




Work-related respiratory health conditions among construction workers: a systematic narrative review

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ABSTRACT

Background Emerging evidence in both developed and developing countries indicate that occupational health hazards and diseases among construction workers constitute a significant public health challenge. While occupational health hazards and conditions in the construction sector are diverse, a burgeoning body of knowledge is emerging about respiratory health hazards and diseases. Yet, there is a notable gap in the existing literature in terms of comprehensive syntheses of the available evidence on this topic. In light of this research gap, this study systematically reviewed the global evidence on occupational health hazards and related respiratory health conditions among construction workers.

Methods Using meta-aggregation, guided by the Condition (respiratory health conditions), Context (construction industry) and Population (construction workers) (CoCoPop) framework and Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, literature searches were conducted on Scopus, PubMed, Web of Science and Google Scholar for relevant studies on respiratory health conditions affecting construction workers. Four eligibility criteria were used in scrutinising studies for inclusion. The quality of the included studies was assessed based on Joanna Briggs Institute's Critical Appraisal tool, while the reporting of the results was guided by the Synthesis Without Meta-analysis guidelines.

Results From an initial pool of 256 studies from the various databases, 25 studies published between 2012 and October 2022 were identified as meeting the inclusion criteria. In all, 16 respiratory health conditions were identified, with cough (ie, dry and with phlegm), dyspnoea/breathlessness and asthma emerging as the top three respiratory conditions among construction workers. The study identified six overarching themes of hazards that are associated with respiratory health conditions among construction workers. These hazards include exposure to dust, respirable crystalline silica, fumes, vapours, asbestos fibres and gases. Smoking and extended period of exposure to the respiratory hazard were found to increase the risk of contracting respiratory diseases.

Conclusions Our systematic review indicates that construction workers are exposed to hazards and conditions that have adverse effects on their health and well-being. Given the considerable impact that work-related health hazards can have on the health and socioeconomic well-being of construction workers, we suggest that the implementation of a comprehensive

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Does the hazardous nature of construction activities and materials expose construction workers to respiratory health conditions?

WHAT THIS STUDY ADDS

⇒ Construction activities and materials expose workers to harmful hazards such as dust, silica, fumes, asbestos and these hazards are associated with a range of health problems ranging from mild respiratory symptoms to severe ones such as respiratory cancers and silicosis.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This review systematically examines the nature and frequency of respiratory hazards and diseases, beyond just conditions related to COPD, among construction workers and identifies effective mitigating strategies for reducing respiratory health conditions among construction workers.

occupational health programme is essential. Such a programme would extend beyond the mere provision of personal protective equipment and would incorporate a range of proactive measures aimed at controlling the hazards and mitigating the risk of exposure to the occupational health hazards.

INTRODUCTION

The construction work sector is unarguably one of the most hazardous work environments.¹ This is because the materials and processes involved in the sector expose its workers to health hazards and accidents with significant public health implications.¹ The construction work environment is both complex and dynamic² with a range of hazardous work materials, processes and activities. In addition to the risks associated with direct or indirect exposure to hazardous materials, the construction workforce, particularly in the informal sector of developing countries, is often characterised by low



levels of formal education. This lack of education may compound the challenges faced by workers in this sector, as they may be less equipped to understand and respond to the potential health risks associated with their work.^{2,3}

Although the range of occupational health hazards and conditions encountered within the construction sector is broad and multifaceted, there is a growing body of research focused specifically on respiratory health hazards and diseases. This emerging field of inquiry is motivated by the recognition of the unique health challenges faced by workers in this industry, particularly in light of the ongoing expansion of construction activities across both developing^{2,4-6} and developed⁷⁻¹⁰ regions of the world. Addressing occupational respiratory health hazards and diseases among construction workers would require research-oriented occupational health strategies. Notably, evidence indicates there has been a positive impact of occupational health strategies over the last 60 years.¹¹ Continuous improvement would depend on recent research capturing changing dynamics in work conditions and work-related legislation. This is particularly critical considering that the construction sector is known to pose significant occupational health hazards and conditions.¹ For instance, recent studies have shown that workers in the construction industry are frequently exposed to a range of airborne pollutants and irritants that can lead to respiratory ailments.^{12,13} Despite the evident risk to worker health, there is a dearth of comprehensive research on the specific respiratory health hazards encountered by construction workers and the levels of impact of these hazards on respiratory health. This gap in knowledge hinders the development and implementation of effective interventions to mitigate these hazards and protect worker health. Borup *et al*¹⁴ conducted a prior systematic review that synthesised evidence on respiratory health conditions among construction workers. However, their review solely focused on chronic obstructive pulmonary diseases (COPDs) and was limited to studies published between 1990 and 2016.

