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# Insights in occupational health and safety 2022

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# Insights in occupational health and safety: 2022

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# Editorial: Insights in occupational health and safety: 2022

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KEYWORDS

**occupational health, occupational safety, prevention, worker, workplace**

Editorial on the Research Topic
Insights in occupational health and safety: 2022

Occupational medicine is rapidly evolving from preventing health and safety risks in the workplace to promoting health for the total wellbeing of the worker according to the NIOSH "Total Worker Health" approach (1). This "*Insights in occupational health and safety: 2022*" Research Topic of 15 articles reflects this trend worldwide, with contributors from Asia, Europe, America, Africa, and Oceania. As for the 2021 edition (2), it includes forward-looking contributions focused on old and new occupational risk factors, recent advances and future perspectives in the field of Occupational Health and Safety.

From this perspective, Saberi et al. carried out an analysis to identify hot topics and Research Topics on occupational disease through the Web of Science from 1975 to 2021. The results showed occupational exposures, epidemiology, mental health, and respiratory diseases were the most important keywords used in these 45 years. In this regard, well-known forms of occupational and non-occupational exposure continue to pose a health risk in several countries of the world, including Italy (3, 4). Zhao et al. investigated the association of coal mine dust lung disease (CMDLD) with nodular thyroid disease in coal miners in China, finding that CMDLD was the strongest independent exposure risk factor for the development of nodular thyroid disease in coal miners. In the same country, Shi et al. conducted an observational trend study on global disease burden and trends of leukemia attributable to occupational risk from 1990 to 2019, finding a substantial reduction in leukemia due to occupational risks. On the other hand, Yuan et al. investigated occupational blood-borne pathogen exposure among dental nurses finding a high prevalence of sharp injuries in particular with syringe needle. Despite significant efforts over the past decade, job-related injuries are still one of the largest reasons contributing to disabilities and life-threatening conditions in developed and developing countries. Penney et al. showed that occupational fatality rates within the Australian commercial fishing industry are significantly higher than currently reported and recurring factors contributing to deaths at sea are unaddressed. Mekonnen et al. conducted a cross-sectional study among coffee processing industry workers in Ethiopia, highlighting a high prevalence of work-related disease symptoms and occupational injuries. Age group 30–39 and 40–49, income level, experience, smoking cigarette were significantly associated with the work-related symptom and training related to the job was significantly associated with occupational injuries. Another sector at high risk of occupational injuries in Ethiopia is construction sector. According to the study conducted by Yosef et al., the overall prevalence of occupational injuries among Bure industrial park construction workers was 39.4%. Being male, being married, no use of personal protective equipment, no training on occupational safety and not satisfied with the

job were the factors associated with occupational injuries. Lee et al. compared the incidence of occupational diseases, avoidable hospitalization and all-cause death between firefighters and non-firefighters in Korea, from 2006 to 2005, finding that the standardized incidence ratios and hazard ratios for most diseases were high for firefighters. These studies show how occupational safety is still a highly relevant and serious issue worthy of academic attention and the research on strategies and policies to improve workers' safety behavior in reducing occupational injuries (Kim et al.) as well as workplace violence (Hu et al.) will become increasingly important in the future.

The "24-h society" that we have been approaching in recent years made night shift work a crucial factor in work organization, with well-established consequences on the workers' health and wellbeing. Regarding this issue Boini et al. evaluated the existing evidence on the effect of night-shift work on cardiovascular risk factors. After selection, 33 systematic reviews were included and the results confirmed an excess risk of diabetes, hypertension and overweight/obesity. Sleep duration is also independently associated with metabolic body size phenotypes (Wang et al.), while occupation type might be an independent factor in the development of diabetes (Habu et al.). Thus, occupational health physicians can give valuable help and support both to employers in planning the best possible shift schedule, and to workers in adopting the most appropriate personal coping strategies through ongoing health promotion interventions on modifiable lifestyle factors (5, 6).

May 11, 2023, marks the end of the COVID-19 public health emergency (7). In In the last 3 years significant increase in the prevalence of mental health disorders in different occupational settings has been associated with the COVID-19 pandemic, particularly for healthcare workers, who are at a high risk of exposure to infection and several psycho-social and work-related risk factors (8–15). Ito et al. explored mental health conditions among occupational therapists during the COVID-19 pandemic, demonstrating a direct link between therapists' mental health conditions and therapy quality. Edgelow et al. discussed the importance of adopting a broader conceptual approach to the study of public safety personnel mental health and proposed a novel model that highlights the need to consider the combined impacts of operational, organizational, and personal factors on public safety personnel mental health.

In conclusion, this "*Insights in occupational health and safety: 2022*" Research Topic includes a variety of occupational health and safety topics that show the new direction taken by research in this field, reflecting the contemporary holistic approach to worker wellbeing to help improve worker health and safety.

## Author contributions

LD: Conceptualization, Supervision, Writing—original draft, Writing—review and editing. AC: Conceptualization, Supervision, Writing—original draft, Writing—review and editing. SS: Conceptualization, Supervision, Writing—original draft, Writing—review and editing. LV: Conceptualization, Supervision, Writing—original draft, Writing—review and editing.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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# Analysis of the research subjects and hot topics of occupational diseases through the Web of Science from 1975 to 2021

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A variety of studies have been conducted in Occupational diseases (ODs) and this makes it difficult for researchers to identify new areas of study. Therefore, the present study was conducted by examining Web of Science data to identify hot topics and research topics on ODs. This is a scientometric study performed using CiteSpace and Gephi software for statistical analysis. The published article in Web of Sciences was searched using the keywords "Occupational disease*" OR "Occupational illness*" OR "Industrial disease*" OR "Industrial illness*". Finally, the countries and institutions and their cooperation, the most important and main topics discussed, and the path of future progress in ODs was analyzed. Preliminary results of the study show that out of 5,947 articles. The results of important journals showed that the American Journal of Industrial Medicine with 233 articles (6.02%), Oxford Occupational Medicine, and International Archives of Occupational and Environmental Health with 86 (2.22%), and 83 (2.15%), respectively. The two producing countries are the United States and Germany, which published 628 and 419 articles, respectively. The results of hot topics showed occupational exposures, epidemiology, mental health, and respiratory diseases were the most important keywords used in these 45 years. It can be concluded that Germany, with its current development trend in the coming years, will surpass the United States based on the number of articles and gain the first rank. Also, future studies can be conducted on respiratory diseases as the most important ODs and health care work as the most important job during the past years.

KEYWORDS

**occupational disease, scientometrics, respiratory disease, epidemiology, occupational health**

## Introduction

Occupational diseases (ODs) can be defined as an illness caused or aggravated by work. The International Labor Organization (ILO) defines ODs as diseases caused by exposure to risk factors of work activities (1). The World Health Organization (WHO) states that an ODs is not defined solely by the disease itself; it is a combination of an illness and its exposure, as well as the relationship between these two norms (2). In another definition, "ODs" are classified into two categories; one is traditional ODs that can be caused only by occupational reasons caused by exposure to chemicals, physical and biological agents. Another case is work-related illnesses that can be exacerbated, stimulated, or affected by work conditions. These are musculoskeletal diseases (MSDs) or cardiovascular diseases (CVDs) that are caused by several factors, including the type of occupation (3).

Estimates for the global incidence of ODs vary considerably. Historically, Alaguney has predicted 4 to 12 ODs per 1,000 employees (4), and Leigh et al. have predicted 4 to 10 million ODs per year (5). The ILO estimates that there are 160 million non-fatal diseases and 2 million deaths a year (6), which account for at least 4% of global gross domestic products or about $2.8 trillion in direct and indirect costs (7). ODs can also reduce the standby time of manpower. They can lead to the rapid elimination of labor from the labor market, causing high-consumption members of society (8). It is predicted that by 2050, about a third of the workforce will have been over 50 years old (9), and this is likely to lead to a sharp decline in labor productivity. In addition, if no one pays attention to the current occupational health of the workforce, it can impose more costs on the governments to health care systems in the future.

These statistics show ODs in the world. Therefore, concerning ODs, studies have been conducted in this field, and as far as the types of diseases have been studied, the study of the risk and burden of the disease helps the authorities to identify and control this disease as much as possible. Because the prevalence of ODs is changing due to the changes in industry and working conditions, the list of ODs has been reviewed both in various studies and in the ILO. This revision has been influenced by the modernization of industry and other international organizations as well as the European Union; it has also been influenced by the development and revision of the National Job List. Therefore, due to the very high number of studies in the field of ODs, the need for these studies has been observed and its important cases are reported to researchers who are studying in this field. In this regard, some studies have reviewed some specific occupational diseases, for example, studies such as "Historical review of the list of ODs recommended by the International Labor Organization" by Kim et al. (6), review studies in the field of specific ODs such as isocyanate (10), a review study of ODs in small and medium industries in Malaysia (11), and the most important ODs in the construction industry (12) have been conducted. However, it is not possible to get study ideas from these studies, and it is not possible to examine and identify hot topics, frequently used keywords, institutions and countries that have conducted the most studies in this field. Therefore, it is necessary to clarify the path of future studies with a scientometric study and provide researchers with results that can better shape their next studies.

Accordingly, with an overview of different studies, it shows that different studies have been conducted over the years and the number and variety of studies in this field is very high and can confuse the researchers; therefore, identifying the most important areas of study for ODs seems to be difficult. Therefore, the present study was conducted by examining Web of Science data to identify hot topics and research topics on ODs in a scientometric study. The present study can predict future development directions by stating the countries, institutions, and publications about ODs and analyzing the frequency of keywords.

## Materials and methods

This is a scientometric study performed using CiteSpace and Gephi software for statistical analysis of citations from scientific sources (13). The first step in a scientometric study is to identify and extract studies in the field under study. Therefore, the search was performed using the keywords and the OR command in the form of "Occupational disease*" OR "Occupational illness*" OR "Industrial disease*" OR "Industrial illness*". All published studies related to the selected keywords on the Web of Science from 1975 to 31/12/2021 were included in the study. The reason for choosing the start date of the studies was the time limit of the Web of Sciences for searching studies.

Finally, in this study, we aimed to create a good plan for future studies and also introduce new study topics for researchers and help them find collaborating partners. Therefore, the following questions were posed:

1) Which countries and institutions study ODs? And who are their colleagues?
2) What are the most important and main topics discussed? What are the most important current issues?
3) What is the path of future progress in ODs?

The database created also included:

- Science Citation Index Expanded (SCI-EXPANDED)
- Social Sciences Citation Index (SSCI)
- Conference Proceedings Citation Index–Science (CPCI-S)
- Conference Proceedings Citation Index–Social Science and Humanities (CPCI-SSH)
- Current Chemical Reactions (CCR-EXPANDED)
- Index Chemicus (IC).

The study was divided into the following five stages:

Step 1: Data were collected through Web of Science according to the search query. The research result was then extracted and saved in the text format recognizable by CiteSpace.
Step 2: The data were cleared. First, synonym keywords were merged. Second, meaningless words like related words and meaningless nouns were removed.
Step 3: The research results were entered into CiteSpace, Gephi, and VOS viewer software. CiteSpace software was used for the initial review of articles; Gephi was used to map the relationships and collaborations, and VOS viewer software was used to analyze the keywords.
Step 4: The research content required for analysis and duration in the software were selected.
Step 5: Graphs and visualization of the results were performed.

After determining the search formula and databases, 5,947 articles related to the purpose of the study were obtained and the information about author, title, publication sources, references, keywords, and abstract was extracted.

## Results and discussion

Preliminary results of the study show that out of 5,947 all type of articles, 44,000 were orginal papers, 557 were Review articles, 568 were Proceeding Paper, and 112 were Letter reports. Of 5,947 articles, 4,450 were in English and the rest were in other languages (624 German studies, 305 French studies, 162 Spanish studies, 117 Portuguese studies, 52 Italian studies, 57 Russian and Polish studies, 38 Turkish studies, 24 Ukrainian studies, 10 Chinese studies, 9 Korean studies, 8 Czech studies, 4 Hungarian studies, 2 Hungerian studies, Dutch, Persian, Slovak, Slovenian and Greek each had 2 studies and Arabic, Galician, Indonesian, Latvian, Swedish each had 2 studies.). Also, the first studies were published in 1975 with 19 studies and since then it has had a growing trend.

Over time, the number of studies until 1991 was under 50 studies per year, and since 1991, with 63 studies, an increasing trend of studies can be seen; also, since 2007, more than 100 studies have been published each year. The highest number of studies was done in 2020 (Figure 1).

The process of publishing studies in terms of citations based on different years can show the importance of the subject of ODs during different years and helps to better examine the keywords and identify important topics of recent years. The results of this section based on the analysis of articles over three 15-year periods from 1975 to 1990, 1991 to 2006, and 2007 to 2021 in Cite Space software showed that in the first 15 years (1975–1990) 279 citations, in the second 15 years 25,767, and during the third 15 years 15,303 references to all articles have been made.

### The most cited studies in the field of ODs

The results of the most cited studies show the importance of an issue in the field of ODs, as shown in Table 1. The article by Grossi et al. (14) had the most citations among different studies (750 citations). This article was published in 1994 in the Journal of Periodontology. The second study was Tong et al., that published in Bulletin of the world health organization and it is about occupational and environmental lead exposure. This paper showed that both occupational and environmental exposures to lead remain a serious problem in many developing and industrializing countries. Acute lead poisoning has become rare in such countries, but chronic exposure to low levels of the metal is still a public health issue. Also, the results of the average citation per year of studies show that the study of Eisner et al. (16), although published in 2010, has 543 citations and is the best study in this regard. This study is about identifying new risk factors and the global burden of chronic obstructive pulmonary disease; since respiratory diseases are the most important ODs (24), this study can help prevent this type of disease by identifying new risk factors. Therefore, it can be concluded that the importance of respiratory diseases, especially chronic obstructive pulmonary disease, is very high in ODs studies.

### The best journals and the top area in the field of ODs

The results of journals that have published articles in this field from the Web of Science show that a total of 500 journals have published articles related to ODs, of which the top 10 journals published a total of 747 articles. The results of the study show that the American Journal of Industrial Medicine with 233 articles (6.02%) has published the most articles in this field. Oxford Occupational Medicine, International Archives of Occupational and Environmental Health, and Journal of Occupational and Environmental Medicine have the highest number of articles with 86 (2.22%), 83 (2.15%), and 62 studies (1.60%), respectively (Table 2). Also, based on the number of citations, it can be seen that the American Journal of Industrial Medicine had the most citations and citations ratio.

A review of the top 10 specialized areas on which studies have been conducted shows that the field of Public Environmental Occupational Health with 1,618 studies is the most important area, and followed by General Internal Medicine with 373 studies and Environmental Sciences Ecology with 278 studies (Figure 2).

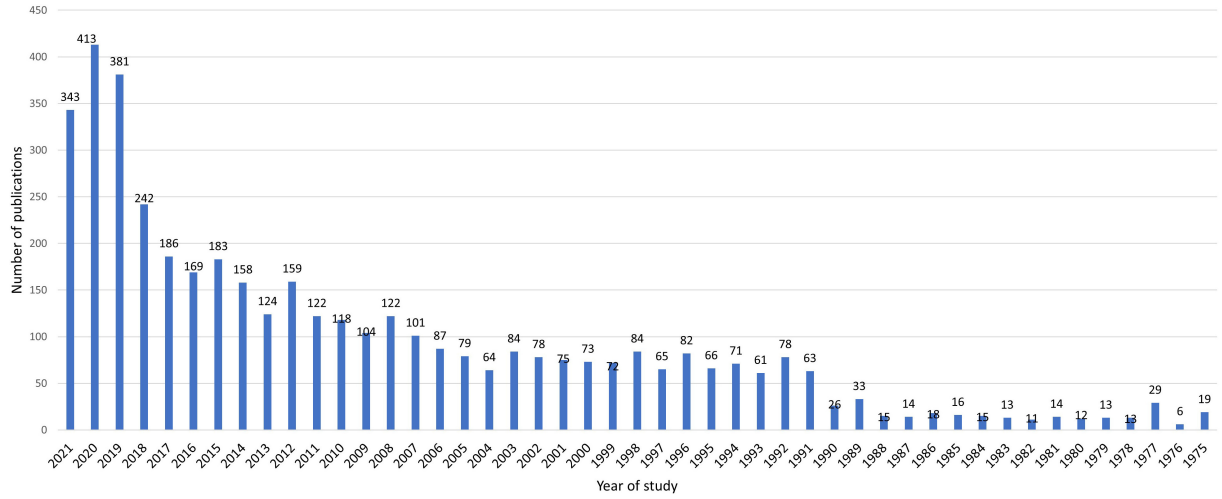


FIGURE 1
The process of publishing articles on occupational diseases over the past 46 years.

TABLE 1 The most cited studies in the field of occupational diseases.

| Authors | Journals | No. Publicati | Citations | ACPY* | References |
|---|---|---|---|---|---|
| Grossi et al. | Journal of Periodontology | 1994 | 750 | 26.79 | (14) |
| Tong et al. | Bulletin of the World Health Organization | 2000 | 579 | 26.32 | (15) |
| Eisner et al. | American Journal of Respiratory and Critical Care Medicine | 2010 | 543 | 45.25 | (16) |
| Warrell | The Lancet | 2010 | 404 | 33.67 | (17) |
| Spelten et al. | Psycho-Oncology: Journal of the Psychological, Social Behavioral Dimensions of Cancer | 2002 | 394 | 19.7 | (18) |
| Pruss-Ustun et al. | American Journal of Industrial Medicine | 2005 | 375 | 22.06 | (19) |
| Gottschalk et al. | Future Microbiology | 2010 | 294 | 24.5 | (20) |
| Theriault et al. | American Journal of Epidemiology | 1994 | 273 | 9.75 | (21) |
| Cohen et al. | Journal of the American Dental Association | 1980 | 271 | 6.45 | (22) |
| Hunt | Journal of Allergy and Clinical Immunology | 2002 | 246 | 12.3 | (23) |

*ACPY, Average Citations per Year.

According to Figure 2, the most important area was Public Environmental Occupational Health. This area generally deals with occupational health and environmental diseases, of which respiratory diseases are the most studied, followed by various cancers (Table 3). As can be seen, this field has been studied separately since 1991 and has dealt with ODs in general. Lung diseases are known as the most common ODs so that about 40% of ODs are related to lung diseases (25). Although thousands of chemicals are used worldwide without any proper testing, a small fraction have been evaluated, at least in part, for carcinogenicity. However, despite a fully established classification by the International Agency for Research on Cancer (IARC), monitoring of occupational exposure to known carcinogens is often lacking nationally. This knowledge gap has been repeatedly cited as a major constraint on occupational cancer prevention and the assessment of occupational cancer burden, which may be addressed (26). In addition to the diseases mentioned in the last 2 years with the pandemic of COVID disease 19, studies of this disease have also been reviewed from an occupational point of view, and in the field of Public Environmental Occupational Health, 15 studies have been reviewed.

## Top 10 producing countries, cited countries and analysis of cooperation in the field of ODs

Using the Web of Science results, we extracted the top 10 countries (Figure 3). The two producing countries are the

TABLE 2 Top 10 journals with the highest number of published studies on occupational diseases.

| No. | Journal name | Impact factor (in 2021) | Number of published studies | Number of citations | The ratio of citations to published studies |
|---|---|---|---|---|---|
| 1 | American Journal of Industrial Medicine | 2.214 | 233 | 5,782 | 24.82 |
| 2 | Occupational Medicine Oxford | 1.611 | 86 | 1,180 | 13.72 |
| 3 | International Archives of Occupational and Environmental Health | 3.015 | 83 | 1,262 | 15.20 |
| 4 | Journal of Occupational and Environmental Medicine | 2.162 | 62 | 1,485 | 23.95 |
| 5 | Archives Des Maladies Professionnelles Et De L Environnement | 0.205 | 53 | 50 | 0.94 |
| 6 | Medicina Del Lavoro | 1.275 | 48 | 160 | 3.33 |
| 7 | Occupational And Environmental Medicine | 4.402 | 48 | 1,133 | 23.60 |
| 8 | Revue Des Maladies Respiratoires | 0.622 | 47 | 200 | 4.26 |
| 9 | Medycyna Pracy | 0.760 | 44 | 165 | 3.75 |
| 10 | International Journal of Environmental Research and Public Health | 3.309 | 44 | 298 | 6.93 |

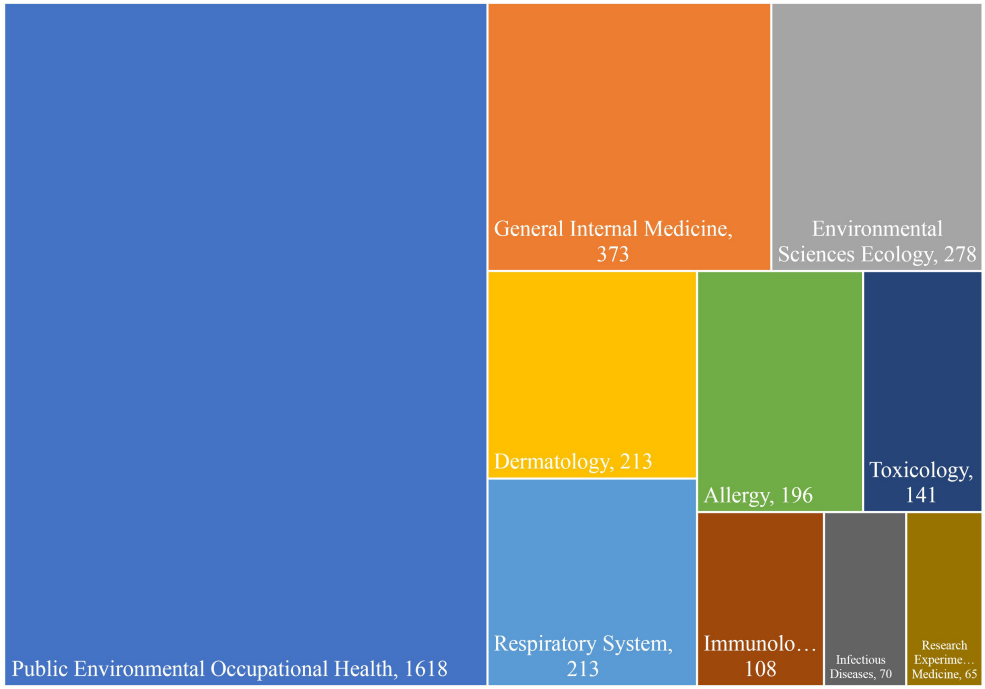


FIGURE 2
Top 10 specialized areas of publishing articles on occupational diseases over the past 46 years.

United States and Germany, which published 628 and 419 articles, respectively. In addition, a review of the first years in which articles on ODs were published shows that the two countries initiating these studies were the United States and France, respectively, which published the article in 1975. Germany, which ranks second in terms of the number of articles, published its first study in 1987, and over time, since 1990, has increased its number of studies to second place. The highest number of studies in this country was in 2015 with 34 studies. This shows that the growth rate of German articles is very high.

Among the top 10 countries are eight developed countries that have published 2,440 articles. However, the two developing countries have published 304 articles. This shows that there is still a large gap between developed and developing countries in ODs research.

Examining the growing curve of Germany and the United States can predict the trend of publishing articles in the next 2 years. After obtaining the annual emission values of the two countries, MINITAB was used to analyze the cumulative growth curve regression. The best fit adj-R square curve for

the United States is 0.341, while for Germany it is 0.721; this indicates that the trend in German article production in the coming years will be much higher than in the United States. The closer the adj-R squares to 1, the better the curve.

The best-suited curves for the United States and Germany are shown in Figures 4, 5. A comparison of Figures 4, 5 shows that the growth rate in Germany is higher than in the United States. This shows that Germany has published more studies on ODs. The number of emissions in the United States was higher than in Germany before 2008, but Germany is developing at a faster pace, while the slope of the chart for the United States is almost constant. The upward trend in the United States began in 1975 and peaked in 1998 and 2006. However, the upward trend in Germany started in 1990 with 8 studies and reached its peak in 2015 with 34 studies.

TABLE 3 Diseases studied in domain Public Environmental Occupational Health by study period.

| Diseases studied | No. studies | Years | | |
|---|---|---|---|---|
| | | 1975–1990 | 1991–2006 | 2007–2021 |
| Respiratory diseases | 282 | 0 | 275 | 7 |
| Cancer | 181 | 0 | 175 | 8 |
| Musculoskeletal disorders | 126 | 0 | 109 | 17 |
| Occupational diseases | 65 | 0 | 57 | 8 |
| Skin diseases | 50 | 0 | 40 | 10 |
| Cardiovascular diseases | 36 | 0 | 24 | 12 |

The results of the Web of Science site showed that 100 countries had studied ODs. The analysis of cooperation relations between the countries shows that Spain (144%), the United Kingdom (123%), and Italy (97%) have higher rates of international cooperation in the top 10 producing countries. This shows that the three countries pay more attention to communication with other international countries (Table 4). Spain published 141 studies and 203 collaborations, showing that all of its studies are produced in collaboration with other countries. In contrast, Brazil and Turkey rank 9th and 10th, respectively, with 17 and 13% of international cooperation, respectively, preferring foreign studies as domestic teamwork. Therefore, it can be concluded that cooperation relations in developed countries are more than in developing countries.

Table 4 also shows the centrality index for all countries. This index indicates the importance of the position of a node in a determination network (27). It measures the value of each of the central nodes in the path connecting to other network nodes based on the shortest path (28); the value of centrality has no role if the node is $< 0.1$. If it is greater than or equal to 0.1, it has a strategic position, in which case it can be a candidate for a turning point, and if it is $> 1$, it is a turning point (critical) and will have a unique position. As the Table shows, only two countries, the United States and the United Kingdom have more centrality (0.1), and the United States, with a centrality of 0.44, has the largest role in occupational disease studies and can be considered as a country with a strategic position in the field of ODs.

Figures 6, 7 show the US cooperation network as the country with the most productivity and Spain as the

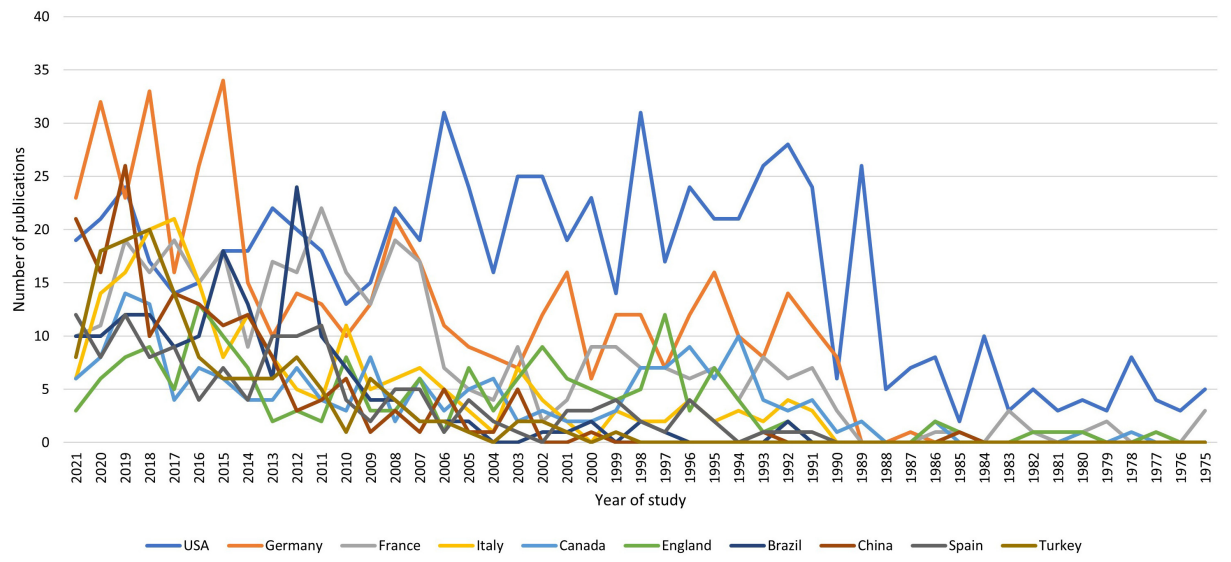


FIGURE 3
Top 10 countries which published articles on occupational diseases over the past 46 years.

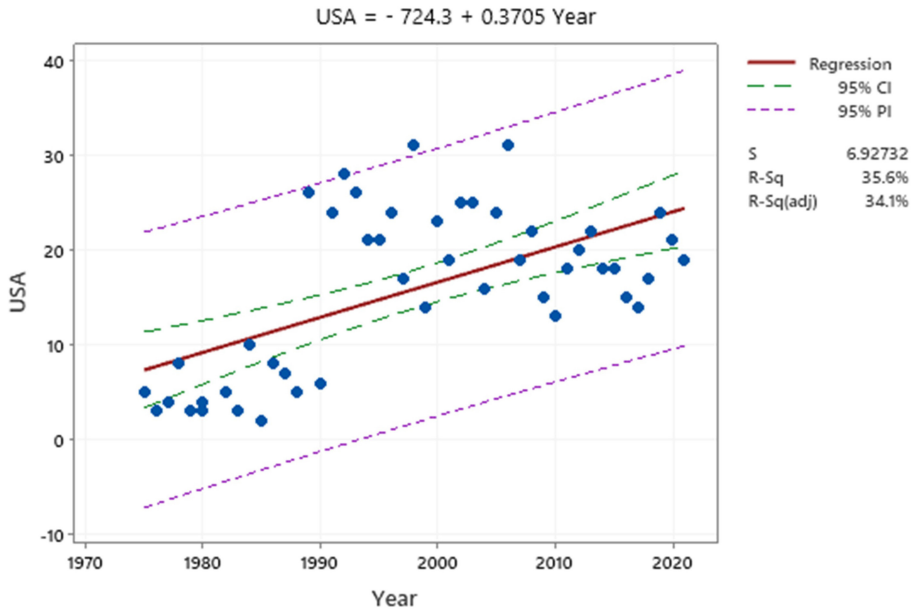


FIGURE 4
Article production curve in the United States.

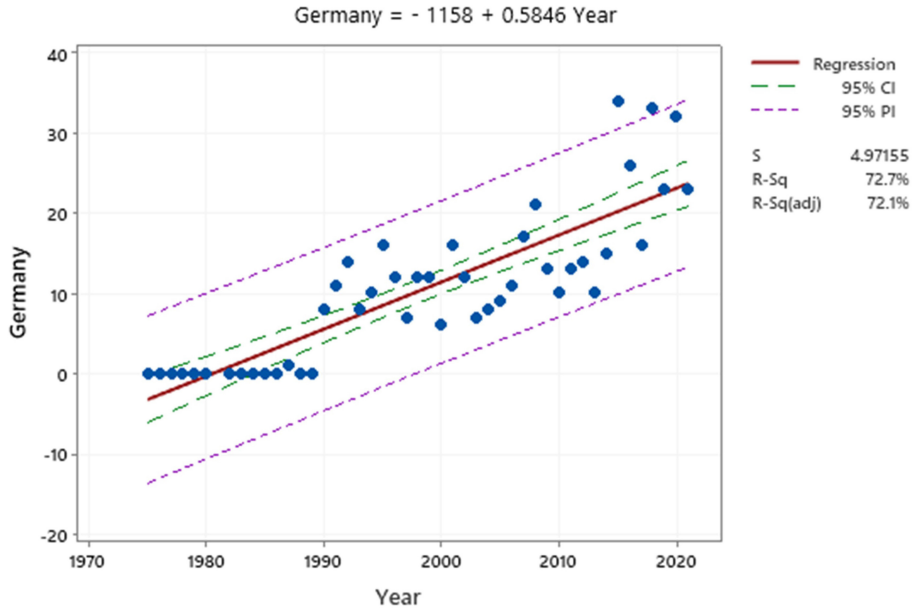


FIGURE 5
Article production curve in Germany.

country with the most cooperation, respectively. As can be seen, these two countries have cooperated with 50 countries each. Gephi software was used for this purpose. According to this software, the thicker the connection line, the more cooperation the two countries have with each other. As Figure 6 shows, the United States has had the most cooperation with Canada with 24 articles, followed by China with 22 articles. Spain also has an extensive cooperation network, with 18 studies having the most cooperation with France.

One way to identify a country's international impact on its science production is the number of times it is cited. The top 10 countries in terms of the number of citations are shown in Table 5. As can be seen, the United States has not only the highest number of citations per article but also the highest number of citations, with an average citation rate of 22 per article from 1975 to 2021 and a total of 16,504 citations with 746 citations. Canada is the fifth most published country and the third most cited country. This means that Canada also has a broad scientific impact on the study of ODs. Comparing the top 10 countries in publication with those in the citation, we can be concluded that 7 of the top 10 countries in the publication are among the top 10 countries in terms of citation, and Flanders, the Netherlands, and Sweden, despite being among the top 10 countries, are not the top producers of articles; they are among the top 10 countries cited. Sweden is the top country in terms of average citations with 68 articles published and 1,877 citations and an average of 28 citations per article. However, Germany and France are lower than other countries by an average of 8 citations per article.

TABLE 4 Top 10 countries in producing studies on occupational diseases.

| Country | No. publications | No. cooperation | International cooperation rate | Centrality |
|---|---|---|---|---|
| USA | 746 | 217 | 0.29 | 0.44 |
| Germany | 480 | 196 | 0.41 | 0.06 |
| France | 354 | 222 | 0.63 | 0.06 |
| Italy | 206 | 200 | 0.97 | 0.05 |
| Canada | 179 | 128 | 0.72 | 0.08 |
| England | 170 | 209 | 1.23 | 0.13 |
| Brazil | 164 | 28 | 0.17 | 0.01 |
| China | 164 | 39 | 0.24 | 0.01 |
| Spain | 141 | 203 | 1.44 | 0.05 |
| Turkey | 140 | 18 | 0.13 | 0.01 |

## Top 10 cited institutions and collaboration analysis

Institutions that have studied ODs can also be important. The results showed that 500 institutes had studied in this field. Also, cooperation in the production of studies is not limited to

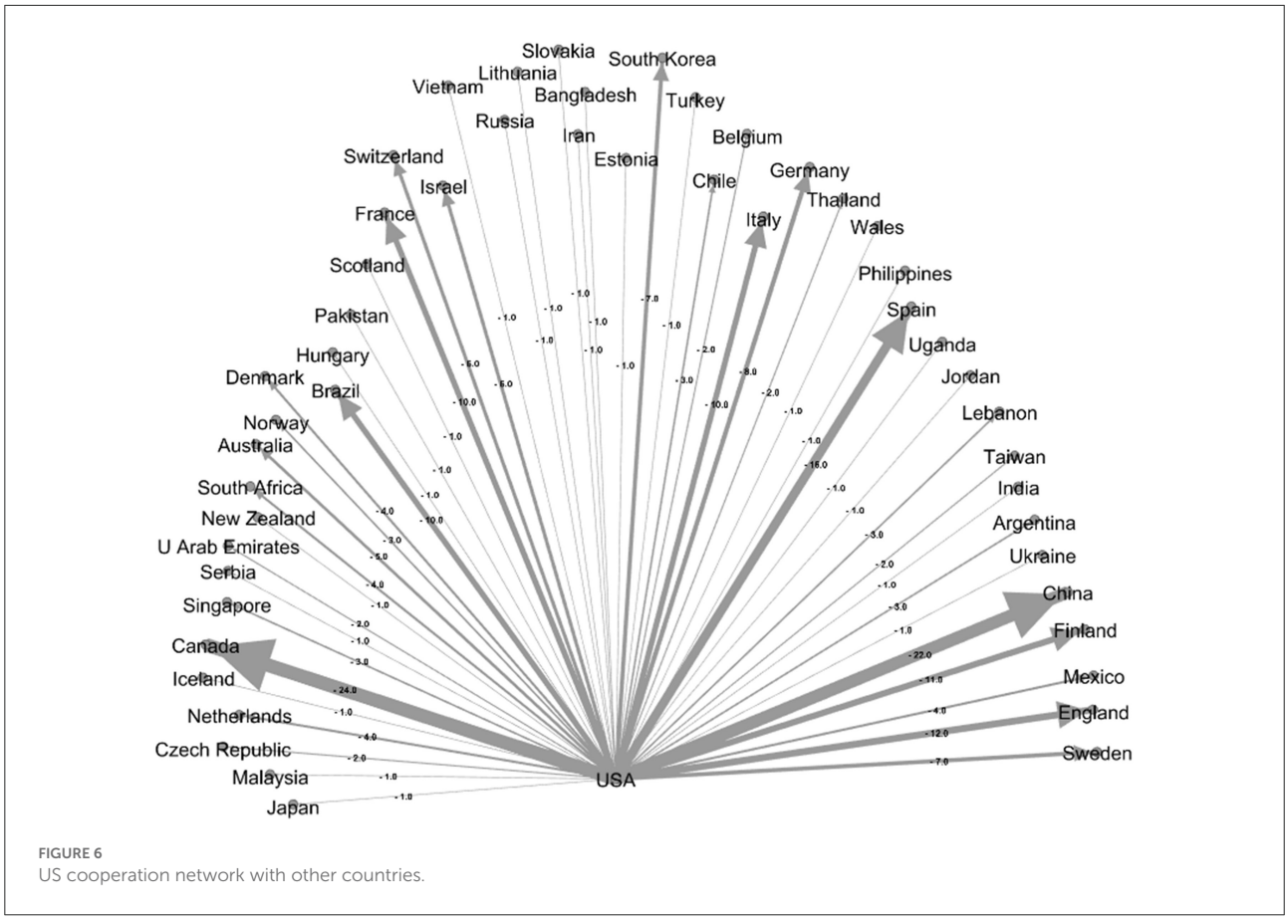


FIGURE 6
US cooperation network with other countries.

