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Design and validation of instruments of working conditions associated with silica and asbestos exposure

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Abstract

The objective of this study is to design and validate two instruments for characterizing on- and off-the-job working conditions associated with exposure to silica and asbestos in the construction sector. The approach involved four phases: (1) literature review to identify key variables related to exposure, (2) development of the survey instruments, (3) content validation by a panel of experts; and (4) pilot testing with workers and occupational health and safety leaders. Two instruments were constructed. Instrument A, aimed at leaders, had 42 items and instrument B, aimed at workers, had 31 items. Instrument A had a content validity coefficient greater than 0.9 for the 100% of the items in the criteria of relevance, adequacy, pertinence, and coherence, and greater than 0.9 in the criterion of clarity for the 95% of the items. Instrument B had greater variability in the content validity coefficient for the criteria of relevance, adequacy, pertinence, coherence, and clarity, with scores greater than 0.9 for the 71%, 42%, 58%, 48%, and 25% of the items, respectively. The pilot test demonstrated participant understanding of 90% of the items in instrument A and 97% in instrument B. The instruments developed can be used to identify working conditions associated with occupational exposure to silica and asbestos in the sector, thereby facilitating evaluation of working conditions.

Keywords occupational exposure, workers, asbestos, silica

What's Important About This Paper

There is a need to develop and validate surveys and other instruments to gather information about working conditions that impact workers' health, as well as the health of their families and communities. This study develops two such instruments, one for workers and the other for managers, tailored to workplaces where crystalline silica and

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asbestos are present. These surveys can be used to evaluate the quality of working conditions, and identify opportunities for implementation of control strategies.

Introduction

Working conditions are the general set of circumstances and characteristics of the work environment, while risk factors are the specific parts of those conditions that have the potential to cause harm. In the construction industry, there are a number of working conditions that increase the level of risk from exposure to carcinogenic chemicals, such as asbestos and silica (Ramada Rodilla et al. 2022). The basic characterization of working conditions is the first and most crucial step in the personal exposure monitoring process and is essential for determining the risk assessment and management strategy. It is at this stage that the chemicals to be assessed are identified, similar exposure groups (SEGs) are established, and an initial estimate of the presence and degree of exposure is made, both for 8-h exposures and for short-term tasks. Thoroughness at this stage, which includes document review, on-site surveys, and discussions with experts and staff, allows for critical and informed decisions to be made, such as determining the need for measurements or qualitatively assessing exposure and proposing preliminary risk reduction measures (Hashimoto et al. 2018a).

Occupational exposure to substances such as asbestos and crystalline silica in the construction sector represents a global public health and occupational health problem. It is estimated that exposure to asbestos causes more than 250,000 deaths per year and more than 1.5 million disability-adjusted life years (DALYs) lost each year (Roy et al. 2025). This epidemiology is similar to that of silica exposure, as studies have shown that the incidence of silicosis has increased by 64.6%, the prevalence by 91.4%, and DALYs by 20.8% (Liu et al. 2023), especially after 15 yr of exposure, the main symptoms is a severe decline in lung function (Keramydas et al. 2020).

The basic characterization of working conditions can be facilitated by structured instruments, such as audit checklists and surveys, but such instruments require validation to establish measurement scales that gather data in a valid and probabilistic way (Bernal-García et al. 2020). Content validation is the first step in the instrument validation process, and uses expert judgement to determine the degree to which an instrument measures the variable in question (Hernández Sampieri et al. 2014).

The objective of this manuscript is to describe the design and validation of two instruments—one for workers and the other for occupational health and safety leaders—to assess working conditions related to occupational exposure to asbestos and silica. Working conditions were defined according to the Spanish National Institute for Safety and Hygiene at Work (INSHT) as "those that influenced by workplace conditionsworkers' health is as well as by contextual factors beyond the workplace" (INSHT 2017). Specifically, intra-workplace working conditions are made up of four subdimensions: (1) material working conditions (materials used, facilities and equipment); (2) factors related to the environment and workplace (space, access and surfaces of the workplace and the conditions of the environment itself); (3) work organization and prevention management, related to the type and/or organization of the task, communication and training, and deficiencies in management; and (4) individual factors, related to the worker's own abilities and characteristics (INSHT 2017). In addition, extra-occupational conditions are recognized as those factors that are external to occupational exposure but that may contribute to the generation of an injury or disease in the worker (INSHT 2017).

Consistent with this framework, the instrument considers two complementary domains. Intra-labor conditions comprise workplace characteristics, including organizational and task-related factors, as well as individual worker characteristics that may increase or modify the risk associated with occupational exposure to asbestos and silica. Extra-labor conditions, in contrast, refer to circumstances outside the workplace that may influence workers' health or vulnerability but are not directly related to occupational exposure. This distinction was adopted to clearly separate workplace-related determinants of exposure from external contextual factors, thereby avoiding conceptual overlap between the two domains.

Methodology

The design and content validation (Galicia Alarcón et al. 2017) of two instruments aimed at leaders in occupational safety and health (OSH) (instrument A) and workers (instrument B) for the characterization of working conditions associated with occupational exposure to silica and asbestos in the construction sector was implemented in four phases.

Phase 1 was a scoping literature review carried out following the JBI methodology with the Prisma ScR extension (López-Cortes et al. 2022). The objective of this review was to identify the key variables related to occupational exposure to asbestos and silica in the construction sector (see Supplementary Materials for methodological details).

Table 1 Characteristics of the group of expert judges.