Given the dynamic nature of working conditions and legislative frameworks, it is imperative to undertake a contemporary and comprehensive synthesis of available evidence. The working environment is continuously evolving, with new occupational hazards emerging and existing ones changing in their manifestation. This underscores the need for periodic reviews of available evidence to ensure that interventions and policies remain current and effective in mitigating risks and promoting occupational health and safety. A contemporary synthesis of the available evidence is vital in order to provide current insights into the status of working conditions, potential hazards and effective interventions. Such a synthesis could facilitate an assessment of trends and changes in the nature and prevalence of hazards, an evaluation of the efficacy of current interventions and identification of gaps in knowledge that require further research. By conducting a current synthesis of available evidence, policy-makers, employers and other stakeholders can be

better equipped to make informed decisions about occupational health and safety and promote the well-being of workers in an ever-changing work environment. The aim of our systematic review is in twofold. First, we aimed to understand, through the synthesis of recent evidence, the nature and frequency of respiratory hazards and diseases, beyond just conditions related to COPD, among workers in the construction sector. Our second aim was to identify effective strategies that could be responsive in reducing if not totally eradicating respiratory health diseases among construction workers.

Conducting a systematic review is indeed justified in our case. Our objective was to ensure a comprehensive evaluation of the existing evidence on the topic, which has not been systematically assessed elsewhere. We aimed to provide a thorough and unbiased analysis of the available studies, identifying research gaps and assessing the quality of the evidence. By conducting this review, we have successfully identified areas where further research is needed and highlighted methodological inconsistencies, conflicting findings and limitations within the existing studies.

Moreover, our systematic review serves as a valuable tool for evidence-based decision-making. Policy-makers, practitioners and researchers can rely on our review to make informed decisions and take appropriate actions. By synthesising the available evidence in a transparent and rigorous manner, we provide a reliable foundation for evidence-based practice and policy development. Therefore, our systematic review contributes significantly to the field by filling the gap in knowledge and informing evidence-based decision-making. It is a vital step in advancing our understanding of 'work-related respiratory health conditions among construction workers' and guiding future research endeavours.

MATERIALS AND METHODS

Search strategies

This systematic review was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The study adopted the CoCoPop framework,¹⁵ that is, Condition (respiratory health conditions), Context (construction industry) and Population (construction workers) to determine the keywords for the literature search, and to form the basis for the inclusion or exclusion of retrieved articles, as well as to inform the approach to data analysis. The CoCoPop framework was used because it is suitable for addressing questions which are relevant to issues such as types of health conditions and their prevalence in a specific population.¹⁵

Two authors (EFB and CB) conducted literature searches on Scopus, Web of Science, Google Scholar and PubMed for relevant studies on respiratory conditions affecting construction workers. Within the context of this review, 'respiratory conditions' referred to any symptom or disease affecting parts of the body involved in

breathing, such as the sinuses, throat, airways or lungs.¹⁶ Thus, in the context of our manuscript, the term ‘conditions’ encompasses a broad range of health outcomes, including both diseases and symptoms. For the purpose of clarity and comprehensiveness, we define conditions as encompassing the following:

- ▶ Diseases—health conditions including various pathological processes characterised by specific structural or functional abnormalities in the body. These diseases may have well-defined clinical manifestations, diagnostic criteria and treatment approaches. Examples of diseases within the scope of our study may include respiratory, lung and larynx cancers, which are characterised by the presence of malignant tumours in the respective organs.
- ▶ Symptoms—health conditions encompassing symptoms, which refer to subjective experiences or manifestations of an underlying health issue. Symptoms may be reported by individuals and can vary in nature and severity. Examples of symptoms relevant to our study may include cough, wheezing and dyspnoea.

Using keywords based on the dimensions of the CoCoPop framework, a thorough search was conducted in the electronic databases with word builders (such as Scopus) as follows (also see online supplemental file—search strategy).

Condition: ‘respiratory health’, ‘respiratory disease’, ‘respiratory sick*’, ‘respiratory ill*’, ‘respiratory disorder’, ‘respiratory problem’, ‘respiratory infection’, ‘respiratory cancer’, ‘respiratory well*’, ‘occupational lung disease’, ‘respiratory condition’, ‘respiratory exposure*’, ‘respiratory symptom*’, ‘lung function’, ‘respiratory pressure’, ‘respiratory disorder’

Context: ‘construction industr*’, ‘construction sector’, ‘construction work*’, ‘construction activit*’, ‘building work*’, ‘building industr*’, ‘building site’, ‘construction site’, ‘construction firm’, ‘construction compan*’, ‘construction job’.

Population: ‘construction labo*’, ‘manual work*’, ‘construction worker*’, ‘contractor’, ‘manual labo*’, ‘construction personnel*’, ‘building worker*’.