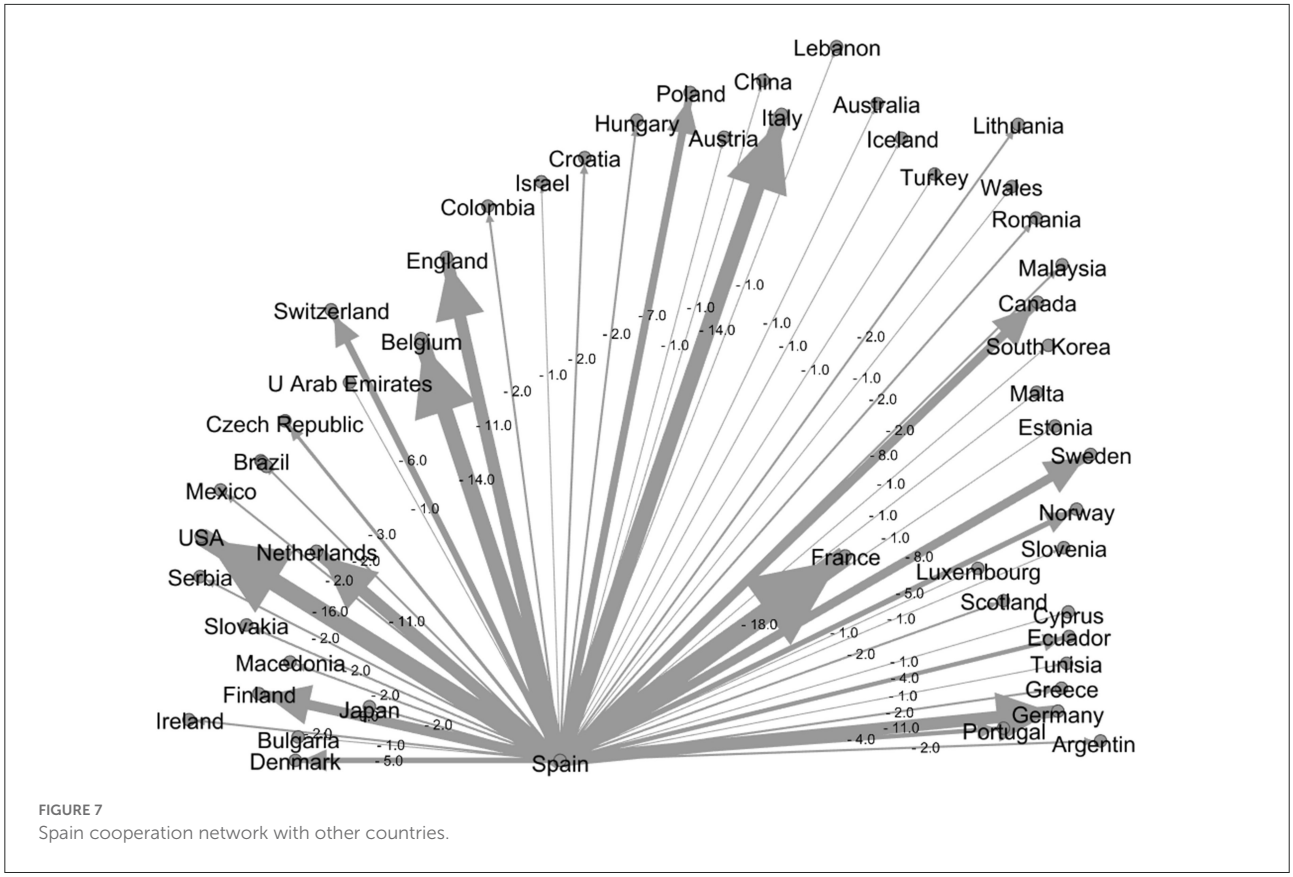


FIGURE 7
Spain cooperation network with other countries.

TABLE 5 Top 10 countries on occupational diseases based on citations.

| Top 10 productive countries | | | | Top 10 highly cited countries | | | |
|---|---|---|---|---|---|---|---|
| **Country** | **No. publications** | **Cited frequency** | **Average citations** | **Country** | **No. publications** | **Cited frequency** | **Average citations** |
| USA | 746 | 16,504 | 22 | USA | 746 | 16,504 | 22 |
| Germany | 480 | 3,961 | 8 | Germany | 480 | 3,961 | 8 |
| France | 354 | 2,698 | 8 | Canada | 179 | 3,225 | 18 |
| Italy | 206 | 2,259 | 11 | Finland | 112 | 2,979 | 27 |
| Canada | 179 | 3,225 | 18 | France | 354 | 2,698 | 8 |
| England | 170 | 2,632 | 15 | England | 170 | 2,632 | 15 |
| Brazil | 164 | 1,132 | 7 | Italy | 206 | 2,259 | 11 |
| China | 164 | 1,758 | 11 | Netherlands | 92 | 1,959 | 21 |
| Spain | 141 | 1,706 | 12 | Sweden | 68 | 1,877 | 28 |
| Turkey | 140 | 650 | 5 | China | 164 | 1,758 | 11 |

countries and is also formed among institutions. The authors' address published in a study is considered as an institution and their collaboration. The top 10 institutions in the field of ODs along with their cooperation with all institutions are shown in Table 6. The results show that 3 institutes are from Germany and confirm the upward trend of studies mentioned in the previous section. Only the two institutions in the United States with the highest number of articles are in the top 10 ranks. Also, three countries, Flanders, Poland, and the Netherlands, which were not among the top 10 countries in terms of the number of articles, with the participation and cooperation of their institutions, are among the top 10 institutions in terms of the number of articles, which shows the role of international cooperation in article production. The results of the cooperation

TABLE 6 Top 10 institutions in producing studies on occupational diseases.

| Institutions | Country | No. publications | No. cooperation | Cooperation rate |
|---|---|---|---|---|
| National Institute for Occupational Safety and Health (NIOSH) | USA | 87 | 98 | 1.13 |
| Finnish Institute of Occupational Health | Finland | 65 | 99 | 1.52 |
| University of Toronto | Canada | 47 | 89 | 1.89 |
| Nofer Institute of Occupational Medicine (NIOM) | Poland | 43 | 98 | 2.28 |
| University of Amsterdam | Netherlands | 38 | 79 | 2.08 |
| University of Erlangen-Nuremberg | Germany | 38 | 26 | 0.68 |
| Ruhr-University Bochum | Germany | 35 | 86 | 2.46 |
| Osnabrück University | Germany | 35 | 99 | 2.83 |
| University of Washington | USA | 33 | 50 | 1.52 |
| Inserm Research institute | France | 32 | 15 | 0.47 |

TABLE 7 Top 10 institutions on occupational diseases based on citations.

| Institutions | Country | No. publications | Cited frequency | Average citations |
|---|---|---|---|---|
| National Institute for Occupational Safety and Health (NIOSH) | USA | 87 | 2,710 | 31.15 |
| Finnish Institute of Occupational Health | Finland | 65 | 1,901 | 29.25 |
| University of North Carolina at Chapel Hill | USA | 25 | 1,562 | 62.48 |
| University of Toronto | Canada | 47 | 1,150 | 24.47 |
| Catholic University of Leuven | Belgium | 28 | 940 | 33.57 |
| Inserm Research institute | France | 32 | 934 | 29.19 |
| Montreal Sacred Heart Hospital | Canada | 22 | 927 | 42.14 |
| University of Massachusetts | USA | 19 | 907 | 47.74 |
| Michigan State University | USA | 19 | 906 | 47.68 |
| Harvard University | USA | 25 | 855 | 34.20 |

showed that the Osnabrück University from Germany and the Finnish Institute of Occupational Health from Flanders had the most cooperation. The collaboration rate shown in Table 4 is the ratio of the number of collaborations to the number of articles published, which shows that the institution has had more collaborations. Osnabrück University from Germany had the most contributions with 35 papers and a collaboration rate of 2.83. Therefore, transnational studies can be done with this institute.

To find the most effective institutions in the field of ODs, the results of cited institutions among the top 10 institutions were analyzed (Table 7). As the results show, there are 5 institutions from the United States, which were only 2 institutions from the top 10 ones in this country, and this shows the importance of cooperation between institutions. On the other hand, in Germany, where three institutions were among the top 10 institutions in terms of the number of articles, there is no institution among the top 10 institutions cited. One institution from Belgium is also one of the 10 cited institutions although Belgium was not among the top 10 countries in the number of articles cited. The top institution in terms of average citations is the University of North Carolina at Chapel Hill, which has 1,562 citations with 25 studies. After that, the University of Massachusetts Institute with 19 studies and 907 citations has had the greatest impact on the study of ODs. This shows that although these two institutes are not among the top 10 institutes in terms of the number of studies, the type of their studies and objectives of their studies are fundamental and form the basis of subsequent studies.

Also among the high citation studies, in addition to the studies listed in Table 1, three studies entitled Negative Impacts of Shiftwork and Long Work Hours with 218 citations from NIOSH (29), Cancer Risk Associated with Occupational Exposure to Magnetic-Field among Electric Utility Workers in Ontario, Quebec, Canada, and France, 1970–1989 with 273 citations from the University of Toronto (21), and the Work-Related Cumulative Trauma Disorders Study of the Upper Extremity with 229 citations from the University of Washington (30) also had the most citations.

## Important topics in the field of ODs

Important keywords and topics usually reflect the current research trends and provide authors with suggestions for future studies. By analyzing the keywords in Cite Space software, we

TABLE 8 Repetition of keywords over the last 15 years periods (from 1975 to 2021).

| 1975–1990 | | 1991–2006 | | 2007–2021 | |
|---|---|---|---|---|---|
| **Keywords** | **Frequency** | **Keywords** | **Frequency** | **Keywords** | **Frequency** |
| Occupational exposures | 1,566 | Occupational exposures | 209 | Occupational exposures | 47 |
| Epidemiology | 902 | Epidemiology | 147 | Mental health | 46 |
| Occupational diseases | 596 | Skin diseases | 85 | Jobs | 44 |
| Respiratory Diseases | 451 | Respiratory Diseases | 72 | Respiratory Diseases | 40 |
| Cancer | 230 | Musculoskeletal disorders | 70 | Epidemiology | 39 |
| Occupational accidents | 166 | Jobs | 57 | Musculoskeletal disorders | 35 |
| Allergy | 147 | Mental health | 37 | Cancer | 24 |
| Musculoskeletal disorders | 131 | Occupational diseases | 32 | Cardiovascular diseases | 22 |
| Jobs | 106 | Cancer | 30 | Noise and vibration diseases | 16 |
| Skin diseases | 76 | Occupational accidents | 17 | Occupational accidents | 9 |
| Cardiovascular diseases | 14 | Allergy | 5 | Skin diseases | 6 |
| Noise and vibration diseases | 4 | Noise and vibration diseases | 1 | Occupational diseases | 2 |
| Mental health | 0 | Cardiovascular diseases | 0 | Allergy | 2 |

can extract the top 10 keywords by classifying them into three periods: 1975 to 1990, 1991 to 2006, and 2007 to 2021. According to the results in Table 8, the keywords of the studies can be classified into three categories of keywords related to the types of ODs, the studied jobs, and the epidemiological studies. This Table shows that in the first period, the words Occupational exposures, Epidemiology, and Occupational diseases ranked first to third, and during the second period, Skin diseases replaced Occupational diseases in the third place. Also, the term Mental health, which was not used at all from 1975 to 1990, has become the second most frequently used term in the period 2007 to 2021; this shows the importance of this issue in the study of occupational diseases. Respiratory Diseases, which are the most important occupational diseases, have been ranked fourth among the keywords in the three study periods and have always been of great importance, showing more jobs than before. Studies have also shown that lung disease has declined in recent years, and ODs including CVDs and MSDs have increased since 1996 after diagnostic criteria were determined. From 1996 to 2009, low back pain accounted for 41.2% of the work-related illnesses, followed by CVDs at 30.3% and MSDs (excluding low back pain) at 25.2% (3).

Figure 8 shows the relationship between the keywords, which is plotted using VOS viewer software. This connection means that the term A is related to the term B; in addition, the term B is related to the term C. It can be concluded that there is a relationship between term A and term C, and this further promotes the scientific findings. Therefore, the analysis of the simultaneous relationship between keywords can raise a new ground in the study of ODs. Figure 8 shows that respiratory diseases, occupational accidents, and allergies are widely used in ODs. Based on the definition of ILO for occupational accidents "an occupational accident is an unexpected and unplanned occurrence, including acts of violence, arising out of or in connection with work, which results in one or more workers incurring a personal injury, disease or death." (31), Since, it can lead to disease, this keyword has been used in studies. Of course, there is a difference between occupational disease and occupational accidents.

To better understand the keywords, we examined Occupational exposures, Epidemiology, Respiratory Diseases, Mental health, and Jobs in detail due to their frequency during different periods. The results of the subcategories of the keyword Occupational exposure showed that this term could be classified into four categories of Exposure, Workplace exposure, Risk factors, and Occupational health. These four words were repeated 420, 478, 417, and 251 times in the first period, respectively; 72, 87, 52, and zero times in the second period; and 7, 7, 13, and 20 times in the third period, respectively. This indicates that workplace exposure is of great importance during the study period, after which the importance of exposure time has been removed and most of the risk factors for ODs have been studied. Therefore, in the field of occupational health in the coming years, researchers can further investigate the risk factors. The keyword Mental Health has been added to those of occupational disease since 2004 and includes items such as stress, burnout, depression, and anxiety, which have increased significantly during the years 2021–2007.

Epidemiological studies in this field can also be divided into several categories (Table 9). The results showed that the study of Prevalence, Mortality, Surveillance, Epidemiology, and Follow up were the most frequent words in the first 15 years, but over time the repetition of these words has decreased and in

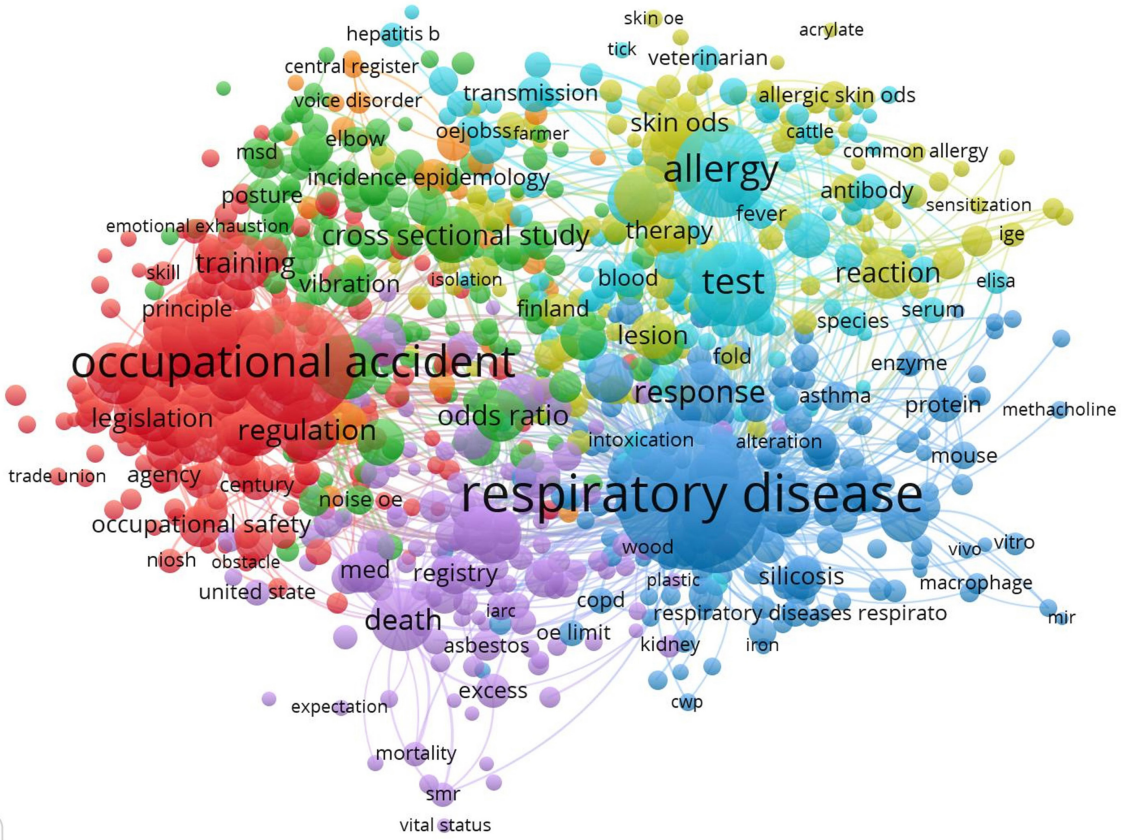


FIGURE 8
Keyword communication network.

TABLE 9 Keywords related to epidemiology.

| Keywords | 1975–1990 | 1991–2006 | 2007–2021 |
|---|---|---|---|
| Prevalence | 229 | 0 | 6 |
| Mortality | 143 | 0 | 13 |
| Surveillance | 86 | 58 | 0 |
| Epidemiology | 173 | 45 | 0 |
| Follow up | 103 | 0 | 2 |
| Intervention | 11 | 0 | 0 |
| Burden of diseases | 27 | 0 | 11 |
| Others | 130 | 44 | 7 |

recent years only the words Mortality and Burden of diseases are important.

As the results of the top areas (Figure 2) and keywords (Table 8) showed, and also based on other studies, respiratory diseases are the most important ODs (32); therefore, respiratory diseases were examined in detail (Table 10). As Table 10 shows, Chronic obstructive pulmonary disease (COPD) has had the highest recurrence among lung diseases over the past 4 decades because it covers a wide range of lung diseases. This category includes words such as lung disease, atherosclerosis, respiratory health, airway inflammation, airways obstruction, and so on. After this disease, occupational asthma was very important from 1975 to 1990, which has decreased in recent years. The results also showed that asbestosis was prevalent from 1975 to 1990, but, with the application of the asbestos removal law, this keyword has not been seen in ODs in recent years. Pneumoconiosis is one of the most common respiratory diseases today, which shows the importance of this disease in recent years. These results are in line with those of previous studies which show that before 1991 most cases of ODs were pneumoconiosis, and since 1991 the proportion of pneumoconiosis among ODs has been reported 67.1% (6).

The results of jobs analysis, which is influential in the type of occupational disease, show that 7 jobs were mentioned among the studies (Table 11). Among these, the most important job over the years has been health care workers. This job is mentioned in most occupational disease studies due to its high importance and numerous risks. On the other hand, the jobs of

TABLE 10 Keywords related to respiratory disease.

| Keywords | 1975–1990 | 1991–2006 | 2007–2021 |
|---|---|---|---|
| Occupational asthma | 154 | 11 | 2 |
| Asbestosis | 48 | 6 | 0 |
| Silicosis | 20 | 0 | 7 |
| Pneumoconiosis | 12 | 0 | 10 |
| Dust exposure | 63 | 9 | 2 |
| Chronic obstructive pulmonary disease (COPD) | 154 | 46 | 19 |

TABLE 11 Keywords related to jobs.

| Jobs | 1975–1990 | 1991–2006 | 2007–2021 |
|---|---|---|---|
| Health care workers | 28 | 46 | 11 |
| Construction workers | 10 | 0 | 5 |
| Miners | 14 | 2 | 0 |
| Agricultural workers | 9 | 3 | 10 |
| Chemical workers | 4 | 2 | 4 |
| Automobile industries | 7 | 1 | 0 |
| Hairdresser | 0 | 2 | 6 |
| Others | 23 | 1 | 6 |

agricultural workers and hairdressers have been more frequent in the past years from 2007 to 2021 than other jobs, and this shows that the study of ODs is only for high-risk and well-known jobs such as construction and mining. Other jobs have been explored in recent years. In addition, the others section included occupations such as capacitor manufacturing workers, bakers, welders, firefighters, and kitchen employees, which were much less frequent than other occupations and could not be categorized separately. These results also indicate that the study of ODs should not be known only in the field of occupations, and future studies can also draw their results from ODs such as agricultural workers, hairdressers, capacitor manufacturing workers, bakers, welders, firefighters, and kitchen employees so that the diseases and risk factors of such occupations are better known.

## Conclusion

The present study examined the main countries, institutions, and publications in the study of ODs and examined the interaction between them. This study also examined the keywords and research trends to find recent hot topics and predict future analysis trends. The conclusion of the present study is as follows:

1) From a study of the top 10 producing countries from 1975 to 2021, it can be seen that the United States and Germany are the two largest countries in producing studies on ODs. However, by analyzing Figures 6, 7, it can be concluded that Germany, with its current development trend in the coming years, will surpass the United States and gain the first rank.
2) The analysis of the cooperation of the top 10 countries showed that the level of cooperation between Spain is the highest, their cooperation reaches 1.40, and they have cooperated with 50 different countries. Also, Spain has the most cooperation (18 studies) with France, which has the highest number. This shows that the two countries have extensive international cooperation.
3) The results of the top 10 institutes show that the National Institute for Occupational Safety and Health (NIOSH) had the highest number of papers with 87 studies and Osnabrück University with 99 collaborations had the highest number of international collaborations. However, the survey showed that 3 out of the top 10 institutions were from Germany.
4) A study of keyword trends showed that researchers have paid more attention to skin diseases and mental health since 1991; this shows the importance of this issue in the study of ODs. Respiratory Diseases have also been ranked fourth among the keywords in three study periods and have always been of great importance.
5) In addition, job analysis shows that health care work has been the most important job during the past years, and then the jobs of agricultural workers and hairdressers in the past years from 2007 to 2021 have become more important than other jobs. Future studies can also report the results of ODs such as agricultural workers, hairdressers, capacitor manufacturing workers, bakers, welders, firefighters, and kitchen employees to better understand the diseases and risk factors of such occupations.
6) For the bibliometric analysis of the journals, the eigenfactor score can be used as an alternative bibliometrics that can help to choose beter journal. It is suggested to be used in future studies.

## Limitations

Our work clearly has some limitations. The most important one lies in the fact that since in scientometric studies in general and the software used, it is not possible to screen studies like what is done in systematic review studies (reading titiles, reading abstract, reading full text, etc), we must extract the most relevant studies by searching. Therefore, if only one disease is searched such as "pneumoconiosis," a large number of studies will be found, many of which are not about occupational diseases. So, we tried to search the studies with a general keywords and only in the field of occupational diseases. By choosing

this search strategy "Occupational disease*" OR "Occupational illness*" OR "Industrial disease*" OR "Industrial disease*" we tried to extract the most studies related to occupational diseases, regardless of the type of disease.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

MJ was the leader of study and edited the final manuscript. HS and HR gathered data and searched the articles and were a major contributor in writing the manuscript. MM and AZ analyzed the data and gathered the top tens and was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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# Sleep duration and metabolic body size phenotypes among Chinese young workers

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The evidence linking sleep duration and metabolic body size phenotypes is limited, especially in young adulthood. In this study, we aimed to examine the association between sleep duration and metabolic body size phenotypes among Chinese young workers and investigate whether discrepancies exist among shift and non-shift workers. A cross-sectional study was performed between 2018 and 2019 in Wuhan, China and 7,376 young adults aged 20–35 years were included. Self-reported sleep duration was coded into four groups: <7, 7–8, 8–9, and ≥9 h per day. Participants were classified into four metabolic body size phenotypes according to their body mass index and metabolic health status: metabolically healthy normal weight, metabolically unhealthy normal weight, metabolically healthy overweight/obesity (MHO), and metabolically unhealthy overweight/obesity (MUO). Multinomial logistic regression models were used to explore the associations between sleep duration and metabolic body phenotypes. Compared with those who slept 7–8 h each night, those with sleep duration <7 h per day had higher odds of MHO (OR 1.27, 95% CI: 1.02–1.56) and MUO (OR 1.22, 95% CI: 1.03–1.43), irrespective of multiple confounders. Stratification analyses by shift work showed that the association between short nighttime sleep and increased odds of MUO was only observed in shift workers (OR 1.26, 95% CI 1.03–1.54). Sleep duration is independently associated with metabolic body size phenotypes among Chinese young adults, while shift work could possibly modulate the association. These results may provide evidence for advocating adequate sleep toward favorable metabolic body size phenotypes in young workers.

KEYWORDS

**sleep duration, body size phenotypes, metabolically healthy obesity, young adults, shift work**

# Introduction

The prevalence of overweight and obesity is on the rise worldwide, especially in the young population (1). Numerous studies have identified overweight and obesity as a key factor for various cardiometabolic complications, such as type 2 diabetes, hypertension, and hyperlipidemia (2), the morbidities of which are also steadily increasing among young adults (3). However, recent studies proposed that body mass index (BMI) level alone is not enough to distinguish people with different health risks, as a special type of obesity is not always accompanied by cardiometabolic abnormalities (4). To better describe the status of metabolism, the healthier phenotype is called metabolically healthy obesity (MHO), which is characterized by a better metabolic profile, lower inflammation level, more subcutaneous and less visceral adipose tissue (4, 5). In contrast, among normal weight population, there exists a subset exhibiting more cardiometabolic abnormalities, named as metabolically unhealthy normal weight (MUNW) (4). A better understanding of the determinants of these metabolic body size phenotypes is promising to promote relevant effective interventions toward favorable conditions (4, 5).

Factors reported to be associated with obesity and metabolic disorders include unhealthy lifestyles, such as excessive intake of calorically dense foods, lack of physical activity, sleep disorders and occupational factors such as shift work (6–8). Among them, sleep, a fundamental need for humans, attracts more and more attention recently. Previous studies have found that sleep could modulate the development of obesity and metabolic abnormalities through regulating the functioning of daily metabolic and hormonal processes and appetite (9). The US National Sleep Foundation suggested adults aged 18–64 years get 7–9 h of sleep each night (10). For Chinese adults, the recommended sleep duration is 7–8 h per day based on the Healthy China 2030. However, sleep curtailment seems to have become highly prevalent over the past few decades. The percentage of US adults sleeping 6 h or less per night has increased by 31% since 1985 (11), and a large population-based study revealed that 23% of Chinese adults reported getting <6 h of sleep (12). Thus, whether and how inadequate sleep affects metabolic health are needed to be explored.

Although some evidence highlighted the role of inadequate sleep duration in obesity and metabolic indicators (9, 13–17), as far as we're concerned, the association between sleep duration and metabolic body size phenotypes has received scant attention. Previous observational studies were mostly based on children, adolescents (18) or general adults with an average age over 40 years old (19), but with little evidence from the Chinese population or young adulthood. What's more, shift work, related to both insufficient sleep and cardiometabolic diseases (8), was not particularly investigated in previous studies. As sleep duration differs across age groups and short sleep duration and subsequent weight gain seem to be more prevalent in young populations (20), studies targeted at this critical life period are needed and may facilitate pertinent preventive strategies. If effective measures are implemented in early adulthood, corresponding risk factor progression may be reduced or prevented in later life (21). Therefore, we aimed to explore the association between sleep duration and metabolic body size phenotypes among Chinese young adults and investigate whether discrepancies exist among shift and non-shift workers.

Abbreviations: BMI, body mass index; MHNW, metabolically healthy normal weight; MUNW, metabolically unhealthy normal weight; MHO, metabolically healthy overweight/obesity; MUO, metabolically unhealthy overweight/obesity; BP, blood pressure; SBP, Systolic blood pressure; DBP, diastolic blood pressure; TG, triglycerides; HDL-C, high-density lipoprotein-cholesterol; FPG, fasting plasma glucose; OR, odds ratio; CI, confidence interval.

# Materials and methods

## Study population

As shown in Figure 1, all employees from Wuhan Metro Group Co., Ltd. were recruited in this cross-sectional study in 2018 and 2019 and 89.2% (11, 960 out of 13, 414) agreed to participate in the current research and finished the questionnaire. For this study, we excluded those who didn't attend a physical examination during 2018–2019 ($n$ = 2, 400), those who were older than 35 years old ($n$ = 493) (22) and those whose BMI value was missing ($n$ = 46) or <18.5 kg/m$^2$ ($n$ = 686) (23). In addition, we removed those who had missing information regarding variables of interest, such as sleep duration, blood pressure, metabolic parameters and other covariates ($n$ = 959). This yielded a final sample size of 7, 376 individuals (6, 095 males, 1, 281 females, with a mean age of 27.1 years).

This study was approved by the Ethics Committee of the Wuhan Centers for Disease Control and Prevention (WHCDCIRB-K-2018042) and written informed consent was obtained from all participants.

## Data collection

All participants were asked to complete a questionnaire and a physical examination. Standardized questionnaires were administered in person by trained interviewers between 2018 and 2019, which included personal characteristics, occupational information, lifestyle behaviors (e.g., smoking, alcohol, sleep, dietary intake and exercise) and medical history. Shift workers were defined as participants with a self-reported history of any work schedule involving irregular working hours instead of a

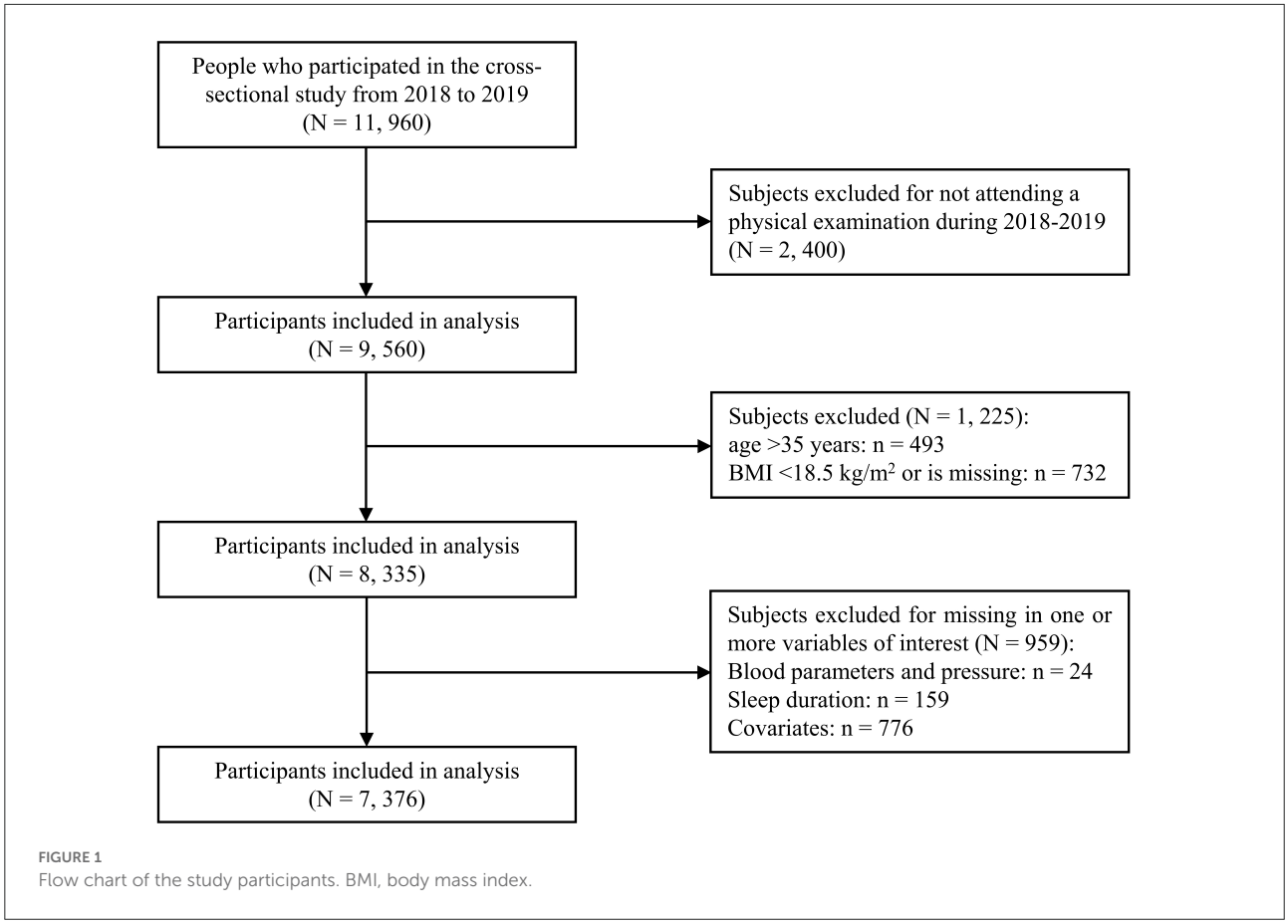


FIGURE 1
Flow chart of the study participants. BMI, body mass index.

normal daytime work schedule for at least 1 year or else were defined as non-shift workers (24). Smokers were defined as those who had smoked at least one cigarette per day in the past 6 months or else were defined as nonsmokers. Drinkers were considered as those who had drunk alcoholic beverages at least once a week in the past 6 months or else were considered as nondrinkers. Regular exercisers referred to those who have engaged in a variety of physical activities aiming at exercising for more than 20 min per time at least once a week during the past year (25). Similar to a previous study (26), self-reported sleep duration was obtained by asking: "What time do you usually go to sleep at night and wake up in the morning over the past one month?", and coded into four groups: short (<7 h/d), normal (7–8 h/d), long (8–9 h/d), and very long (≥9 h/d).

Physical examinations were conducted between May 2018 and October 2019 at assigned physical examination centers in Wuhan, Hubei Province. Body weight and standing height were measured with subjects wearing light clothing and no shoes. BMI was calculated as weight/height squared (kg/m$^2$). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken in a sitting position after at least 5-min rest. Fasting plasma sample was drawn in the morning after an overnight fast. Concentrations of triglycerides (TG), high-density lipoprotein-cholesterol (HDL-C), and fasting blood glucose (FBG) were measured in the medical centers' laboratories following standard procedures.

## Definition of metabolic body size phenotypes

According to the Working Group on Obesity in China criteria (27), we categorized participants using their BMI into normal weight (18.5–23.9 kg/m$^2$), overweight (24.0–27.9 kg/m$^2$), obesity (≥28.0 kg/m$^2$). Metabolically healthy condition was defined by the current harmonized criteria (28): Participants who met none of the following metabolic abnormalities were considered metabolically healthy: (1) Elevated TG: TG ≥150 mg/dl (1.7 mmol/l), or use of lipid-lowering drugs; (2) Reduced HDL-C: HDL-C <40 mg/dl (1.0 mmol/l) in men or <50 mg/dl (1.3 mmol/l) in women, or use of lipid-lowering drugs; (3) Elevated BP: SBP ≥130 mmHg and/or DBP ≥85 mmHg, or use of antihypertensive drugs; (4) Elevated FPG: FPG ≥100 mg/dl (5.6 mmol/l), or use of antidiabetic drugs.

Based on their BMI categories and metabolic health status, participants were classified into four metabolic body size phenotypes: metabolically healthy normal weight (MHNW), metabolically unhealthy normal weight (MUNW), metabolically healthy overweight/obesity (MHO), and metabolically unhealthy overweight/obesity (MUO). The obesity group was combined with the overweight group due to insufficient sample sizes, consistent with previous study (18).

## Statistical analysis

The characteristics of participants were presented as the mean ± standard deviation (SD) or median (interquartile range, IQR) for continuous variables or as number (percentages) for categorical variables across sleep duration groups or the four phenotypes. The analysis of variance (ANOVA) and Chi-square test were performed to compare differences between groups. Subgroup analyses were conducted using Tukey-Kramer's multiple comparisons. Because of the skewed distribution of TG, log-transformed TG was analyzed. Multinomial logistic regression models were performed to examine the associations of sleep duration and metabolic body phenotypes after controlling for various covariates, and further stratified by shift work status to explore whether differences exist among shift and non-shift workers. The reference group was considered as the participants with a sleep duration of 7–8 h/d, which was thought to have the lowest all-cause mortality (29). Covariates were selected based on published literature (19, 26), including age (continuous), gender (male, female), marital status (single, not single), shift work (yes, no), smoker (yes, no), drinker (yes, no), regular exerciser (yes, no) and family history of hypertension (yes, no), diabetes (yes, no) and hyperlipemia (yes, no). Multivariable logistic regression models were then used to further investigate the associations between sleep duration and BMI categories and individual components of metabolic abnormalities. To assess the stability and robustness of our findings, we further adjusted for the consumption of fruit, vegetable, tea and coffee in sensitivity analyses. All statistical analyses were performed using SAS 9.4 software for Windows (SAS Institute Inc., Cary, NC). A two-sided $P < 0.05$ was considered statistically significant.

# Results

## Basic characteristics of participants

Table 1 shows the characteristics of the study population according to sleep duration groups. A total of 7,376 participants were included in this study. The average age of the whole participants was 27.1 years (SD: 2.9). Men made up the majority of the population (6,095, 82.6%). Two-thirds of the participants lived single lives (66.2%). According to their self-reported sleep duration, participants fell into four groups, including <7 h/d (22.0%), 7–8 h/d (31.1%), 8–9 h/d (24.8%), and ≥9 h/d (21.1%). Across four sleep duration groups, there were significant differences in age, gender, marital status, shift work, smoking status, alcohol drinking, physical activity, family history of diabetes, BMI categories, and the levels of TG, HDL-C, and BP (all $P < 0.05$). For example, with the increase of sleep duration, the percentage of smokers gradually declined (<7 h/d: 27.8%, 7–8 h/d: 22.1%, 8–9 h/d: 19.4%, ≥9 h/d: 17.6%, $P < 0.001$). Shift workers accounted for a substantial part of long sleepers (87.2%), followed by 71.4% in the group of 8–9 h/d, 69.5% in the group of <7 h/d, and 60.2% in the group of 7–8 h/d ($P < 0.001$). As sleep duration increased, more people were of normal weight and fewer were overweight or obese ($P < 0.001$). The sociodemographic characteristics, lifestyles and metabolic indicators were similar between participants included in the present study and those excluded among young adults with a BMI ≥ 18.5 kg/m$^2$ who completed the questionnaire and the physical examination during 2018 and 2019 (Supplementary Table S1).