Variable	Category	Percentage	Number of judges (*n*)
Gender	Male	71	5
	Female	29	2
Postgraduate training	Yes	100	7
Occupational health and safety training	Yes	71	5
	No	29	2
Industrial safety training	Yes	14	1
	No	86	6
Training in statistics and public health	Yes	14	1
	No	86	6
Work experience related to OSH or the construction sector.	Yes	86	6
	No	14	1
Experience in research and validation of instruments	Yes	71	5
	No	29	2

Phase 2 was the design and construction of the instruments. The design was based on working conditions described by the INSHT of Spain (INSHT 2017), with updating of vocabular to align with the Colombian regulatory and technical framework and the understanding of the target organizations of study. This meant working conditions were divided into intra-labor conditions and extra-labor conditions as main dimensions, with subdimensions that related risk factors of each working condition. Based on the results of the literature review, a qualitative content analysis reduced working conditions to essential contents in a matrix, which made it possible to identify the variables related to the dimensions and subdimensions previously established. Once the variables were identified, the items of the instruments and their response options were constructed. The process was carried out by means of discussion tables made up of researchers linked to the study, with expertise in OSH, health and industrial hygiene, allowing the definition of the content of the data and information collection instruments.

Phase 3 was the validation of the content of the instruments. This phase consisted of performing psychometric analysis of the instruments to determine their content validity through an expert judgment (Escobar Pérez and Cuervo-Martínez 2008).

Nine expert judges were selected based on their training and experience in OSH or industrial hygiene, as well as in instrument validation processes. They were invited to participate voluntarily; however, only seven accepted due to scheduling conflicts. This number of experts was considered adequate according to the literature (Escobar Pérez and Cuervo-Martínez 2008; Hashimoto et al. 2018a). Table 1 shows the main characteristics of the judges who comprised the expert panel.

The experts made their assessment through an evaluation tool built by the researchers that required each expert to assign a value for each item on a Likert-type scale for the criteria of: relevance, sufficiency, pertinence, coherence and clarity.

For the data analysis of the content validation process, the content validity coefficient (CVC) was calculated (INSHT 2017) and 95% confidence intervals were used for this coefficient; the cut-off point for considering a good degree of agreement was $\geq$0.7 (70%) (Merino-Soto and Livia-Segovia 2022).

Based on the results obtained from this validation, adjustments were made to the instruments.

Phase 4 was a pilot test to determine the comprehensibility of each item among potential users of the instruments. A judgmental or discretionary sampling strategy was used to select participants (Supo 2014). Participants were recruited from three companies in the construction sector, from three different geographical regions of the country, that achieved a result equal to or higher than the median (88/100 points) of the audits carried out in 2023 by a certifying entity under the RUC® (Uniform Contractors Register). For each of these companies, the SG-SST manager participated in completing instrument A, and at least two workers from each company participated in completing instrument B. These workers had to be in the field and performing activities involving exposure to these substances. Once participants voluntarily agreed to participate, they were informed that they had to complete the instrument and indicate for each of the questions and answer options whether they were understandable or not (López et al. 2019; Ramada Rodilla et al. 2022).

Table 2 Description of OHSMS managers and workers participating in the pilot test.

	OHSMS/company officials who completed instrument A $n = 3$	*n*	%	Employees who completed form B $n = 6$	*n*	%
Gender	Men	1	33	Men	6	100
	Women	2	67	Women	0	0
Academic background	Professional	2	67	Elementary	1	17
	Specialization	1	33	High school	2	33
				Technician	3	50
Length of service with the company	Average time in years	8 yr		Average time in years	7.61 yr	
Total experience	In OHS	11.6 yr		In construction	23.8 yr	
Average age	35.3 yr			55.5 yr		

Table 2 shows the characteristics of the participants in the pilot test.

The application of the pilot test instruments was conducted virtually and directed by the research team. The data from this pilot test was analyzed using response frequency for each of the three options regarding the comprehensibility of the instrument: fully comprehensible, partially comprehensible, not comprehensible, evaluating the relative frequency percentage for each item.

The research project from which this manuscript arises was endorsed by the Ethics and Research Methodology Committee CEMIN, of the National Institute of Health under code 032/2020. In addition, all the expert judges for content validation, leaders of the Occupational Safety and Health Management System (OSHMS) and workers of the companies that participated in the pilot test signed the respective informed consent.

Results

The scoping review of the literature following the PRISMA methodology found 179 articles (83 on asbestos and 96 for silica). The extracted variables were the following: methodology used for the characterization of working conditions, instruments used for the measurement of working conditions, variables of working conditions identified and considered in the evaluation by each tool used (hazard identification and risk assessment, occupational exposure assessment, documentation and monitoring of occupational exposure history, control measures to mitigate exposure, health effects, individual conditions related to the development of diseases, extra-occupational factors related to the development of the disease, risk knowledge and risk perception) and whether the tool is validated or not (see Supplementary Materials). The references that support each of the items can be found in Tables 3 and 4.

In phase, two instruments were designed: instrument A addressed to leaders, managers or coordinators of the occupational health and safety management systems and instrument B addressed to the workers of the companies in the construction sector. For both instruments, the dimensions (D) and subdimensions (S) of working conditions are identified in Tables 3 and 4. Dimension 2 (D2) has no subdimensions because all its variables referred to variables of exposure to silica and/or asbestos outside the workplace.. Finally, the items were grouped according to the activities carried out to perform risk management, denoted IG.