Databases were searched using combinations of these keywords, for instance ‘OR’ was used for the terms within each dimension and ‘AND’ for combining the three dimensions. An asterisk at the end of a search keyword was used to cover a broad range of results within the keyword. Additionally, the following search term was used in Google Scholar, which is a database without word builders: ‘respiratory diseases among construction workers’. The first five pages in Google Scholar were screened. Also, the searches were restricted to studies published within the last 10 years, that is, studies between 2012 and 2022 were considered. In total, 256 publications were retrieved.

Inclusion and exclusion criteria

After a thorough literature search, a set of criteria was developed to ensure that only the most relevant studies were included in this review. The review was restricted to studies that had been published in English and focused on any type of respiratory health condition associated with any construction work and affecting construction workers. Construction work referred to any work carried out in connection with construction, alteration, conversion, fitting-out, commissioning, renovation, repair, maintenance, refurbishment, demolition, decommissioning or dismantling of a structure.¹⁷ Studies related to the prefabrication of elements, other than at a place specifically established for the construction work, for use in the construction work and those focusing on mining or the exploration of or extraction of minerals were not classified as construction work. Also, within the construction workers’ category, original research that focused on different subgroups including professional and non-professional, gender, site and non-site based, etc in any type of construction activities (demolishing, excavation, concreting, etc) was included. We also excluded literature reviews and editorials.

Patient and public involvement

None.

Study screening and selection

The study selection process involved the removal of duplicate studies (n=73) from the search results using the ‘Find Duplicates’ function in the Endnote software before the screening process. The titles and abstracts of the remaining studies were exported from Endnote to Microsoft Office Excel. During the screening process, each study’s title and abstract were independently examined for eligibility against the inclusion and exclusion criteria by all authors. The Excel sheet was used to mark included studies as green, excluded studies as red and undecided studies as yellow. A dedicated column was created for reviewers to provide reasons for excluding ‘ineligible’ studies.

Studies with four or more green marks were automatically selected for full-text review, while those with four or more red marks were automatically excluded from further consideration. Any discrepancies in study inclusion or exclusion were resolved through group discussions. For instance, there were disagreements on the inclusion or exclusion of six of the studies and on thorough group discussions, two of the studies were included and four were excluded. This screening process resulted in the removal of 199 articles, leaving a total of 29 studies for further evaluation. These remaining studies underwent a detailed full-text reading, which followed the inclusion and exclusion criteria and study objectives. The resultant lists from the full-text reading were independently prepared by all research team members and compared. Any differences that arose were resolved

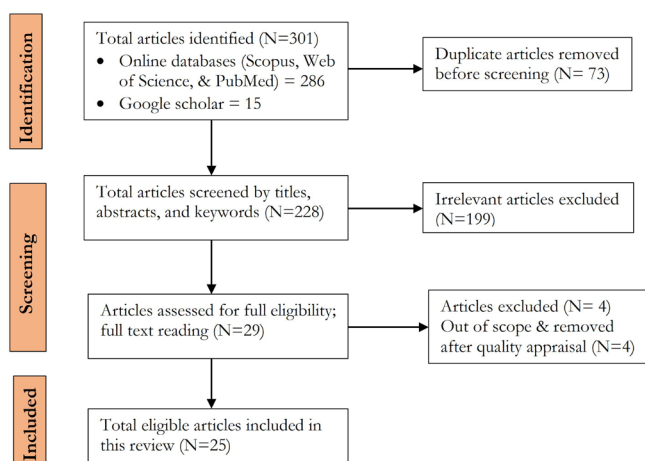


Figure 1 Flow diagram of literature search and selection for the systematic review.

through discussion, ultimately leading to the retention of 25 studies for the review. This sample size ($n=25$) is considered adequate for a comprehensive review of the topic, as it falls within the range of published systematic reviews of a similar nature (eg, Frimpong *et al*¹⁸). To provide a visual representation of the study selection process, a flow diagram is presented in figure 1.

Data extraction strategy

To extract the data for the included study, Microsoft Office Word was used to create a template containing various relevant thematic areas, including authors and publication date, study design, country of study, research participants, number of participants, respiratory conditions identified, hazards workers were exposed to, length of exposure and key conclusions of the study. Data were extracted by five of the authors independently and the resultant extracted data were examined by the remaining author independently. Any disagreements that arose among the reviewers were consistently resolved through discussion. Summaries of the extracted data are presented in the online supplemental table.