## Metabolic characteristics of study population across metabolic body size phenotypes

Table 2 lists the metabolic characteristics of the study population according to metabolic body size phenotypes. The participants were classified into MHNW (35.2%), MUNW (23.9%), MHO (11.9%), and MUO (29.0%). Constituting 29.0% of the overweight/obese individuals, the MHO group presented better metabolic parameters than the MUNW group and the MUO group (lower TG, SBP, DBP and FBG and higher HDL-C), but worse than the MHNW group (higher TG, SBP, DBP, and lower HDL-C) (all $P < 0.05$). The MHO and MUO groups had a higher proportion of individuals with a sleep duration of <7 h/d (MHO: 26.0%, MUO: 26.1% vs. MHNW: 19.4%) and a lower proportion of those who slept longer than 9 h/d (MHO: 15.5%, MUO: 18.0% vs. MHNW: 26.0%) than those in the MHNW group, as is shown in Figure 2.

## Association of sleep duration and metabolic body size phenotypes

The multinomial logistic regression analysis was performed to identify the association between sleep duration and metabolic body size phenotypes after adjusting for age, gender, marital status, shift work, smoking status, drinking status, physical activity and family history of hypertension, diabetes and hyperlipemia (Table 3). Compared with those with normal sleep

TABLE 1 Basic characteristics of study population according to sleep duration.

| Characteristics | Sleep duration, h/d | | | | |
|---|---|---|---|---|---|
| | <7 ($N = 1,625$) | 7–8 ($N = 2,290$) | 8–9 ($N = 1,832$) | ≥9 ($N = 1,629$) | $P^{\dagger}$ |
| Age (years, mean ± SD) | 27.5 ± 3.0 | 27.3 ± 2.9 | 27.1 ± 2.9 | 26.5 ± 2.7 | **<0.001** |
| Gender (*n*, %) | | | | | **<0.001** |
| Male | 1,480 (91.1) | 2,058 (89.9) | 1,514 (82.6) | 1,043 (64.0) | |
| Female | 145 (8.9) | 232 (10.1) | 318 (17.4) | 586 (36.0) | |
| Marital status (*n*, %) | | | | | **<0.001** |
| Single (unmarried, divorced or widowed) | 1,079 (66.4) | 1,475 (64.4) | 1,162 (63.4) | 1,166 (71.6) | |
| Not single (married or partnered) | 546 (33.6) | 815 (35.6) | 670 (36.6) | 463 (28.4) | |
| Shift worker (*n*, %) | 1,130 (69.5) | 1,378 (60.2) | 1,308 (71.4) | 1,421 (87.2) | **<0.001** |
| Smoker (*n*, %) | 452 (27.8) | 506 (22.1) | 355 (19.4) | 286 (17.6) | **<0.001** |
| Drinker (*n*, %) | 332 (20.4) | 441 (19.3) | 311 (17.0) | 249 (15.3) | **<0.001** |
| Regular exerciser (*n*, %) | 667 (41.0) | 1,079 (47.1) | 927 (50.6) | 655 (40.2) | **<0.001** |
| Family history of hypertension (*n*, %) | 392 (24.1) | 533 (23.3) | 394 (21.5) | 379 (23.3) | 0.305 |
| Family history of diabetes (*n*, %) | 203 (12.5) | 237 (10.3) | 136 (7.4) | 174 (10.7) | **<0.001** |
| Family history of hyperlipemia (*n*, %) | 53 (3.3) | 49 (2.1) | 38 (2.1) | 46 (2.8) | 0.070 |
| BMI categories (*n*, %) | | | | | **<0.001** |
| Normal weight (18.5–23.9 kg/m$^2$) | 838 (51.6) | 1,332 (58.2) | 1,097 (59.9) | 1,090 (66.9) | |
| Overweight (24.0–27.9 kg/m$^2$) | 523 (32.2) | 700 (30.6) | 538 (29.4) | 395 (24.2) | |
| Obesity (≥28.0 kg/m$^2$) | 264 (16.2) | 258 (11.3) | 197 (10.8) | 144 (8.8) | |
| TG [mmol/L, median (IQR)] | 1.2 (0.8, 1.8) | 1.2 (0.8, 1.7) | 1.1 (0.8, 1.6) | 1.0 (0.7, 1.5) | **<0.001***|
| HDL-C (mmol/L, mean ± SD) | 1.4 ± 0.3 | 1.4 ± 0.3 | 1.4 ± 0.3 | 1.5 ± 0.3 | **<0.001** |
| SBP (mmHg, mean ± SD) | 122.8 ± 13.6 | 122.4 ± 13.5 | 122.2 ± 13.4 | 120.2 ± 13.3 | **<0.001** |
| DBP (mmHg, mean ± SD) | 71.9 ± 10.0 | 71.7 ± 9.7 | 72.0 ± 9.5 | 71.2 ± 9.4 | 0.074 |
| FPG (mmol/L, mean ± SD) | 5.1 ± 0.8 | 5.0 ± 0.6 | 5.1 ± 0.7 | 5.0 ± 0.6 | 0.415 |

Basic characteristics of study population according to sleep duration are presented as mean ± SD or median (IQR) for continuous variables or as number (percentages) for categorical variables.

BMI, body mass index; TG, triglyceride; HDL-C, high density lipoprotein-cholesterol; BP, blood pressure; FPG, fasting plasma glucose.

† *P*-values were calculated by ANOVA or Chi-square test as appropriate. Values in bold represent statistically significance ($P < 0.05$).

*Log-transformed TG were used to calculate the P-values because of skewed distribution.

duration (7–8 h/d), those with sleep duration <7 h/d had higher odds of MHO (OR 1.27, 95% CI 1.02–1.56, $P < 0.05$) and MUO (OR 1.22, 95% CI 1.03–1.43, $P < 0.05$), irrespective of confounding factors. ORs with 95% CIs for all variables adjusted for in model 3 are shown in Supplementary Table S2.

Multivariable logistic regression models were used to further assess the independent effect of sleep duration on BMI categories and metabolic abnormalities, as shown in Figure 3 and Supplementary Table S3. Compared with those who slept 7–8 h/d, those with short sleep duration (<7 h/d) were associated with increased odds of overweight and obesity (OR 1.26, 95% CI 1.11–1.44, $P < 0.001$). Those who slept 8–9 h/d were related to higher blood pressure (OR 1.23, 95% CI 1.07–1.41, $P < 0.01$). Those with nighttime sleep of ≥9 h/d were at higher odds of elevated FPG (OR 1.29, 95% CI 1.06–1.56, $P < 0.05$). Besides, those who slept 8–9 h/d and ≥9 h/d showed a higher tendency toward metabolically unhealthy status (OR 1.11, 95% CI 0.98–1.27 and OR 1.13, 95% CI 0.98–1.30, respectively).

## Association of sleep duration and metabolic body size phenotypes in shift and non-shift workers

Stratification analyses by shift work (Table 4) were also performed. The association between short nighttime sleep and an increased prevalence of MUO was observed only in shift workers (OR 1.26, 95% CI 1.03–1.54, $P < 0.05$), and the relationship between <7 h/d sleep and MHO disappeared (OR 1.24, 95% CI 0.94–1.61, $P = 0.124$). In non-shift workers, we did not find any association between sleep duration and metabolic body size phenotypes.

## Sensitivity analyses

We further adjusted for daily consumption of vegetables, fruit, tea and coffee (Supplementary Table S4). The associations

TABLE 2 BMI and metaboliccharacteristics across metabolic body size phenotypes.

| Variables | MHNW ($N = 2,596$) | MUNW ($N = 1,761$) | MHO ($N = 876$) | MUO ($N = 2,143$) | $P^{\dagger}$ |
|---|---|---|---|---|---|
| BMI (kg/m$^2$) | $21.3 \pm 1.5^{a}$ | $21.7 \pm 1.5^{b}$ | $26.2 \pm 1.9^{c}$ | $27.3 \pm 2.7^{d}$ | **<0.001** |
| TG (mmol/L) | $0.8\ (0.6, 1.1)^{a}$ | $1.1\ (0.8, 1.8)^{b}$ | $1.1\ (0.8, 1.4)^{c}$ | $1.9\ (1.2, 2.6)^{d}$ | **<0.001*** |
| HDL-C (mmol/L) | $1.5 \pm 0.3^{a}$ | $1.4 \pm 0.3^{b}$ | $1.4 \pm 0.2^{c}$ | $1.3 \pm 0.2^{d}$ | **<0.001** |
| SBP (mmHg) | $114.1 \pm 9.2^{a}$ | $126.4 \pm 13.7^{b}$ | $117.2 \pm 8.0^{c}$ | $129.7 \pm 13.4^{d}$ | **<0.001** |
| DBP (mmHg) | $67.1 \pm 6.9^{a}$ | $73.9 \pm 9.6^{b}$ | $68.3 \pm 7.0^{c}$ | $76.9 \pm 10.2^{d}$ | **<0.001** |
| FPG (mmol/L) | $4.9 \pm 0.4^{a}$ | $5.2 \pm 0.6^{b}$ | $4.9 \pm 0.4^{a}$ | $5.2 \pm 1.0^{c}$ | **<0.001** |

BMI and metabolic characteristics of four body size phenotypes are presented as mean ± SD or median (IQR) as appropriate.
MHNW, metabolically healthy normal weight; MUNW, metabolically unhealthy normal weight; MHO, metabolically healthy overweight/obesity; MUO, metabolically unhealthy overweight/obesity; BMI, body mass index; TG, triglycerides; HDL-C, high density lipoprotein-cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose.
$^{\dagger}$ $P$-value by ANOVA. Values in bold represent statistically significance ($P < 0.05$).
$^{a,b,c,d}$ Same letters indicate no statistical significance based on Tukey-Kramer's multiple comparison.
*Log-transformed TG were used to calculate the $P$-values because of skewed distribution.

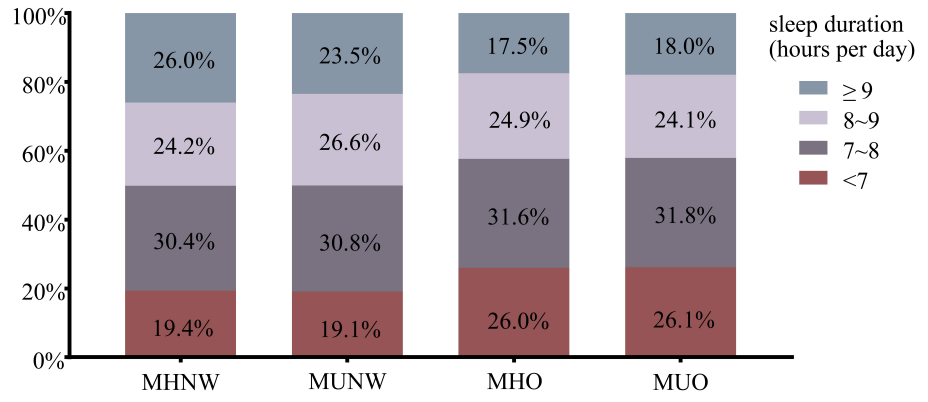


FIGURE 2
The proportion of sleep duration across metabolic body size phenotypes. MHNW, metabolically healthy normal weight; MUNW, metabolically unhealthy normal weight; MHO, metabolically healthy overweight/obesity; MUO, metabolically unhealthy overweight/obesity.

of short sleep duration with MHO and MUO were still obtained after adjusting for daily consumption of vegetables and fruit. After we further adjusted for daily consumption of tea and coffee, the relationship between short sleep duration and MHO remained (OR 1.37, 95% CI 1.10–1.70, $P < 0.01$). However, the relationship between short sleep duration and MUO did not reach the threshold of statistical significance (OR 1.16, 95% CI 0.98–1.38, $P = 0.083$).

## Discussion

In the present study, the associations between sleep duration and metabolic body size phenotypes were evaluated among Chinese young workers. We found that compared with normal sleep duration, short nighttime sleep increased the odds of MHO and MUO after adjusting for socioeconomic, lifestyle and disease history confounders. With regard to BMI categories and components of metabolic syndrome, short sleepers appeared to have higher odds of overweight/obesity, while long sleepers had higher odds of elevated blood pressure and fasting plasma glucose. Additionally, the associations between sleep duration and body size phenotypes differed by shift work.

Metabolic body size phenotypes, mutually defined by BMI categories and metabolic health, were proposed in the context where using BMI alone could misclassify people into current health status or potential risks of future clinical outcomes (4, 5, 30). Compared with MUO, an MHO phenotype is characterized by lower liver fat content, greater insulin sensitivity, better insulin secretion and cardiorespiratory fitness (5, 31). Previous research suggested that although people classified as MHO may still bear a higher risk of all-cause mortality and cardiovascular events than MHNW, its risk is substantially lower than MUO (32). In this setting, discovering modifiable factors related to these phenotypes is beneficial for instituting simple lifestyle changes to prevent the development of cardiometabolic diseases, and previous studies have found lifestyles, such as daily exercise and not smoking as potential influencers (5, 32).

TABLE 3 Odds ratios (95% confidence intervals) of metabolic body size phenotypes according to sleep duration categories in multinomial logistic regression models.

| Sleep duration (h/d) | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| **MUNW** | | | |
| <7 | 0.98 (0.82–1.16) | 0.97 (0.81–1.16) | 0.96 (0.80–1.15) |
| 7–8 | Ref | Ref | Ref |
| 8–9 | 1.08 (0.92–1.28) | 1.15 (0.98–1.36) | 1.17 (0.99–1.38) |
| ≥9 | 0.90 (0.76–1.06) | 1.10 (0.93–1.31) | 1.10 (0.92–1.31) |
| **MHO** | | | |
| <7 | **1.30 (1.05–1.60)*** | **1.27 (1.03–1.57)*** | **1.27 (1.02–1.56)*** |
| 7–8 | Ref | Ref | Ref |
| 8–9 | 0.99 (0.80–1.22) | 1.09 (0.89–1.34) | 1.10 (0.90–1.36) |
| ≥9 | **0.65 (0.52–0.81) *** ** | 0.91 (0.72–1.15) | 0.92 (0.73–1.16) |
| **MUO** | | | |
| <7 | **1.29 (1.10–1.51)**** | **1.25 (1.06–1.47)**** | **1.22 (1.03–1.43)*** |
| 7–8 | Ref | Ref | Ref |
| 8–9 | 0.95 (0.82–1.11) | 1.09 (0.93–1.29) | 1.11 (0.95–1.31) |
| ≥9 | **0.66 (0.56–0.78)*** ** | 1.09 (0.92–1.30) | 1.07 (0.89–1.28) |

MUNW, metabolically unhealthy normal weight; MHO, metabolically healthy overweight/obesity; MUO, metabolically unhealthy overweight/obesity.
Model 1: unadjusted.
Model 2: adjusted for age and gender.
Model 3: model 2 plus marital status, shift work, smoking status, drinking status, physical activity and family history of hypertension, diabetes and hyperlipemia.
Significance was represented as bold characters, $^{*}P < 0.05$, $^{**}P < 0.01$ and $^{***}P < 0.001$.

To our knowledge, at present there are limited studies examining the association between sleep duration and metabolic body size phenotypes. Ryu et al. found sleep duration different across body size phenotypes with MHO and MUO groups having shorter sleep among Korean general adults (19). Lim et al. found that sleeping <5 h was associated with higher odds of being MHO among Korean children and adolescents (18). Our findings in Chinese young adults are consistent with these results. Although the underlying mechanism of this association is not yet well-elucidated, it is conceivable that the adverse effects of inadequate sleep on obesity and metabolic function could act in this process. Notably, our further analyses about sleep duration with BMI categories and metabolic health showed that short sleep duration was associated with overweight/obesity but not metabolic unhealthy status, which, in line with above studies (18, 19), suggested that excess weight may contribute more than metabolic alterations to the relationship between insufficient sleep and metabolic body size phenotypes. A plausible explanation for it may be that it takes much longer time to develop metabolic alterations than to gain weight (18).

The observed association between short sleep duration and obesity is supported by previous studies (33, 34). A meta-analysis summarized that a reduction of 1 h in sleep per day was associated with an increase of 0.35 kg/m$^2$ in BMI among adults (13). Several mechanisms linking short sleep duration with obesity have been proposed. First, it is generally accepted that sleep appears to play a critical role in modulating energy and

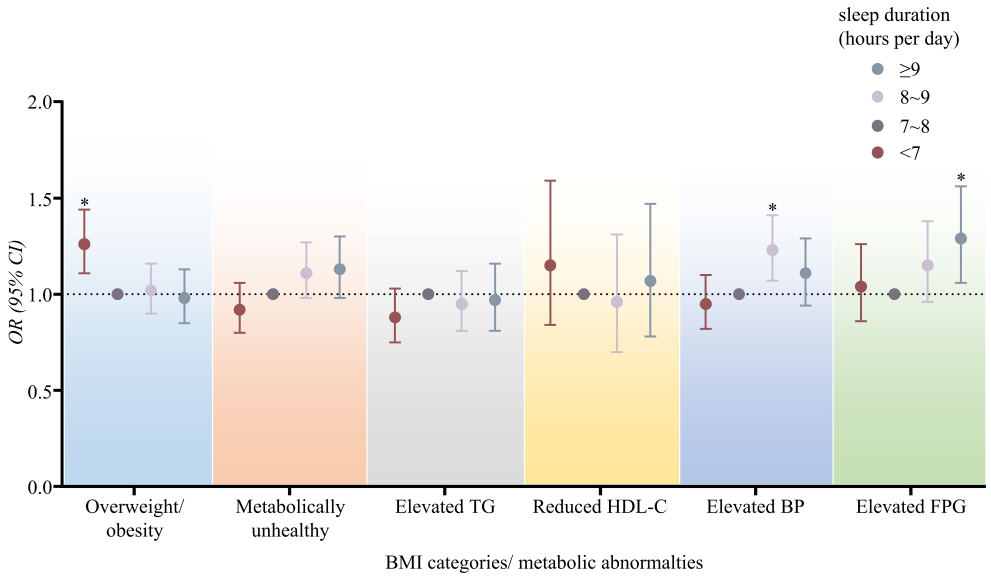


FIGURE 3
ORs (95% CIs) of BMI categories and metabolic abnormalities according to sleep duration in logistic regression models. OR, odds ratio; CI, confidence interval; TG, triglycerides; HDL-C, high density lipoprotein-cholesterol; BP, blood pressure; FPG, fasting plasma glucose. *$P < 0.05$. All models were adjusted for age, gender, marital status, shift work, smoking status, drinking status, physical activity. Further adjustment for BMI and family history of hypertension, diabetes or hyperlipemia were made when accessing the association between sleep duration and metabolic abnormalities.

TABLE 4 Odds ratios (95% confidence intervals) of metabolic body size phenotypes according to sleep duration categories stratified by shift work in multinomial logistic regression models.

| Sleep duration (h/d) | Non-shift workers (N = 2,139) | | | Shift workers (*N* = 5,237) | | |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| **MUNW** | | | | | | |
| <7 | 0.88 (0.64–1.20) | 0.87 (0.64–1.19) | 0.87 (0.63–1.19) | 1.02 (0.82–1.27) | 1.02 (0.82–1.26) | 1.00 (0.81–1.25) |
| 7–8 | Ref | Ref | Ref | Ref | Ref | Ref |
| 8–9 | 1.21 (0.91–1.61) | 1.23 (0.92–1.63) | 1.25 (0.94–1.66) | 1.04 (0.85–1.27) | 1.13 (0.92–1.38) | 1.15 (0.94–1.41) |
| ≥9 | 0.89 (0.61–1.32) | 0.95 (0.64–1.41) | 0.96 (0.64–1.42) | 0.91 (0.75–1.10) | 1.14 (0.93–1.39) | 1.14 (0.93–1.39) |
| **MHO** | | | | | | |
| <7 | **1.45 (1.03–2.04)*** | 1.39 (0.99–1.96) | 1.36 (0.97–1.93) | 1.25 (0.96–1.63) | 1.24 (0.95–1.62) | 1.24 (0.94–1.61) |
| 7–8 | Ref | Ref | Ref | Ref | Ref | Ref |
| 8–9 | 0.82 (0.56–1.19) | 0.84 (0.58–1.22) | 0.85 (0.58–1.24) | 1.10 (0.85–1.42) | 1.23 (0.95–1.59) | 1.25 (0.97–1.62) |
| ≥9 | **0.55 (0.32–0.96)*** | 0.64 (0.37–1.12) | 0.63 (0.36–1.11) | **0.70 (0.54–0.91)**** | 1.01 (0.77–1.32) | 1.01 (0.77–1.32) |
| **MUO** | | | | | | |
| <7 | 1.27 (0.96–1.67) | 1.17 (0.89–1.55) | 1.14 (0.85–1.51) | **1.31 (1.08–1.60)**** | **1.29 (1.05–1.58)*** | **1.26 (1.03–1.54)*** |
| 7–8 | Ref | Ref | Ref | Ref | Ref | Ref |
| 8–9 | 1.06 (0.81–1.39) | 1.10 (0.84–1.46) | 1.16 (0.88–1.54) | 0.92 (0.76–1.12) | 1.09 (0.89–1.33) | 1.11 (0.91–1.36) |
| ≥9 | 0.74 (0.51–1.08) | 0.91 (0.62–1.35) | 0.92 (0.62–1.37) | **0.67 (0.55–0.80)***** | 1.14 (0.93–1.39) | 1.12 (0.91–1.38) |

MUNW, metabolically unhealthy normal weight; MHO, metabolically healthy overweight/obesity; MUO, metabolically unhealthy overweight/obesity.
Model 1: unadjusted.
Model 2: adjusted for age and gender.
Model 3: model 2 plus marital status, smoking status, drinking status, physical activity and family history of hypertension, diabetes and hyperlipemia.
Significance was represented as bold characters, $^{*}P < 0.05$, $^{**}P < 0.01$ and $^{***}P < 0.001$.

lipid metabolism in tissues. Population-based studies found that self-reported short sleep duration was associated with decreased leptin levels and increased ghrelin in blood independent of BMI, which could elevate hunger and appetite, resulting in chronically predisposing an individual to overweight or obesity (17). In addition, longer awake time may result in greater fatigue, which tends to decrease physical activity and increase sedentary behavior (35). Sleep-wake cycles also regulate sympathetic nervous system, whose activity gradually decreases during the deep sleep stages of non-REM sleep, while sympathetic nervous activity is elevated during REM sleep and wakefulness stage. Less sleep means less non-REM sleep, resulting in overactivation of sympathetic nervous system, thus a significant reduction of circulating concentrations of catecholamines epinephrine and norepinephrine can be observed in individuals having short sleep duration (36).

In contrast, unanimous agreement has not yet been reached about the effect of sleep duration on metabolic abnormalities. Some studies showed a *U*-shape pattern for sleep duration and higher risks of metabolic syndrome (37), while others confirmed the association only in short sleepers (14, 38) or long sleepers (15), or indicated no significant association between them (33). In the current study, sleep duration was not significantly associated with metabolically unhealthy status after adjustment. However, a trend existed between longer nighttime sleep and metabolically unhealthy status, possibly because long sleep was associated with elevated BP and elevated FPG. Several reasons may contribute to the inconsistency between studies, including different sizes and age structures of the study samples, the fluctuation of BP levels and FPG levels even throughout a day, and unmeasured or unknown confounders.

In stratification analyses, the odds of MUO induced by sleep reduction in groups having shift work were higher in our study, which is important to note given that metro work is a special type of work providing public service for much long time every day and that nearly three-quarters of our participants had shift work experience for at least 1 year. This difference may be caused through effects of shift work on physiological maladaptation to chronically sleeping and eating at abnormal circadian times (8), changes in sleep patterns (24), and decreased secretion of insulin and resting metabolic rate (39). Although further studies are required to better understand the interplays of shift work and sleep with respect to metabolic body size phenotypes, these exploratory results might shed light on finding the key subpopulations in whom adequate sleep duration should be first promoted to prevent cardiometabolic diseases.

Several limitations also need to be considered. First, the cross-sectional design only indicated the association, and the underlying causality cannot be reached. What's more, measurements including sleep duration were self-reported. However, subjective reports of habitual sleep have been shown to be moderately correlated with Actigraphy-measured sleep among adults (40). Third, a single measurement of metabolic parameters might lead to potential misclassification although it's

a common practice in large epidemiology studies. Despite these, our study adds new information on the association between sleep duration and metabolic body size phenotypes among young adults.

Taken together, short sleep duration was independently associated with MHO and MUO among Chinese young adults, and its influence appeared to be different depending on shift work. Current results provide scientific evidence for advocating adequate sleep toward favorable metabolic body size phenotypes in young adults.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of the Wuhan Centers for Disease Control and Prevention (WHCDCIRB-K-2018042). The patients/participants provided their written informed consent to participate in this study.

## Author contributions

JW: data curation, conceptualization, methodology, formal analysis, and writing original draft. DX: conceptualization, formal analysis, visualization, and writing original draft. BS and JL: investigation and data curation. LX and WC: data curation and validation. LL: funding acquisition, resources, project administration, and writing—review and editing. HW: project administration and supervision. FY: conceptualization, funding acquisition, resources, supervision, project administration, and writing—review and editing. All authors read and approved the final manuscript.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1017056/full#supplementary-material

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# Death at sea—the true rate of occupational fatality within the Australian commercial fishing industry

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Although the safety performance of the Australian commercial fishing industry has been the subject of multiple investigations, it has ultimately remained undefined. While most Australian industries notify industry regulators of significant workplace incidents and injuries in their operations, the majority of persons in the commercial fishing industry are contractors who are paid piecework and in some jurisdictions specifically excluded from the worker compensation legislation, meaning that most occupational injuries, including fatalities, are not captured in the centralized worker compensation data sets. This study presents the analysis of a systematic review of industry databases, published academic, and, Australian coroners reports to assist improve the definition of the nation's commercial fishing industry safety performance. The analysis shows occupational fatality rates are significantly higher than currently reported, and recurring factors contributing to deaths at sea remain unaddressed. The study is significant as it demonstrates how workplace injuries and deaths can be hidden within data sets applying broad industry classification and provides a foundation for future research in Australian fishing and other industries.

KEYWORDS

**Fishing, Safety, occupational, coroner, Australian, fatality**

## Introduction

The Australian Commercial Fishing Industry (ACFI) directly employs approximately 6,000 persons. On average, the industry produces 174,000 tons of product per year, with an economic value of $5.3 bn, representing a strong contribution to the Australian economy (1). The industry is diverse with a wide range of vessel types, fishing techniques, and is geographically spread around much of the 36,000 km of Australian coastline (2). Employment related to wild catch fishing is estimated at between 5,600 and 7,500 people in recent seasons (3, 4), with an average of 4,292 full-time and 1,675 part-time employees per year over the period.

Although the detail of Australian occupational health and safety legislation varies between its States and Territories, henceforth referred to as States, the general principles are based on the United Kingdom's Robens-style legislation (5). The occupational health and safety legislation requires organizations to implement a risk-based approach to

eliminate or minimize risks as so far as is reasonably practicable and create a safe workplace, which is regulated by a State government agency. In addition, each State has workers' compensation legislation which provides a no-blame insurance-based system to provide income and rehabilitation assistance, including medical and other expenses associated with workplace injuries (6). Each State reports worker compensation summary data and information, including fatalities, to Safe Work Australia which compiles and reports regularly. The annual report includes comparison and trends over time between States, industries, hazards, and interventions (7). Safe Work Australia works with States and industry to set the agenda for performance improvement and inform national policy (8).

However, the commercial fishing industry regulation is not consistent and comprises a complex mix of Federal and State agencies, with legislation specific to geographic regions, the species being fished, licensing and operation of vessels, and the prevention of illegal fishing in Australian waters. While fishing vessels are considered a workplace consistently across all jurisdictions legislation, the people who work on them may not be deemed to be workers or employees. The classification of workers is dependent upon the applicable occupational health and safety, and worker's compensation legislation (9–18).

For example, The Western Australian Workers' Compensation and Injury Management Act 1981 (10) defines a worker as follows:

> "*any person who has entered into or works under a contract of service or apprenticeship with an employer, whether by way of manual labor, clerical work, or otherwise and whether the contract is expressed or implied, is oral or in writing*".

However, this Western Australian Act specifically excludes crews of fishing vessels as these workers:

> "*in respect to injuries occurring to such members of a fishing vessel as contribute to the cost of working that vessel, and are remunerated by shares in the profits or the gross earnings of the working of that vessel*".

Similarly elsewhere, such as in Queensland, which has the largest fishing fleet, crews of fishing vessels do not receive salary or wages, instead their income is a share of the profits, or loss, of the vessel, after running costs and other liabilities are deducted. In effect, this "share catch" income arrangement results in the workers being self-employed contractors in their workplace, and they personally are responsible for paying their tax, superannuation (i.e., pension), and frequently medical and other insurances (19, 20).

In effect, the exclusion of fishing crew being classified as a worker removes most obligations on the employer to report workplace incidents and injuries to the workers/crew. Crew may of course report workplace injuries to their insurer; however, this may have an impact on the cost of the insurances. These circumstances have created systemic under-reporting of incidents and injuries in the commercial fishing industry.

Safe Work Australia categorizes the worker compensation data and information using the Australian and New Zealand Industrial Classification (ANZSIC). As ANZSIC coding groups "business units carrying out similar productive activities" together (21), commercial fishing, farming, and agriculture are collectively considered one group and are reported as such in occupational databases and reports (7, 8, 22–24).

Safe Work Australia (7) reports agriculture, forestry, and fishing in the top two industry classifications from 2003 to 2018 for total fatalities per year, with transport, postal, and warehousing having the highest total number of fatalities for 7 of the 16 years analyzed.

In 2004, agriculture, forestry, and fishing recorded 77 fatalities, the highest number observed from the data reviewed. In 2019, the lowest number, 30 fatalities, was recorded. Agriculture, forestry, and fishing recorded the highest fatality rate per 100,000 workers for 15 of the 16 years, peaking at 21.6 fatalities per 100,000 workers in 2004 and recording the lowest in 2019 of 9.1 fatalities per 100,000 workers. As Safe Work Australia reports the fishing industry data combined with agriculture and forestry, analysis of fishing-specific data is not possible.

Safe Work Australia reports rates of injury and fatality per 100,000 workers regardless of injury or size of industry. Noting that the ACFI only has a workforce of approximately 6,000 people (1), we hypothesized that reporting of injuries and fatalities in this manner dilutes and hides the true contextualized rates of fatality in the ACFI. Furthermore, we posit that the rates of occupational fatality in the industry may be significantly higher than currently acknowledged in existing reporting. The combination of employment arrangements, lack of inclusive legislative requirements to report occupational injuries, and the collective grouping of commercial fishing with other industries in occupational statistical databases give rise to the problem statement: "*the true state of safety performance within the Australian commercial wild catch fishing industry remains unknown*".

International literature and data sets (25–27) report commercial fishing as one of the world's most dangerous occupations with reoccurring factors of causation. It is therefore hypothesized that the contextualized rate of occupational fatality within the ACFI is higher than currently reported, and reoccurring causes of injury and death are present. To answer this question, this research aims to answer the following:

1. What is the contextualized rate of occupational fatality within the Australian wild catch commercial fishing industry?
2. What are the recurring contributing factors of occupational fatality within the Australian wild catch commercial fishing industry?

This study aims to answer these questions and improve understanding of the true state of safety within the ACFI. We attempt to do this through two separate systematic literature reviews of (1) published research focussed on the ACFI and (2) coronial investigations and other safety investigations and reports relevant to the ACFI with results presented according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist. The results are then distilled to identify the number of fatalities within the industry with greater accuracy, while thematic analysis is completed to identify the recurring contributing factors.

The motivation for, and significance of, the study is 2-fold. First, the results of the study may assist the development of targeted safety interventions within the ACFI and the reduction of avoidable fatalities within the industry. Second, the findings with regards to the suitability of current data classification and analysis may have broader-reaching impacts across Australian workplaces wherever broad industry data classifications have the potential to disguise or dilute actual injury and fatality rates.

The study is subsequently presented as follows. First, we present the methodology of the study and detail the search terms, inclusion criteria, and limitations of the systematic literature reviews. Next, we present the results of each review before discussing their implications and recommending potential industry improvements. Finally, we provide our conclusion and recommendations for future research.

## Methodology

In the first phase of the study, a systematic review of contemporary studies on occupational health and safety within the ACFI was completed. This systematic review enabled the identification, examination, and synthesis of relevant academia, government, and industry reports. The second phase of the study involved a systematic review and thematic analysis of Australian coronial findings and safety investigations related to ACFI incidents. This narrative approach was selected due to both the anticipated heterogeneous and limited research available, as well as enabling a review of the 'state of knowledge' of the field (28).

For Phase 1, studies meeting the following criteria were included in the analysis: peer-reviewed studies or reports, as well as post-incident reviews, inquiries, and inquests after incidents, published by government and non-government organizations (in Australia, industry research is completed by both sectors). Two review authors independently tested the search criteria and completed the initial search before reviewing the titles and abstracts, and selecting final articles for detailed full-text analysis. Any disagreement was resolved by discussion and majority decision between all article authors. Following the removal of duplications, the titles and abstracts were screened. The results are presented according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist.

TABLE 1 Search terms.

| | |
|---|---|
| Sources | Medline, ProQuest, Scopus, Web of Science, and Google Scholar |
| Search terms | Australia* *AND* fish* *AND* (industry OR commercial) AND (fatal* OR death OR safe* OR health) |
| Limits | English Language AND Published Between 2001–2020 |

The symbol * indicate standard nomenclature in searches.

The search strategy included only terms relating to the occupational health and safety of crew on fishing vessels in the Australian wild catch fishing industry (Table 1). A secondary search of bibliographies identified further literature for inclusion. Completed in September 2020, the review included English-language papers published in the last 20 years (2001–2020) to ensure currency of evidence. Seminal papers from outside the date range were considered for inclusion where appropriate. Databases included Medline, ProQuest, Scopus, Web of Science, and Google Scholar. Non-English-speaking literature, abstracts, citations, thesis, unverified or unsubstantiated press or news media reports, and articles that are not related to occupational safety of crew on fishing vessels in the Australian wild catch fishing industry were excluded. A review of the "gray literature" in Google was subsequently completed using the same search terms (Table 1). This literature review was informed by a consideration of industry literature, policy and non-peer-review professional journals or publications, and non-medical media.

For Phase 2, as the databases reviewed were specific to Australian incidents within the relevant jurisdictions, all available reports related to commercial fishing were screened. Databases included Australian Coroners Courts in each State (i.e., Australian Capital Territory "ACT", New South Wales "NSW", Northern Territory "NT", Queensland "QLD", South Australia "SA", Tasmania "TAS", Victoria "VIC", and Western Australia "WA") including all coronial published inquiries, findings, and reports into deaths, as well as safety investigations and reports by the Australian Transport Safety Bureau (ATSB) and Australian Maritime Safety Administration (AMSA). The search was completed in September 2020. Two review authors independently tested the search criteria and completed the initial search before reviewing the titles and abstracts and then selecting final articles for detailed full-text analysis. Any disagreement was resolved by discussion and majority decision between all authors. Following the removal of duplications, the titles and abstracts were screened. The results are presented according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist.

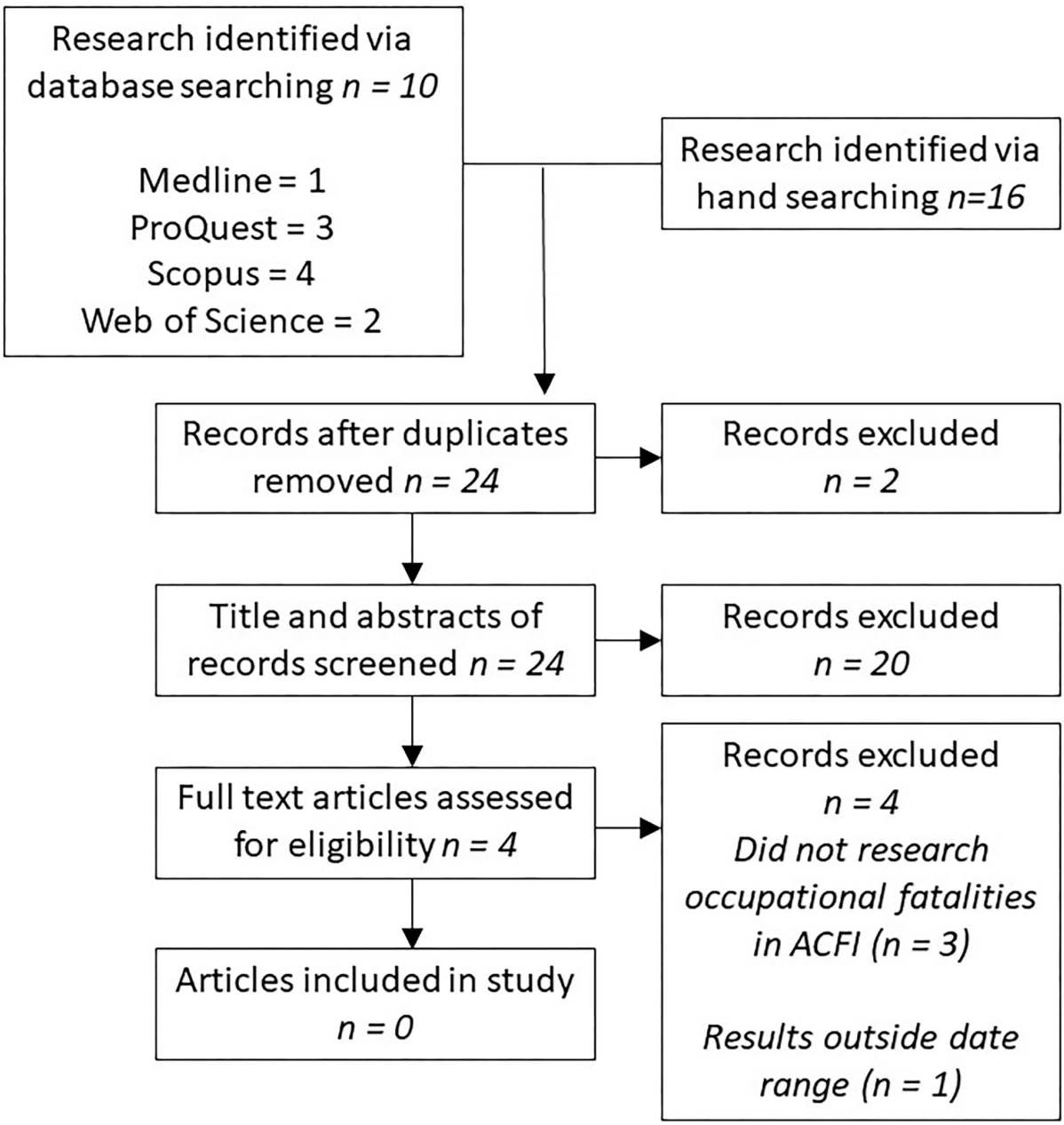


FIGURE 1
Phase 1 systematic literature review of peer-reviewed academia presented in accordance with PRISMA guidelines.