As mentioned above, instrument A included two dimensions: intra labor conditions (D1) and extra labor conditions (D2). Dimension 1 was made up of four subdimensions related to risk factors that could cause health effects: material working conditions (S1), conditions related to the environment and workplace (S2), individual conditions (S3) and conditions of work organization and prevention management (S4) and 39 items, which were grouped into eight groups (IG). In instrument A, 93% of the items correspond to the main dimension of intra labor conditions (D1), while 7% correspond to the dimension of extra-workplace conditions (D2). 2% corresponded to the dimension of extra-work conditions (D2), which was made up of 3 items and these formed a group of items. Thus, instrument A consisted of 2 dimensions, 4 subdimensions, 9 items groups and 42 items (Table 3).

Instrument B, like instrument A, was made up of two dimensions: intra-work conditions (D1) and extra-work conditions (D2). Dimension 1 included the same four subdimensions as instrument A. This dimension had 27 items and seven item groups, accounting for 87% of the items in instrument B. And, like instrument A, dimension 2 did not have subdimensions because the four items in this

Table 3 Dimensions and sub dimensions of the instrument A, directed to leaders and/or people in charge of the OSHMS.

Instrument A					
Working conditions dimension (D)	**Sub dimension (S)**	**Item (I)**	**Item group (IG)**	**Theoretical and regulatory basis**	**Information source**
Intra labor conditions (D1)	Work organization and prevention management conditions (S4)	1	Hazard identification and risk assessment (IG1)	The recognition of asbestos and silica as Group 1 carcinogens (IARC) and their potential to cause pneumoconiosis is incorporated. Early detection of emission sources and classification of intrinsic hazards must be carried out to activate preventive manageme	IARC (2012), Wang et al. (2023), Schlünssen et al. (2023), Huntley et al. (2023), Hoy and Chambers (2020), Rey-Brandariz et al. (2023), Presidencia de la República de Colombia (2015), Ministerio del Trabajo (2019).
	Environmental and workplace conditions (S2)	2			
		3			
	Individual conditions (S3)	4			
	Work organization and prevention management conditions (S4)	5			
	Material working conditions (S1)	6			
	Work organization and prevention management conditions (S4)	7	Occupational exposure assessment (IG2)	Quantification of airborne contaminant concentrations is necessary to determine the level of risk and prioritize areas. Furthermore, it defines the hygienist's competency, the sampling strategy (GES), and the use of NIOSH analytical methods (500, 600, 7500, 7400).	Hashimoto et al. (2017, 2018b), Mulhausen (2015), Andrews and O'Connor (2020), Cherrie (2023), Bullock (2015), Petit et al. (2017), Ministerio de Salud y Protección Social (2021), Ministerio de Trabajo y Seguridad Social (1979), Ministerio del Trabajo (2022).
		8			
	Environmental and workplace conditions (S2)	9			
		10			
		11			
		12			
		13			
	Work organization and prevention management conditions (S4)	14			

(*continued*)

Table 3 Continued

Instrument A					
Working conditions dimension (D)	**Sub dimension (S)**	**Item (I)**	**Item group (IG)**	**Theoretical and regulatory basis**	**Information source**
	Work organization and prevention management conditions (S4)	15 16 17	Documentation and monitoring of occupational exposure history (IG3)	They allow the traceability of the accumulated exposure load, essential for medical diagnoses and legal assessments, based on a systematic record of tasks, durations and estimated levels to reconstruct the exposure history.	Kang et al. (2021), Choi et al. (2016), Cherrie et al. (2018), Fontana et al. (2021), Noelle et al. (2023), Finnish Institute of Occupational Health (2014), Tossavainen (1997), Wolff et al. (2015), Ramada Rodilla et al. (2022).
	Work organization and prevention management conditions (S4)	18	Marking, delimitation and cleanliness of work areas (IG4)	They allow for the establishment of access control to critical areas and the prevention of cross-contamination or resuspension of dust, through the establishment of signage that meets the requirements of "Danger Asbestos" warning signs and the use of double lockers for work clothes.	Obmiński and Janeczek (2020), Instituto Nacional de Higiene y Seguridad en el Trabajo de España (2016), Ministerio de Trabajo y Seguridad Social (1979).
	Material working conditions (S1)	19 20	Occupational exposure controls (IG5)	It allows the identification of the implementation of the hierarchy of controls (engineering, administrative and PPE) to mitigate the release of fibers, such as the design of dynamic confinements, negative pressure and wet methods of dust control and the safe handling of friable material.	Instituto Nacional de Seguridad y Salud en el Trabajo (2010, 2012a, 2012b), Department of Health and Human Services (2007).
	Work organization and prevention management conditions (S4)	21 22 23	Risk communication and training (IG6)	It allows identifying how the transfer of technical information to the worker is ensured to improve self-care and regulatory compliance and the use of Safety Data Sheets (SDS) and explicit communication of risk levels.	Occupational Safety and Health Administration (2012), Marant Micallef et al. (2019), Labrèche et al. (2019), Purdue et al. (2015), Congreso de Colombia (1993), Presidente de la República de

(*continued*)