Data synthesis and presentation

The study sought to provide a narrative review of the literature, and not to statistically analyse the variables of interest, and therefore, the data were synthesised (narratives, tables and visuals) using meta-aggregation instead of meta-analysis.^{18 19} Typically, meta-aggregation seeks to provide a true picture of the existing body of literature by merging and not reinterpreting findings obtained from the studies included in a systematic review.¹⁹ Thus, meta-aggregation was appropriate for this current review which focuses on providing a clearer overview of the respiratory health conditions among construction workers. Meta-analysis is deemed inappropriate to use in this review because there are significant differences in the attributes of the included studies (ie, sample types, study contexts,

study designs, interventions, health conditions, etc) which breach the condition of ‘heterogeneity’ required for meta-analysis.²⁰ Following the analysis, the results of the review were reported using the PRISMA framework.

Addressing publication bias and heterogeneity

To mitigate the potential influence of publication bias, we implemented a series of robust strategies within our systematic review. First and foremost, we conducted an extensive literature search encompassing various databases, including Scopus, PubMed and Web of Science. This comprehensive search approach allowed us to capture a broad spectrum of relevant studies. Furthermore, we recognised the importance of including grey literature in our analysis, as it often provides valuable insights not found in traditional peer-reviewed publications. Hence, we used Google Scholar to identify pertinent grey literature sources, thereby ensuring a more comprehensive representation of the available evidence. Moreover, in the interest of transparency and scientific integrity, we have diligently reported the methodologies employed throughout our review process. By providing a detailed account of our literature search strategy and the steps taken to identify and include grey literature, we offer transparency to readers and potential users of this manuscript. Moreover, this transparency serves as a cautionary note, enabling readers to discern any specific information that may not have been explicitly reported in this review. Through the rigorous implementation of these strategies, we have strived to augment the robustness, rigour and comprehensiveness of our work while minimising the potential impact of publication bias.

Regarding heterogeneity present in the data, we employed a qualitative synthesis method, specifically narrative synthesis, as the most appropriate approach. This involved categorising the studies based on shared characteristics or factors and conducting separate analyses of their respective results. The primary focus of this synthesis approach was to provide a comprehensive summary of the findings, identifying recurring themes and patterns across the included studies without employing statistical pooling techniques. By adopting this approach, we were able to accommodate the inherent heterogeneity observed within the available evidence. Also, by adhering to rigorous inclusion criteria, we ensured methodological consistency and rigour in our systematic review, thereby enhancing the robustness and validity of our findings.

Method for assessing the quality of the included studies

The methodological quality of the included studies was assessed by four authors (EFB, IYA, CB, and EOB) using the Joanna Briggs Institute’s (JBI) standardised critical appraisal instrument (table 1). A quality appraisal assessment using the JBI method typically involves evaluating the studies included in the systematic review based on several criteria. In this systematic review, a list containing

Table 1 Results of quality appraisal using the Joanna Briggs Institute's critical appraisal tool

Study/criteria	Were the criteria for inclusion in the sample clearly defined?	Were the study subjects and the setting described in detail?	Was the exposure measured in a valid and reliable way?	Were objective, standard criteria used for measurement of the condition?	Were confounding factors identified?	Were strategies to deal with confounding factors stated?	Were the outcomes measured in a valid and reliable way?	Was appropriate statistical analysis used?
Krishnakumar <i>et al</i> ³⁰	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
Mo <i>et al</i> ³¹	Yes	Yes	Yes	Unclear	Yes	Unclear	Yes	Yes
Sari <i>et al</i> ³³	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mandal and Dutta ³⁷	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Keer <i>et al</i> ⁸	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
Sachdeva <i>et al</i> ²⁹	Yes	Unclear	Yes	Yes	Unclear	Unclear	Yes	Yes
Sulaiman <i>et al</i> ¹³	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes
Rose <i>et al</i> ³²	No	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
Rando <i>et al</i> ⁴²	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rachiotis <i>et al</i> ³⁶	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes
Tüchsen <i>et al</i> ²¹	Yes	No	Yes	Yes	No	NA	Yes	Yes
Mariammal <i>et al</i> ³⁵	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Doney <i>et al</i> ²²	Yes	NA	Yes	Yes	ON	NA	Yes	Yes
Alicandro <i>et al</i> ²³	Yes	No	Yes	Yes	ON	NA	Yes	Yes
Ghimire and Neupane ⁴⁰	Yes	No	Yes	Yes	ON	No	Yes	Yes
Kurth <i>et al</i> ³³	Yes	Yes	Yes	Yes	ON	Unclear	Yes	Yes
Hamid <i>et al</i> ³⁴	Yes	Yes	Yes	Yes	ON	Unclear	Yes	Yes
Boelter <i>et al</i> ²⁴	Yes	Yes	Yes	Yes	ON	No	Yes	Yes
Banerjee <i>et al</i> ²⁵	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Vallières <i>et al</i> ³⁸	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nicol <i>et al</i> ²⁶	Unclear	Yes	Yes	Yes	ON	No	Yes	Yes
Fareed <i>et al</i> ²⁷	Yes	Yes	Yes	Yes	ON	No	Yes	Yes
Mohankumar <i>et al</i> ²⁸	Yes	Yes	Yes	Yes	ON	ON	Yes	Yes
Tavakol <i>et al</i> ¹²	Yes	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes
Wang <i>et al</i> ⁴¹	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