## Calculating contextualized fatality rates

Contextualized fatality rates ($F_c$), that is the fatality rate within each industry per 10,000 Australian workers as opposed to fatality rate per 100,000 Australian workers, will be calculated using equation (1):

$$F_c = F_t / W_t \quad (1)$$

where $F_t$ is the number of fatalities reported over the time period assessed in years; and $W_t$ is the average number of workers in the industry during the same time period.

# Results

The search in Phase 1 (Figure 1) yielded only four studies suitable for full review in the study. Of these works, only one

TABLE 2 ACFI fatalities by mechanism of injury 2003–2013 [Data from (31)].

| Mechanism of death | Finfish trawling | Line fishing | Marine | Marine n.e.c | Prawn fishing | Rock lobster | Total |
|---|---|---|---|---|---|---|---|
| Boat fire—drowning | | | | | 1 | | 1 |
| Diving—shark attack | | | | 2 | | | 2 |
| Drowning—not otherwise classified | | | 4 | | 1 | | 5 |
| Drowning—capsize | 4 | | | 3 | 2 | | 9 |
| Drowning—fall overboard | 2 | 2 | 4 | 2 | 2 | 1 | 13 |
| Drowning—entangled in net | | | 3 | | | | 3 |
| Drowning—nets caught, capsizing boat | | | 2 | | 5 | | 7 |
| Drowning—scuba related | | | 1 | | | | 1 |
| Drowning—washed overboard | | | | 1 | | | 1 |
| Drowning—diving & entangled | | | | 1 | | | 1 |
| Drowning—collision at sea | | | | | 1 | | 1 |
| Electrocution | | 1 | 1 | | | | 2 |
| Entanglement | 2 | | | | | | 2 |
| Fire | | | | 2 | | | 2 |
| Head injury—waves | | | | | | 2 | 2 |
| Pully / winch | | | | | 1 | | 1 |
| Tractor | | | | | 1 | | 1 |
| Unknown | | | | 1 | | | 1 |
| Total | 8 | 3 | 15 | 12 | 14 | 3 | 55 |

*Note—the "Marine" classification is the overarching category and is used when specific detail of the sector is unknown from the data. The "Marine (nec)" classification is used when another type of known fishing has been involved but is not listed.

explored work-related fatalities and was deemed potentially suitable for inclusion in the review; however, the date range examined in the study was 1989 to 1992 and was subsequently excluded. No academia was therefore identified as being suitable for inclusion in the study. Handsearching "gray literature", that is industry reports, initially identified 13 possible results, ultimately yielding five reports suitable for inclusion in the study (8, 29–32).

Industry literature (29, 31) reports higher ACFI fatality rates than those reported by Safe Work Australia (23). Extracted from Safe Work Australia data of occupational fatalities, Brooks (29) reported 14 occupational fatalities between 2003 and 2010. Confirming the limitations of using occupational health and safety reporting to accurately calculate incidents within the ACFI previously discussed in this paper, Lower (31) subsequently extracted data directly from the National Coroners Information System (NCIS) and reported 55 occupational fatalities between 2003 and 2013 (33 occupational fatalities between 2003 and 2010 in comparison with Brooks' figures). By comparison, DMIRS (30) reports four fatalities between 2009 and 2019 in the Fishing, Hunting, and Trapping industry subdivision, but does not specify which of these incidents (if any) are attributable to wild catch fishing. Both the remaining texts, the Commonwealth of Australia, report "*They never came home*" (8) and Lyons "*Best Practice Review of Workplace Health and Safety Queensland*" (32) cite ANZSIC division data that does not differentiate between agriculture, forestry, and fishing.

Chronological analysis of the data reported by Lower (31) and categorization by both mechanism of fatality, and wild catch fishing industry sector, is detailed in Table 2. Collectively, drowning accounts for 75% of all fatalities, with capsize (including capsizing as a probable result of nets being caught) being a substantial contributor to fatalities, accounting for 29% of all deaths. Prawn fishing is the most dangerous known sector, accounting for 25% of fatalities during the period. On average, there are 5.5 fatalities annually across the sector for the period. Unfortunately, neither exposure nor task level analysis and description were provided across the different industry sectors within the literature reviewed or within the ANZSIC database from which the industry sectors are drawn. This subsequently prevents more detailed analysis or description within this study.

The search in Phase 2 identified 22 reports for inclusion, 19 from coronial inquiries and three ATSB reports (Figure 2). One duplication was identified (i.e., one coronial and ATSB report investigated the same incident), and two reports related to incidents occurring prior to 2001. These three reports were excluded, resulting in 19 reports included in the study. Analysis of findings that matched the search criteria is summarized in Table 3. The issues of vessel stability, lack of action by regulators, and lack of enforcement of safety regulations were recurrent, particularly in cases of multiple fatalities.

Fatality rates within the ACFI per 10,000 workers as a comparison against the other highest-ranking Australian industries are calculated using equation 1 and are detailed

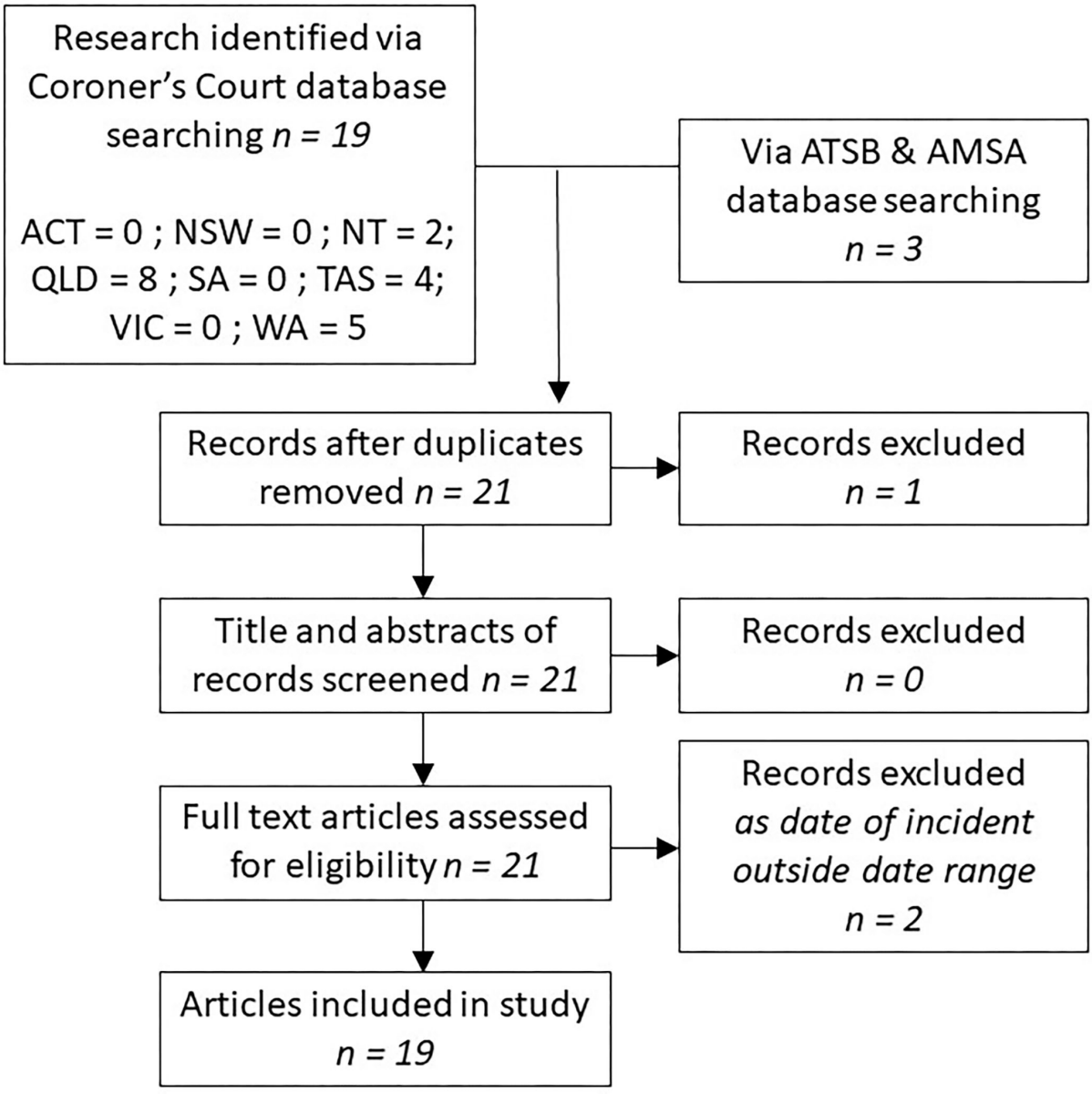


FIGURE 2
Phase 2 systematic literature review presented in accordance with PRISMA guidelines.

in Table 4. These figures indicate that average occupational fatality rates per 10,000 workers in Australian commercial fishing, calculated at 9.2, are higher than Agriculture and Road Freight Transport by a factor of 2.8 and 3.8, respectively, and higher than Construction by a factor of 30.7. The calculated rate of 9.2 fatalities per 10,000 within the ACFI is significantly higher than the peak rate of 21.6 fatalities per 100,000 workers in 2004 (equivalent to 2.2 fatalities per 10,000 workers) reported by Safe Work Australia (23).

## Discussion

The absence of peer-reviewed academic research into occupational injuries and fatalities within the ACFI was unexpected by the research team and is itself concerning, especially given the reputation of the industry internationally as being one of the most dangerous in the world (26, 27). In his synthesis of 16 international fishing industry case studies, Knapp (26) concluded that fishing was the world's most dangerous occupation, and both effective regulation and

TABLE 3 Coronial finding and ATSB report summary.

| Year | Mechanism of death | Notes | Reference |
|---|---|---|---|
| 2018 | Sea snake bite | Neurotoxic venom, prawn trawler, remote location | D0164/2018 |
| 2016 & 2017 | Capsize and drowning | Vessel stability, significant modification detrimental to stability post required testing. Multiple fatalities | COR 2016/1622, 2016/1637, 2017/4709, 2017/4711, 2018/5398, 2018/5402, 2018/5405, 2018/5407. |
| 2016 | Fell overboard and drowned | Work accident | 1572/2016 |
| 2015 | Capsize and drowning | Vessel stability, non-compliance with regulations, failure of regulators, substantial modifications to the extent "it would have been considered a new vessel" para 282. Multiple fatalities | 1190/2015; 1191/2015; 11,036/2015 |
| 2013 | Capsize and drowning | Vessel sea worthy—unknown cause of capsize. | 2013/2509 |
| 2013 | Traumatic head injury | Work accident | Cooper (2017) |
| 2013 | Electrocution | Noncompliance with Work Health and Safety legislation, previous coronial recommendations for similar death, confusing regulatory regime, lack of response by regulators | D210/2013 |
| 2012 | Drowning | Drowning secondary to air embolism during dive operations | 6,008-2012 |
| 2009 | Capsize and drowning | Nets hooked. 13 year old vessel compliant with stability requirements at time of constructed, not tested since. Multiple fatalities. | 16/08/2012; 04/09/2012; 05/09/2012 |
| 2006 | Capsize and drowning | Poor safety attitude, lack of union safety protection, lack of response by regulators | COR 2012/05(6) |
| 2006 | Fell overboard and drowned | Recommendation regulators to make EPIRB and Personal Floatation Devices mandatory | 892/06(8) |
| 2004 | Capsize and drowning | Vessel stability, nets hooked, lack of response by regulators | COR-632/05(8) |
| 2003 | Drowning post collision with bulk carrier | Drowning post collision with bulk carrier | ATSB 195 |
| 2001 | Drowning | Drowning post arm being caught in rope and being dragged overboard. | 4,066/01 |

TABLE 4 Contextualized fatality rates per 10,000 workers.

| Industry | Workforce | Fatalities | Fatalities per 10,000 workers in that industry |
|---|---|---|---|
| Fishing | 6,000[a] | 5.5[b] | 9.2 |
| Agriculture | 231,415[c] | 76.6[b] | 3.3 |
| Road freight transport | 142,808[d] | 34[e] | 2.4 |
| Construction | 1050,000[f] | 35[g] | 0.3 |

[a]average workforce within limits reported (3, 33).
[b]average fatalities over the period reported (31).
[c]average workforce from 2011 to 2016 calculated from (34).
[d](35).
[e](22).
[f](36).
[g]average annual fatalities 2003–2018 (23).

safety improvements could only be achieved when the extent of the problem is understood. Within the ACFI, this is not the case, and the true rate of occupational injury remains unknown. Estimating the expected number of workplace injuries in the ACFI, and how this compares to the data held by existing databases of workplace injuries held by the Australian Government remains problematic. The omission of ACFI occupational injuries from worker compensation-based data sets, combined with the lack of regulatory enforcement within the industry, results in little, if any, available data (37). This issue is not unique to Australia, with Maritime New Zealand (38) and McGuiness et al. (27) acknowledging that significant under-reporting within the industry is common across the globe. Accordingly, this suggests that the ACFI has remained relatively under-scrutinized from an academic perspective and is largely informed by industry reports and government data sets which do not appear to provide an accurate representation of the state of the industry.

The first research question can therefore only be partially answered with any certainty. Based on the available data, the average occupational fatality rate per 10,000 workers in Australian commercial fishing is calculated at 9.2, almost 4.2 times higher than the peak rate of 2.2 reported by Safe Work

Australia (23). This demonstrates the inclusion of commercial fishing in the same ANZSIC Division A coding as agriculture and forestry is misleading as it significantly dilutes the actual fatality rates within the industry. Significant discrepancy is evident between stated national occupational health and safety data sets and actual fatality rates within the ACFI. In turn, this has the potential to misdirect national safety priorities and regulatory reforms that data should be used to guide decision makers. We noted these data sets were referenced in "*They never came home—the framework surrounding the prevention, investigation and prosecution of industrial deaths in Australia*" (8) which makes recommendations regarding the strategic direction of national occupational health and safety initiatives across Australian industry.

The second research question can also be answered with limited certainty. The issues of vessel stability, lack of action by regulators, and lack of enforcement of safety regulations were recurrent, particularly in cases of multiple fatality. As with other issues within the ACFI, they appear consistent with commercial fishing internationally (26, 27). Comments of Magistrate O'Connell [39, para 2] summarize the sentiment across the multiple inquiries within the ACFI (39):

> "*the circumstances are a significant concern as 18 commercial fishermen have died at sea in the waters off Queensland in the years since 2004. Too many persons in the fishing and trawling industry have been lost over the years and despite a number of inquests recommending improved safety measures little has actually changed or been implemented despite technology being available*".

The conclusion of Judge Cavanagh [40, para 1] was particularly damning, stating (40)

> "*In my view, the evidence at this inquest has highlighted the unacceptable and indeed the shameful state of workplace safety on large numbers of Australian domestic fishing vessels. The lack of regulation and enforcement by authorities is of great concern*".

The reasons for these factors remaining unaddressed within the industry may not only be as a result of incomplete and invalid data, but also due to the unique employment arrangements within the ACFI that fail to promote worker protection. As Barnes 2006, [41, p9] articulates (41),

> "*in other dangerous industries, unions have successfully lobbied for legislation to reduce the risks to workers so that when anybody enters a mine or a building site they are required to wear steel capped boots and hard hats. In the fishing industry where many of the workers have limited education and other employment opportunities and unionism is almost non-existent, a level of risk that would not be tolerated in shore based jobs is the norm*".

The primary limitation of this study is also one of the strengths and key findings. The lack of reliable and valid data with which to make robust conclusions impeded the ability of the study to accurately compare ACFI injury rates with other occupational groups. At the same time, this finding is significant as it demonstrates that existing Australian occupational health and safety data sets do not recognize impacts of employment arrangements within the ACFI on the validity of occupational injury and fatality statistics. Future research investigating ACFI injury rates through industry-specific structure surveys and injury analysis similar to studies conducted in Norway (27) may in part provide an indication of these rates.

Three limitations of all national safety reporting in Australia identified in the course of this study are the following:

1. potentially misleading unit of fatality or injury per 100,000 workers across the Australian workforce;
2. use of ANZSIC Division coding for data analysis by Safe Work Australia which broadly classifies industry groups as opposed to ANZSIC Group coding; and
3. the lack of alignment between report narratives and the coded pattern of injury in the reports analyzed.

To improve the safety performance of the ACFI informed by a comprehensive incident and injury data set, we recommend the following:

1. develop an estimate of the contextualized rates of occupational fatality and injury, informed by an analysis of the industry incident and injury reports and reporting, and structured with the ANZSIC coding system;
2. Recognize contractors who are paid piecework as workers, and giving them the same protection in the workplace as other Australian workers, across all legal jurisdictions;
3. Engage with industry stakeholders including employers and Regulators concerning the prevention of high consequence incidents such as those involving vessel stability (e.g., regulator workplace inspections and stability checks);
4. Assess the pros and cons of reporting occupational fatality and injury rates per 10,000 workers in an industry, as opposed to diluting the rates using the 100,000 workers; and
5. Informed by the above, review the Safe Work Australia priority industries league table, and associated performance improvement initiatives.

## Conclusion

The aims of this research were to determine the contextualized rate of fatality and to identify recurring contributing factors of occupational fatality within the Australian wild catch commercial fishing industry. Through the application of a systematic literature review of peer-reviewed academia, industry reports, coronial documents, and the critical

review of industry-specific data, these aims have been achieved, albeit with limited certainty.

Using industry contextualized fatality rates, commercial fishing in Australia (excluding aquaculture) is the most dangerous Australian occupation with a contextualized average annual fatality rate of 9.2 fatalities per 10,000 workers. By comparison, the next two highest industries identified were Agriculture (3.3 fatalities per 10,000 workers) and Road Freight Transport (2.4 fatalities per 10,000 workers).

However, the true rate of contextualized injury cannot be determined due to a lack of valid and robust industry data reported *via* the States' Workers Compensation regulator to Safe Work Australia. It appears this situation is caused by the specific exclusion in the legislation of fishing crew as workers, thereby removing the fishing crew employer's obligation to report incidents and injuries.

Multiple and extensive coronial investigations have not only repeatedly acknowledged the fishing industry as a highly dangerous occupation, but also have found vessel instability, lack of action by regulators, and lack of enforcement of safety regulations were recurrent themes, particularly in cases of multiple fatality.

Further research is required to determine the true state of safety within the Australian wild catch commercial fishing industry. We recommended this research should focus on attitudes toward reporting within the ACFI; adoption of coronial recommendations; impacts of safety interventions; and vessel safety and regulatory compliance.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

GP was the lead researcher and primary contributer. WB and MC both provided a substantial contribution to the paper. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



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# Association of coal mine dust lung disease with Nodular thyroid disease in coal miners: A retrospective observational study in China

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**Background:** Coal dust is a major risk factor for the occupational health of coal miners, and underground workers with coal mine dust lung disease (Coal miners with coal mine dust lung disease (CMDLD) may have a higher risk of developing Nodular thyroid disease (NTD). The aim of this study was to investigate the relationship between coal mine dust lung disease and the development of Nodular thyroid disease in coal miners.

**Methods:** This was a clinical retrospective observational study that included 955 male coal miners from 31 different coal mining companies in Huainan, Anhui Province, China, who were examined in April 2021 at the Huainan Occupational Disease Prevention and Control Hospital to collect all their clinical physical examination data, including general conditions, laboratory test indices and imaging indices. Based on the presence or absence of Nodular thyroid disease, 429 cases with Nodular thyroid disease were classified as the diseased group and 526 cases without Nodular thyroid disease were classified as the control group. Logistic regression was used to analyse the correlation between the occurrence of Nodular thyroid disease in coal miners, and further single- and multi-factor logistic regression was used to screen the risk exposure factors for Nodular thyroid disease in coal miners.

**Results:** Age, coal mine dust lung disease (CMDLD), red blood cells (RBC), mean red blood cell volume (MCV), albumin (ALB), albumin/globulin (A/G), indirect bilirubin (IBIL), globulin (GLOB), total bilirubin (TBil) and myeloperoxidase (MPO) were associated with the development of Nodular thyroid disease in coal miners ($p < 0.05$) The results of univariate and multifactorial logistic regression analysis showed that CMDLD (OR:4.5,95%CI:2.79–7.51) had the highest OR and CMDLD was the strongest independent risk exposure factor for the development of Nodular thyroid disease in coal miners.

**Conclusions:** There is a strong correlation between coal mine dust lung disease and Nodular thyroid disease in underground coal miners, and clinicians need to be highly aware of the high risk of NTD in coal miners with CMDLD and adopt individualized clinical prevention strategies.

KEYWORDS

**coal miners, underground operating environment, coal mine dust lung disease, Nodular thyroid disease, retrospective observational study**

## Introduction

Coal is China's main energy resource and about 70% of China's electricity comes from coal-fired power plants, and there are currently >6 million (1) underground miners, which is a large occupational health population. With the world economy growing at a rapid pace, raw coal production and total coal production have increased significantly and the number of underground miners continues to grow (2). The increasing mining and use of coal has led to an increasing number of coal miners being exposed to the health hazards of coal mine dust (3), and the occupational health of coal miners is in urgent need of widespread medical attention.

The lung diseases of coal miners caused by long-term inhalation of coal mine dust are collectively known as coal mine dust lung diseases (CMDLD). CMDLD includes coal workers' pneumoconiosis (CWP), silicosis, bronchiectasis, emphysema and cancer (4, 5). CWP is a classic preventable but not fully curable occupational CMDLD (6), with >4,000 new cases of CWP diagnosed in coal miners each year, and long-term coal dust exposure is the leading cause of death from respiratory disease and complications in coal miners (7–9). Coal dust can cause respiratory diseases in coal miners, but also endocrine diseases, cardiovascular diseases and other multi-system diseases (10–12). Nodular thyroid disease is a common endocrine disorder and a large retrospective study analyzed data (13) from clinical physical examinations of 16,929 medical staff and found that the prevalence of Nodular thyroid disease in men was around 34%.

In this study, we collected clinical examination data from 955 male coal miners operating in underground environments. Four hundred and twenty nine coal miners had Nodular thyroid disease, and their prevalence was as high as 44.9%. Therefore, we hypothesize that the prevalence of Nodular thyroid disease in coal miners is higher than in other occupational groups, which may be related to the long-term exposure of coal miners to coal dust environment, and coal miners with CMDLD may be at a high risk of developing Nodular thyroid disease Coal miners with CMDLD may be at high risk of developing Nodular thyroid disease, but there are no studies on the association between CMDLD and NTD in coal miners. This study investigated the association between coal mine dust lung disease and Nodular thyroid disease in coal miners by retrospectively analyzing clinical examination data from 955 coal miners with underground operations in Huainan, Anhui Province, China, in 2021, with the aim of providing precise prevention strategies for primary prevention of Nodular thyroid disease in coal miners.

## Materials and methods

### Study population

This is a clinical retrospective observational study that collected clinical physical examination data from 955 male coal miners from 31 different coal mining companies in Huainan City, Anhui Province, China, who were examined in April 2021 at the Occupational Disease Prevention and Control Hospital in Huainan City, Anhui Province, China. Inclusion criteria: (1) Male coal miners aged ≥18 years. (2) No serious organic lesions. (3) In addition to the routine physical examination, the physical examination also included thyroid and lung examinations, and the physical examination information was complete and free of defects. Exclusion Criteria: (1) Serious cardiovascular, cerebrovascular, liver, kidney or other serious primary diseases. (2) Those with severe mental disorders or who are unable to cooperate with the medical examination for various reasons. (3) Those with a history of surgery or chemotherapy for malignant tumors. (4) Those with malignant diseases or serious systemic infections. (5) Incomplete thyroid and lung physical examination data. Finally, 955 male coal miners met the study requirements and were included in the observation. All personally identifiable information was encrypted by the researchers, no personal privacy was disclosed, and the ethical requirements of the ethical review committee of the First Affiliated Hospital of Anhui University of Technology (Huainan First People's Hospital) were met.

## Statistical analysis

The study was statistically analyzed using 4.0.3 statistical software. Quantitative data were determined to be normal using the Shapiro normality test, with normally distributed data expressed as ($\bar{x} \pm s$) and independent samples $t$-test for comparison between groups; non-normally distributed data were expressed as M ($P_{25}$, $P_{75}$) and wilcox test for comparison between groups. Qualitative data were statistically described using frequencies (%) and comparisons between groups were made using the $\chi 2$ test or Fisher's exact test. Factors influencing Nodular thyroid disease were analyzed using one-way and multi-way logistic regression analysis. Differences were considered statistically significant when bilateral $p$-values were $<0.05$.

# Diagnostic criteria

(1) Diagnosis of coal mine dust lung disease: In this study, coal mine dust lung disease refers to a range of lung diseases caused by long-term exposure to coal mine dust, including pneumonia, pneumoconiosis, silicosis, dust-related diffuse fibrosis (DDF) and chronic obstructive pulmonary disease (COPD) (14, 15). Pulmonary imaging is performed on coal miners using Siemens Somatom Definition AS 64-row 128-slice spiral CT, United Imaging UCT580 40-row 40-slice spiral CT, United Imaging UDR770 and UDR260 digital radiographs, and all imaging diagnoses of coal mine dust lung disease are made by two or more qualified imaging physicians.

(2) Diagnosis of Nodular thyroid disease: The diagnosis of Nodular thyroid disease in this study was based on clinical manifestations, laboratory tests and imaging examinations of the coal miners, and the diagnosis of Nodular thyroid disease was in accordance with the diagnostic criteria of the Chinese guidelines for the diagnosis and treatment of Nodular thyroid disease (16). Thyroid ultrasound examination of coal miners using Myriad Resona 7, Myriad DC-8 EXP, Myriad DC-80, Toshiba APLIO 500, Siemens ACUSON Oxana 2,a linear array high frequency probe is used with a probe frequency of 5∼15 MHz, where thyroid nodules were classified in accordance with the diagnostic criteria of the 2020 Chinese Guidelines for Ultrasound Risk Stratification of Thyroid Nodules for Malignancy: C-TIRADS (17). According to the C-TIRADS classification criteria, thyroid nodules were classified according to their ultrasound presentation. Thyroid nodules with solid, very hypoechoic, microcalcifications, blurred margins, irregular morphology and vertical growth or extrathyroidal invasion were defined as suspicious malignant features and assigned 1 point each, while comet tail artifacts were defined as benign features and assigned−1 point. Each thyroid nodule was assigned a value and summed, and those with−1 score were classified as category 2 with 0 risk of malignancy; those with 0 score were classified as category 3 with <2% risk of malignancy; those with 1 score were classified as category 4a with 2–9% risk of malignancy; those with 2 scores were classified as category 4b with 10–49% risk of malignancy; those with 3–4 scores were classified as category 4c with 50–90% risk of malignancy; and those with 5 scores and above were classified as category 5 with >90% risk of malignancy 90%. All nodular thyroid diseases were diagnosed by 2 ultrasonographers with the title of attending physician or higher.

# Results

## Baseline clinical characteristics of the participants

In this study, clinical physical examination data of 955 coal miners were summarized. The number of coal miners with Nodular thyroid disease was 429 and the number of coal miners without Nodular thyroid disease was 526. After statistical test analysis, Age, CMDLD, RBC, MCV, ALB, A/G, IBIL, GLOB, TBil, and MPO were statistically significant between the two groups of coal miners with Nodular thyroid disease, while the remaining variables were not statistically significant between groups ($P$-value $>$ 0.05), as shown in Table 1. We further did correlation heat map for these 10 statistically significant variables. The analysis revealed that CMDLD was an independent predictor and none of the other variables were correlated, while TBIL was definitely correlated with IBIL and A/G was correlated with ALB (Figure 1). As IBIL and A/B were more characteristic, we chose IBIL and A/B instead of TBIL and ALB in order to reduce the interference of confounding factors.

## Univariate and multifactorial logistic regression analysis of nodular thyroid disease in coal miners

Univariate and multivariate logistic regression analyses were performed using whether the patient had Nodular thyroid disease as the dependent variable (normal-0, abnormal-1) and whether they had coal mine dust lung disease as the independent variable (normal-0, abnormal-1) (Table 2). The results of the univariate analysis showed that the differences in having CMDLD, MPO, GLOB, ALB, A/G, AGE and RBC were all statistically significant ($p < 0.05$). All parameters included in the above univariate analysis were further analyzed by multi-factor logistic regression, with OR values suggesting the relative risk of developing Nodular thyroid disease in coal miners. The results showed that CMDLD (OR: 5.11, 95% CI: 3.15–8.29), MPO (OR: 1.00, 95% CI: 1.00–1.01), GLOB (OR: 1.06, 95% CI: 1.02–1.10), ALB (OR: 0.85, 95% CI: 0.80–0.90), A/G (OR. CMDLD, GLOB, and AGE were all independent risk

TABLE 1 Baseline clinical characteristics of two groups of coal miners.

| Characteristics | Non-Nodular thyroid disease ($n = 526$) | Nodular thyroid disease ($n = 429$) | Statistic | *P*-value |
|---|---|---|---|---|
| CMDLD | | | 52.472 | <0.001*** |
| 0, *n*% | 503 (95.63%) | 347 (80.89%) | | |
| 1, *n*% | 23 (4.37%) | 82 (19.11%) | | |
| Age, year, M ($P_{25}$, $P_{75}$) | 39 (33.25, 48) | 43 (36,50) | −4.479 | <0.001*** |
| LDL-C, mmol/L, M ($P_{25}$, $P_{75}$) | 2.76 (2.36, 3.2) | 2.84 (2.39, 3.36) | −1.792 | 0.073 |
| HDL-C, mmol/L, M ($P_{25}$, $P_{75}$) | 1.17 (1.03, 1.38) | 1.16 (1.02, 1.35) | 0.460 | 0.646 |
| WBC, $10^9$/L, M ($P_{25}$, $P_{75}$) | 6.51 (5.66, 7.49) | 6.5 (5.55, 7.74) | −0.500 | 0.617 |
| RBC, $10^{12}$/L, M ($P_{25}$, $P_{75}$) | 4.98 (4.76, 5.22) | 4.91 (4.7, 5.15) | 2.680 | 0.007** |
| MCV, fL, M ($P_{25}$, $P_{75}$) | 92.2 (89.93, 94.6) | 92.6 (90.5, 95.1) | −2.116 | 0.034* |
| ALB, g/L, M ($P_{25}$, $P_{75}$) | 47.39 (45.88, 48.66) | 46.62 (44.9, 48.08) | 5.080 | <0.001*** |
| A/G, M ($P_{25}$, $P_{75}$) | 1.67 (1.53, 1.8) | 1.6 (1.44, 1.73) | 4.820 | <0.001*** |
| GGT, U/L, M ($P_{25}$, $P_{75}$) | 28.7 (20.17, 43.85) | 30.95 (21.6, 48.43) | −1.830 | 0.067 |
| ALT, U/L, M ($P_{25}$, $P_{75}$) | 21.1 (14.78, 30.8) | 22.05 (15.57, 31) | −0.957 | 0.339 |
| AST/ALT, M ($P_{25}$, $P_{75}$) | 1.01 (0.79, 1.3) | 1 (0.79, 1.31) | 0.622 | 0.534 |
| IBIL, umol/L, M ($P_{25}$, $P_{75}$) | 9.5 (7.4, 12.3) | 9.85 (8.22, 12.88) | −2.181 | 0.029* |
| ALP, U/L, M ($P_{25}$, $P_{75}$) | 72.95 (60.9, 86.93) | 74.55 (64.5, 84.8) | −1.309 | 0.191 |
| GLOB, g/L, M ($P_{25}$, $P_{75}$) | 28.42 (26.5, 30.47) | 29.32 (27.07, 31.62) | −3.652 | <0.001*** |
| DBil, umol/L, M ($P_{25}$, $P_{75}$) | 3.8 (2.88, 5) | 3.9 (3.1, 5.1) | −1.480 | 0.139 |
| TBil, umol/L, M ($P_{25}$, $P_{75}$) | 13.3 (10.5, 17.1) | 13.85 (11.4, 17.7) | −2.107 | 0.035* |
| TP, g/L, M ($P_{25}$, $P_{75}$) | 75.5 (73.3, 78.2) | 75.8 (73.11, 78.49) | −0.268 | 0.789 |
| FBG, mmol/L, M ($P_{25}$, $P_{75}$) | 6 (5.67, 6.47) | 6 (5.67, 6.5) | −0.461 | 0.645 |
| BUA, μmol/L, M ($P_{25}$, $P_{75}$) | 330.05 (277.15, 380.7) | 328.8 (282, 379.15) | −0.404 | 0.686 |
| CYFRA21-1, ng/ml, M ($P_{25}$, $P_{75}$) | 2.21 (1.96, 2.52) | 2.22 (2, 2.51) | −1.155 | 0.248 |
| MPO, U/ml, M ($P_{25}$, $P_{75}$) | 68.18 (53.83, 89.52) | 74.63 (60.8, 98.25) | −3.829 | <0.001*** |
| Lp-PLA2, M ($P_{25}$, $P_{75}$) | 336.15 (252.28, 432.65) | 323.18 (241.2, 405.54) | 1.649 | 0.099 |

HDL-C, High-density lipoprotein cholesterol; LDL-C, Low-density lipoprotein cholesterol; ALB, Serum albumin; GLOB, globulin; IBIL, Indirect bilirubin; Lp-PLA2, Lipoprotein-associated phospholipase; A2,MPO, Myeloperoxidase; CYFRA21-1, Cytokeratin 19 fragment; MCV, Mean red blood cell volume; RBC, Red blood cells; WBC, Leukocytes; TBil, Total bilirubin; A/G, Albumin/globulin; GGT, Glutamyl transpeptidase; ALT, Glutathione aminotransferase; AST/ALT, Glutathione/glutathione transaminase; ALP, Alkaline phosphatase; DBil, Direct bilirubin; TP, Total protein; FBG, Plasma fibrinogen; BUA, Blood uric acid. (*P < 0.05, **P < 0.01, ***P < 0.001).

factors for the development of Nodular thyroid disease in coal miners. In addition, the OR for CMDLD was the highest of all independent risk factors (Figure 2). Therefore, having CMDLD is the strongest independent risk exposure factor for Nodular thyroid disease in coal miners ($p < 0.0001$) and clinicians should focus on the risk of Nodular thyroid disease in coal miners with CMDLD.

## Discussion

Coal dust is the most significant risk factor for occupational health risks to coal miners (18). McBean et al. (14) suggested that the majority of coal mine dust lung diseases are associated with coal dust exposure. Not only that, but several researchers (7, 19) have found that coal dust is not only a risk factor for coal miners to develop coal mine dust lung disease, but also a high risk factor for coal miners to develop Nodular thyroid disease. Coal miners exposed to chronic coal dust are at high risk of Nodular thyroid disease, however, the association between coal mine dust lung disease (CMDLD) and Nodular thyroid disease in coal miners is currently unclear, and investigating the risk factors for Nodular thyroid disease in coal miners is of great significance for the primary prevention of Nodular thyroid disease in coal miners. In this study, a retrospective observational study based on clinical examination data of 955 male coal miners from 31 different coal mining companies in Huainan, Anhui Province, China, found that CMDLD was the strongest risk factor for the development of Nodular thyroid disease in coal miners and that clinicians should pay more attention to the development of Nodular thyroid disease in coal miners with CMDLD and take early and effective preventive strategies.