Table 3 Continued

Instrument A					
Working conditions dimension (D)	**Sub dimension (S)**	**Item (I)**	**Item group (IG)**	**Theoretical and regulatory basis**	**Information source**
					Colombia (2018), Ministerio del Trabajo y Salud y Protección Social (2021).
	Work organization and prevention management conditions (S4)	24 25 26 27 28	Surveillance of the health conditions of workers exposed to asbestos and silica (IG7)	They allow for the early identification of health effects and specific respiratory protection as a last barrier, and the existence of detection and prevention based on ILO X-ray protocols, spirometry, tomography, vaccination schedules and smoking cessation programs.	Takahashi and Landrigan (2016), Wolff et al. (2015), Anttila and Boffetta (2020), Frost (2013), Collatuzzo et al. (2023), Douglas and Van den Borre (2019), IARC (2012), Congreso de la República de Colombia (2019), Ministerio del Trabajo (2025), Ministerio de la Protección Social (2003).
	Individual conditions (S3)	29 30			
	Work organization and prevention management conditions (S4)	31 32 33 34 35 36			
	Work organization and prevention management conditions (S4)	40 41 42	Organization's disposition (IG8)		
Extra labor conditions (D2)		37 38 39	Conditions of extra-occupational exposure that increase the risk of developing respiratory disease from exposure (IG9)	It allows the identification of exposure to chemical substances outside of work that enhance respiratory disease (environmental and paraoccupational exposure), based on the location of housing with respect to emission sources and the presence of asbestos in home renovations.	Fontana et al. (2021), Noelle et al. (2023), Kang et al. (2021).
Total number of questions in instrument A		42			

Table 4 Dimensions and sub dimensions of the instrument B, directed to workers.

Instrument B					
Working conditions dimension (D)	**Sub dimension (S)**	**Item (I)**	**Item group (IG)**	**Theoretical and regulatory basis**	**Information source**
Intra labor conditions (D1)	Work organization and prevention management conditions (S4)	1	Hazard identification and risk assessment (IG1)	They allow identification of whether the worker recognizes hazardous materials and associates their exposure with serious health risks.	IARC (2012), Wang et al. (2023), Schlünssen et al. (2023).
	Environmental and workplace conditions (S2)	2			
		3			
	Individual conditions (S3)	4			
	Work organization and prevention management conditions (S4)	5			
	Material working conditions (S1)	6			
		7			
	Environmental and workplace conditions (S2)	8	Occupational exposure assessment (IG2)		
		9			
	Work organization and prevention management conditions (S4)	10	Marking, delimitation and cleanliness of work areas (IG3)	They allow us to assess whether the worker applies hygiene protocols to avoid contaminating clean areas.	Occupational Safety and Health Administration (s.f.), Ministerio de Trabajo y Seguridad Social (1979), Instituto Nacional de Higiene y Seguridad en el Trabajo de España (2016).
	Material working conditions (S1)	11	Occupational exposure controls (IG4)	It allows identifying if there are management practices on the construction site that reduce the presence of dust in the air, such as humidification, use of vacuuming, training, among others.	Instituto Nacional de Seguridad y Salud en el Trabajo (2010, 2012b), Obmiński and Janeczek (2020).
		12			
	Work organization and prevention management conditions (S4)	13	Risk communication and training (IG5)		
		14			
	Work organization and prevention management conditions (S4)	15	Surveillance of the health conditions of workers exposed to asbestos and silica (IG6)	They allow us to establish whether the worker actively participates in the fit-testing and understands the	Occupational Safety and Health Administration (2006), Wolff et al. (2015), Finnish Institute of
		16			
	Individual conditions (S3)	17			
		18			

(*continued*)

Table 4 Continued

Instrument B					
Working conditions dimension (D)	**Sub dimension (S)**	**Item (I)**	**Item group (IG)**	**Theoretical and regulatory basis**	**Information source**
	Work organization and prevention management conditions (S4) Individual conditions (S3) Work organization and prevention management conditions (S4)	19 20 21 22 23 24 25		importance of their medical fitness.	Occupational Health (2014).
	Individual conditions (S3)	30 31	Perceived risk, risk awareness and perceived risk behaviors (IG7)	It allows us to understand how attitude and knowledge influence the adoption of safe behaviors. It allows us to identify the correlation between risk awareness and the prevention of silicosis/ asbestosis.	Wang et al. (2023)
Extra labor conditions (D2)		26 27 28 29	Conditions of extra-occupational exposure that increase the risk of developing respiratory disease from exposure (IG8)	It allows mapping of secondary (home) contamination and previous exposures or second occupations, due to risk from washing work clothes and proximity to quarries/factories.	Noelle et al. (2023), Fontana et al. (2021), Kang et al. (2021).
Total number of questions in instrument B		31			

dimension were related to extra-work exposure conditions, items that were grouped into a single IG; 13% of the items corresponded to the extra-work conditions dimension. In summary, instrument B consisted of 2 dimensions, 4 subdimensions, 8 item groups, and 31 items (Table 4).

Items that have a validity coefficient value (CVC) below 70% (<0.7) in some of their validation criteria (relevance, sufficiency, pertinence, coherence and clarity) are highlighted in bold in Tables 5 and 6. In instrument A, the criteria of relevance, sufficiency, pertinence and coherence obtained a CVC higher than 90% in all items; and the criterion of clarity obtained a CVC lower than 90% in 2 items (Table 5). In instrument B, relevance had a lower value of agreement among the judges and ranged between 60% and 70% for 6.5% of the items; the sufficiency criterion ranged between 60% and 70% in 9.7% of the items; the coherence criterion ranged between 50% and 60% in 3.2% of the items and between 60.1% and 70% in 3.2% of the items

Table 5 Validation of the instrument A content.