All these studies were included in the systematic review.

links to the published included studies was exported into Excel and shared among four authors (EFB, IYA, CB, EOB) for review. Eight questions were used to assess the quality of each included study, namely: ‘Were the criteria for inclusion in the sample clearly defined?’, ‘Were the study subjects and the setting described in detail?’, ‘Was the exposure measured in a valid and reliable way?’, ‘Were objective, standard criteria used for measurement of the condition?’, ‘Were confounding factors identified?’, ‘Were strategies to deal with confounding factors stated?’, ‘Were the outcomes measured in a valid and reliable way?’ and ‘Was appropriate statistical analysis used?’. Four response options were provided for each question: ‘yes’, ‘no’, ‘unclear’ or ‘not applicable’. Generally, we resolved to include studies with at least five ‘yes’ answers to the eight questions. However, each author was given the freedom to decide whether a paper should be included or otherwise and a column was provided for comments on why a paper should be excluded. Following that, one author (IYA) compiled and vetted all the decisions; and all discrepancies were settled through discussion.

Quality assessment results

As shown in [table 1](#), all the twenty-five studies were included in the final decision as all the studies were evaluated positively in five or more questions. Specifically, the results from the appraisal show that all the studies conducted appropriate statistical analysis and measured outcomes validly and reliably. However, there were ‘no’ responses to some questions indicating the possibility of bias in some of the results. Based on our assessment, 11 out of the 25 studies^{12 13 21–29} either did not identify confounding factors or provided unclear confounders which suggest a potential risk of bias in those studies. Additionally, 6 studies^{9 30–34} out of the 14 studies that identified the presence of confounders provided unclear strategies used to deal with the confounding factors. This implies that causality should not be assumed in those studies.

We found that three studies^{26 32 35} did not clearly define the criteria for inclusion in their samples indicating that the selection of participants in those studies may be subjective, leading to potential bias in the results. This may further imply that the study samples may not be representative of the population of interest, or the results may be affected by other factors that were not considered. Thus, it may be unclear whether participants were selected based on a specific set of characteristics or if the samples in those studies were selected randomly.

All the 25 studies were rated high in terms of whether the exposure variables were measured in a valid and reliable way. However, the measurement of exposure was deemed unclear in one study.³⁶ This means that the accuracy and consistency of the data collected for the exposure variable in the study may be questionable. To this end, the general results of the quality appraisal exercise using the JBI approach show that the quality of most studies can be

considered moderate, but this should be interpreted in conjunction with the weaknesses described.

RESULTS

Overview of included studies

A total of 25 studies were included in the review. Most of the studies (n=24) were published as peer-reviewed journal articles between 2012 and 2022 and 1 was a case report. In terms of the study designs, the majority were cross-sectional studies (n=14) and quantitative cohort studies (n=4). The review encompasses a collective sample size of at least 1 684 516 individuals who are employed in the construction industry. Sample sizes within this population vary considerably, ranging from as few as six individuals to a maximum of 1 068 653—including 8 studies with sample sizes less than 100, 11 studies with sample sizes between 100 and 1000 and 6 studies with sample sizes more than 1000. The study samples were mainly dominated by males. The studies focused on various construction workers such as tradespeople, labourers and construction supervisors. A total of 15 countries were represented, with the USA (n=6) and India (n=6) having the highest number of studies. Additional details on the studies included in this review are provided in online supplemental table.

Work-related respiratory conditions affecting construction workers

A total of 16 specific respiratory conditions were derived from the included studies (see [figure 2](#)). The frequencies, as shown in [table 2](#), have been used to rank each respiratory condition according to how often they were identified in the included studies. The top three respiratory conditions identified are cough (ie, dry and with phlegm) (n=13), dyspnoea/ breathlessness (n=7) and asthma (n=6), while the least identified conditions included pneumoconiosis (n=1), emphysema (n=1), haemoptysis (n=1) and acute respiratory distress syndrome (n=1). Altogether, majority of the frequent conditions identified relate to respiratory symptoms—these include cough (n=13), dyspnoea/ breathlessness (n=7), wheezing/ whistling in chest (n=5) and chest congestion/ tightness (n=4). However, though not the most frequent cases, the

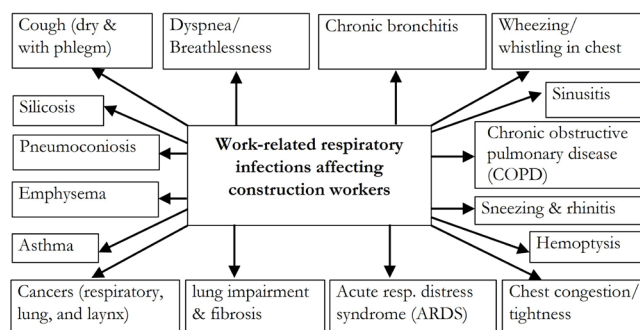


Figure 2 Work-related respiratory conditions among construction workers.