Nodular thyroid disease is one of the most common non-communicable diseases in developing countries (20). Because thyroid disorders rarely lead to serious life-threatening conditions, they are often overlooked (21), leading to their progression to malignant levels. In recent years, Nodular thyroid

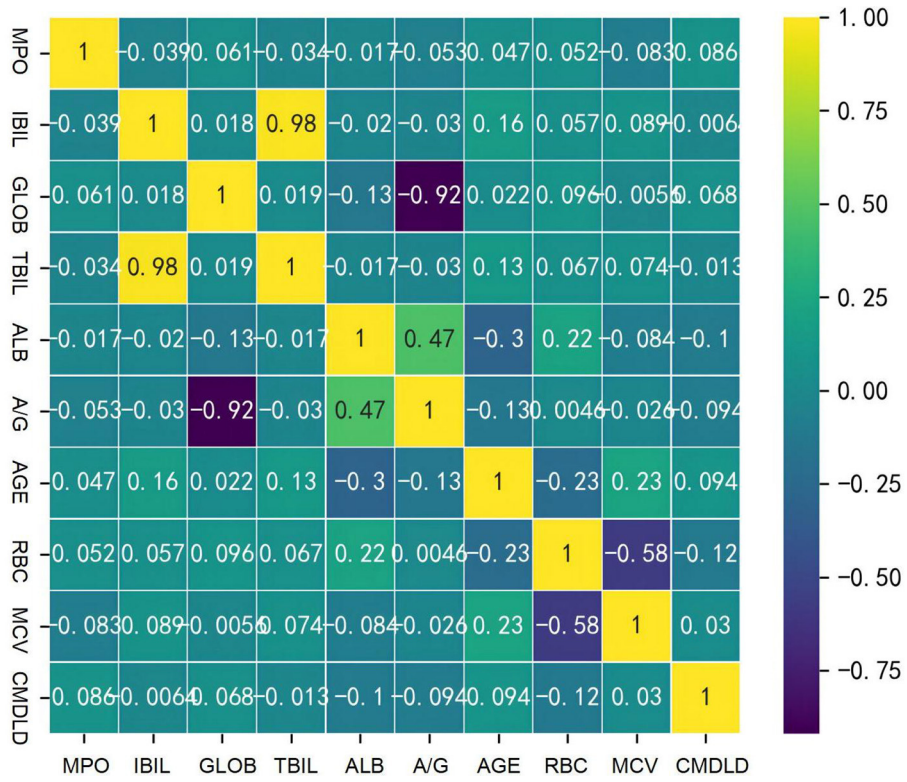


FIGURE 1
Heat maps of correlation of clinical features in coal miners.

TABLE 2 Univariate and multifactorial logistic regression analysis of the occurrence of thyroid disease in coal miners.

| Variables | *N* | Univariate analysis | | Multivariate analysis | |
|---|---|---|---|---|---|
| | | OR (95%CI) | *P*-value | OR (95%CI) | *P*-value |
| CMDLD | 955 | / | / | / | / |
| 0 | 850 | / | / | / | / |
| 1 | 105 | 5.17 (3.19∼8.37) | $P < 0.0001$*** | 5.11 (3.15∼8.29) | $P < 0.0001$*** |
| MPO | 955.0 | 1.00 (1.00∼1.01) | 0.01* | 1.00 (1.00∼1.01) | 0.01* |
| IBIL | 955.0 | 1.02 (0.99∼1.05) | 0.11 | 1.02 (0.99∼1.05) | 0.12 |
| GLOB | 955.0 | 1.06 (1.03∼1.11) | $P < 0.0001$*** | 1.06 (1.02∼1.10) | $P < 0.0001$*** |
| TBIL | 955.0 | 1.02 (1.00∼1.04) | 0.13 | 1.02 (1.00∼1.04) | 0.11 |
| ALB | 955.0 | 0.86 (0.81∼0.91) | $P < 0.0001$*** | 0.85 (0.80∼0.90) | $P < 0.0001$*** |
| A/G | 955.0 | 0.24 (0.13∼0.43) | $P < 0.0001$*** | 0.26 (0.14∼0.47) | $P < 0.0001$*** |
| Age | 955.0 | 1.03 (1.02∼1.05) | $P < 0.0001$*** | 1.03 (1.02∼1.05) | $P < 0.0001$*** |
| RBC | 955.0 | 0.65 (0.46∼0.93) | 0.02* | 0.61 (0.42∼0.87) | 0.01* |
| MCV | 955.0 | 1.03 (1.00∼1.06) | 0.05 | 1.03 (1.00∼1.06) | 0.06 |

*$P < 0.05$, ***$P < 0.001$. All indicate significant differences compared between groups.

disease has been on the rise, with the overall prevalence of Nodular thyroid disease among adults over 18 years of age in China reaching 50%, according to the latest survey data from 2020 (22, 23). Statistical analysis of the data in this study found that 955 male coal miners had a 44.9% chance of developing Nodular thyroid disease, and that the prevalence of Nodular thyroid disease among male coal miners working underground was significantly close to the overall prevalence.

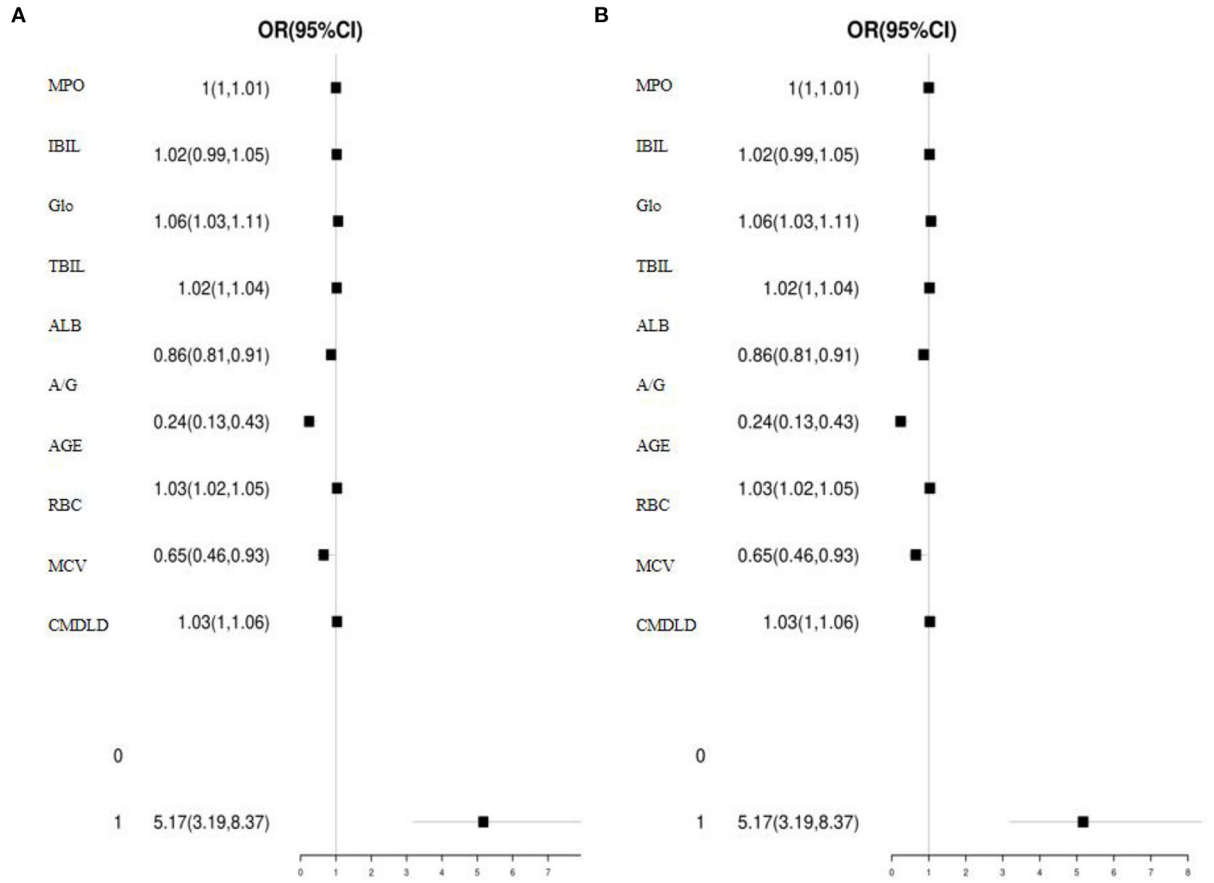


FIGURE 2
**(A,B)** Univariate and multifactorial analysis of forest plots for the occurrence of nodular thyroid disease in coal miners.

In a previous study, Koeger et al. (24) found that middle-aged male coal miners with occupational exposure to coal dust silica developed not only silicosis but also Graves' disease, an autoimmune disorder. This study was limited by the small sample size and therefore only identified Graves' disease as a cause of Nodular thyroid disease due to coal dust exposure and did not investigate the association between Graves' disease and silicosis. This study collected clinical examination data from 955 male coal miners from 31 different coal mining companies in Huainan, Anhui Province, China. The large sample size and the wide range of data sources in this study have reduced the bias of the study due to insufficient sample size. In addition, the 70 clinical physical examination variables collected in this study (including general information, laboratory test indicators, and imaging test indicators) were analyzed by univariate and multifactorial logistic regression, and after multifactorial analysis, CMDLD (OR = 5.21, $p < 0.0001$), GLOB (OR = 1.06, $p < 0.0001$), Age (OR = 1.03, $p < 0.0001$) were found to be 0.0001 as independent risk factors for the development of Nodular thyroid disease in coal miners, with CMDLD having the highest OR, much greater than the other two variables, indicating that CMDLD is the highest risk exposure factor for the development of Nodular thyroid disease in coal miners, and is statistically significant. Therefore, focusing on screening for Nodular thyroid disease in coal miners with CMDLD and adopting targeted prevention strategies are important measures to effectively reduce the occurrence of Nodular thyroid disease in coal miners.

There is a lack of research on the mechanism of the relationship between CMDLD and the development of Nodular thyroid disease in coal miners. This study suggests that there may be two main associations. Firstly, when exposed to coal dust for long periods of time, the body adjusts cortisol, thyroid hormone and insulin levels for protective adaptive regulation, and when endocrine gland function reserves are depleted and the body's ability to adapt decreases, coal miners are prone to develop pneumoconiosis (25) and consequently Nodular thyroid disease with abnormal thyroid hormones.

Tsukatani et al. (26) found that silicosis caused calcification of paratracheal and upper mediastinal lymph nodes in patients with papillary thyroid carcinoma (PTC), and later surgical pathology demonstrated the presence of both silica nodules and microtransformations of PTC in the paratracheal lymph nodes of patients with PTC; therefore, the silica component of coal dust may be a causative factor between CMDLD and Nodular thyroid disease. Second, an immunological and neurological analysis of the pathogenesis of CMDLD may better explain the existence of a relationship between CMDLD and Nodular thyroid disease in coal miners. The direct toxic effects of silica and monosilicic acid in coal dust on the lungs may be accompanied by an attack on other organs of the organism (27). At the same time, secondary hypoxia due to dust-silica lung may result in inadequate stimulation and excretion of certain hormones, leading to dysfunction of the hypothalamic-pituitary-thyroid axis, which in turn leads to the development of thyroid disorders.

However, there are some limitations that need to be taken into account when interpreting the results of this study. First, the data we collected on physical examinations of coal miners were missing data on coal miners' history of alcohol consumption, smoking, family history of Nodular thyroid disease, body mass index, years of underground work, number of shifts per month and some thyroid hormone blood biochemical indicators, variables that may be associated with the occurrence of Nodular thyroid disease in coal miners. Secondly, due to the fixed nature of the medical examination package, we were unable to obtain further pathological follow-up of the association between Nodular thyroid disease and coal mine dust lung disease, which prevented an in-depth investigation into the pathogenesis of CMDLD and NTD. In the future, we will conduct experimental studies to further investigate the mechanisms by which coal dust causes Nodular thyroid disease and CMDLD in animals. Thirdly, the population in this study was exclusively from Huainan, Anhui Province, China, and no data from other coal miners of different geographical or ethnic origin were included, which may have biased the results of the study. In the next step, we will expand the sample size collection to include data from coal miners from different regions, countries and ethnicities in China, so that this study can have a wider clinical utility.

This study found a high correlation between coal mine dust lung disease and the development of Nodular thyroid disease in coal mine workers, and that coal mine dust lung disease is a high risk factor for the development of Nodular thyroid disease in coal mine workers. With the exception of thyroiditis, any benign change in Nodular thyroid disease is associated with an increased risk of thyroid cancer (28). Nodular thyroid disease has a serious impact on the occupational health of coal miners. The disease can place additional physical, mental and financial burdens on coal miners and their families, and may even shorten life expectancy, and requires the joint attention of government departments and the medical community.

## Conclusion

Mine miners who are chronically exposed to working in a coal dust environment are at high risk of developing nodular thyroid disease. It is worth noting that Age, CMDLD, RBC, MCV, ALB, A/G, IBIL, GLOB, TBil, and MPO are influential factors for the development of nodular thyroid nodular disease in coal miners, with CMDLD being the strongest risk exposure factor for nodular thyroid disease in coal miners. Therefore, clinicians should be highly concerned about the high risk of nodular thyroid in coal miners with CMDLD and take early and individualized preventive and therapeutic measures, which are of great clinical value to improve the occupational health and safety of coal miners with thyroid.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients was not required to participate in this study in accordance with the national legislation and the institutional requirements.

## Author contributions

FZ and HZ contributed to the writing of the manuscript, design of the study, and statistical analysis. DR and C-mL contributed to the conception and design of this study. YG, YW, DL, and ZZ contributed to data retrieval and manuscript review. QL, XS, and LY contributed to data collection and data collation. All authors made significant contributions to the research process of this manuscript, read, and approved the submitted manuscript.

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Medical staff from the Huaihe Energy Occupational Disease Prevention and Control Institute, China, participated in the data collection.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



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# Global disease burden and trends of leukemia attributable to occupational risk from 1990 to 2019: An observational trend study

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**Background:** Leukemia caused by occupational risk is a problem that needs more attention and remains to be solved urgently, especially for acute lymphoid leukemia (ALL), acute myeloid leukemia (AML), and chronic lymphoid leukemia (CLL). However, there is a paucity of literature on this issue. We aimed to assess the global burden and trends of leukemia attributable to occupational risk from 1990 to 2019.

**Methods:** This observational trend study was based on the Global Burden of Disease (GBD) 2019 database, the global deaths, and disability-adjusted life years (DALYs), which were calculated to quantify the changing trend of leukemia attributable to occupational risk, were analyzed by age, year, geographical location, and socio-demographic index (SDI), and the corresponding estimated annual percentage change (EAPC) values were calculated.

**Results:** Global age-standardized DALYs and death rates of leukemia attributable to occupational risk presented significantly decline trends with EAPC [−0.38% (95% CI: −0.58 to −0.18%) for DALYs and −0.30% (95% CI: −0.45 to −0.146%) for death]. However, it was significantly increased in people aged 65–69 years [0.42% (95% CI: 0.30–0.55%) for DALYs and 0.38% (95% CI: 0.26–0.51%) for death]. At the same time, the age-standardized DALYs and death rates of ALL, AML, and CLL were presented a significantly increased trend with EAPCs [0.78% (95% CI: 0.65–0.91%), 0.87% (95% CI: 0.81–0.93%), and 0.66% (95% CI: 0.51–0.81%) for DALYs, respectively, and 0.75% (95% CI: 0.68–0.82%), 0.96% (95% CI: 0.91–1.01%), and 0.55% (95% CI: 0.43–0.68%) for death], respectively. The ALL, AML, and CLL were shown an upward trend in almost all age groups.

**Conclusion:** We observed a substantial reduction in leukemia due to occupational risks between 1990 and 2019. However, the people aged 65–69 years and burdens of ALL, AML, and CLL had a significantly increased trend in almost all age groups. Thus, there remains an urgent need to accelerate efforts to reduce leukemia attributable to occupational risk-related death burden in this population and specific causes.

KEYWORDS

**leukemia, AML, ALL, global burden disease, death rate**

# Introduction

Cancer has the highest mortality rate among all human diseases (1). The World Health Organization (WHO) classifies tumors based on evidence that tumors occur in various organ systems. It is the global standard for diagnosis, research, cancer registration, and public health monitoring (2). Some kinds of cancer grow rapidly, while others grow slowly. Most kinds of leukemia progress quickly. Hematological tumors can be divided into three different categories, namely, leukemia, lymphoma, and myeloma (3). Among them, leukemia can be further divided into acute myeloid leukemia (AML), acute lymphoid leukemia (ALL), chronic lymphoid leukemia (CLL), chronic myeloid leukemia (CML), and other leukemia (4). In this study, we found that AML and ALL had higher DALY rates and death rates compared with other kinds.

Acute myeloid leukemia is the most common in elderly patients, but the incidence rate in young people is also increasing every year (5), with an incidence of over 20,000 cases per year in the United States alone (6). It has been estimated that ∼21,450 adults (11,650 men and 9,800 women) will be diagnosed with AML in 2019 (7). Of all subtypes of leukemia, AML has the highest mortality rate (62%) (7). The excessive accumulation of immature hematopoietic cells in blood and bone marrow, gene mutations, genetics, and other factors will lead to the occurrence of tumors (8). ALL is the most common subtype of childhood leukemia. ALL have a high mortality rate due to excessive accumulation of immature lymphocytes in the peripheral blood and bone marrow (9, 10).

Occupational exposure has been related to higher risks of several kinds of cancer (11, 12). It has brought tremendous health and economic burden for people all over the world (13). However, insufficient attention has been paid to the detection, diagnosis, and monitoring of occupational exposure and its associated diseases, especially leukemia. It is well-accepted that occupational exposure to formaldehyde and benzene causes leukemia (14, 15). The researchers compared occupational exposure to formaldehyde with the risk of leukemia in community-based case-control studies. The proportion of leukemia in occupationally exposed cohorts will increase significantly (16). In 2009, the International Agency for Research on Cancer (IARC) regarded formaldehyde as a risk factor for leukemia (17, 18). Researchers often focus on the relationship between formaldehyde and general lymphohematopoietic cancer or leukemia, but the issue of occupational exposure has not attracted their attention (16, 19, 20).

The Global Burden of Disease (GBD) study was originally authorized by the World Bank and added to the landmark World Development Report 1993 (21). Since 1990, GBD has made the most comprehensive efforts to systematically monitor and master the world's health problems (22). We used the GBD database to analyze leukemia attributable to occupational risk incidences and deaths in the general population by sex, social development index (SDI), and reason for the 1990–2019 period at regional and global levels. We aimed to provide valuable insights into data-based healthcare regimens and provide a better understanding of the global burden of leukemia attributable to occupational risk as an important complement to previous GBD studies.

# Methods

## Data sources

Data on the burden of leukemia attributable to occupational risk were downloaded from the Global Health Data Exchange GBD Results Tool (http://ghdx.healthdata.org/gbd-results-tool), including death rates and disability-adjusted life years (DALYs). GBD values were reported as estimated values with 95% uncertainty intervals (UIs), and a posterior distribution was used to calculate the 25th and 975th ranked estimates from random 1,000 draws (23). Information such as the socio-demographic index (SDI) and corresponding age-standardized rates was also downloaded from this website for the following correlation analysis. Based on the SDI, 204 countries and territories were divided into five super regions, namely, low, low-middle, middle, middle, and high SDI (24, 25). According to GBD 2019, SDI is an indicator of a country's level of health

TABLE 1 The number and age-standardized rate of DALYs and death of leukemia attributable to occupational risk in 1990 and 2019.

| | DALYS (95% UI) | | | | | Deaths (95% UI) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | | 2019 | | EAPC (95% CI) | 1990 | | 2019 | | EAPC (95% CI) |
| | Number | Age-Standardized rate | Number | Age-Standardized rate | | Number | Age-Standardized rate | Number | Age-Standardized rate | |
| Global | 80,359 (39,266–118,130) | 1.5609 (0.7676–2.2942) | 113,715 (54,505–167,831) | 1.3986 (0.669–2.0648) | −0.38% (95% CI: −0.58 to −0.18%)* | 1,612 (792–2,369) | 0.0326 (0.0161–0.0481) | 2,455 (1,181–3,645) | 0.0299 (0.0144–0.0445) | −0.3% (95% CI: −0.45 to −0.14%)* |
| **Gender** | | | | | | | | | | |
| Male | 46,410 (22,691–68,190) | 1.7925 (0.8719–2.6295) | 66,189 (32,299–98550) | 1.6267 (0.7944–2.4214) | −0.33% (−0.41 to −0.24%)* | 932 (460–1,370) | 0.0378 (0.0186–0.0557) | 1,425 (699–2,131) | 0.035 (0.0172–0.0524) | −0.33% (−0.53 to −0.14%)* |
| Female | 33,949 (17,064–51,519) | 1.3279 (0.6663–2.011) | 47,526 (21,915–71,940) | 1.1703 (0.5417–1.7683) | −0.44% (−0.69 to −3.33%)* | 680 (340–1,032) | 0.0275 (0.0137–0.0416) | 1,030 (478–1,563) | 0.025 (0.0116–0.0379) | −0.27% (−0.30 to −0.23%)* |
| **Age group** | | | | | | | | | | |
| 15–49 year | 69,226 (34,198–101,973) | 2.5524 (1.2609–3.7598) | 90,522 (42,924–133,843) | 2.3,004 (1.0908–3.4013) | −0.36% (−0.58 to −0.13%)* | 1,229 (607–1,808) | 0.0453 (0.0224–0.0667) | 1,635 (783–2,420) | 0.0416 (0.0199–0.0615) | −0.3% (−0.51 to −0.09%)* |
| 50–69 year | 9,616 (4,607–14,350) | 1.4097 (0.6754–2.1037) | 18,828 (8,926–28,358) | 1.3654 (0.6473–2.0565) | −0.11% (−0.16 to −0.06%)* | 302 (144–451) | 0.0442 (0.0211–0.0661) | 589 (280–887) | 0.0427 (0.0203–0.0643) | −0.11% (−0.19 to −0.04%)* |
| 70+ year | 1,517 (608–2,360) | 0.7528 (0.3015–1.1712) | 4,365 (1,892–6,819) | 0.9413 (0.408–1.4706) | 0.79% (0.69–0.88%)* | 81 (33–126) | 0.0402 (0.0162–0.0624) | 230 (101–358) | 0.0497 (0.0218–0.0773) | 0.74% (0.64–0.84%)* |
| **SDI region** | | | | | | | | | | |
| High SDI | 12,245 (3,626–20,127) | 1.3381 (0.3967–2.1986) | 13,025 (4,307–21,114) | 1.0821 (0.3572–1.7444) | −0.71% (−0.82 to −0.61%)* | 282 (83–463) | 0.03 (0.0088–0.0493) | 343 (108–558) | 0.0251 (0.0082–0.0408) | −0.6% (−0.64 to −0.55%)* |
| High-Middle SDI | 21,953 (11,034–32,036) | 1.8066 (0.9141–2.6395) | 25,292 (12,559–37,288) | 1.5348 (0.7621–2.2598) | −0.55% (−0.81 to −0.28%)* | 442 (223–646) | 0.037 (0.0187–0.0541) | 552 (272–817) | 0.0318 (0.0158–0.0473) | −0.51% (−0.74 to −0.28%)* |
| Middle SDI | 30,894 (14,963–45,905) | 1.8519 (0.8966–2.7548) | 44,229 (20,790–65,558) | 1.6778 (0.7894–2.4881) | −0.34% (−0.59 to −0.09%)* | 590 (286–876) | 0.0375 (0.0182–0.0557) | 925 (435–1383) | 0.0348 (0.0164–0.052) | −0.22% (−0.4 to −0.03%)* |
| Low-Middle SDI | 11,144 (5,399–16,808) | 1.1395 (0.5449–1.7147) | 20,970 (9,883–31,866) | 1.1817 (0.5556–1.7971) | 0.13% (−0.05–0.31%) | 216 (103–325) | 0.0235 (0.0113–0.0353) | 432 (202–659) | 0.0252 (0.0119–0.0385) | 0.24% (0.09–0.38%)* |
| Low SDI | 4,081 (1,876–6,554) | 1.019 (0.4688–1.6285) | 10,119 (4,754–15,494) | 1.1048 (0.5093–1.6935) | 0.28% (0.2–0.37%)* | 81 (37–130) | 0.0219 (0.0102–0.0351) | 201 (93–309) | 0.0241 (0.011–0.0372) | 0.33% (0.24–0.42%)* |

*(Continued)*





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TABLE 1 (Continued)

| | DALYS (95% UI) | | | | | Deaths (95% UI) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | | 2019 | | EAPC (95% CI) | 1990 | | 2019 | | EAPC (95% CI) |
| | Number | Age-Standardized rate | Number | Age-Standardized rate | | Number | Age-Standardized rate | Number | Age-Standardized rate | |
| **Type of cause** | | | | | | | | | | |
| Acute lymphoid leukemia | 12,017 | 0.223 | 22,397 | 0.2788 | 0.78% | 218 | 0.0042 | 419 | 0.0052 | 0.75% |
| | (5,800–18,336) | (0.1069–0.34) | (10,592–33,563) | (0.1318–0.418) | (0.65–0.91%)* | (105–334) | (0.002–0.0064) | (198–633) | (0.0025–0.0078) | (0.68–0.82%)* |
| Acute myeloid leukemia | 15,418 | 0.3035 | 31,670 | 0.3891 | 0.87% | 321 | 0.0066 | 712 | 0.0087 | 0.96% |
| | (7,407–23,786) | (0.1446–0.468) | (15,108–47,562) | (0.185–0.5846) | (0.81–0.93%)* | (152–498) | (0.0031–0.0103) | (346–1080) | (0.0042–0.0131) | (0.91–1.01%)* |
| Chronic lymphoid leukemia | 2,637 | 0.0572 | 5,710 | 0.0687 | 0.66% | 70 | 0.0016 | 155 | 0.0019 | 0.55% |
| | (1,247–4,046) | (0.0269–0.0877) | (2,703–8,702) | (0.0324–0.1047) | (0.51–0.81%)* | (32–108) | (0.0007–0.0025) | (74–237) | (0.0009–0.0028) | (0.43–0.68%)* |
| Chronic myeloid leukemia | 10,354 | 0.2065 | 13,455 | 0.1652 | −0.74% | 216 | 0.0045 | 285 | 0.0035 | −0.86% |
| | (4,989–15,725) | (0.0996–0.3129) | (6,353–20,693) | (0.078–0.2542) | (−0.89 to −0.6%)* | (105–327) | (0.0022–0.0068) | (132–438) | (0.0016–0.0053) | (−1.03 to −0.69%)* |
| Other leukemia | 39,933 | 0.7709 | 40,483 | 0.4969 | −1.51% | 787 | 0.0158 | 884 | 0.0108 | −1.33% |
| | (19,388–60,206) | (0.3764–1.1628) | (19,388–59,947) | (0.2374–0.736) | (−1.7 to −1.32%)* | (380–1182) | (0.0076–0.0236) | (425–1316) | (0.0052–0.016) | (−1.48 to −1.19%)* |
| **Southeast Asia, east Asia, and Oceania** | | | | | | | | | | |
| Southeast Asia | 8,013 | 1.8404 | 14,872 | 2.0371 | 0.36% | 153 | 0.0377 | 310 | 0.043 | 0.47% |
| | (3,908–12,237) | (0.8829–2.8079) | (6,972–22,458) | (0.9542–3.0779) | (0.14–0.58%)* | (74–233) | (0.0183–0.0573) | (146–470) | (0.0202–0.0652) | (0.31–0.63%)* |
| East Asia | 28,451 | 2.1654 | 29,187 | 1.7044 | −0.83% | 543 | 0.0432 | 616 | 0.034 | −0.84% |
| | (14,364–42,465) | (1.0907–3.2396) | (14,636–44,374) | (0.8521–2.5867) | (−1.33 to −0.34%)* | (271–809) | (0.0218–0.0644) | (312–934) | (0.017–0.0514) | (−1.23 to −0.44%)* |
| Oceania | 84 | 1.4493 | 206 | 1.6147 | 0.39% | 2 | 0.0292 | 4 | 0.033 | 0.43% |
| | (38–136) | (0.6591–2.3427) | (86–365) | (0.672–2.8499) | (0.31–0.47%)* | (1–3) | (0.0131–0.0473) | (2–7) | (0.0137–0.0575) | (0.36–0.51%)* |
| **Sub-Saharan Africa** | | | | | | | | | | |
| Western Sub-Saharan Africa | 1,301 | 0.8805 | 3,323 | 0.9098 | 0.11% | 26 | 0.0187 | 65 | 0.0195 | 0.14% |
| | (630–1,983) | (0.4208–1.3465) | (1,452–5,392) | (0.3995–1.4641) | (−0.01–0.24%) | (12–39) | (0.0089–0.0287) | (28–104) | (0.0085–0.031) | (0–0.27%)* |
| Central Sub-Saharan Africa | 456 | 1.0641 | 1,122 | 1.0326 | −0.09% | 9 | 0.0223 | 21 | 0.0216 | −0.1% |
| | (213–725) | (0.5–1.7038) | (520–1,850) | (0.4854–1.7219) | (−0.31–0.13%) | (4–14) | (0.0104–0.0353) | (10–36) | (0.01–0.0358) | (−0.31–0.11%) |
| Southern Sub-Saharan Africa | 693 | 1.5077 | 698 | 0.8289 | −2.14% | 13 | 0.0309 | 13 | 0.0165 | −2.11% |
| | (316–1,063) | (0.6848–2.3022) | (304–1,109) | (0.3623–1.2965) | (−2.61 to −1.67%)* | (6–20) | (0.0143–0.047) | (6–21) | (0.0072–0.0256) | (−2.6 to −1.63%)* |
| Eastern Sub-Saharan Africa | 1,892 | 1.3829 | 4,615 | 1.4389 | 0.14% | 37 | 0.03 | 92 | 0.0323 | 0.26% |
| | (836–3,251) | (0.6181–2.3596) | (2,009–7,528) | (0.621–2.3458) | (0–0.27%)* | (17–64) | (0.0137–0.0508) | (40–150) | (0.0139–0.0531) | (0.11–0.41%)* |

*(Continued)*





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TABLE 1 (Continued)

| | DALYS (95% UI) | | | | | Deaths (95% UI) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | | 2019 | | EAPC (95% CI) | 1990 | | 2019 | | EAPC (95% CI) |
| | Number | Age-Standardized rate | Number | Age-Standardized rate | | Number | Age-Standardized rate | Number | Age-Standardized rate | |
| South Asia | 7,959 (3,829–11,931) | 0.8339 (0.4039–1.2503) | 16,167 (7,637–25,073) | 0.8775 (0.415–1.3532) | 0.17% (−0.11–0.45%) | 158 (76–237) | 0.0176 (0.0085–0.0266) | 337 (157–518) | 0.019 (0.0089–0.0292) | 0.25% (−0.01–0.51%) |
| **Latin America and Caribbean** | | | | | | | | | | |
| Tropical Latin America | 2,759 (1,283–4,032) | 1.9048 (0.8934–2.7924) | 4,344 (1,981–6544) | 1.76 (0.8031–2.6522) | −0.26% (−0.39 to −0.13%)* | 54 (25–79) | 0.0397 (0.0187–0.0583) | 94 (42–142) | 0.0378 (0.0171–0.0572) | −0.15% (−0.27 to −0.03%)* |
| Caribbean | 548 (262–816) | 1.616 (0.767–2.4065) | 990 (449–1,511) | 2.0017 (0.907–3.0462) | 0.76% (0.61–0.91%)* | 11 (5–16) | 0.0342 (0.0164–0.051) | 22 (10–33) | 0.0431 (0.0196–0.0657) | 0.82% (0.68–0.96%)* |
| Andean Latin America | 863 (405–1,355) | 2.5525 (1.1909–3.9913) | 2,123 (939–3,345) | 3.2553 (1.4393–5.1235) | 0.81% (0.11–1.51%)* | 17 (8–26) | 0.0528 (0.0248–0.0825) | 43 (19–69) | 0.0683 (0.0307–0.1079) | 0.86% (0.19–1.54%)* |
| Central Latin America | 3,386 (1,654–4,978) | 2.2682 (1.1108–3.3323) | 7,057 (3,264–10,531) | 2.6878 (1.2418–4.0114) | 0.61% (0.33–0.89%)* | 63 (31–93) | 0.0457 (0.0225–0.0672) | 142 (66–214) | 0.0548 (0.0255–0.0825) | 0.64% (0.38–0.89%)* |
| North Africa and Middle East | 4,688 (2,220–7,329) | 1.6619 (0.7832–2.5851) | 10,081 (4,560–15,281) | 1.5789 (0.71–2.3953) | −0.17% (−0.27 to −0.07%)* | 94 (44–145) | 0.0359 (0.0169–0.0555) | 210 (94–318) | 0.0346 (0.0154–0.0525) | −0.13% (−0.21 to −0.04%)* |
| **Central Europe, eastern Europe, and central Asia** | | | | | | | | | | |
| Central Europe | 1,275 (374–2,116) | 0.9737 (0.2878–1.6158) | 1,252 (332–2,154) | 0.9031 (0.2423–1.5514) | −0.27% (−0.44 to −0.11%)* | 29 (8–48) | 0.0213 (0.0062–0.0353) | 33 (9–58) | 0.0211 (0.0056–0.0365) | −0.04% (−0.19–0.12%) |
| Central Asia | 1,443 (653–2,159) | 2.1779 (0.9832–3.2557) | 1,936 (834–2,968) | 1.9269 (0.8316–2.958) | −0.41% (−0.65 to −0.17%)* | 27 (12–41) | 0.0432 (0.0195–0.0646) | 38 (16–59) | 0.0388 (0.0168–0.0597) | −0.35% (−0.61 to −0.09%)* |
| Eastern Europe | 3,077 (830–5,227) | 1.257 (0.3367–2.1329) | 2,297 (593–3,982) | 0.965 (0.2501–1.6661) | −0.83% (−1.54 to −0.12%)* | 66 (18–113) | 0.0263 (0.007–0.0447) | 53 (13–93) | 0.0205 (0.0053–0.0359) | −0.77% (−1.24 to −0.29%)* |
| **High-income regions** | | | | | | | | | | |
| High-Income North America | 4,526 (1,240–7,650) | 1.4366 (0.3921–2.4279) | 4,584 (1,182–7,868) | 1.0589 (0.2726–1.8226) | −1.03% (−1.29 to −0.76%)* | 108 (29–182) | 0.0336 (0.0091–0.0566) | 127 (33–219) | 0.0261 (0.0067–0.0448) | −0.83% (−0.95 to −0.7%)* |
| High-Income Asia Pacific | 2,576 (742–4,313) | 1.3413 (0.3881–2.2398) | 1,868 (509–3,158) | 0.8374 (0.2295–1.4079) | −1.65% (−1.88 to −1.42%)* | 56 (16–94) | 0.0284 (0.0081–0.0476) | 50 (13–85) | 0.0186 (0.005–0.0315) | −1.45% (−1.63 to −1.28%)* |
| Australasia | 220 (63–370) | 0.9914 (0.2819–1.6638) | 301 (78–513) | 0.8674 (0.2243–1.4794) | −0.43% (−0.6 to −0.26%)* | 5 (1–9) | 0.0232 (0.0066–0.0392) | 8 (2–14) | 0.0215 (0.0056–0.0369) | −0.24% (−0.4 to −0.07%)* |
| Western Europe | 4,925 (1,365–8,254) | 1.1406 (0.3169–1.9094) | 4,950 (1,282–8,350) | 0.9437 (0.2439–1.5911) | −0.68% (−0.85 to −0.51%)* | 116 (32–196) | 0.0254 (0.007–0.0427) | 136 (35–232) | 0.022 (0.0056–0.0375) | −0.52% (−0.64 to −0.4%)* |
| Southern Latin America | 1,225 (587–1,797) | 2.5276 (1.2148–3.7119) | 1,743 (787–2,590) | 2.4186 (1.0947–3.5928) | −0.17% (−0.29 to −0.06%)* | 26 (13–38) | 0.0541 (0.0261–0.0795) | 39 (18–58) | 0.0526 (0.0236–0.0783) | −0.12% (−0.22 to −0.01%)* |

The asterisks represent statistically significant.





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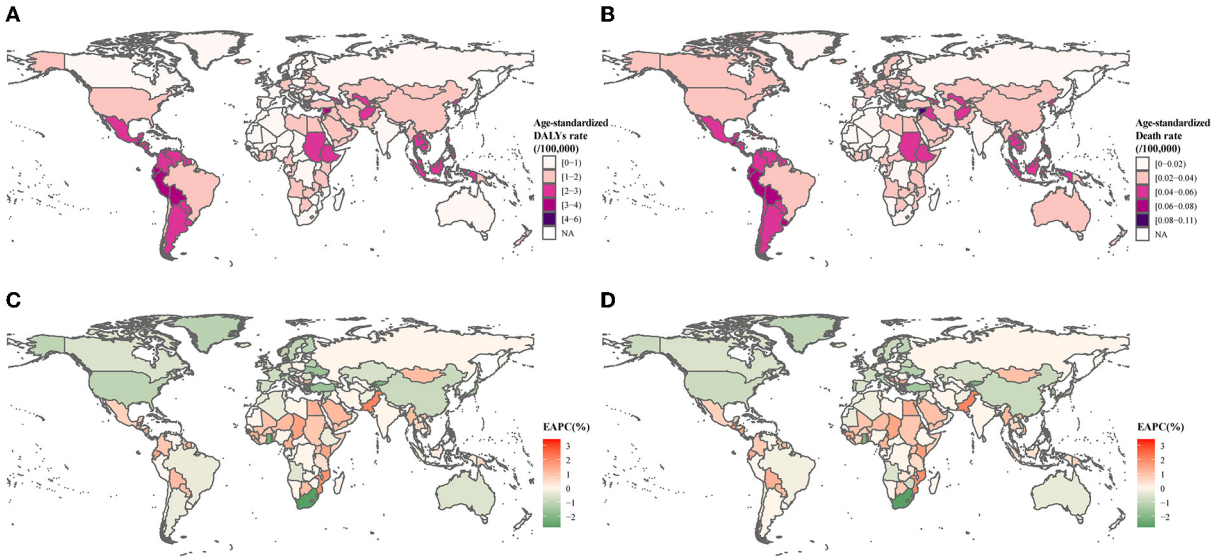


FIGURE 1
Age-standardized DALY and death rates in 2019 for leukemia attributable to occupational risk. **(A)** Age-standardized disability-adjusted life years rate. **(B)** Age-standardized death rates. **(C)** Estimated annual percent change of disability-adjusted life years rate. **(D)** Estimated annual percent change of death rates.

development, based on fertility rates for women under 25 and total fertility rates for men, education attainment among those 15 years of age and older, and 10-year lag-distributed average individual incomes (26).