Working conditions dimension	No. item	Relevance % (IC 95%)	Sufficiency % (IC 95%)	Pertinence % (IC 95%)	Coherence % (IC 95%)	Clarity % (IC 95%)
D1	I1	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I2	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I3	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	90 (74.4 to 100)
	I4	97 (82.7 to 100)	93 (79.3 to 100)	97 (82.7 to 100)	93 (79.3 to 100)	**87 (69.7 to 100)**
	I5	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I6	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I7	97 (82.7 to 100)	93 (79.3 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	90 (74.4 to 100)
	I8	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I9	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I10	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)	97 (82.7 to 100)
	I11	90 (74.4 to 100)	90 (74.4 to 100)	90 (74.4 to 100)	90 (74.4 to 100)	90 (74.4 to 100)
	I12	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I13	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I14	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I15	93 (79.3 to 100)	93 (79.3 to 100)	93 (79.3 to 100)	93 (79.3 to 100)	93 (79.3 to 100)
	I16	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	90 (74.4 to 100)
	I17	93 (79.3 to 100)	93 (79.3 to 100)	93 (79.3 to 100)	93 (79.3 to 100)	93 (79.3 to 100)
	I18	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I19	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I20	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I21	90 (74.4 to 100)	90 (74.4 to 100)	90 (74.4 to 100)	90 (74.4 to 100)	**87 (69.7 to 100)**
	I22	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I23	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I24	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I25	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I26	97 (82.7 to 100)	93 (79.3 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I27	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I28	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I29	97 (82.7 to 100)	93 (79.3 to 100)	93 (79.3 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I30	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	93 (79.3 to 100)
	I31	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I32	97 (82.7 to 100)	93 (79.3 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	90 (74.4 to 100)
	I33	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I34	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I35	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I36	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I40	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I41	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I42	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
D2	I37	93 (79.3 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I38	93 (79.3 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)
	I39	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)	97 (82.7 to 100)

(Table 6). Finally, the clarity criterion scored between 50% and 60% in 3.2% of the items and between 60.1% and 70% in 6.5% of them (Table 6).

In the two instruments, the experts made observations on the adjustment of the items, mainly in terms of wording, which were incorporated. The researchers,

Table 6 Validation of instrument B content.

Working conditions dimension	No. item	Relevance % (IC 95%)	Sufficiency % (IC 95%)	Pertinence % (IC 95%)	Coherence % (IC 95%)	Clarity % (IC 95%)
D1	I1	94 (81.1 to 100)	86 (70.9 to 100)	91 (78.2 to 100)	91 (78.2 to 100)	91 (78.2 to 100)
	I2	91 (78.2 to 100)	**69 (51.4 to 84.6)**	80 (64.1 to 95.9)	74 (57.6 to 90.4)	**57 (41.7 to 74.3)**
	I3	89 (73.5 to 100)	89 (73.5 to 100)	89 (73.5 to 100)	86 (70.9 to 100)	86 (70.9 to 100)
	I4	94 (81.1 to 100)	89 (73.5 to 100)	97 (86.3 to 100)	89 (73.5 to 100)	83 (66.5 to 97.5)
	I5	97 (86.3 to 100)	94 (81.1 to 100)	94 (81.1 to 100)	91 (78.2 to 100)	86 (70.9 to 100)
	I6	86 (70.9 to 100)	83 (66.5 to 98)	86 (70.9 to 100)	80 (64.1 to 95.9)	80 (64.1 to 95.9)
	I7	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)	94 (81.1 to 100)	94 (81.1 to 100)
	I8	83 (66.5 to 100)	77 (61.8 to 94)	74 (57.6 to 90.4)	74 (57.6 to 90.4)	74 (57.6 to 90.4)
	I9	86 (70.9 to 100)	80 (64.1 to 96)	86 (70.9 to 100)	80 (64.1 to 95.9)	71 (55.5 to 88.5)
	I10	91 (78.2 to 100)	91 (78.2 to 100)	86 (70.9 to 100)	89 (73.5 to 100)	80 (64.1 to 95.9)
	I11	97 (86.3 to 100)	83 (66.5 to 98)	97 (86.3 to 100)	91 (78.2 to 100)	83 (66.5 to 97.5)
	I12	94 (81.1 to 100)	89 (73.5 to 100)	91 (78.2 to 100)	86 (70.9 to 100)	86 (70.9 to 100)
	I13	97 (86.3 to 100)	91 (78.2 to 100)	97 (86.3 to 100)	94 (81.1 to 100)	86 (70.9 to 100)
	I14	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)	89 (73.5 to 100)
	I15	94 (81.1 to 100)	89 (73.5 to 100)	94 (81.1 to 100)	94 (81.1 to 100)	86 (70.9 to 100)
	I16	91 (78.2 to 100)	83 (66.5 to 98)	89 (73.5 to 100)	89 (73.5 to 100)	83 (66.5 to 97.5)
	I17	97 (86.3 to 100)	80 (64.1 to 96)	91 (78.2 to 100)	86 (70.9 to 100)	77 (61.8 to 94.2)
	I18	94 (81.1 to 100)	94 (81.1 to 100)	89 (73.5 to 100)	89 (73.5 to 100)	89 (73.5 to 100)
	I19	86 (70.9 to 100)	86 (70.9 to 100)	83 (66.5 to 97.5)	80 (64.1 to 96)	77 (61.8 to 94.2)
	I20	97 (86.3 to 100)	89 (73.5 to 100)	94 (81.1 to 100)	94 (81.1 to 100)	89 (73.5 to 100)
	I21	97 (86.3 to 100)	91 (78.2 to 100)	97 (86.3 to 100)	91 (78.2 to 100)	86 (70.9 to 101.1)
	I22	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)	94 (81.1 to 100)	91 (78.2 to 101.1)
	I23	97 (86.3 to 100)	91 (78.2 to 100)	97 (86.3 to 100)	94 (81.1 to 100)	91 (78.2 to 101.1)
	I24	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 101.1)
	I25	**69 (51.4 to 85)**	**66 (49.4 to 82.6)**	**66 (49.4 to 82.6)**	**69 (51.4 to 84.6)**	**63 (45.5 to 78.5)**
	I30	**77 (61.8 to 94)**	**74 (57.6 to 90)**	**77 (61.8 to 94)**	**77 (61.8 to 94.2)**	**71 (55.5 to 88.5)**
	I31	**66 (49.4 to 83)**	**63 (45.5 to 78.5)**	**63 (45.5 to 78.5)**	**60 (43.6 to 76.4)**	**63 (45.5 to 78.5)**
D2	I26	97 (86.3 to 100)	94 (81.1 to 100)	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)
	I27	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)	97 (86.3 to 100)
	I28	80 (64.1 to 96)	80 (64.1 to 96)	80 (64.1 to 96)	80 (64.1 to 95.9)	74 (57.6 to 90.4)
	I29	94 (81.1 to 100)	94 (81.1 to 100)	94 (81.1 to 100)	94 (81.1 to 100)	94 (81.1 to 100)