Table 2 Variable ranks of respiratory conditions among construction workers

Respiratory condition	Studies, n	Rank
Cough (dry and with phlegm)	12	1
Dyspnoea/breathlessness	7	2
Asthma	6	3
Wheezing/whistling in chest	5	4
Cancers (respiratory, lung and larynx)	4	5
Chest congestion/tightness	4	
Silicosis	3	6
Lung impairment and fibrosis	3	
Chronic bronchitis	2	7
Sinusitis	2	
Chronic obstructive pulmonary disease	2	
Sneezing and rhinitis	2	
Pneumoconiosis	1	8
Emphysema	1	
Haemoptysis	1	
Acute respiratory distress syndrome	1	

number of studies identifying severe and chronic diseases were significant—these diseases include cancers (n=4), silicosis (n=3) and lung impairment and fibrosis (n=3).

Respiratory hazards among construction workers

Figure 3 illustrates the identification of six distinct themes relating to the hazards that are responsible for respiratory conditions among construction workers. Also, the frequencies in table 3 rank each hazard based on how often they were identified in the included studies. In all, dust (n=15) presented the topmost hazard causing respiratory conditions among construction workers. These dusts were described as those produced as a result of construction activities such as excavation or tunnelling, demolition, sandblasting, grinding, masonry

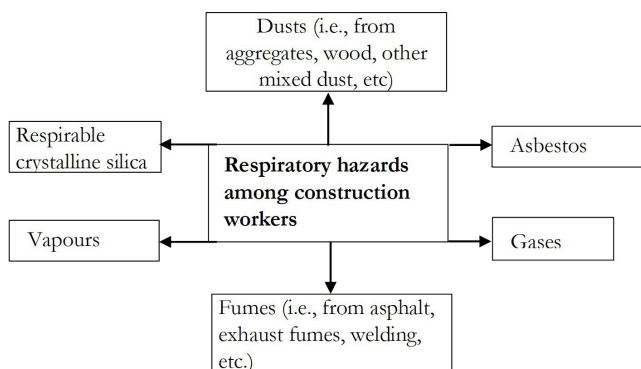

Figure 3 Hazards causing respiratory conditions among construction workers.

Table 3 Variable ranks of hazards causing respiratory conditions among construction workers

Respiratory hazards	Studies, n	Rank
Dust (ie, from aggregate, wood, other mixed dust, etc)	15	1
Respirable crystalline silica	8	2
Fumes (ie, from asphalt, exhaust fumes, welding, etc)	6	3
Vapours	2	4
Asbestos fibres	2	
Gases	1	5

works, rock drilling, road grading, milling and laying, as well as cutting, planing and sanding of wood. After the dust, respirable crystalline silica (RCS) (n=8) ranked as the second highest hazard causing respiratory conditions in construction. Typically, RCS is categorised as a type of construction dust and the description of some of the ‘dust-causing activities’ above suggests that some of the dust produced may be RCS. Nonetheless, eight of the included studies distinctively mentioned RCS as a major hazard causing respiratory conditions in construction workers. Construction activities that produced RCS include mixing of cement and concrete, demolition, rock drilling, works involving fine particles of cement, fly ash, bricks, mortar and sandstone. Other hazards identified include fumes (ie, from asphalt, exhaust fumes, welding, etc), vapours, asbestos fibres and gases.

Furthermore, insights from the included studies revealed that smoking habits and the reluctance to use personal protective equipment among the construction workers increased the risk of contracting respiratory diseases.^{34 37 38} On the length of exposure to hazards, studies such as Fareed *et al*,²⁷ Sulaiman *et al*¹³ and Mandal and Dutta³⁷ highlighted that the prevalence of respiratory condition is higher if the construction worker has an extended exposure to the respiratory hazard. For instance, Mandal and Dutta³⁷ found that the OR values of the prevalence of respiratory disorder with >10 years of exposure to bitumen fumes varied from 2 to 4.5. Also, the finding from Fareed *et al*²⁷ indicated that decrease in lung functions among tunnel workers was significantly correlated with the duration of exposure (hours per day).