The SDI values range between 0 and 1, which reflect the degree of social development. Our research is compliant with the Guidelines for Accurate and Transparent Health Estimates Reporting.

## Definitions

The occupational risk was defined as patients' long-term exposure to carcinogenic factors in the working environment. These kinds of occupational carcinogenic factors include chemical, physical, and biological (27). The DALYs by age, sex, year, and region were collected from GBD 2019. The DALYs is a summary measure that quantifies the overall burden of disease (28, 29).

## Statistical analysis

We estimated the number of deaths or DALYs, age-standardized rate DALYs, and deaths to quantify leukemia attributable to occupational risk by age, year, and region.

The estimated annual percentage change (EAPC) was calculated to quantify the trends of burdens of leukemia attributable to occupational risk from 1990 to 2019. The regression model was used to fit the age-standardized rate (ASR), that is, $\ln(\mathrm{ASR}) = \alpha + \beta X + \varepsilon$, where y stands for the burden rate and x for the calendar year. EAPC was calculated by $100 \times [\exp(\beta) - 1]$, and its 95% confidence interval (CI) could also be calculated from the model (24, 25, 30). With the EAPC value and its 95% CI above zero, the corresponding age-standardized rate (ASR) was in an upward trend and *vice versa* (31). Moreover, to gain a better understanding of the relationship between the EAPC of ASR and possible facts, a local weighted scatter plot smoothing regression was used to display more detailed information (24, 25). All statistical analyses were done using R (version 3.6.0).

# Results

## The distribution and its change trend of leukemia attributable to occupational risk

The global age-standardized DALYs and death rates of leukemia attributable to occupational risk were 1.5609, 95% UI: 0.7676–2.2942 for DALYs and 0.0326, 95% UI: 0.0161–0.0481 for deaths in 1990 and 1.3986, 95% UI: 0.669–2.0648 for DALYs and 0.0299, 95% UI: 0.0144–0.0445 for deaths in 2019. Male individuals had higher age-standardized rates than female individuals in leukemia attributable to occupational risk. Global age-standardized DALYs and death rates presented significantly decline trends with EAPCs [−0.38% (95% CI: −0.58 to −0.18%)

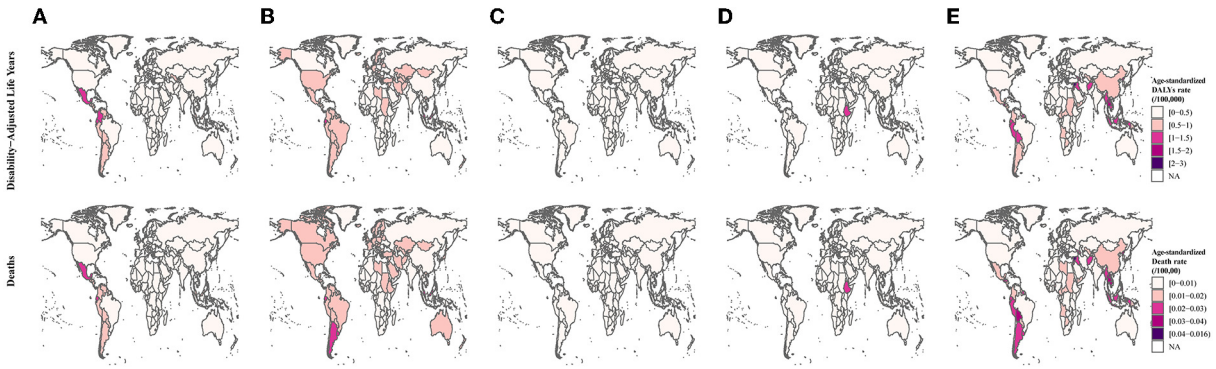


FIGURE 2
Differences in types of leukemia are attributable to occupational risk. **(A)** Acute lymphoid leukemia. **(B)** Acute myeloid leukemia. **(C)** Chronic lymphoid leukemia. **(D)** Chronic myeloid leukemia. **(E)** Other leukemia.

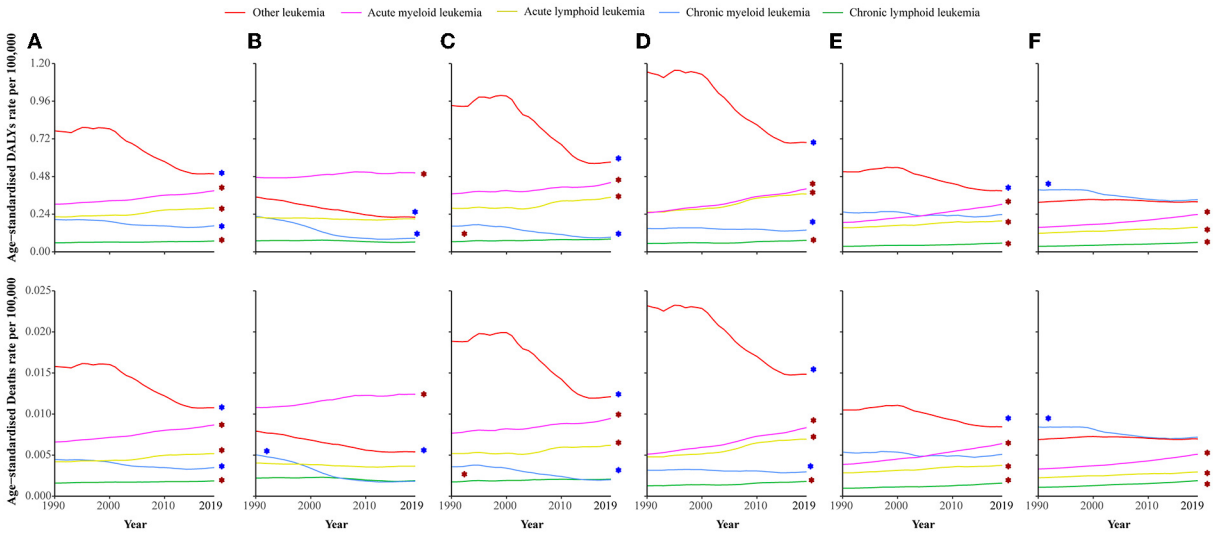


FIGURE 3
Age-standardized DALY and death rates of different types of leukemia attributable to occupational risk among SDI quintiles between 1990 and 2019. **(A)** Age-standardized DALY and death rates of leukemia are attributable to occupational risk globally. **(B)** High-SDI countries. **(C)** Higher-middle-SDI countries. **(D)** Middle-SDI countries. **(E)** Lower-middle-SDI countries. **(F)** Low-SDI countries. SDI, social development index. The red asterisk represents a significant rise trend, and the blue asterisk represents a significant decrease trend.

for DALYs and −0.30% (95% CI: −0.45 to −0.146%) for death] (Table 1). The highest age-standardized DALYs and death rates were observed in the regions of Andean Latin America, Central Latin America, and the Caribbean, whereas the lowest age-standardized incidence rates were seen in Southern sub-Saharan Africa (Figures 1A,B). The most pronounced increase in age-standardized DALYs and death rates was detected in the regions of Latin America and the Caribbean (Andean Latin America, Central Latin America, and the Caribbean), sub-Saharan Africa (Eastern sub-Saharan Africa and Western sub-Saharan Africa), and Southeast Asia and Oceania (Figures 1C,D, Table 1).

## Impact of occupational risk on each leukemia

In 2019, ALL and AML were the leading causes of leukemia attributable to occupational risk-related DALYs and death rates. Both ALL and AML attributable to occupational risk were heavy in Central Latin America, Andean Latin America, and Southern Latin America (Figure 2, Supplementary Table 1). Globally, the age-standardized DALYs and death rates of ALL, AML, and CLL were presented a significantly increase trends with EAPCs [0.78% (95% CI: 0.65–0.91%), 0.87% (95% CI: 0.81–0.93%), and 0.66% (95% CI: 0.51–0.81%) for DALYs, respectively, and

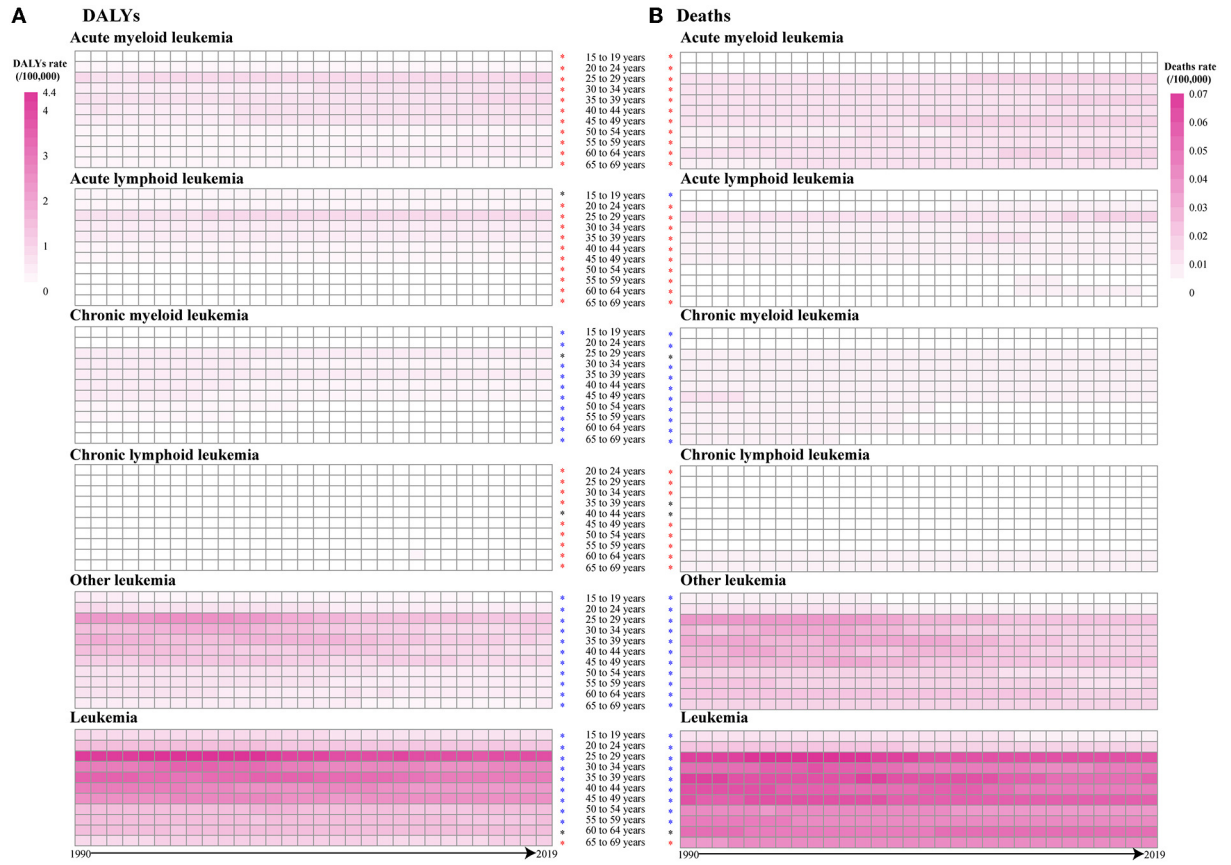


FIGURE 4
The DALY and death rates of leukemia were attributable to occupational risk among different age groups between 1990 and 2019. Red asterisks represent an uptrend, blue asterisks represent a decline, and black asterisks represent a steady trend. **(A)** DALYs and **(B)** Deaths.

0.75% (95% CI: 0.68–0.82%), 0.96% (95% CI: 0.91–1.01%), and 0.55% (95% CI: 0.43–0.68%) for death, respectively], whereas the age-standardized DALYs and death rates of CML and other leukemia were significantly decreased. For SDI quintiles, except for the high SDI level region, the ALL, AML, and CLL were significantly increased in other SDI levels region (Figure 3, Supplementary Table 2).

## Leukemia attributable to occupational risk age distribution structure

We analyzed the DALYs and death rates of leukemia attributable to occupational risk in three different age groups. The results indicated that most DALYs and deaths occurred in 25–29 years in the globe. Overall, the leukemia attributable to occupational risk was significantly increased in people aged 65–69 years [0.42% (95% CI: 0.30–0.55%) for DALYs and 0.38% (95% CI: 0.26–0.51%) for death]. The burdens of ALL, AML, and CLL were increased in almost all age groups while decreased in CML and other leukemia (Figure 4).

## Relationship between SDI and the burdens of leukemia attributable to occupational risk

In 2019, the highest age-standardized rates of leukemia attributable to occupational risk-related deaths and DALYs were observed in countries in the Middle-SDI [1.6778 (95% UI: 0.7894–2.4881) DALYs per 100,000 people and 0.0348 (95% UI: 0.0164–0.052) deaths per 100,000 people]. Figure 5 and Supplementary Figure 1 show the changes in age-standardized DALYs and death rates across the SDI by region from 1990 to 2019. Five regions with the highest SDI exhibited a decline in the age-standardized rate of leukemia attributable to occupational risk-related DALYs and deaths, whereas five regions with the lowest SDI experienced an increasing trend. The regions with

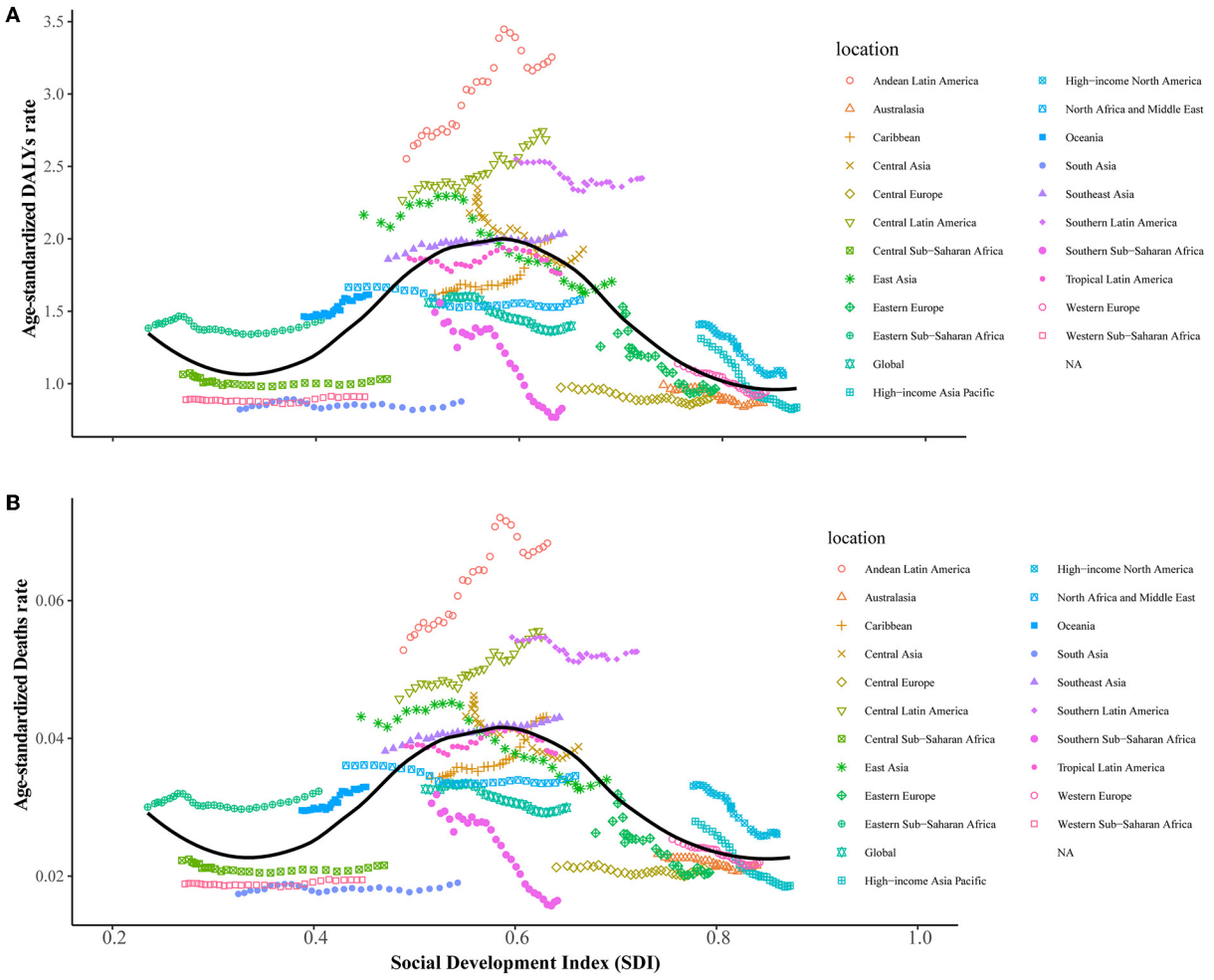


FIGURE 5
Age-standardized DALY and death rates were attributable to leukemia attributable to occupational risk across 21 GBD regions by the socio-demographic index for both sexes combined in 1990–2019. **(A)** Age-standardized DALYs rates. **(B)** Age-standardized death rates.

middle SDI show greatly varied. The associations between age-standardized DALYs and death rates and SDI across countries in 2019 are shown in Supplementary Figure 1.

## Discussion

In this study, we reported the disease burden of leukemia attributable to occupational risk-related deaths and their trends from 1990 to 2019 at the global, regional, and country levels. Our findings showed several key points. Changes between different countries and regions in the burden and trends in total and particular leukemia attributable to occupational risk-related deaths across the globe were found in our research. In general, regions of Andean Latin America, Central Latin America, and the Caribbean were the so-called hotspot regions with the highest age-standardized rates of total leukemia attributable to occupational risk-related deaths in 2019. Overall, most countries and regions showed a decrease in age-standardized DALYs and death rates. The DALYs and deaths of leukemia caused by occupational risk in elderly people is higher than that in other age groups, and the burdens are on the rise.

We analyzed the epidemiological trends of leukemia attributable to occupational risk by calculating the EAPC values from 1990 to 2019. As everyone knows, aging is an important factor contributing to leukemogenesis. Accompanied by aging gene mutations, changes in internal environmental homeostasis and mitochondrial dysfunction make the risk of leukemia higher in the elderly than in the young people (32–35). The marked increase in leukemia attributable to occupational risk in Latin America in terms of deaths and DALYs can be partially explained by the fact that humans in these countries and regions are mostly engaged in physical labor and have more opportunities to come into contact with toxic substances such as formaldehyde and

benzene. Besides, long-term poverty, poor access to healthcare, a lower awareness regarding occupational risk, inadequate prevention measures and screening, and a lower proportion of treatment together make low-income countries more susceptible to leukemia attributable to occupational risk than high-income countries (36–38). Therefore, in the subsequent campaign to eliminate leukemia attributable to occupational risk, more attention and health resources were warranted in developing countries and low-income regions.

Of note, our research found that, among all leukemia caused by occupational risk, the age-standardized DALYs and death rates were particularly observed in ALL and AML. The possible reasons can be listed as follows. First, the standard of leukemia classification has changed. For example, the World Health Organization (WHO) classification (2, 39), recognized as a standard for disease diagnosis and public health monitoring worldwide, has been revised from the primary to the 5$^{th}$ edition during the past 60 years (2). French-American-British (FAB) classification (40) and MICM classification (Morphology, Immunology, Cytogenetics, and Molecular) classification (41). Meanwhile, the diagnostic criteria for leukemia have also changed (42, 43). In terms of the countries and regions' distribution of these two kinds of leukemia, in Mexico and Latin America, the age-standardized DALYs and death rates were the highest, possibly because of the most common of these two types of leukemia in young adults and regional economic development. Thus, accurate surveillance data were important for developing a prevention-and-control program and providing valuable countermeasures to estimate the impact of those programs (44, 45). Elderly people were found to have disproportionately high DALYs and death rates in total leukemia attributable to occupational risk-related deaths, which might be due to age factors. For one thing, the DALYs and death rates of leukemia will increase with age, so the DALYs and death rates of the elderly will be higher than that of young adults. For another, if the elderly were exposed to toxic and harmful substances such as formaldehyde and benzene during adolescence, these substances will not immediately cause reactions after exposure but will slowly accumulate in the body, and symptoms will slowly emerge with age (46, 47). Our findings call for an urgent need to accelerate efforts to reduce leukemia attributable to the occupational risk burden in elderly people. Male individuals generally had higher age-standardized DALYs and death rates than female individuals for leukemia attributable to occupational risk-related deaths, possibly because men were the main part of social labor and were more engaged in heavy physical labor, thus, they had more chances to contact toxic and harmful substances. In addition, the burden of leukemia itself is higher in men than in women (48, 49).

Most countries had a decrease in age-standardized rates of DALYs and death rates for leukemia attributable to occupational risk-related deaths, whereas the absolute DALYs and death cases increased from 1990 to 2019. Leukemia attributable to occupational risk-related deaths still represents a global public health challenge, especially in Latin America and other developing countries, where more attention and health prevention services are warranted. Our study also suggested an upward trend of leukemia attributable to occupation risk among elderly people. ALL, AML, and CLL showed an upward trend in almost all age groups. Thus, there remains an urgent need to accelerate efforts to reduce leukemia attributable to occupational risk-related death burden in this population and specific causes.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

## Author contributions

WX designed the study. DX, CC, HS, YY, and YX accessed and verified the data. XY, HT, AL, and JJ analyzed the data and interpreted the results. YS, YH, XT, and DC wrote the manuscript. All authors revised the manuscript from the preliminary draft to submission.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1015861/full#supplementary-material

SUPPLEMENTARY FIGURE 1
Age-standardized DALY and death rates were attributable to leukemia attributable to occupational risk across countries and territories by the socio-demographic index for both sexes combined in 2019. **(A)** Age-standardized DALYs rates. **(B)** Age-standardized death rates.

SUPPLEMENTARY TABLE 1
Differences in types of leukemia attributable to occupational risk in 21 GBD regions.

SUPPLEMENTARY TABLE 2
The trends of different types of leukemia attributable to occupational risk among SDI quintiles between 1990 and 2019.

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# Evaluating occupational exposures of dental nurses: A retrospective study

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**Objective:** The objective of this study was to investigate occupational blood-borne pathogen exposure among dental nurses and their attitudes toward infected patients, as well as the effectiveness of the training course, to provide a scientific basis for improving the quality of safety management in the dental hospital.

**Materials and Methods:** The study was conducted using questionnaires administered from November 2019 to December 2019 in three hospitals in Sichuan Province, China. Frequencies for answers were calculated and presented as percentages.

**Results:** In total, 257 valid questionnaires were returned. Most (61.9%) nurses stated that they were involved in occupational exposure. Among them, 154 had experienced sharp injuries, and the syringe needle was the most common instrument for injuries (45.8%). Twenty-two individuals had mucosal exposure, and the proportion of eye exposure was the highest (90.9%). Only associations between training and mucosal membrane exposure were found; however, the relevance was weak ($r = 0.141$). Of the participants, 86.4% felt morally responsible for taking care of patients with infectious diseases, and most (92.6%) said they would continue with this career.

**Conclusion:** Occupational exposure, particularly to sharp injuries, was common in medical care among dental nurses; however, vocational training had little effect on their incidence. As dental nurses still have positive attitudes toward patients with infectious diseases, more effective training should be conducted.

KEYWORDS

**occupational exposures, dental nurse, sharp injury, mucous membrane exposures, training course**

## Introduction

Occupational exposure is defined as a situation in which healthcare workers are exposed to harmful substances or pathogens of infectious diseases during the process of diagnosis, treatment, and nursing (1). Previous studies have shown that the widespread prevalence of blood infectious diseases is a major risk factor for the transmission of blood-borne pathogens when occupational exposure has occurred, including hepatitis B virus (HBV), hepatitis C virus (HCV), human immunodeficiency virus (HIV), and *Treponema pallidum* (TP) infection (2–5). The government's official statistics in China reported 1,847,230 cases of blood-borne diseases in 2021. The reported incidence rate was 1.3103/100,000, and the mortality rate was 1.43/100,000, an increase of 6.4 and 3.2%, respectively, compared with 2020. The latest statistical report showed that HIV was ranked in the top five disease causes of mortality in China, and hepatitis was also ranked in the top five for morbidity and mortality (6).

Generally, nurses are involved in frontline work; they directly participate in medical treatment, and the quality of their work is related to patients' medical safety, therapy, and recovery (7). Previous studies have shown that nurses have a higher occupational exposure rate than doctors (8, 9). The job of dental nurses is particular because they are exposed to many special sharp instruments, such as endodontic files and ultrasonic tips. Meanwhile, oral operations result in the spatter of many aerosols and saliva drops, which may greatly increase the risk of occupational exposure (10). In this special period, dental practitioners also have a high risk of being exposed to COVID-19 owing to their close contact with saliva drops and aerosols (11).

Previous studies have predominantly focused on the occupational exposure of medical students and dentists in oral clinics (3, 12). In a study focused on nurses, Alanko et al. (13) found that about 41% had reported work-related dermatitis due to occupational exposure; however, few studies have explored the exposures of sharp injuries and mucous membranes. Therefore, this study aimed to investigate the frequency and details of dental nurses' occupational exposure, to assess their attitudes toward infected patients, and to investigate their decisions regarding future careers. In addition, this study explored whether vocational training could decrease the incidence of occupational exposure to improve occupational exposure prevention and control measures.

## Materials and methods

This study was approved by the Institutional Review Board of the West China Hospital of Stomatology, Sichuan University (WCHS-IRB-CT-2022-298). Informed consent was obtained from all participants. This questionnaire was pretested in a pilot study group ($n = 10$) and evaluated in terms of the subjects' understanding and language skills. Based on their replies, we refined the questions and reformulated the questionnaire to make it more suitable for dental nurses (Supplementary material 1). This survey was conducted with 300 dental nurses in three hospitals, including the West China Hospital of Stomatology of Sichuan University (in Chengdu), Mianyang Stomatological Hospital (in Mianyang), and the Department of Stomatology, Hospital of Chinese Traditional Medicine in Meishan (in Meishan), from November to December 2019.

The questionnaire consisted of 14 questions, investigating (1) dental nurses' general characteristics, such as working years, educational background, HBV vaccination immunization, and experience of vocational course, (2) exposure events, including the type and timing of occupational exposure and the sharps and fluids that caused occupational exposure, (3) occupation expectations and attitudes toward patients with infectious diseases. Questionnaires were distributed to dental nurses in these three hospitals, and participation was anonymous and voluntary.

The data were analyzed using SPSS version 20.0 (IBM, USA). Frequencies were calculated and presented as percentages. Comparisons between the data groups were performed using the chi-squared test, with a significance level of $p < 0.05$. Spearman's correlation coefficient was performed to analyze the relationship between the vocational training course and occupational exposure.

## Results

A total of 291 nurses finished the questionnaires (response rate: 97%), of which 34 forms which were incomplete were excluded from the analysis. The numbers and characteristics of the participants are listed in Table 1. Most of the nurses (90.7%) had received vocational training before or during work, and about half (47.5%) were tested for blood-borne pathogens every year. Meanwhile, 232 of the total had received HBV vaccines.

Table 2 shows the rate of occupational exposure among dental nurses. Of the 257 cases, 159 were involved occupational exposure, accounting for 61.9%. Sharp injuries accounted for 155 cases and involved exposure to instruments, including scalpels, suture needles, syringe needles, and barbed broaches. Twenty-two nurses (8.6%) had experienced mucous membrane exposure. Figure 1 shows the number of sharp injuries. These events occurred before, during, and after the surgery. The most common time point was the preparation of sharp objects (39.4%). Exposure also occurred at the point of waste disposal (32.9%), followed by the process of operation (22.6%), and the point of transferring sharp objects (11.0%). Of these, 5.2% of them even did not know when they experienced sharp injuries. Of the 155 cases of sharp injuries, the syringe needle was the most common causative instrument of injuries (45.8%).

TABLE 1 Basic characteristics of the study participants ($n = 257$).

| Features | *N* (%) |
|---|---|
| **Basic information** | |
| **Educational background** | |
| Master degree or above | 2/257 (0.8) |
| Bachelor degree | 135/257 (52.5) |
| College degree | 120/257 (46.7) |
| College degree or below | 0/257 (0) |
| **Length of service** | |
| ≤1 year | 119/257 (46.3) |
| 1 ≤ 5 years | 50/257 (19.5) |
| 5 ≤ 10 years | 61/257 (23.7) |
| ≥10 years | 27/257 (10.5) |
| **Overall self-impression** | |
| **Have you taken the training course on occupational exposure?** | |
| Yes | 233/257 (90.7) |
| No | 24/257 (9.3) |
| **Have you received the HBV vaccine?** | |
| Yes | 232/257 (90.3) |
| No | 16/257 (6.2) |
| Not clear | 9/257 (3.5) |
| **Are you tested for HBV, TP, and HIV every year?** | |
| Yes | 122/257(47.5) |
| No | 135/257(52.5) |

HBV, hepatitis B; TP, Treponema pallidum; HIV, human immunodeficiency virus.

TABLE 2 Number (percentage) of participants who have experienced occupational exposure ($n = 257$).

| Features | *N* (%) |
|---|---|
| **Have you ever experienced occupational exposure?** | |
| Yes | 159/257 (61.9) |
| No | 98/257 (38.1) |
| **Have you ever experienced mucous membrane exposure?** | |
| Yes | 22/257 (8.6) |
| No | 235/257 (91.4) |
| **Have you ever experienced sharp injuries exposure?** | |
| Yes | 155/257 (60.3) |
| No | 102/257 (39.7) |

Endodontic files (28.4%), suture needles (11%), scalpels (8.4%), drilling needles (7.1%), and ultrasonic tips (6.5%) were also common (Figure 1).

Figure 2 shows the exposure time, exposure part, and pollutant exposure of the mucous membrane. Among the mucous membrane exposures, the proportion of eye exposures was much higher (90.9%) than in the nasal (4.5%) or oral cavity (4.5%). Exposure occurred mainly during clearing up the instruments (45.5%) and irrigation in patients (36.4%). Therefore, waste fluid (45.5%) and saliva (27.3%) were the main contaminants in mucosal exposure. Interestingly, splashing during the operation (13.6%) was not the main factor of mucosal exposure.

Of the participants, 86.4% felt morally responsible for caring for patients with infectious diseases. Furthermore, 80.5% did not feel scared of this career, even with knowledge of the risk of occupational exposure, and most (92.6%) stated that they would continue with this career (Table 3).

No association was found between vocational training and sharp injuries (Table 4), although a relationship between training and mucous membrane exposure was found ($p < 0.05$). Meanwhile, the results showed that the occurrence of mucous membrane exposure could be influenced by work experience ($p < 0.01$).

## Discussion

Occupational exposure may have side effects on medical staff's psychological problems, bringing about a socioeconomic burden (14–16). In our study, more than 60% of dental nurses experienced occupational exposure, while 90% had already participated in the training course before or during work. No association was found between training and sharp injuries (Table 4), although a relationship between training and mucous membrane exposure was found ($p < 0.024$). Meanwhile, the data showed that the occurrence of mucous membrane exposure could be influenced by working experience ($p < 0.01$). After taking a training course on occupational exposure and the accumulation of working experiences, nurses may be more properly able to use personal protective equipment that can effectively prevent waste fluid or saliva drops from contacting the faces or skin (17). In our study, waste fluid (45.5%) and saliva (27.3%) were the two main contaminants associated with mucosal exposure. Regarding sharp injuries, we did not find a significant correlation between work experience and sharp injuries. The data revealed that syringe needles (45.8%), endodontic files (28.4%), and suture needles (11%) were the top three causative agents of sharp injuries. Needlestick injury was still the most common sharp injury, which agrees with the result of a previous study (18). These oral instruments are so slender that they puncture personal protective equipment easily; therefore, the common use of personal protective equipment sometimes cannot avoid sharp injuries effectively.

Of the 257 valid returned questionnaires, 159 nurses stated that they had experienced occupational exposure, while 155 had experienced sharp injuries, accounting for 60.3% of the total number. This was slightly higher than the results reported in Nigeria (18). This increasing ratio might be related to the development of dental instruments, such as high-speed rotating engine—driven NiTi endodontic files, which are widely used in root canal surgery. This commonly used instrument could

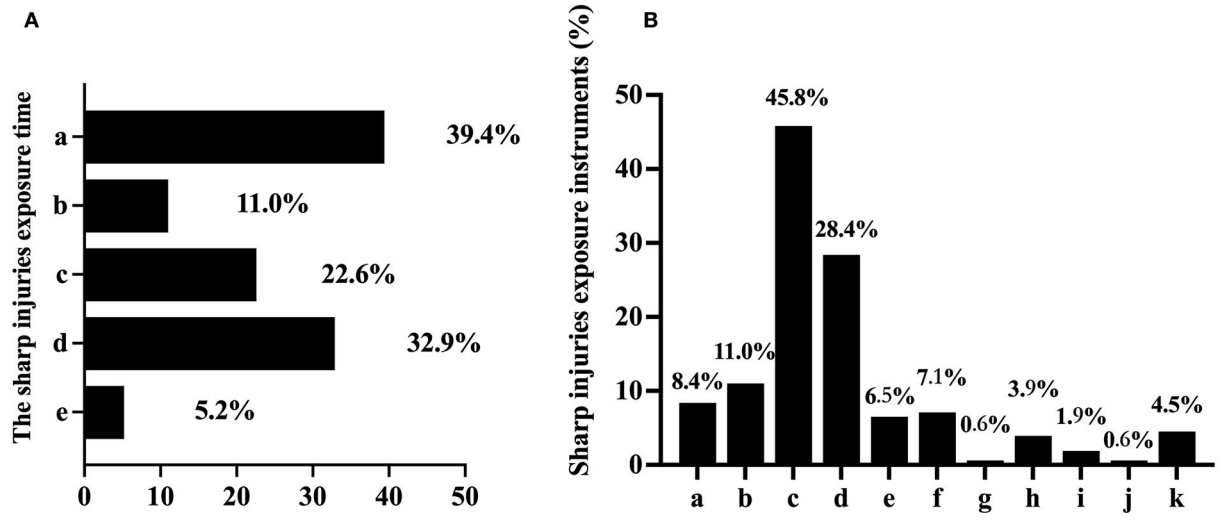


FIGURE 1
The basic situation of sharp injury exposures (%). **(A)** The exposure time of sharp injuries; a. preparing sharp objects; b. transferring sharp objects; c. operation; d. discarding waste; e. unclear. **(B)** Instruments which may induce sharp injuries: a. scalpel; b. suture needle; c. syringe needle; d. endodontic file; e. ultrasonic tip; f. drilling needle; g. gracey curette; h. periodontal probe; i. barbed broach; j. irrigation needle; k. ligature wire.

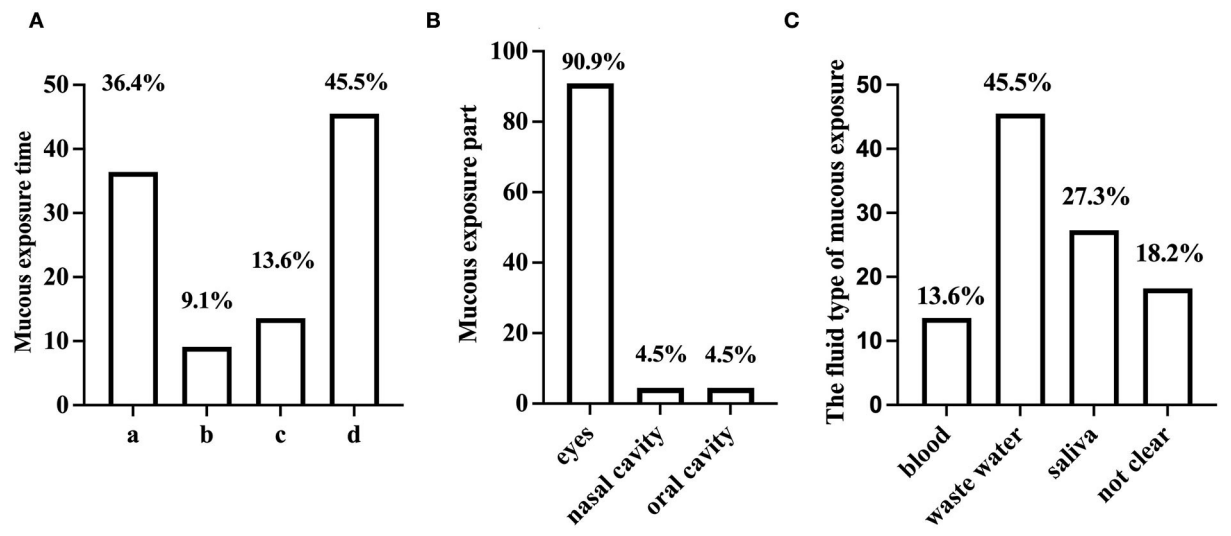


FIGURE 2
The basic situation of mucous membrane exposure (%). **(A)** The exposure time of the mucous membrane; a. irrigation; b. patients talking; c. splash during the operation; d. discarding waste. **(B)** Mucous membrane exposure. **(C)** The fluid type of mucous membrane exposure.

not be stopped immediately when the treatment was finished, which might add to the risks of sharp injuries (19). In regular clinical work, the structures of most oral instruments, such as endodontic files, suture needles, scalpels, drilling needles, and ultrasonic tips, are also sharp (20), which may increase the risk of injury during exposure. The syringe needle was also the most common instrument that led to dental nurses' injuries (45.8%); this result was similar to that of a previous study (21). Syringes are often used to administer local anesthesia or during drug injections for mucosal diseases. The pain caused by injection causes patients to move, resulting in an increase in occupational exposure (22). Furthermore, syringes used in oral treatment are sharper than most others because of the fragility of the mucous membrane; this factor may be easily overlooked during rushed clinic work. These may also explain the high proportion of needlestick injuries in occupational

TABLE 3 Occupational expectation ($n = 257$).

| Features | *N* (%) |
|---|---|
| **Are you willing to take care of patients with blood-borne pathogens?** | |
| Yes | 222/257 (86.4) |
| No | 35/257 (13.6) |
| **Are you scared of this career because of the occupational exposure?** | |
| Yes | 50/257 (19.5) |
| No | 207/257 (80.5) |
| **Have you ever thought about giving up this career because of the occupational exposure?** | |
| Yes | 19/257 (7.4) |
| No | 238/257 (92.6) |

exposure. In addition, when anesthesia was required during the treatment, the nurses sometimes helped the dentists recap the needle cap, which inevitably led to exposure. In addition, the narrow space for oral operations also increases the risk of exposure (23).