according to their expertise in the phenomenon under study, did not find it necessary to eliminate any item; however, the items of instrument B that obtained a lower percentage of qualification in the criteria of relevance, sufficiency, pertinence, coherence and clarity were modified.

The pilot test of instrument A determined 38 of the 42 questions (corresponding to 90%) were totally comprehensible. In the remaining 10% of the items, 67% of the participants responded that they were understandable, in 7% (33%) that they were partially understandable and finally, in 2% of the items (33%) of the participants indicated that they were not understandable. The four items (which had discrepancies in less than 70% of the respondents) were adjusted in their wording, as the observations were semantic adjustments rather than the elimination or replacement of questions.

In the specific case of the question 3, which was initially worded as, *If in question 2 you selected Asbestos fibers or dust containing silica, where do you identify the presence of these substances?,* the question was adjusted to, *If in question 2 you selected Asbestos fibers or dust containing silica, in which of the following construction activities and processes do you identify the presence of these substances?* Question 10, initially worded as, *Does your organization have a quantitative occupational exposure assessment strategy within its industrial hygiene program?,* was adjusted to, *Yes, your organization has a*

quantitative occupational exposure assessment strategy within its industrial hygiene program. Several response options were then provided for selection, in accordance with current legal regulations. The adjustment of these questions primarily involved providing more response options to avoid generating too many responses that could not be systematically organized later. The question 16, the initial question was, *Does the organization have an information system/database of the occupational population exposed to silica and asbestos stratified according to risk level?,* which was adjusted to, *Which of the following information systems/databases of the population occupationally exposed to silica and asbestos has your organization implemented?* This change was made because according to the participants in the pilot test, the response options were not consistent with the wording of the question.

With respect to the comprehensibility of instrument B, it was evident that when assessing the general level of comprehension of the questionnaire, 30 of the 31 questions (representing 97% of the items) were totally comprehensible, for the most part, by 100% of the participants; only 4 items had a discrepancy in comprehensibility in 17% of the participants. On item 2, only 50% of the participants indicated that the question was understandable, 17% partially understandable and 33% that it was not understandable. The six items (which had a discrepancy of less than 85% of the participants) in this test were adjusted in wording as in instrument A. In the specific case of this instrument, the comments were intended to leave the question and add examples of each type of response in parentheses, as was done for question 11, in which examples of each of the ventilation systems were added, in less technical terms (see Supplementary Materials).

This pilot test also identified that the estimated time required to administer each instrument was 40 to 50 min for instrument A and 30 to 40 min for instrument B.

The two instruments had different types of responses: multiple and dichotomous, thus obtaining the final version of instrument A and instrument B (see Supplementary Materials).

Discussion

According to the results obtained and the methodological rigor established and implemented, it was determined that the two instruments were valid and understandable: the items established allow characterizion of working conditions in the construction sector associated with occupational exposure to crystalline silica dust and asbestos fibers. Although there are no validation processes for instruments that can be compared with the results of this study with respect to the working conditions of the sector, there is scientific literature on occupational exposure to silica or asbestos; therefore, the selection of questions or items was based on those elements that have been consistently identified as crucial in previous studies for the characterization of this exposure in the work and non-work environment. The lack of similar studies and instruments (Ossa et al. 2018) motivated the development of these two instruments, and the instruments developed in this study will enable characterization of working conditions that determine the worker's health in the physical, mental and social spheres (Prieto 2002; Ramada Rodilla et al. 2022).

Instrument A is relevant because 100% of the items had a CVC score equal to or higher than 90%, indicating that the 42 items are essential to determine the working conditions within two dimensions and five subdimensions of this construct (López et al. 2019; Ramada Rodilla et al. 2022).