Recommended control measures

To control the identified respiratory hazards on construction sites and reduce workers’ exposure to these hazards, several strategies were recommended in the included studies. Figure 4 illustrates the categories of recommended control strategies. The majority of the studies advocated for the provision and proper use of appropriate personal (or respiratory) protective equipment (PPEs), because it was found that, among other factors, the reluctance to use PPEs (such as masks and respirators) among the construction workers increased their risk of getting

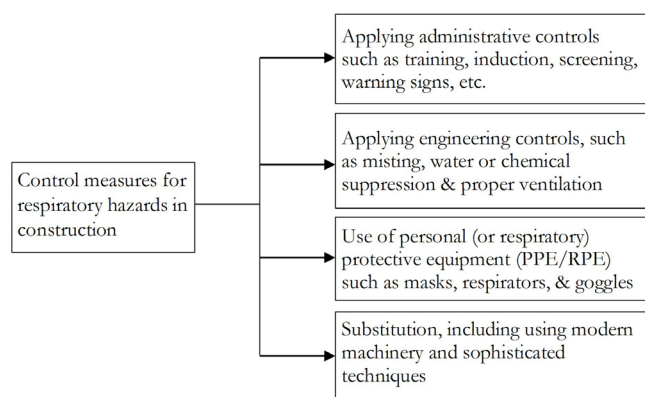


Figure 4 Recommended respiratory hazard control measures.

respiratory diseases.^{35 37} In addition to the use of PPEs, other strategies have been suggested, including applying engineering controls—such as misting, water or chemical suppression and proper ventilation,^{13 35} applying administrative controls—such as training, induction, pre-employment health screening, warning signs, etc.^{27 35} and substitution—such as using modern machinery and sophisticated techniques.³⁷

DISCUSSION

The objectives of our systematic review are twofold. First, we aimed to comprehensively examine recent evidence to elucidate the nature and frequency of respiratory hazards and diseases (beyond COPD) that are prevalent among workers in the construction sector. Second, we aimed to identify effective strategies that may be used to mitigate or even eliminate the incidence of respiratory health diseases among construction workers. Overall, the results of this systematic review indicate that construction workers are at increased risk of work-related respiratory hazards and diseases, compared with workers from other sectors such as retail workers, bus drivers and other non-construction workers who were used as controls in the included studies. Data from our included studies show 16 specific work-related respiratory diseases commonly reported among construction workers. Furthermore, the result show that cough, dyspnoea, asthma, wheezing and cancers of the lung and larynx rank in the top five common respiratory diseases examined among workers in the construction sector. Interestingly, smoking increases both susceptibility and severity of these respiratory health conditions. This necessitates the inclusion of health promotion and behaviour change in occupational health and safety efforts in the construction sector.

Furthermore, it is also important to identify specific respiratory health hazards in the construction sector to re-engineer both the work environment processes to reduce, if not totally eradicate these hazards. The results of our systematic review identify six common examined hazards in the literature. Ranking these hazards, we found that dusts, RCS and fumes ranked in the top three

most commonly reported hazards. Other hazards are asbestos fibres which ranked fourth, with vapours and gas found to be the least reported respiratory hazards.

The materials and processes of work in the civil construction sector make dust a common hazard among workers in this sector, thereby predisposing them to respiratory and other health-related conditions. For instance, COPDs are more common among construction workers compared with workers in other occupations who are not exposed to dust.¹⁴ A similar result was found in a recent survey among construction workers whose respiratory health was compared with that of workers in non-dust-prone occupations (bus drivers and retail workers) in New Zealand.⁹ Dust from cement, sand, wood and other materials when inhaled pose respiratory health threat. Importantly, the length of exposure to occupation-related dust among construction workers further increases their vulnerability to respiratory health problems. Recent evidence^{9 39} indicate that construction workers who have been in the sector for a longer period, for example, over 10 years were more likely to report respiratory health diseases than those who have spent less than 10 years as construction workers.⁹

Health-related problems arising from exposure to dust also apply to other hazards such as vapours, silica, fumes and gas. Some of the studies included in this review, identified and stressed the adverse effect of dust and asphalt fume inhalation on the health and well-being of construction workers in China,³¹ Denmark,²¹ India,^{25 29 29 37} and Malaysia.¹³ Similar findings were also reported in studies among construction workers in Canada,³⁸ Iran,¹² Nepal,⁴⁰ Saudi Arabia,²⁷ the UK²⁶ and the USA.^{22 24 32 33 41 42} Importantly, some of the studies included in our review suggest that exposure to work-related hazards may be associated with respiratory cancer incidence and prevalence among construction workers in Canada,³⁸ Greece,³⁶ Italy,²³ the USA^{24 41} and Turkey.⁴³ Though more studies in this regard are important, the evidence associating workplace hazards and lung cancer among construction workers is strengthened by the fact that some of the studies included in this review used a control sample for comparability with non-construction workers.^{23 38 41}