Our results showed that vocational training did not reduce the rate of occupational exposure. The possible reasons for this are as follows: First, most of them did not pay sufficient attention to the risk of infectious disease in this high-risk environment, and only half of the respondents (47.5%) underwent annual blood testing for infectious disease, although almost all underwent the training course. In total, 232 of all patients had been injected with HBV vaccine before, which may reduce the risk of HBV infection. However, HBV antibody levels may decrease over time, and the protective effect on the human body is weakened (24). Therefore, regular blood testing is essential. Meanwhile, the data showed the most common exposure time (39.4%) was during the preparation of sharps before treatment. At this moment, nurses may regard the instruments as sterile and therefore of low risk, resulting in insufficient attention being paid. In addition, they may use sharp instruments directly instead of tweezers, which increases exposure risks. Second, the existing training mode was not sufficiently effective to reduce occupational exposure (25). The knowledge conveyed in the regular teaching mode is often boring and difficult to understand and is not synchronized with clinical work. Therefore, although most participants underwent the training course, they also had a high rate of sharp injuries. Incorrect separation of the syringe and needle during needle recapping is considered as the most important risk factor associated with sharp injuries (25–27). Furthermore, 5.2% of nurses stated that they did not even know when they experienced sharp injuries. Not knowing when the injury occurred may have resulted in incorrect or insufficient post-exposure handling, which would directly increase the risks of blood-borne pathogen transmission. Heavy clinical work may be another reason why nurses had no time to pay sufficient attention to correct operations, resulting in them ignoring the training contents (28–30).

Mucous membrane exposure is another common occupational exposure. The percentage of individuals who had experienced mucous membrane exposure (8.6%) was far lower than that of individuals with sharp injuries (61.9%) in our study. This might suggest that the necessary personal protective equipment was used to a greater extent. Eye exposure was the most common mucous membrane exposure in our study, accounting for 90.9% of occurrences. This indicated that most nurses did not use protective equipment to protect eyes (14). During treatment, the eyes require constant attention during the operation, and unprotected eyes are likely to be exposed to unpredictable liquid splashes in different directions. As the vision of goggles and face shields is blocked, some nurses may take them off to flexibly cooperate with the dental operations, which greatly increased the risks of mucous membrane exposures (31). The exposure rates of the nasal cavity (4.5%) and oral cavity (4.5%) were relatively low, probably because of the use of masks. Rozanska et al. (1) found that occupational exposure rates decreased with working experience, but increased again after 5 years of working. Therefore, up-to-date training is important throughout the entire career period.

Although the rate of occupational exposure was high in the dental nurse group, we were glad to see that most did not refuse to treat individuals with infectious diseases. They did not feel scared of this career and stated that they would continue in the same field (32, 33). Therefore, training courses on occupational exposure should put this theory into practice and help nurses to improve their awareness to reduce the risk of occupational exposure. It is also necessary to establish standardized operations. For example, it is recommended to use double gloves, cover the needle cap with one hand, and rigorously use protective equipment (34, 35). Furthermore, hospital administration should encourage employees to perform blood tests regularly and to improve occupational exposure report systems (36, 37). Only with the efforts made in a variety of aspects can we reduce the rate of occupational exposure and improve the business confidence of medical staff.

Unfortunately, this survey was only conducted in Sichuan Province, meaning that selection bias and regional specificity are both limitations of this research. Thus, multi-center surveys should be conducted to verify the details of the occupational exposure of dental nurses.

## Conclusion

Occupational exposure, particularly to sharp objects, is a serious problem for dental nurses performing medical care. We found that vocational training had little effect on sharp injuries; however, it could reduce the incidence of mucous

TABLE 4 Correlation between nurses' characteristics and occupational exposures.

| | Educational Background | Length of service | Training course on occupational exposure |
|---|---|---|---|
| Occupational exposure | −0.038 | 0.025 | 0.059 |
| Sharp injuries exposure | 0.036 | −0.016 | −0.069 |
| Mucous membrane exposure | −0.088 | −0.161** | 0.141* |

*$p < 0.05$, **$p < 0.01$.

membrane exposure to some extent. Despite the high risk of occupational exposure, dental nurses still had positive attitudes toward patients with infectious disease. Therefore, diverse and targeted vocational training is imperative to improve the safety awareness of dental nurses and to reduce the risk of occupational exposure.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding authors.

## Ethics statement

This study was approved by the Institutional Review Board of the West China Hospital of Stomatology, Sichuan University (WCHS-IRB-CT-2022-298). The patients/participants provided their written informed consent to participate in this study.

## Author contributions

HY, RS, and JY had full access to all data used in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. HY, ZL, FL, and JY designed the study. HY, ZL, and JY developed and tested the data collection forms. HY, YM, and WC acquired, conducted, and interpreted the data. HY, RS, FL, and JY drafted the manuscript. All authors critically revised the manuscript and read and approved the final manuscript.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1010531/full#supplementary-material

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# What do we know about the effect of night-shift work on cardiovascular risk factors? An umbrella review

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**Objective:** To evaluate the existing evidence on the effect of night-shift work and its subtypes (permanent and rotating) on cardiovascular risk factors: diabetes, lipid disorders, being overweight, hypertension, smoking habits, sedentariness, and occupational psychosocial stressors.

**Method:** A Web of Sciences and Cochrane review library search was conducted to identify systematic reviews with or without meta-analysis dealing with the quantification of the link between night-shift work and the studied cardiovascular risk factors in working populations. We used the AMSTAR 2 to evaluate the quality of each review. The main results of the included systematic reviews were compiled in a summary structured around the different cardiovascular risk factors.

**Results:** After selection, 33 systematic reviews were included: nine for diabetes, four for lipid disorders, nine for being overweight, four for hypertension, two for smoking habits, three for occupational psychosocial stressors and two for sedentariness. The results confirmed an excess risk of diabetes of about 10% regardless of the type of night work. A stated excess risk of being overweight at around 25% was also highlighted for shift workers overall, which could reach 38% among night-shift workers. An increased risk of obesity, estimated at 5% for night-shift workers and at 18% for rotating shift workers, was observed. An excess risk of hypertension was estimated at around 30% when considering the broad definition of shift work and when night periods were included in rotating shifts. The literature provided inconsistent results for the link between lipid disorders and night-shift work. Shift workers appeared to be more likely to smoke. The link between shift work and occupational psychosocial stressors was scarcely explored in the available studies. Sedentariness was scarcely considered in systematic reviews, which prevents any firm conclusions.

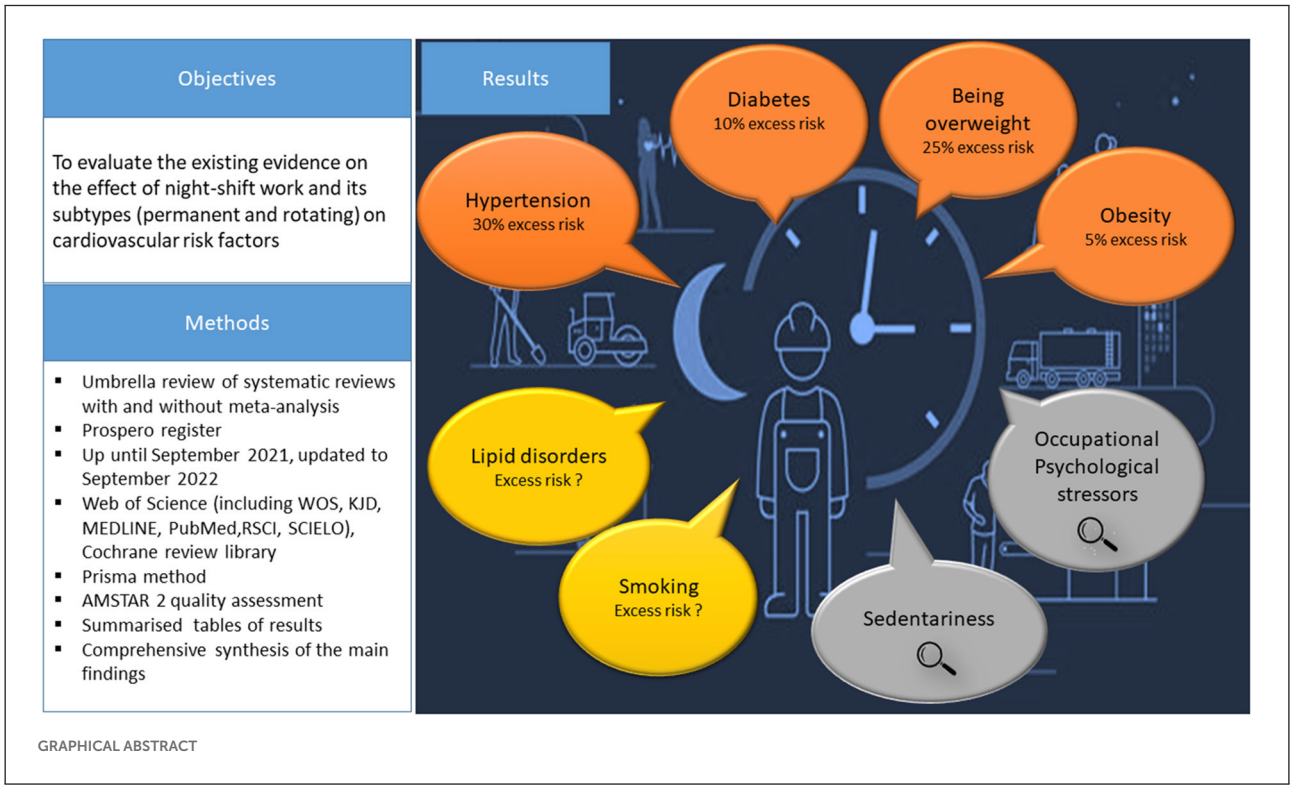
**Conclusion:** The consequences of night work in terms of diabetes, being overweight/obesity and hypertension are established. Monitoring of these cardiovascular risk factors for these night-shift workers could be implemented by practitioners. In contrast, the links with lipid disorders,

sedentariness, smoking habits, and occupational psychosocial stressors warrant further investigation.

**Systematic review registration:** https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021275212, PROSPERO (ID CRD42021275212)

KEYWORDS

**night-shift work, lipid disorders, overweight, smoking, sedentariness, psychosocial stressors at work, diabetes and hypertension, shift work**




GRAPHICAL ABSTRACT

## Context

Despite advances in diagnosis and in treatment, cardiovascular disease has remained a major concern over the last few decades, having almost doubled worldwide between 1990 and 2019 (1). Although a significant decline in age-standardized mortality rates and, to a lesser extent, age-standardized prevalence rates over the past 20 years, cardiovascular disease has remained among the leading cause of mortality and morbidity worldwide (1). Diabetes, hypertension, being overweight, sedentariness, lipid disorders and tobacco consumption remained the main modifiable risk factors contributing to the global burden of cardiovascular diseases in 2019 (1). Early improvement of these modifiable well-known cardiovascular risk factors remains the challenge fixed by all the experts in acute guidelines (2).

However, the literature provides more and more articles on the potential effect of working conditions on these cardiovascular risk factors (3, 4). Some of these working conditions are modifiable or at least adaptable. Among them, night-shift work is closely scrutinized. Although regulated, the use of such working-time patterns is not marginal. Approximately 19% (24% men; 14% women) of workers in the EU carried out night work in 2016 (5). An increased risk of any cardiovascular disease has been observed in night-shift workers, up to 40% (6–8). The pathophysiological mechanisms explaining

the associations between shift work and cardiovascular disease rely on several complex and interrelated pathways, including cardiovascular risk factors as mediators (9). Circadian stress due to night-shift work can indeed induce physiological, behavioral, and psychosocial stress that leads to health conditions predictive of cardiovascular diseases. Therefore, a substantial literature on the effects of shift work on cardiovascular risk factors has been provided over the last few decades, leading to the publication of numerous systematic reviews on this topic. The time has now come to say what we know and what we intend to do about it over the next few years.

This umbrella review aimed to evaluate the existing evidence on the effect of night-shift work and its subtypes (permanent and rotating) on cardiovascular risk factors—these being diabetes, lipid disorders, being overweight, hypertension, smoking habits, sedentariness, and occupational psychosocial stressors.

# Methods

## Search strategy

The search strategy was determined *a priori*, and the protocol was registered to PROSPERO (ID CRD42021275212). No deviation from the PROSPERO protocol was made.

A literature search was conducted to retrieve eligible systematic reviews with or without meta-analysis that addressed the above research objective. Flowcharts, using the PRISMA method (9, 10), summarized the different steps of the article selection for each investigated cardiovascular risk factor. The following databases were searched for eligible reviews from inception to September 2021, updated to September 2022: Web of Science (including WOS, KJD, MEDLINE, PubMed, RSCI, SCIELO) and Cochrane review library. Moreover, screening the reference lists of the selected papers completed the searches. Relevant reviews listed and not found by the main step of research strategy were integrated, as it needed.

For working hour schedules, the following MeSH terms and key words included in "title" or in "abstract" were used: shift work, shift workers, night workers, night work, night shift work, night shift workers, night-shift work, night-shift workers, shift working, rotating shift, rotating shift workers and irregular working hours.

These terms were successively combined with several term groups including the following MeSH terms or keywords in "title" or in "abstract":

1) **diabetes:** diabetes, glycemia, glucose, diabetes mellitus, NIDDM, non-insulin-dependent, type 2 diabetes and truncated terms: diab*.
2) **lipid disorders:** lipids, cholesterol, triglycerides, apolipoprotein, chylomicron, very low-density lipoprotein, low-density lipoprotein, high-density lipoprotein (HDL) and truncated term: lip*.
3) **being overweight:** body mass index, weight, obesity, obese, waist circumference.
4) **hypertension:** blood pressure, hypertension, high blood pressure, systolic pressure and diastolic pressure.
5) **smoking habits:** tobacco, smoking.
6) **sedentariness:** sedentary, sedentariness, sedentarity, physical activity.
7) **occupational psychosocial stressors:** psychosocial risk, psychosocial factors, stress.

The detailed search strategy is provided in Supplementary Table A.

## Inclusion and exclusion criteria and articles selection

Any systematic review published in English or French, dealing with quantification of the relationship between night-shift work and studied cardiovascular risk factors in the working population was included. Narrative, comprehensive and mechanistic reviews were excluded, as well as research protocol without any result. Reviews focusing on long working hours, or atypical or irregular working hours were not considered here. The list of excluded articles with the reason of exclusion is available in Supplementary Table B.

For each investigated topic, two out of three independent experts in occupational health and cardiovascular epidemiology areas (YE, SB, EB) independently conducted the articles selection by using defined search terms in databases. The results obtained from the search were exported to EndNote X8TM (Clarivate Analytics, Philadelphia, USA), which enabled to identify the duplicates and to remove them.

The next step involved selecting articles based on the screening of titles and abstracts independently conducted by two out of three experts (SB, EB, YE), who also conducted a further selection after reading the full articles. If there was a disagreement, a discussion with a fourth expert (JF) resolved it. All steps were clearly reported.

## Data extraction

Two out of three experts (YE, SB, EB) independently extracted the following information from each included systematic review:

- citation details
- objective of the systematic review or meta-analysis
- type of databases sourced and searched and date range of database searching publication
- information about the studies included in the review: publication date range, number and type of studies, country

of origin, rating of the quality of the studies, details of participants and setting/context
- types of exposure to working hour schedules and their duration
- definition of the examined outcome and its assessment
- adjustment factors
- main results including the summary of the effect size estimate [risk ratio (RR), odds ratio (OR), hazard ratio (HR), or incident risk ratio] with the 95% confidence intervals (CIs)

If there was a disagreement, a discussion with the third expert resolved it.

## Quality assessment of the selected articles—Risk of bias

To evaluate the quality of the reviews, we used AMSTAR 2 (a measurement tool for assessing systematic reviews, version 2) (11). The sixteen items assessed were: 1: complete research question and criteria (PICO); 2: registered protocol; 3: justification of study design; 4: comprehensive literature search; 5: study selection in duplicate; 6: data extraction in duplicate; 7: justification of excluded studies; 8: description of included studies; 9: assessing the risk of bias (RoB); 10: reporting on the sources of funding for the studies included; 11: meta-analysis using appropriate statistical methods combining results; 12: meta-analysis assessing the impact of RoB; 13: interpretation/discussion of results must include risk of bias of studies; 14: discussion of heterogeneity; 15: investigation of publication bias in meta-analysis; 16: reporting conflict of interest. All included systematic reviews were rated as "yes", "partial yes" or "no" according to the AMSTAR-2 checklist.

## Strategy for data synthesis

A narrative synthesis of the main findings from the included studies described in data extraction tables was conducted and structured around the type of cardiovascular risk factors.

# Results

One thousand and forty-five (1,045) reviews were identified according to the eligibility criteria for all studied cardiovascular risk factors, and the results were as follows: 205 for diabetes, 41 for lipid disorders, 234 for being overweight, 121 for hypertension, 60 for smoking habits, 122 for sedentariness, and 262 for occupational psychosocial stressors. After screening, 31 full texts of systematic reviews were retained. Two additional systematic reviews on sedentariness were identified during the update period. Seven separate flowcharts summarized the selection process using the PRISMA guidelines and the reasons of some full text exclusion (Supplementary Figure A). Main findings were described by cardiovascular risk factors, including the quality assessment of each included systematic review according to the AMSTAR-2 checklist (Figure 1).

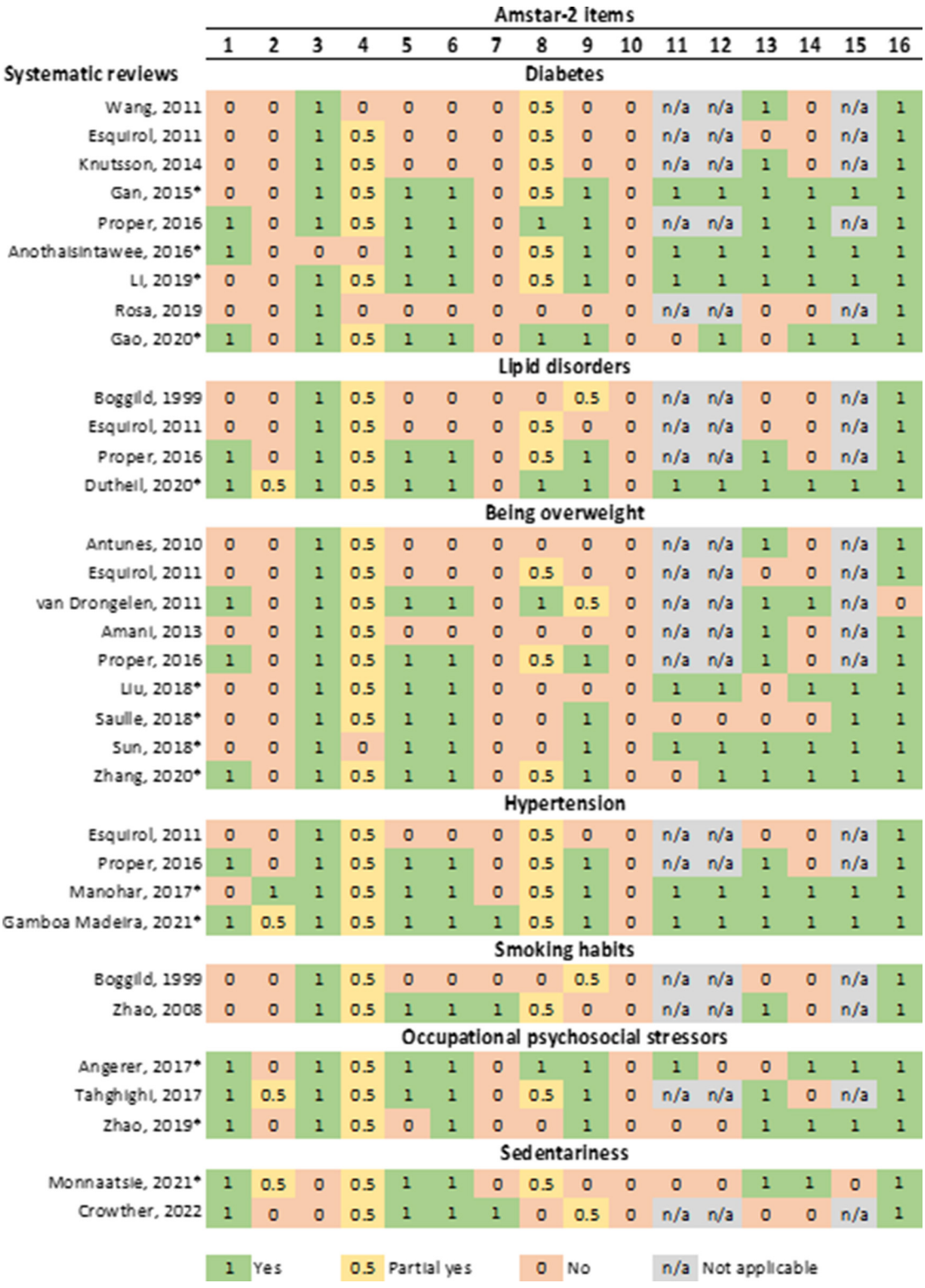
## Diabetes

The Supplementary Figure A displays the different steps of the reviews selection related to the relationship between night-shift work and diabetes. After reading the full text of 26 reviews, 17 were excluded mainly because they were narrative (53%) or did not evaluate the association of interest (35%). Nine systematic reviews with or without meta-analyses were finally considered for this purpose: five systematic reviews (12–16) and four meta-analyses (17–20) (Supplementary Table C).

According to the AMSTAR-2 checklist (Figure 1), the four meta-analyses and only 1 review (14) met most of the quality criteria (68–77% of criteria completely or partially met). Item no. 4 (comprehensive literature search) and item no. 8 (description of included studies) were often partially met. The criteria related to an *a priori* protocol registration (item no. 2), to the justification of excluded studies (item no. 7) and to the reporting on the sources of funding for the studies included (item no. 10) were never provided. The oldest systematic reviews (12, 13, 16) did not report in detail the method used to perform the systematic review (AMSTAR-2 items no. 3, 4, 5, 6).

In total, fifty-one primary studies were analyzed in the different systematic reviews with and without meta-analyses, covering a period of 20 years (from 1999 to 2018, only one study was published in 1983). Among the 5 systematic reviews without meta-analyses, three systematic reviews were based on longitudinal studies (13–15). Esquirol et al. included 13 longitudinal and 11 cross-sectional studies published between 2001 and 2010 (12). Later, Proper et al. considered 9 longitudinal studies published from 2005 to 2015 (14). Rosa et al. conducted a systematic review on the global health of shift work in nurses and retained only one study on diabetes (15). The four systematic reviews with meta-analyses did not consider all studies referenced in two systematic reviews previously performed (12, 14). Two systematic reviews with meta-analyses only considered the results of longitudinal studies (17, 20). The four systematic reviews with meta-analyses were published between 2015 and 2020 (17–20). Li et al. (20) performed an updated meta-analysis undertaken by Gan et al. (18) and only included cohort studies. Anothaisintawee et al. focused on sleep disturbance and conducted a meta-analysis on a subgroup of 10 studies undertaken specifically on shift work (17).

In each systematic review with meta-analyses, the number of studies varied from 11 to 21 (prospective studies from 6 to 12), with the number of participants ranging from 226,652 (18) to 639,880 (19), mixing men and women from different occupations (industry or healthcare or heterogeneous). The



| Systematic reviews | Amstar-2 items | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Diabetes** | | | | | | | | | | | | | | | | |
| Wang, 2011 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | n/a | n/a | 1 | 0 | n/a | 1 |
| Esquirol, 2011 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0.5 | 0 | 0 | n/a | n/a | 0 | 0 | n/a | 1 |
| Knutsson, 2014 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0.5 | 0 | 0 | n/a | n/a | 1 | 0 | n/a | 1 |
| Gan, 2015* | 0 | 0 | 1 | 0.5 | 1 | 1 | 0 | 0.5 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Proper, 2016 | 1 | 0 | 1 | 0.5 | 1 | 1 | 0 | 1 | 1 | 0 | n/a | n/a | 1 | 1 | n/a | 1 |
| Anothaisintawee, 2016* | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0.5 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Li, 2019* | 0 | 0 | 1 | 0.5 | 1 | 1 | 0 | 0.5 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Rosa, 2019 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | n/a | n/a | 0 | 0 | n/a | 1 |
| Gao, 2020* | 1 | 0 | 1 | 0.5 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| **Lipid disorders** | | | | | | | | | | | | | | | | |
| Boggild, 1999 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0.5 | 0 | n/a | n/a | 0 | 0 | n/a | 1 |
| Esquirol, 2011 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0.5 | 0 | 0 | n/a | n/a | 0 | 0 | n/a | 1 |
| Proper, 2016 | 1 | 0 | 1 | 0.5 | 1 | 1 | 0 | 0.5 | 1 | 0 | n/a | n/a | 1 | 0 | n/a | 1 |
| Dutheil, 2020* | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Being overweight** | | | | | | | | | | | | | | | | |
| Antunes, 2010 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | n/a | n/a | 1 | 0 | n/a | 1 |
| Esquirol, 2011 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0.5 | 0 | 0 | n/a | n/a | 0 | 0 | n/a | 1 |
| van Drongelen, 2011 | 1 | 0 | 1 | 0.5 | 1 | 1 | 0 | 1 | 0.5 | 0 | n/a | n/a | 1 | 1 | n/a | 0 |
| Amani, 2013 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | n/a | n/a | 1 | 0 | n/a | 1 |
| Proper, 2016 | 1 | 0 | 1 | 0.5 | 1 | 1 | 0 | 0.5 | 1 | 0 | n/a | n/a | 1 | 0 | n/a | 1 |
| Liu, 2018* | 0 | 0 | 1 | 0.5 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| Saulle, 2018* | 0 | 0 | 1 | 0.5 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Sun, 2018* | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Zhang, 2020* | 1 | 0 | 1 | 0.5 | 1 | 1 | 0 | 0.5 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| **Hypertension** | | | | | | | | | | | | | | | | |
| Esquirol, 2011 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0.5 | 0 | 0 | n/a | n/a | 0 | 0 | n/a | 1 |
| Proper, 2016 | 1 | 0 | 1 | 0.5 | 1 | 1 | 0 | 0.5 | 1 | 0 | n/a | n/a | 1 | 0 | n/a | 1 |
| Manohar, 2017* | 0 | 1 | 1 | 0.5 | 1 | 1 | 0 | 0.5 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Gamboa Madeira, 2021* | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 1 | 0.5 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Smoking habits** | | | | | | | | | | | | | | | | |
| Boggild, 1999 | 0 | 0 | 1 | 0.5 | 0 | 0 | 0 | 0 | 0.5 | 0 | n/a | n/a | 0 | 0 | n/a | 1 |
| Zhao, 2008 | 0 | 0 | 1 | 0.5 | 1 | 1 | 1 | 0.5 | 0 | 0 | n/a | n/a | 1 | 0 | n/a | 1 |
| **Occupational psychosocial stressors** | | | | | | | | | | | | | | | | |
| Angerer, 2017* | 1 | 0 | 1 | 0.5 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| Tahghighi, 2017 | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 0 | 0.5 | 1 | 0 | n/a | n/a | 1 | 0 | n/a | 1 |
| Zhao, 2019* | 1 | 0 | 1 | 0.5 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| **Sedentariness** | | | | | | | | | | | | | | | | |
| Monnaatsie, 2021* | 1 | 0.5 | 0 | 0.5 | 1 | 1 | 0 | 0.5 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| Crowther, 2022 | 1 | 0 | 0 | 0.5 | 1 | 1 | 1 | 0 | 0.5 | 0 | n/a | n/a | 0 | 0 | n/a | 1 |

1 Yes | 0.5 Partial yes | 0 No | n/a Not applicable

FIGURE 1
Quality assessment of included systematic reviews on the link between night-shift work and cardiovascular risk factors using AMSTAR-2 (*systematic review with meta-analysis). Footnotes AMSTAR-2 items-1, complete research question and criteria (PICO); 2, registered protocol; 3, justification of study design; 4, comprehensive literature search; 5, study selection in duplicate; 6, data extraction in duplicate; 7, justification of excluded studies; 8, description of included studies; 9, assessing the risk of bias (RoB); 10, reporting on the sources of funding for the studies included; 11, meta-analysis using appropriate statistical methods combining results; 12, meta-analysis assessing the impact of RoB; 13, interpretation/discussion of results must include risk of bias of studies; 14, discussion of heterogeneity; 15, investigation of publication bias in meta-analysis; 16, reporting conflict of interest.

quality of the included studies was systematically evaluated by specific quality tools (e.g., NOS, AHRQ checklist), with a level of satisfactory quality retained by the authors. The diabetes diagnosis was based on fasting plasma glucose (FPG), glycated hemoglobin (HbA1c), oral glucose tolerance test (OGTT), a diabetes death certificate, a self-report or a medical report.

An excess risk estimated at around 10% of developing diabetes among shift workers compared to day workers was consistently found in the meta-analyses. The statistically significant overall pooled adjusted ORs ranged from 1.08 to 1.15 for shift work, from 1.08 to 1.42 for rotating shift work and from 1.09 to 1.19 for night-shift work. This increased risk seems to be higher in men (18, 20). A dose-response effect was highlighted in female shift workers only, with an increased risk of 5-7% every 5 years (19, 20) (Table 1).

## Lipid disorders

From the eleven systematic reviews assessed for eligibility, four met the criteria (Supplementary Figure A): three systematic reviews (12, 14, 21) and one meta-analysis (22). Six did not report any calculated risk and one focused on mechanistic hypotheses, which could potentially explain the link between shift work and lipid disorders.

The Proper et al. (14) and Dutheil et al. (22) papers reached a good level of quality according to AMSTAR-2 (Figure 1).

In total, eighty-five primary studies were included in the four systematic reviews. The systematic review with meta-analyses (22) encompassed about 50 and 60% of the primary studies analyzed by Esquirol et al. (12) and Proper et al. (14), respectively, and added forty new primary studies.

The four systematic reviews covered the period from 1976 to 2019 (Supplementary Table D). Around 231,500 participants mainly from the industry were included in these four reviews. Except for self-reported lipid measurement in one primary study, results of the others were based on blood measurements. Dutheil et al. conducted meta-analyses to explore the impact of night-shift work on several types of lipid disorders (22).

A high triglyceride level was the most reported change of lipid disorders in shift workers compared to day workers from the three systematic reviews (12, 14, 21), with a 12% risk excess estimated by Dutheil et al. (22). Results for total cholesterol, HDL-C and LDL-C were inconsistent, even though some authors supported an increased risk of hypercholesterolemia after exposure to 20-year shift work (12). With high heterogeneity, some mean differences of lipid levels according to different type of shift work were suggested by Dutheil et al., notably lower HDL-C among permanent night shift work and rotating night-shift work (22) (Table 2).

## Being overweight

Nine systematic reviews were identified on the consequences of night-shift work on weight gain during working life (12, 14, 23–29) (Supplementary Figure A). Among them, four proposed results of meta-analyses (25–27, 29).

The quality of the systematic reviews was highest for most recent systematic reviews with meta-analysis (27, 29) (Figure 1).

Two meta-analyses published in 2018 included 27 and 28 primary studies respectively, with an overlap of 65% (25, 27). For nurses, four out of seven primary studies considered in Saulle's meta-analysis (26) were also included in one of Zhang's (29).

The total number of participants for these systematic reviews varied from 11,537 (28) to 311,334 (25). Primary studies included were published between 1986 and 2017 (Supplementary Table E). The weight increase was dealt with by using either the classic threshold of BMI (<25/25–30/>30 kg/m$^2$ to distinguish a normal weight, being overweight or being obese, respectively) or the threshold of waist circumference adapted to gender (≥80/≥94 or 88 cm) to determine abdominal adiposity, or weight changes during a defined period. Some authors distinguished being obese and being overweight, some of them considered both in analyses. Moreover, some authors reported results concerning overall shift work and other authors reported more specific results for rotating shift work and night shift work.

From meta-analyses, when overall shift workers were considered, an increased significant risk of being overweight ranging from 1.25 (25) to 1.32 (27) was observed, while it was assessed as 0.95 (0.24–1.14) among nurses (29). For obesity, Liu et al. and Sun et al. confirmed a significant excess risk ranging from 17% (25) and 25% (27) for shift work. Among nurses, based on four studies, Saulle et al. did not highlight any significant risk of obesity (26) whilst 2 years later, the results based on eight studies confirmed an excess risk of 12% (29). When subgroup analyses were undertaken, rotating shift work increased the risk of being overweight to 21% and the risk raised to 38% for night-shift work (25). A statistically significant increase of obesity risk was observed for rotating shift work (18%) and for night work (5%) (25). A dose-response effect was highlighted in primary studies included in Sun et al. (27) and Esquirol et al.'s (12) reviews. The density (number of nights per month) and duration of exposure increased the risk of being overweight/obesity (27): the threshold was not exactly determined but a duration of exposure of over 6 years has been put forward and a BMI gain of 0.24 kg/m$^2$ was estimated for each year of night work (Table 3).