According to these results obtained, it is necessary to mention that, with the CVC obtained in this phase, it is corroborated that the dimensions, subdimensions, and variables established in instrument A are relevant and important for the construct and allow the identification of risk factors in the work environment that can affect the health of workers exposed to these two substances (Roy et al. 2025). Specifically, instrument A incorporates the principal factors consistently identified in the literature as influencing occupational chemical exposure, including the type of industry (Noelle et al. 2023), occupation (Fajardo-Zapata et al. 2013; Fontana et al. 2021), exposure duration and frequency (Huh et al. 2022), the characteristics and magnitude of the chemical agent or particulate material present in the workplace (Labrèche et al. 2019; Bernstein 2022), and the implementation of exposure control measures, such as personal protective equipment and engineering controls, which influence workers' exposure levels and associated risk (Belackova et al. 2024). The positive CVC results indicate that experts considered these domains to be appropriate and representative of the construct assessed by the instrument. In summary, using the statistical parameters of the content validation process for instrument A, the experts considered the items to be relevant, coherent, sufficient, and clear, as they were conceptually aligned with the dimension they intended to measure. These characteristics are fundamental to ensuring that the instrument accurately reflects the theoretical construct and contributes to its overall validity (Boateng et al. 2018), as well as the representativeness and exhaustiveness of the construct (Polit and Beck 2006; Zamanzadeh et al. 2015). It is important to note that those items with a lower percentage in their CVC were semantically adjusted.

However, none were eliminated, since it is from this initial process that the authors indicate that adequate or inadequate risk management could be provided for exposure to chemical substances in sectors such as construction (Zapata-Alvarez et al. 2021; Ramada Rodilla et al. 2022; Jiménez et al. 2024).

Similarly, these results showed that the subdimensions of workplace conditions denote the circumstances, environment, and specific situations that directly affect workers' health while performing their duties within the work environment (Fajardo-Zapata et al. 2013), one of which is exposure to chemical contaminants.

Furthermore, the high level of comprehensibility observed during the pilot tests supports the practical applicability of the instrument, indicating that the items can be interpreted consistently by the target population, an essential aspect for minimizing measurement error and improving data quality (Boateng et al. 2018). For the proper establishment of controls, it is important to identify variables that determine occupational exposure (Andrews and O'Connor 2020; Gómez et al. 2024), variables that were included in the two instruments designed and validated.

The identification of these conditions that determine exposure to these carcinogenic substances makes it possible to guarantee the effectiveness of the control measures established in the companies, such as: cleaning of the workplace and changes in the process or substitution, engineering, administrative and personal protective equipment control measures (Belackova et al. 2024).

Proper implementation allows reducing risk levels to improve working conditions, prevent health effects such as lung cancer, mesothelioma, among others (Hernández Sampieri et al. 2014), maximize job satisfaction, OSH organizational culture and business competitiveness (Moran-Fuentes et al. 2022). Therefore, in instrument A, a group of questions was also established to know the disposition of the leader or person in charge of the OSH management system regarding the implementation of management practices to improve working conditions in the face of this occupational exposure.

For instrument B, the items were oriented to assess workers' perception and knowledge of working conditions, including their ability to identify the danger of asbestos and silica and to recognize the correct implementation of the controls established by the organization. Given this audience, the wording of items was adjusted to a less technical language than instrument A. The results of the content and comprehensibility validation of instrument B had greater variability than instrument A. This may be due to the in the CVC in the five criteria evaluated for content validity. This may be due to the educational level of the working population in this sector, which is mostly elementary school (Ossa et al. 2018), and presents great variability in their education (Zapata-Alvarez et al. 2021).

In this sense, the knowledge and perceptions of workers allow us to identify those aspects in which the training and education of both those responsible for OSHMS and the workers should be strengthened, with respect to the management of risks to carcinogenic substances, an essential aspect to adequately prevent this occupational exposure and to increase risk perception in the work environment. Therefore, the active participation, communication, and education of all actors involved in OSH in companies is fundamental to improving working conditions in the sector, especially regarding exposure to carcinogenic chemicals such as silica and asbestos In addition, studying and measuring risk perception by means of valid and reliable instruments has improved results in the prevention of health damage, since it increases the involvement of workers in risk management (Ossa et al. 2018), as well as risk awareness (Zapata-Alvarez et al. 2021).

In this context, both the instrument addressed to those responsible for the OSHMS (A) and to the workers (B), contains the same group of items aimed at characterizing the methods and forms of participation for hazard identification and risk assessment, communication and knowledge of the level of risk of occupational exposure to silica and asbestos and the control measures implemented by the employer and adopted by the worker (Aryal and Morley 2020), aspects that must be informed to all actors in the companies in the sector.

Regarding the extra-work conditions dimension, the findings support the inclusion of this domain as part of the proposed instruments, as the expert evaluation indicated that the selected items appropriately represent the construct. Although minor differences were observed between instruments A and B during the validation process, these variations do not alter the overall interpretation that the dimension captures relevant aspects of workers' circumstances beyond the workplace.

This is particularly important because occupational health is influenced not only by workplace exposures but also by contextual factors that may modify individual susceptibility, cumulative exposure, and health outcomes (World Health Organization 2010; Consonni et al. 2020; Krabbe et al. 2024). Therefore, incorporating extra-work conditions broadens the scope of the assessment and provides a more comprehensive characterization of the factors associated with occupational risk. For the particular case of these instruments, variables are included that allow the identification of this environmental exposure to silica and/or asbestos such as: place of residence and other environmental exposures given by daily life activities where there is a possible exposure, variables that are important to identify and document in the SG-SST of the

organizations. Taking into account these results, it was found that in the scientific literature these items are important to include since exposure to these two substances is not only found in the working population of the sector, but also to the families of the exposed workers. The emission of this particulate material into the environment represents a danger to public health, affecting the health of the general population (an example of this is the exposure of children and women by direct contact with asbestos or crystalline silica through a family member who is exposed) or being a contributor to the generation of diseases derived from occupational exposure to these substances (Hoy and Chambers 2020; Lysaniuk et al. 2020; Roy et al. 2025).

