.14, 2.93)	1.10 (−0.38, 2.58)
Factory CNC	54 (9.9)	11.1 (6.2)	−1.77 (−3.79, 0.26)	−1.14 (−3.10, 0.83)
Other some direct or 2° exposure	24 (4.4)	13.0 (7.3)	0.16 (−2.74, 3.07)	0.23 (−2.67, 3.13)
Other minimal 2° exposure	73 (13.3)	12.5 (6.3)	−0.41 (−2.20, 1.38)	−0.43 (−2.46, 1.60)
Longest job in stone benchtop industry				
Factory machinist	318 (58.1)	13.1 (7.1)	Ref	Ref
Installer	98 (17.9)	13.5 (7.2)	0.44 (−1.15, 2.02)	0.16 (−1.36, 1.69)
Factory CNC	48 (8.8)	10.8 (6.0)	**−2.27 (−4.39, −0.15)**	−1.59 (−3.66, 0.47)
Other some direct or 2° exposure	33 (6.0)	12.7 (7.2)	−0.39 (−2.89, 2.12)	−0.36 (−2.92, 2.19)
Other minimal 2° exposure	50 (9.1)	13.0 (6.1)	−0.04 (−2.13, 2.04)	0.26 (−2.16, 2.68)

Abbreviations: 2° exposure, secondary exposure; CNC, computer numeric control operator; PSS-10, Perceived Stress Scale.
[a]Adjusted for age, sex, smoking, depression/anxiety and interpreter use.

depression. Clinical markers, including spirometry below the LLN and chest x-ray, were not predictors of increased stress. Restrictions on aerosol-generating procedures due to COVID-19 limited the number of participants who could complete spirometry.

With each worsening category of dyspnoea, stress increased. We hypothesize that it is the distressing experience of dyspnoea that increases stress as this is something which the worker is aware of, whereas they may not be aware of abnormal clinical markers. The authors of the dyspnoea score suggest it is the 'single most important factor that limits that person's ability to function on a day-to-day basis'.[25] In patients with ILD, dyspnoea was an independent predictor of anxiety and depression.[19] Conversely, in patients with chronic obstructive pulmonary disease (COPD), anxiety was a predictor of dyspnoea.[27] After adjusting for anxiety and depression history in our analysis, the association between dyspnoea and stress remained significant. Whilst exercise training is beneficial at improving 6-min walk test distance and HRQOL measurements, it does not reduce mMRC dyspnoea scores in asbestosis and silicosis and other dust-related respiratory diseases[28] or ILD.[29] Approaches such as 'treatable traits' that include patients in decision-making, and target comorbidities with interventions, result in personalized disease management and an end-goal of improved outcomes.[30] This approach has been used in asthma and COPD, and has not been explored in occupational lung diseases, but could be a focus of future research.

The finding of high stress in those who had left the artificial stone benchtop industry may reflect symptomatic workers who are unable to continue working. Those who have recently left the industry have a higher mMRC dyspnoea score than those who remain in the industry.[26] Some workers from the artificial stone benchtop industry are able to change jobs or industries to avoid RCS exposure. Others are unable to continue working and need to stop work permanently, which has a substantial impact on future earning capacity and mental health. Young age, unemployment and lower education levels are all independent factors known to cause higher levels of stress in national surveys of adults.[31]

A past or present diagnosis of anxiety or depression predicted elevated stress, and participants referred for further assessment by an RP reported higher stress. In a Brazilian study of semi-precious stone workers, participants with silicosis reported worse on the physical health, psychological and environment domains of the WHOQOL-BREF instrument,[16] suggesting a similar trend to our findings. Early attendees reported higher stress, which may indicate those with more symptoms and therefore more stress were more likely to respond early to the call for screening. Simple silicosis may be present without symptoms,[2] therefore

caution should be noted for asymptomatic workers who do not experience dyspnoea, and may not be aware of the urgent need for health assessments. Furthermore, in silica-exposed workers, silicosis continued to be diagnosed after the cessation of exposure.[13,14]

Both interpreter use and overseas birth indicated lower stress scores. Prior research has identified that culturally validated and translated HRQOL instruments require different cut-off scores compared to English versions.[32] It is not known whether the differences observed in our cohort compared with those who used an interpreter represent a true lower level of stress, or a difference due to other factors. Future research could be aimed at better understanding this effect, given the large proportion of our cohort who were born overseas. Validated translations of the PSS-10 questionnaire exist in other languages, including Chinese,[33] Greek[34] and Spanish,[35] which could be utilized where available.

Up to 15 years in the industry was predictive of elevated stress, compared to low exposure duration (0–4 years); however, this association was not observed for exposure durations over 15 years. Although artificial stone has been in use for over 20 years, its popularity in Australia has increased in the past decade, indicating that workers with longer periods of exposure will not necessarily have more RCS exposure compared to those with fewer years of exposure.

Although the difference between never and current smokers was significant in the univariate analysis, it is hypothesized that the increased PSS-10 score observed in current smokers was due to smoking being a common stress-relief method, rather than a cause of higher stress. Furthermore, smoking causes dyspnoea, which independently increases stress.

The difference in stress between men and women was not significant, which differs from the well-established trend in both English and non-English speaking populations with the PSS instrument.[31,33–35] This may be explained by the small number of women included in analysis, but may also reflect a difference in roles within the stone benchtop industry.

As our research was performed at the initial assessment, it serves as a baseline for future assessments, as workers navigate the medical, compensatory and medico-legal systems. The effect of media attention regarding the risks of development of a silica-associated disease was not investigated in this study, but could be included in future research. In Australian studies of workers receiving compensation, interactions with healthcare providers have been identified as a source of stress, particularly for complex conditions.[36] Workers receiving compensation through WSV who speak a language other than English as their primary language require more healthcare resources and financial support than native English speakers.[37] Future research that includes longitudinal measurements of clinical markers, silica-associated diagnosis, industry and occupation will allow further understanding of these factors in the artificial stone benchtop industry.

This research has highlighted the importance of dyspnoea as a significant predictor of elevated perceived stress in workers from the artificial stone benchtop industry. It can therefore be used as a simple way of identifying those who may require additional support through the assessment, follow-up and compensation pathways. Interventions that are aimed at reducing dyspnoea may also lower perceived stress, however this requires further research.

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CONFLICT OF INTEREST

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AUTHOR CONTRIBUTION

Fiona Hore-Lacy: Conceptualization (lead); data curation (supporting); formal analysis (supporting); methodology (lead); writing – original draft (lead). **Jessy Hansen:** Formal analysis (lead); methodology (supporting); writing – review and editing (equal). **Christina Dimitriadis:** Data curation (lead); methodology (supporting); project administration (lead); writing – review and editing (equal). **Ryan Hoy:** Methodology (supporting); project administration (supporting); writing – review and editing (equal). **Jane Fisher:** Conceptualization (supporting); methodology (supporting); supervision (equal); writing – review and editing (equal). **Deborah Glass:** Conceptualization (supporting); methodology (supporting); supervision (equal); writing – review and editing (equal). **Malcolm R. Sim:** Conceptualization (supporting); methodology (supporting); supervision (equal); writing – review and editing (equal).

DATA AVAILABILITY STATEMENT

Data cannot be shared for ethical and privacy reasons.

HUMAN ETHICS APPROVAL DECLARATION

This study was performed in accordance with the Declaration of Helsinki and approved by Monash University Human Research Ethics Committee—approval: 17730. All adult participants provided written informed consent to participate in this study.

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