These respiratory health conditions may have a significant impact on these workers' overall health and well-being as well as on their level of productivity. Construction work involves the use of materials and processes that expose workers to considerable respiratory health hazards. Thus, the data synthesised from this systematic review reflect and align with emerging evidence on the high level of respiratory health hazards and diseases among construction workers in both developing and developed countries.^{2 4-8} Consequently, occupational health and safety within the construction work context should extend tokenistic use of personal protective equipment. A more strategic occupational safety process in the construction sector should begin with ensuring that individuals with underlying health conditions—which could increase vulnerability to and/or severity of respiratory conditions—are either

encouraged to seek alternative career paths or provided greater protection. This is essential, as construction workers in Brazil who did not undergo pre-employment spirometry were more likely to report respiratory health diseases.² Thus, a proactive occupational health strategy for workers in the construction sector should also entail a strong surveillance or biological monitoring system² for early detection of carcinogenic and non-carcinogenic respiratory and other health conditions. Such early detection would be vital to designing appropriate prophylactic and therapeutic responses.

Other proactive and strategic efforts include occupational health education and health promotion messages for workers in the construction sector. Occupational health education is required as continuous conversations would increasingly improve workers' awareness of hazards in the work sector and empower them with requisite skills and processes to protect, maintain and promote their health. In the same vein, health promotion messages through information, education and communication resources and strategies could help in preventing behavioural practices such as smoking, which could increase the vulnerability and severity of work-related respiratory diseases among construction workers.^{2 7 39}

Therefore, protecting, promoting and improving the occupational health and safety of construction workers—beyond the correct and consistent use of effective respiratory protective equipment—is important. As previously mentioned, the use of these protective equipments must not be tokenistic but a conscious proactive and effective strategy to reduce the health effects of these hazards. It is also important to engineer the physical work environment to ensure effective and adequate ventilation in enclosed work settings and putting other effective reduction and protective practices in place. Such engineering controls include misting, water or chemical suppression of dusts and proper ventilation. Also, it is important for contractors to substitute hazardous equipment (such as those producing excessive dusts, fumes and gases) with non-hazardous ones, and adopt different working methods to avoid the production of these hazards. Adopting all these proactive strategies is vital because chronic and acute respiratory health conditions resulting from short-term or long-term exposure to hazardous materials and/or processes in the construction sector have enormous health^{9 14} and socioeconomic¹⁰ implications.

Limitations

Despite the contribution of this systematic review, there are a couple of research limitations worth mentioning. First, although the review was conducted in line with international protocol guidelines for conducting systematic reviews, the findings could still be subjected to indexing, publication and reporting bias because the scope of the search was limited to Scopus, Web of Science, PubMed and Google Scholar. Second, due to language limitations, only studies published in English were included in the

review. Possibly, this could have led to the omission of eligible studies in other languages, resulting in a potential selection bias. Third, only research articles published online were included, suggesting that this review could be limited in scope, since not all case studies and cohort studies outcomes are published online. Fourth, some of the studies included in this review have small sample sizes and have cross-sectional study design, suggesting that the results cannot easily be generalised. Finally, there were variety in the study outcomes and exposures to respiratory health hazards in the construction industry, and this did not allow for determining the specific relationships among the respiratory conditions and health hazards.

CONCLUSION

Our systematic review indicates that construction workers are exposed to hazards and conditions that have adverse effects on their health and well-being. Work processes in the construction sector expose workers in this sector to harmful hazards such as dust, silica, fumes, asbestos and other hazards. These hazards are associated with a range of health problems ranging from mild respiratory health conditions to severe ones such as respiratory cancers and silicosis. Evidence from our review indicates that construction workers who have spent a longer time in the sector have greater vulnerability and severity of work-related respiratory health problems. Since exposure to work-related health hazards has enormous health and socioeconomic well-being and functioning of construction workers, we advocate for a strategic occupational health programme for construction workers beyond the tokenistic use of personal protective equipment.

Contributors EFB conceived the topic. EFB and CB conducted the literature search. IYA, EOB, SRO, CB and EFB conducted the screening of studies. Data were extracted independently by IYA, EOB, EFB and CB, and the extracted data were scrutinised independently by SRO. EOB, SRO, CB and EFB independently assessed the methodological quality of the included studies. Differences that arose were resolved through a discussion with the fifth author IYA. SRO and EFB conducted the data synthesis and was reviewed by IYA. IYA, EOB, SRO, CB and EFB contributed to drafting the manuscript and provided critical feedback on the final output. EFB acts as guarantor.

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