Furthermore, the inclusion of the evaluation of individual and non-occupational factors stems from the fact that some studies on exposure to carcinogenic agents in work environments, such as silica and asbestos, have corroborated the synergy between these factors and purely intra-occupational factors, which exponentially increase the risk of developing preventable diseases such as pneumoconiosis and cancer.

It is important to emphasize that the inclusion of these variables does not displace the employer's responsibility for guaranteeing safe working conditions; on the contrary, it complements the comprehensive characterization of occupational exposure to these hazardous chemicals. In the specific case of pneumoconiosis, evidence shows that the exposure-disease relationship is not uniform, but rather can be modulated by individual conditions such as respiratory history, lifestyle habits such as smoking, or biological susceptibility, as well as the existence of non-occupational exposure (Olsson et al. 2024; Aktas et al. 2025; Mundt et al. 2025). In this sense, the inclusion of these variables contemplates an epidemiological and preventive approach, as it allows the identification of subgroups of greater vulnerability, improves the interpretation of risk levels and guides more specific health surveillance strategies, within the framework of risk management, maintaining the principle of prioritizing control measures on the work environment.

Occupational and environmental exposure to these carcinogenic chemicals has a strong association with serious but preventable diseases. This risk mitigation and reduction of the incidence and prevalence of diseases such as pneumoconiosis and cancer can be achieved by improving working conditions and highly effective control measures (Hoy and Chambers 2020; Lysaniuk et al. 2020) that can be implemented in the workplace.

Therefore, having valid and understandable instruments such as the ones constructed, allows making decisions based on valid data and establishing improvement actions in the processes and in the occupational health and safety management systems of the organizations, where there is exposure to these chemicals, since the results obtained in this study allow the application of these instruments to be replicated in other contexts, as these instruments can be completed by researchers with knowledge of OHS or industrial hygiene, and/or those responsible for OHSMS to carry out a diagnosis of the existing working conditions in the organization based on a self-report using instrument A, and the report made by workers based on questionnaire B. The results of this diagnosis will be a fundamental input for establishing improvements in risk management practices aimed at addressing gaps in hazard identification or missing controls to be established to mitigate risk based on compliance with the hierarchy of controls.

An adequate risk management and handling of these substances in the work environment contributes to reduce the occupational exposure of the working population to the different pollutants, as well as to prevent and mitigate the impact on public health and global labor, since based on the results obtained from the application of these instruments, regulatory bodies can develop policies and technical standards that regulate aspects such as the performance of hygiene measurements as a fundamental aspect for qualitatively or quantitatively identifying exposure and/or the implementation of more far-reaching controls such as the elimination and substitution of these substances in different industrial sectors, in accordance with the current regulations applicable to each country, which in the case of Colombia are Resolution 2400 of 1979, Law 1968 of 2019, Resolution 2467 of 2022, among others.

To this end, this designed and validated instrument serves as a precursor that can provide information on the current state of working conditions, guide the design of representative sampling strategies, and define SEGs, in accordance with specialized methodologies for diagnosis and administrative intervention, but without replacing the direct quantification of occupational exposure. Therefore, a clear direction for future studies lies in scaling up the qualitative and administrative information collected with this instrument to the industrial hygiene phase, specifically measurement, through the integration of high-precision tools such as exposure estimation models like the Advanced REACH Tool (ART), spreadsheets for managing direct measurements like those by Susan Arnold, or data quality checklists by Catherine Simmons and Paul Hewitt. Its use is indispensable for constructing robust Occupational Exposure Matrices (OLMs) and determining the Cumulative Exposure Burden (CEB), ensuring the acquisition of precise and quantitative exposure levels, essential for correlating working conditions with long-term health outcomes. These tools were not integrated here, given the scope of the study and the instrument designed.

A limitation of this study is that the pilot test was conducted with a small number of companies compared to the total number of companies in the country within this sector. Therefore, it is necessary to apply the instruments to other populations with similar characteristics to increase the evidence confirming the psychometric properties developed in this work.

Conclusions

The two instruments designed were valid and understandable for the working population of the construction sector for the characterization of intra labor and extra labor working conditions associated with silica and asbestos exposure in the construction sector.

It is recommended for future studies to continue testing and statistical analysis under other psychometric parameters, and where the cross-cultural adaptation and/or validation of these instruments will be carried out. These instruments were developed and validated for this study but can be replicated in other industries where there is exposure to chemicals.

Author contributions

All the authors participated in the analysis of the variables, items and dimensions that would make up the instrument, as well as in the drafting and revision of this article.

Study contributions

The manuscript presents the first instrument designed and validated to characterize working conditions with silica and asbestos exposure in construction, a key sector in developing countries. These tools allow the prevention of serious occupational diseases through improvements in the work environment. Their application contributes to public policies, occupational health surveillance and risk prevention in communities affected by environmental exposures.

Authorship responsibilities

The authors emphasize that all information indicated in the manuscript is our responsibility.

Supplementary material

Supplementary material is available at *Annals of Work Exposures and Health* online.

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Conflicts of interest

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.

Data availability

The data underlying this article are available in the article and in its online supplementary material.

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