## Hypertension

After the initial research identifying 121 articles, 108 were excluded based on title and abstract. Of the remaining 13 reviews, nine were excluded in full-text screening. Therefore,

TABLE 1 Main results of systematic reviews focused on the link between shift work and diabetes.

| References, Country | Type-Shift work (*n*) | Assessment of outcomes (*n*) | Confounding factors (*n*) | Main results shift work vs. day work (*n*) |
|---|---|---|---|---|
| Wang et al. (16), UK | Rotating (4)<br>Unspecified (2) | Type 2 diabetes (1) Diabetes mellitus (5)<br>Diabetes death certificate (1)<br>FPG or patient under treatment (1)<br>MD (4) | NA (1)<br>Adjustments (5) | Rotating: HR = 1.67 (0.57–4.90) (♂ 1); Rotating 2-shift RR = 1.73 (0.85–3.52)/Rotating 3-shift RR = 1.33 (0.74–2.36) (♂ 1)<br>Shift work: Age groups (♂ 1); (30–39 yo) OR = 6.75 (1.31–56.1); (40–49 yo) OR = 1.22 (0.68–2.10); (50–59 yo) OR = 0.93 (0.53–1.55)<br>Shift work: diabetes mortality: per year $\beta \times 10^{-5} = 4.14$ (2.46–5.81) (♂ 1)<br>Exposure duration: Rotating night ≥10 years adjusted for age: RR = 1.64 (1.11–2.37); multiple adjustment including BMI: RR = 0.98 (0.66–1.45) (♀ 1) |
| Esquirol et al. (12), France | Permanent Night (3)<br>Rotating (21)<br>Unspecified (2)<br>Evening (1) | Type 2 Diabetes (1) Diabetes mellitus (23)<br>Glycaemia (11)<br>HbA1c (8)<br>FPG (2)<br>OGTT (2)<br>RPG (1)<br>Self-reported (1)<br>Unknown (2) | NA(11)<br>Adjustments (13) | Longitudinal studies: significant effect (7):<br>Shift work: OR = 1.56 (1.18–2.05) (1); OR = 1.35 (1.05–1.75) (1)<br>Shift work duration ♂: age > 50 yo and 19–32 years exposure: 5% increase of risk (1)<br>Shift work: Glycaemia>110 mg/dL = 5.1% vs. 3.8% for DW (1)<br>Cross-Sectional studies: significant effect (4):<br>Night shift: OR = 1.7 (0.8–3.6) (1); 2-shift: OR = 2.5 (1.1–4.3) (1)<br>Longitudinal studies non-significant effect (13) |
| Knutsson and Kempe (13), Sweden | Rotating (5) | Type 2 diabetes (5)<br>Type 1 diabetes (1)<br>OGTT (1)<br>Death certificate (1)<br>Self-reported (1)<br>HbA1c (2) | NA(1)<br>Adjustments (4) | Rotating ♂: HR = 1.67 (0.59–4.90) (1); SRR = 1.24 (0.91–1.70)/SRR = 2.29 (0.97–5.40) (1) OR = 1.35 (1.05–1.75) (1)<br>2-shift ♂: RR = 1.73 (0.85–3.52) (1); 3-shift ♂: RR = 1.33 (0.74–2.36) (1)<br>Rotating duration ♂: 10–19/20–29/≥30 years: SRR = 1.41 (0.18–11.30)/1.92 (0.5– 7.32)/2.85 (1.15–7.08) (1)<br>Rotating duration ♀: 1–2/3–9/10–19/≥ 20 years: HR = 1.03 (0.98–1.08)/1.06 (1.01–1.11)/1.10 (1.02–1.18)/1.24 (1.13–1.37) (1)<br>Rotating ♀: HR per 5 years = 1.05 (1.04–1.06) (1) |
| Gan et al. (18), China Meta-analysis | Night shift (3)<br>Rotating (3 × 8) (4)<br>Mixed rotating (2 × 8/3 × 8) (2)<br>Unspecified (2) | Type 2 diabetes (4) Diabetes mellitus (7)<br>Diabetes death certificate (1)<br>Self-reported or medical/register report (10)<br>FPG (2)<br>HbA1c (2) | NA (1)<br>Adjustments (11) | Shift work: RR = 1.08 (1.05–1.12), $I^2$ 40.9% (corrected for publication bias) (11)<br>Night shift: OR = 1.09 (1.04–1.14), $I^2$ 37.6% (3)<br>Rotating shift: OR = 1.42 (1.19–1.69), $I^2$ 13.4% (4)<br>Subgroup analyses<br>Shift work: cohort studies OR = 1.12 (1.06–1.19), $I^2$ 52.9%/cross-sectional studies OR = 1.06 (1.03–1.09), $I^2$ 10.9%<br>Shift work: OR = 1.09 (1.04–1.14) for ♀, $I^2$ 54.3%/OR = 1.37 (1.20–1.56) for ♂, $I^2$ 0.0% |

*(Continued)*



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TABLE 1 (Continued)

| References, Country | Type-Shift work (*n*) | Assessment of outcomes (*n*) | Confounding factors (*n*) | Main results shift work vs. day work (*n*) |
|---|---|---|---|---|
| Proper et al. (14), Netherlands | Permanent Night (1)<br>Rotating (8) | Type 2 diabetes (2)<br>Diabetes mellitus (7)<br>Glycaemia (4)<br>OGTT (1)<br>RPG (1)<br>FPG (1)<br>HbA1c (4) | NA (2)<br>Adjutments (7) | Shift work: High FPG: age (25–29 yo) 32.9 vs. 23.1%; NS for other age classes (1)<br>HbA1c OR = 1.35 (1.05–1.75) (1)<br>Shift work: ♂ Positive relation with HbA1c; ♀ NS (1)<br>Shift work: no association with FPG (2)<br>Rotating: OR = 1.56 (1.18–2.05) (1)<br>Rotating 3-shift: OR = 2.62 (2.17–3.17); Rotating 2-shift: OR = 1.78 (1.49–2.14) (1)<br>Rotating 3-shift: RR = 1.33 (0.74–2.36); Rotating 2-shift: RR = 1.73 (0.85–3.52) (1)<br>Shift duration: OR per 10 years = 1.05 (1.01–1.09) (1) |
| Anothaisintawee et al. (17), Thailand<br>Meta-analysis | Rotating (5)<br>Unspecified (6) | Type 2 Diabetes (4)<br>Diabetes mellitus (7)<br>FPG (4), HbA1c (3)<br>OGTT (2)<br>Self-reported (4)<br>Medical diagnosis or treatment (6) | Adjustments (8)<br>Unspecified (2) | Shift work: RR = 1.40 (1.18–1.66), $I^2$ 95% (11); adjusted for BMI, other covariates RR = 1.15 (1.08–1.22) (8)<br>Rotating: RR = 1.60 (1.20–2.14), $I^2$ 97.3% (5); adjusted for BMI, other covariates RR = 1.15 (1.06–1.25) (5) |
| Li et al. (20), China<br>Meta-analysis | Permanent night (4)<br>Evening (4)<br>Rotating (5)<br>Unspecified (3) | Type 2 diabetes (2)<br>Diabetes mellitus (10)<br>Diabetes death certificate<br>Self-reported or medical/register report<br>HbA1c | Adjustment (12) | Shift work: RR = 1.12 (1.07–1.17), $I^2$ 38.9% (corrected for publication bias) (12)<br>Night/Evening shift: RR = 1.19 (1.09–1.30), $I^2$ 52.2% (4)<br>Rotating shift RR = 1.11 (1.06–1.16), $I^2$ 48.2% (5)<br>Dose-response analyses: Shift work: RR = 1.07 (1.04–1.09), $I^2$ 0% per 5-year exposure (2, ♀)<br>Subgroups analyses:<br>Shift work: RR = 1.21 (1.08–1.17) for ♀, $I^2$ 46.9%/RR = 1.28 (1.16–1.42) for ♂ (1)<br>Shift work: RR = 1.13 (1.07–1.19) for follow-up ≥10 years, $I^2$ 49.5%/RR = 1.17 (1.10–1.24) for follow-up <10 years (1) |
| Rosa et al. (15), Italy | Night shift (1) | Type 2 diabetes<br>Register (1) | MD | Night shift: HR = 1.58 (1.25–1.99) (1) |
| Gao et al. (19), China<br>Meta-analysis | Night shift (10)<br>Rotating (4)<br>Evening (2)<br>Unspecified (5) | Type 2 Diabetes (21)<br>FPG<br>HbA1c<br>OGTT<br>Random plasma glucose | NA (4)<br>Adjustments (17) | Shift work: RR = 1.10 (1.05–1.14), $I^2$ 37.2% (21)<br>Night shift: RR = 1.15 (1.08–1.24), $I^2$ 60.7% (10)<br>Rotating: RR = 1.08 (1.04–1.12), $I^2$ 0% (4)<br>Dose-response analyses (3, ♀):<br>RR = 1.05 (1.03–1.07) per 5-year exposure of shift work; RR = 1.17 (1.11–1.24) for 15 years of shift work |

(*n*), number of studies concerned; SW, shift work; FPG, Fasting plasma glucose; OGTT, Oral Glucose Tolerance Test; RPG, Random-plasma glucose; HbA1c, glycated hemoglobin MD, Missing Data; NA, non Adjusted.



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TABLE 2 Main results of systematic reviews focused on the link between shift work and lipid disorders.

| References, Country | Type - Shift work (*n*) | Assessment of outcomes (*n*) | Confounding factors (*n*) | Main results shift work vs. day work (*n*) |
|---|---|---|---|---|
| Boggild and Knutsson (21), Nordic countries | Unspecified (16) | TC (16)<br>TG (12) measurements<br>HDL/LDL (3) | MD | TC (16): no difference TC level (10); higher TC level for SW or different organizations of SW (5); lower TC for male SW, but no difference for women (1)<br>Significant changes between 3 and 20% in cholesterol (3)<br>HDL-C and LDL-C: no difference (3)<br>TG (12): No difference (8); higher TG for SW (4); higher values for counter clockwise than clockwise rotation (1) |
| Esquirol et al. (12), France | Permanent night (5)<br>Rotating (18)<br>Unspecified (2) | TC (13)<br>TG (6)<br>HDL (8)<br>LDL (6) measurements,<br>HighTG (6)<br>LowHDL (6)<br>HighTC (3)<br>Self-reported highTC (1) | NA (8)<br>Adjustments (15) | TC: Longitudinal studies:<br>- no difference of Hypercholesterolemia (5); higher hypercholesterolemia in SW (2)<br>- TC mean increase in SW (1)<br>- TC level raised 14 years later ≥20/≥25/≥30/≥40%; OR = 1.16 (1.07–1.26)/1.16 (1.05–1.28)/1.11 (0.98–1.25)/1.30 (1.07–1.58) (2)<br>- Exposure duration: a 5% risk of 20% increase TC for SW > = 20 years (1); increase of TC level with exposure duration for SW ♂ ≥30 y but not ♀ ≥30 y SW (1)<br>TC: Cross-sectional studies: no difference of Hypercholesterolemia (5); higher Hypercholesterolemia in SW (1)<br>HDL-C: no difference of hypoHDLemia (7); higher hypoHDLemia (5)<br>LDL-C: no difference of LDLemia (5)<br>TG: no difference of Hypertriglyceridemia (3); higher hypertriglyceridemia in SW (6) |
| Proper et al. (14), Netherlands | Permanent night (1)<br>Rotating (8)<br>Unspecified (3) | TC (7)<br>TG (4)<br>HDL (3)<br>LDL (1) measurements,<br>HighTG (3)<br>LowHDL (3)<br>HighTC (1)<br>LDL/HDL (1) | NA (3)<br>Adjustments (9) | TC: higher TC level (5); no difference of TC (5)<br>HDL-C, LDL-C, TG: positive association (5); no difference (5) |
| Dutheil et al. (22), France<br>Meta-analysis | Permanent night<br>Rotating<br>Unspecified | SMD or high level of TC, LDL, low level of HDL | NA for main results | TC increase: Only permanent night shift: SMD = 0.22 (0.01–0.42) $p = 0.043$, $I^2$ 60.3% (4)<br>Hypercholesterolemia: NS results<br>HDL-C decrease: Permanent night shift: SMD = −0.16 (−0.32 to 0.00), $p = 0.05$, $I^2$ 72.3%; Rotating 3 × 8 shift SMD = −0.10 (−0.17 to −0.02), $p = 0.01$, $I^2$ 78.8%; Non-specified shift: SMD = −0.08 (−0.15 to −0.01), $p = 0.027$, $I^2$ 81.7%;<br>HypoHDLemia: NS results<br>LDL-C increase: NS results<br>TG increase: permanent night shift SMD = 0.18 (0.03–0.33), $p = 0.017$, $I^2$ 73.8% (7); Rotating 3 × 8 shift SMD = 0.09 (0.03–0.16), $p = 0.004$, $I^2$ 73.6% (21)<br>Rotating 2 × 12 shift: SMD = 0.07 (0.01–0.13), $p = 0.017$, 31.6% (11); Unspecified shift SMD = 0.11 (0.03–0.18), $p = 0.004$, $I^2$ 80.9% (12)<br>Hypertriglyceridemia: OR = 1.12 (1.01–1.23), $p < 0.001$, $I^2$ 55.2% |

(*n*), number of studies concerned; SW, shift work; HDL-C, High-Density Lipoprotein Cholesterol; LDL-C, Low-Density Lipoprotein Cholesterol; TC, Total Cholesterol; TG, Total Triglycerides; SMD, standardized mean difference; MD, Missing Data; NA, Non Adjusted.





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TABLE 3 Main results of systematic reviews focused on the link between shift work and being overweight.

| References, Country | Type -Shift work (*n*) | Assessment of outcomes (*n*) | Confounding factors (*n*) | Main results shift work vs. day work (*n*) | |
|---|---|---|---|---|---|
| Antunes et al. (24), Brazil | Night shift (1)<br>Rotating (3)<br>Unspecified (5) | BMI (8)<br>BMI ≥25 kg/m² (1)<br>WHR (5) | Adjustments (4)<br>MD (5) | **Significant higher weight (9):**<br>Shift work: higher BMI (♂, 1); increase BMI and WHR (♂, 1)<br>Night shift: higher BMI (♂, 1); Rotating: increase BMI and WHR (♂, 1)<br>3-shift: higher WHR (♂, 1) | **Shift duration:** correlation with BMI (1); ♀ ≥ 30 yo, higher WHR (1); increase BMI and WHR (1)<br>Rotating duration: correlation $r = 0.19$, $p < 0.05$ with BMI (♂, 1)<br>No significant weight difference (1): 3-shift: no difference BMI (♂, 1) |
| Esquirol et al. (12), France | Permanent night (3)<br>Rotating (18)<br>Unspecified (1) | Weight change (2)<br>BMI (15);<br>BMI ≥ 25 or ≥ 30 kg/m² (4)<br>WC (3); WC ≥ 80 or ≥ 94 cm (2)<br>WHR (6); WHR > 0.9 (1) | NA (12)<br>Adjustments (10) | **Threshold values of weight (5):** Shift work: prevalence obesity, 9.6% vs. 8.5%, $p < 0.004$ (♀, 1)<br>Shift work: BMI ≥30 kg/m², ♀ OR = 1.39 (1.25–1.55); ♂ OR = 1.44 (1.27–1.64) (1)<br>Rotating: OR = 1.12 (0.88–1.42) for WC ≥ 94 cm (♂, 1)<br>Rotating: prevalence of obesity NS; WHR > 0.9 OR = 1.19 (0.92–1.56) (♂, 1)<br>12 h-permanent night: BMI ≥25 kg/m², OR = 2.7 (1.6–4.5); WC ≥80 cm OR = 2.9 (1.7–5.1) (♀, 1)<br>**Continuous variables (1):**<br>Shift work: higher WC or BMI (9); Rotating: lower BMI (♂, 2)<br>Shift work: no significant difference (♂, 2) | **Duration (5):**<br>Rotating: BMI increase, 0.89 vs. 0.62 kg/m², $p < 0.05$ after 10-year exposure (♂, 1)<br>Rotating: correlation $r = 0.19$, $p < 0.05$ with BMI (♂, 1)<br>Night: weight gain since starting the job on current shift, + 4.3 vs. 0.9 kg, $p < 0.02$ (♀, 1)<br>Shift work: significant 1-year follow-up decrease of BMI (1)<br>Rotating: BMI no difference (1) |
| van Drongelen et al. (28), The Netherlands | Permanent night (2)<br>Rotating (5)<br>Unspecified (2) | BMI change (4)<br>Weight change (4)<br>WC change (2) | NA (2)<br>Adjustments (6) | **BMI change:** significant effect (3)<br>Shift work: 10-year FU ΔBMI, mean: 0.89 vs. 0.62, $p = 0.001$ (1)<br>Rotating: 1-year FU ΔBMI, %: 0.63 vs. 0.40, $p = 0.002$ (1)<br>Rotating: 1-year FU ΔBMI, mean: −0.33 vs. 0.07, $p = 0.01$ (1)<br>**BMI change**: NS effect (1): Shift work: 5-year FU ΔBMI: −0.05 (95% CI −0.024 to 0.15), $p = 0.63$ (1)<br>**Weight change:** significant effect (2): Shift work: 1-year FU Δweight, mean: −1.02 vs. 0.28 kg, $p = 0.007$ (1)<br>Permanent night: FU unknown: Δweight, mean: 4.4 vs. 0.7 kg, $p = 0.008$ (1) | **Weight change:** NS effect (2): Shift work: 5-year FU, Correlation coefficient, $p$ = NS (1)<br>Rotating: 1-year FU Δ weight mean: 3-day rotating 0.73, 5-day rotating shift 0.89 kg vs. 1.02 kg, $p$ = NS (1)<br>**WC change:** NS effect (2): Rotating: 1-year FU ΔWHR mean:−0.0102 vs. −0.0053, $p = 0.25$ (1)<br>Rotating: 1.5-year FU ΔWC−0.1 vs. +0,2 cm, $p$ = NS (1) |

*(Continued)*





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TABLE 3 (Continued)

| References, Country | Type -Shift work (*n*) | Assessment of outcomes (*n*) | Confounding factors (*n*) | Main results shift work vs. day work (*n*) | |
|---|---|---|---|---|---|
| Amani and Gill (23), Iran | Night shift (1)<br>Rotating (4)<br>Unspecified (4) | BMI ≥ 30 or ≥ 25 or ≥ 27 kg/m² (5);<br>Weight change (1);<br>BMI (4) | NA (4)<br>Adjustments (5) | Significant higher weight (7):<br>Shift work: higher BMI (♂, 2)<br>Shift work: overweight OR = 1.60 (1.28–2.06) (♀ 1);<br>OR = 1.54 (1.06–2.25) (♀, 1)<br>Shift work: higher obesity prevalence (♂, 1)<br>Shift work: obesity significant OR = 1.4 (1) | Rotating duration: significant correlation $r = 0.19$, $p < 0.05$ with BMI (♂, 1)<br>Night shift: overweight OR = 3.3 (1.3–8.2); 5-year weight gain > 7 kg: OR = 2.9 (1.2–6.9) (♀, 1)<br>3-shift: higher WHR (♂, 1)<br>Shift work: significant 1-year follow-up decrease of BMI (1)<br>No significant weight difference (2) |
| Proper et al. (14), Netherlands | Night shift (5)<br>Rotating (12)<br>Unspecified (5) | Weight change (3)<br>BMI (10);<br>BMI ≥25 or ≥ 30 kg/m² (5)<br>WC (2); WC ≥ 80 or ≥ 94 cm (2)<br>WHR (2) | NA(2)<br>Adjustments (17) | Shift work:<br>BMI or weight: positive relation (10); negative relation (1); no relation (4)<br>WC: positive relation (2); negative relation (0); no relation (2)<br>Obesity: positive relation (7); negative relation (0); no relation (3) | |
| Liu et al. (25), China Meta-analysis | Night shift (5)<br>Rotating shift (18)<br>Unspecified (4) | BMI ≥ 25 or ≥ 23 kg/m² (11);<br>WC ≥ 94 cm (1)<br>BMI ≥ 25 or ≥ 30 kg/m² (23);<br>Total fat % (1); ICD-10 (1) | Adjustments (27) | **Overweight:**<br>Shift work: RR = 1.25 (1.08–1.44), $I^2$ 80.7% (12)<br>Rotating shift: RR = 1.21 (1.02–1.43), $I^2$ 73.2% (8)<br>Night shift: RR = 1.38 (1.06–1.80), $I^2$ 28.5% (5)<br>Shift work: RR = 1.14 (0.97–1.35), $I^2$ 84.3% (♀, 6); RR = 1.46 (0.98–2.15), $I^2$ 51.2% (♂, 5) | **Obesity:**<br>Shift work: RR = 1.17 (1.12–1.22), $I^2$ 92.2% (23)<br>Rotating shift: RR = 1.18 (1.08–1.29), $I^2$ 91.7% (17)<br>Night shift: RR = 1.05 (1.00–1.10), $I^2$ 81.0% (7)<br>Shift work: RR = 1.19 (1.06–1.34), $I^2$ 90.8% (♀, 13)/RR = 1.27 (1.10–1.46), $I^2$ 81.9% (♂, 9) |
| Saulle et al. (26), Italy Meta-analysis | Unspecified (7) | BMI> 25 or > 30 kg/m² (4)<br>BMI (2)<br>WC (1) | MD | Shift Work: BMI >30 kg/m²: OR = 1.00 (0.66–1.50), $I^2$ 74.5% (nurses) (4) | |
| Sun et al. (27), China Meta-analysis | Night shift (15)<br>Rotating (16)<br>Unspecified (4) | Weight/BMI gain (2)<br>BMI ≥ 25 or 25–29.9 or ≥30 kg/m² (28)<br>WC or WHR (9) | NA (3)<br>Adjustments (25) | **For obesity/overweight**<br>Overall shift: OR = 1.23 (1.17–1.29), $I^2$ 90.7% (28)<br>Rotating: OR 1.14 (1.05–1.23), $I^2$ 67.5% (15)<br>Permanent night: OR = 1.43 (1.19–1.71), $I^2$ 70.8% (7)<br>Shift work: BMI ≥25 kg/m²: OR = 1.32 (1.15–1.51), $I^2$ 72.9% (14)<br>BMI ≥30 kg/m²: OR = 1.25 (1.11–1.45), $I^2$ 95.9% (11) | Dose-response (frequency and duration) (4)<br>Trend toward obesity risk with the increase of night shifts per month (2)<br>Night shift: BMI ≥30 kg/m²: ≥21 nights/month OR = 3.42 (1.95–6.03) (1); ≥8 nights/month: OR = 3.9 (1.5–9.9) (1)<br>Night shift: WHR ≥0.85, ≥8 nights/month OR = 2.4 (1.2–4.9) (1)<br>Increase of BMI per year of night: 0.24 (0.12–0.37) kg/m² (1) |
| Zhang et al. (29), China Meta-analysis | Night shift (5)<br>Shift work (6) | BMI ≥25 or ≥30 or >30 kg/m² (10)<br>WC ≥80 cm or WC ≥88 cm (2) | MD | **For obesity/overweight**<br>Overall shift: OR = 1.05 (0.97–1.14), $I^2$ 0.% (11)<br>Shift work: OR = 0.99 (0.59–1.38), $I^2$ 52.9% (6)<br>Night shift: OR = 1.12 (1.03–1.21), $I^2$ 97.2% (5) | Shift work: BMI ≥25 kg/m² OR = 0.95 (0.24–1.14), $I^2$ 81.8% (2)<br>Shift work: BMI ≥30 kg/m² OR = 1.12 (1.03–1.20), $I^2$ 95.1% (8)<br>Shift work: WC ≥80 cm OR = 3.21 (1.29–7.98) (1)<br>Shift work, ♀: OR = 1.09 (0.84–1.35), $I^2$ 96.1% (7) |

(*n*), number of studies concerned; SW, shift work; BMI, Body Mass Index; WHR, Waist Hip Ratio; WC, Waist circumference; NS, Non Significant MD, Missing Data; FU, Follow-up; NA, Non Adjusted.





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four reviews were eligible papers: two systematic reviews with meta-analysis (30, 31), two without meta-analysis (12, 14) (Supplementary Figure A).

The quality of the included systematic reviews, assessed using AMSTAR-2 (Figure 1), was high for the latest reviews with meta-analysis (30, 31), with the highest level for Gamboa Madeira et al. in 2021 (30). In most reviews, the inclusion and exclusion criteria (12, 14, 30, 31), the study selection and the data extraction (14, 30, 31) were clearly stated. The search strategies were incomplete in the four systematic reviews and the included primary studies were partially described. The risk of bias was assessed in the primary studies of most reviews (14, 30, 31).

Only two primary studies overlapped in Manohar and Gamboa Madeira's systematic reviews with meta-analyses.

Supplementary Table F provides an overview of the characteristics of the included systematic reviews. The four systematic reviews were published from 2011 to 2021, gathering primary studies published between 1986 and 2015. These primary studies were conducted in Africa, Americas, Asia, and Europe. The number of studies included in each systematic review ranged from 19 to 45. Finally, 81 unique primary studies addressed the question about shift work and hypertension. The risk of hypertension was examined by using either referenced threshold values or change in systolic and diastolic blood pressure.

An elevated risk of hypertension for rotating shift work with or without night shift was observed and estimated at 1.34 (1.08–1.67) (31) and 1.26 (0.94–1.68) (30). Gamboa Madeira et al. estimated a significantly positive magnitude of blood pressure (BP) change for: (1) permanent night shifts (increased systolic BP (SBP) of 2.52/diastolic BP (BP) of 1.76 mmHg); (2) rotating shifts with nights (increased SBP of 0.65 mmHg); (3) rotating shifts without nights (increased SBP of 1.28 mmHg) in comparison to day workers (30) (Table 4).

## Smoking habits

Out of the 60 articles identified in the initial research, 52 were excluded based on title and abstract (Supplementary Figure A). Of the eight reviews potentially eligible for inclusion, six were excluded in full-text screening mainly due to the absence of estimated risk between shift work and smoking habits. Therefore, two systematic reviews without meta-analysis were included (21, 32).

Zhao's systematic review fulfilled most of the AMSTAR-2 criteria (Figure 1).

The two systematic reviews covered 23 primary studies (17 cross-sectional and six prospective) published from 1976 to 2004, without overlapped studies (Supplementary Table G).

Participant details (sex, age, and occupation), countries, and type of shift work were missing in Boggild and Knutsson's (21). The seven primary studies included in Zhao's were conducted in Europe (3) and Asia (1), among different types of shift workers in various occupational sectors (32).

Fifty percentage of the 23 primary studies reported a significantly higher tobacco consumption in shift workers in comparison to day workers (21, 32), with a potential effect during the first year of shift work (32) (Table 5).

## Occupational psychosocial stressors

After reading the full text of 20 reviews, three were finally considered for this purpose (Supplementry Figure A): one systematic review (33) and two systematic reviews with meta-analyses (34, 35).

The quality criteria were met for all the considered reviews (56–77% of criteria met), especially the one of Taghighi (Figure 1). Item no. 4 (comprehensive literature search) was partially met. As previously underlined, the criteria related to an *a priori* registered protocol (item no. 2), to the justification of excluded studies (item no. 7) and to the reporting on the sources of funding for the studies included (item no. 10) were almost never provided.

Supplementary Table H summarized the main characteristics of the three selected reviews (33–35).

Firstly, Taghighi et al. focused on the psychological functioning and resilience of nurses who carry out shift work. The authors selected 37 primary qualitative and quantitative studies, with comparison to day workers (17 studies) and between different types of shift work (20 studies) (33). Most were quantitative and cross-sectional studies. Psychological functioning was measured using different outcomes: (a) general psychological wellbeing or quality of life, (b) depression, anxiety or stress and (c) job satisfaction or burnout. The synthesis of the different results revealed that shift work seemed to limit social life and to be associated with work/family conflict, low levels of wellbeing, poor mental health and high levels of burnout. However, the authors could not definitively come to a conclusion, because these significantly negative effects of shift work were only observed in several studies and contrasted based on the different types of night-shift work.

Secondly, based on workers from different job sectors, the two systematic reviews with meta-analyses examined the impact of night-shift work on mental health defined as depression or psychological distress using standardized questionnaires or psychiatric diagnoses (34, 35). Angerer et al. considered 11 prospective studies published between 1989 and 2015 (34). Zhao et al. mixed cross-sectional ($n = 22$) and longitudinal ($n = 11$) primary studies published during 2002–2017 and included mainly shift workers using surveys from the general working population (35).

From the five longitudinal studies, Angerer et al. reported a non-statistically significant elevated meta RR for depression of 1.42 (0.92–2.19) for shift workers vs. day workers. The results

TABLE 4 Main results of systematic reviews focused on the link between shift work and hypertension.

| References, Country | Type - Shift work (*n*) | Assessment of outcomes (*n*) | Confounding factors (*n*) | Main results shift work vs. day work (*n*) |
|---|---|---|---|---|
| Esquirol et al. (12), France | Permanent night (5)<br>Rotating (33)<br>Evening (2) | HTN (13)<br>BP measures (14)<br>24-h Ambulatory BP (5)<br>HTN history (2) | NA (15)<br>Adjustments (19) | **Longitudinal studies**:<br>Shift work: HTN OR = 1.10 (1.01–1.20) (1); progression from mild to severe HTN OR = 1.23 (1.05–1.44) (1)<br>Shift work: raised systolic or diastolic BP: significantly (3), no difference (7)<br>Sub-group analyses:<br>- Age and Shift work: 30–39 yo (NS); 40–49 yo OR = 1.62 (1.17–2.24); 50–59 yo (NS) (1)<br>- Duration and shift work: ♂ ≥30 yo: SW duration positively associated with SBP ($p < 0.05$);<br>♀ <30 yo: SW duration inversely associated with DBP ($p < 0.05$) (1);<br>SBP and DBP associated with duration of SW ($p < 0.05$); BP fell morning to afternoon to night ($p = 0.03$) (1)<br>- Shift work after 1-year follow-up: NS change in BP (1) |
| Proper et al. (14), Netherlands | Permanent night (1)<br>Rotating (13)<br>Unspecified (5) | HTN (11)<br>BP mesures (7)<br>Self-reported (3)<br>Register (1) | NA (2)<br>Adjustments (15)<br>Unspecified (2) | Shift work: significant increased risk of HTN (9); NS (6)<br>Permanent night: HTN OR = 0.9 (0.6–1.2) (1)<br>Shift work: significant elevated risk of increased BP (1); NS (6) |
| Manohar et al. (31), USA Meta-analysis | Rotating (18)<br>Permanent night (4)<br>Irregular (2)<br>Unspecified (4) | HTN (18)<br>Self-reported BP (7)<br>BP measures (1)<br>MD (1) | NA (2)<br>Adjustments (25) | Shift work: cohort studies: HTN pooled OR = 1.31 (1.07–1.60), $I^2$ 90%; cross-sectional studies: HTN pooled OR = 1.10 (1.00–1.20), $I^2$ 85%<br>Rotating: cohort studies: HTN pooled OR = 1.34 (1.08–1.67), $I^2$ 91%<br>Permanent night: cross sectional studies: HTN pooled OR = 1.07 (0.85–1.35), $I^2$ 83%<br>Sub-group analyses:<br>Rotating: cohort studies HTN ♂ pooled OR = 1.21 (1.04–1.40), $I^2$ 63%; HTN ♀ pooled OR = 1.01 (0.70–1.44), $I^2$ 14%<br>Permanent night: cross-sectional studies ♀ pooled OR = 1.07 (0.88–1.30), $I^2$ 66% |
| Gamboa Madeira et al. (31), Portugal Meta-analysis | Permanent night (14)<br>Rotating with night (30)<br>without night (4)<br>Unspecified (8) | HTN (14)<br>BP measures (41) | NA (32)<br>Adjustements (13) | Rotating with night: HTN pooled OR = 1.26 (0.94–1.68), $I^2$ 90% (8)<br>Rotating without night: HTN OR = 1.00 (0.88–1.15) (1)<br>Permanent night: HTN pooled OR = 1.00 (0.80–1.27), $I^2$ 35% (6)<br>Permanent night: increase mean difference SBP = 2.52 mmHg (0.75–4.29), $I^2$ 91% (12); DBP = 1.76 mmHg (0.41–3.12), $I^2$ 93% (12)<br>Rotating with night: increase mean difference SBP = 0.65 mmHg (0.07–1.22), $I^2$ 69% (28); DBP = 0.12 mmHg (−0.31 to 0.54), $I^2$ 65% (25)<br>Rotating without night: increase mean difference SBP = 1.28 mmHg (0.18–2.39), $I^2$ 93% (4); DBP = 0.60 mHg (−0.24 to 1.43), $I^2$ 92% (4) |

(*n*), number of studies concerned; HTN, Hypertension; SBP and DBP, Systolic and Diastolic Blood Pressure; MD, Missing Data; NA, Non adjusted; NS, Non significant.



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TABLE 5 Main results of systematic reviews focused on the link between shift work and smoking habits.

| References, Country | Type - Shift work (*n*) | Assessment of outcomes (*n*) | Confounding factors (*n*) | Main results shift work vs. day work (*n*) |
|---|---|---|---|---|
| Boggild and Knutsson (21), Nordic countries | Unspecified (16) | Smokers, % (14)<br>Cigarettes/day (2) | NA | Tobacco consumption:<br>- Cross sectional studies: Significantly higher (6), lower (1), no difference (5)<br>- Prospective studies: at baseline of studies: higher (2);<br>After 6-months follow-up, no difference of number of new smokers and no change habits (1) |
| Zhao and Turner (32), Australia | Permanent night (2)<br>Rotating (2)<br>Evening (1)<br>Unspecified (3) | Smokers, % (5)<br>Cigarettes/day (2) | Adjustments (1)<br>MD (6) | - Shift work: current smokers OR = 1.3 (1.1–1.6) (1)<br>- Rotating shift: current smokers: 40 vs. 34.3%, $p = 0.058$ (1); % of every day smokers: NS (1)<br>- Permanent night: more likely to smoke and smoked significantly ($p < 0.01$) more cigarettes/day (1)<br>- Shift work: significantly higher tobacco consumption, $p = 0.027$ (1)<br>- Shift work: after 1-year follow-up, significantly higher number of cigarettes/day (1) |

(*n*), Number of studies concerned; MD, Missing Data; NA, Non Adjusted; NS, Non Significant.

differentiated according to the type of working populations: two out of the three reports from the same study in nurses did not confirm an increased risk of depression in those who work shifts, whereas four out of the six studies conducted in the general working population suggested such relationship (34). This conclusion was in line with results of Zhao et al. (35): with shift work defined as a broad binary indicator and based on four longitudinal studies, the authors revealed an excess risk of mental health problems in shift workers compared to non-shift workers [meta OR = 1.32 (1.01–1.73)]. The authors reported inconclusive results about gender differences, even if some studies provided evidence of more vulnerability to shift work in females. Finally, when considering shift work as night or evening work, only two out of six cross-sectional and three out of six longitudinal studies showed a significant association between shift work and poor mental health (35) (Table 6).

## Sedentariness

Until September 2021, none of the 122 reviews addressed the relationship between shift work and sedentariness after applying the eligibility criteria (Supplementary Figure A). However, when updating to September 2022, two systematic reviews were retrieved: one with meta-analysis (36) and one without meta-analysis (37) (Supplementary Table I).

The quality of the included systematic reviews was moderate. While the inclusion and exclusion criteria, the study selection, and the data extraction were well-described, the risk of bias was not assessed.

Only one primary study was included in both systematic reviews.

The two systematic reviews gathered 52 primary studies (49 in Monnaatsie et al. and three in Crowther et al.) among workers from different job sectors covering the period 2001–2021. The total number of participants for these systematic reviews varied from 29,701 to 310,710.

In the meta-analysis, Monnaatsie et al. studied the prevalence of meeting physical activity guidelines, time spent in moderate-to-vigorous physical activity and in sedentary behavior (36). No significant difference was found in the prevalence of meeting physical activity guidelines and for the time spent in moderate-to-vigorous physical activity among shift-workers compared to non-shift workers. Time spent in sedentary behavior was lower in shift workers than non-shift workers [SMD = −0.2 (−0.50; −0.001)] (Table 7).

# Discussion

## Main findings

A comprehensive synthesis of the main findings from the 33 included systematic reviews, structured around the type of cardiovascular risk factors was conducted. From this umbrella review, which aimed to evaluate the existing evidence on the effect of night-shift work and its subtypes on cardiovascular risk factors, the key findings can be displayed as two categories: well-established results and those that require further research (Graphical Abstract).

The results asserted an excess risk of diabetes at around 10%, regardless of the type of night-shift work, with a suspected dose-response effect in women (increased risk of 5–7% every 5 years). A stated excess risk of being overweight at around 25% was also reported for overall shift workers; and it could reach 38%

TABLE 6 Main results of systematic reviews focused on the link between shift work and occupational psychosocial stressors.

| References, Country | Type - Shift work (*n*) | Assessment of outcomes (*n*) | Confounding factors (*n*) | Main results shift work vs. day work (*n*) |
|---|---|---|---|---|
| Angerer et al. (34), Germany<br>Meta-analysis | Permanent night (5)<br>Rotating (11)<br>Irregular (2) | **Depression:** GHQ-12; HADS; COPSOQ; Prescriptions of antidepressants; Psychiatric interview; ICD | Adjustments (11) | **Depression**: Shift work: pooled OR = 1.42 (0.92–2.19), $I^2$ 74.4% (5); Shift work with autonomy in their schedule planning: lower risk of depressive symptoms (1) |
| Tahghighi et al. (33), Australia | Shift work (5)<br>Rotating (28)<br>Permanent night (17) | **Wellbeing/Quality of Life**: 1 item measure of wellbeing; Scale of the negative effects of work time; Conflict between work and family rating scale; Chinese health questionnaire 12-item; WHOQOL-BREF<br>**Job satisfaction:** Job satisfaction scales; Standard shift work index questionnaire; Job, family and life satisfaction scale<br>**Burnout:** MBI; CBI; Job stress questionnaire from the Korean occupational stress scale<br>**Depression, Anxiety and Stress:** NSS; BDI-II; CES-D; PHQ-9; HAD-S; Taiwan nurse stress checklist; STAI-Y; Profile of mood states; GHQ-12<br>**Resilience and Coping**: Coping questionnaire; Hardiness and resilience Scales | MD | **Wellbeing/Quality of Life (8)**: Association between Shift work and poor quality of life and low psychological wellbeing, dependent on the type of shifts<br>**Job satisfaction/Burnout (11):** Higher rates of burnout in the shift workers (5); Impact of different types of shift work on job satisfaction and burnout: mixed results (6)<br>**Depression, Anxiety and Stress (17):** inconsistent results<br>**Resilience and Coping (9):** inconsistent results |
| Zhao et al. (35), Australia<br>Meta-analysis | Shift work (12)<br>Rotating (5)<br>Permanent night or evening (12)<br>Irregular (14) | **General mental health**: Kessler-6 (4); SF-36/SF-12 (7); GHQ-12 (5); ILfeld psychiatric symptoms index (3)<br>**Depression:** CES-D (8); BDI (3); WHO wellbeing scale (3); NHP (1); CIDI-SF (1); PHQ-9 (1); HAD-S (1); STAI-Y (1) | NA (6)<br>Adjustments (27) | **Mental health problems:** Shift work: OR = 1.32 (1.01–1.73), $I^2$ 63% (4); Night/Evening work: significant association (5/12) |

(*n*), number of studies concerned; MD, missing data; NA, non adjusted.



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TABLE 7 Main results of systematic reviews focused on the link between shift work and sedentariness.

| References, Country | Type - Shift work (*n*) | Assessment of outcomes (*n*) | Confounding factors (*n*) | Main results shift work vs. day work (*n*) |
|---|---|---|---|---|
| Monnaatsie et al. (36), Australia Meta-analysis | Shift work (26)<br>Rotating (13)<br>Night (25) | IPAQ (9)<br>Other questionnaire (22)<br>Self-report (3)<br>Actigraph (14)<br>Accelerometer (3)<br>Calorie counter (1) | MD (49) | Meeting physical activity guidelines: shift work: 8–63.4%/non-shift work 3–67.7%; OR = 0.84 (0.68–1.03), $I^2$ 93.3% (12)<br>Time spent in physical activity/day: shift work 13.2%/non-shift work 14.2%, NS; SMD = −0.1 (−0.4 to 0.2), $I^2$ 98.8% (12)<br>Time spent in sedentary behavior/day: shift work 37.0%/non-shift work 39.0%; SMD = −0.2 (−0.5 to −0.001) (7) |
| Crowther et al. (37), Australia | Permanent night (2)<br>Rotating (3) | Questionnaire (3) | NA (3) | Shift work:<br>14–19% inactive (1)<br>Significant increase physical inactivity over time (1)<br>No significant change in physical activity over time (1) |

(*n*), number of studies concerned; MD, missing data; NA, non adjusted; NS, non significant.

among night-shift workers. When it comes to obesity, elevated risks estimated at 5% for night-shift workers and at 18% for rotating shift workers were observed, with an increase of this risk based on the density and duration of exposure. An excess risk of hypertension was estimated at around 30% when the broad definition of shift work was considered and when night periods were included in rotating shift work.

Literature provided inconsistent results for the relationship between lipid disorders (total cholesterol, HDL-C, LDL-C) and night-shift work, with a probable variation according to the type of shift work (lower HDL-C level among permanent and rotating night-shift workers). Although no clear conclusion can be drawn, shift workers appeared to be more likely to smoke. The relationship between shift work and occupational psychosocial stressors was scarcely explored in available studies. However, the consequences of night-shift work on mental health disorders (depression, in particular) were further investigated, with an increased risk of depression at 32–42%. Finally, the sedentariness was scarcely considered in systematic reviews, which prevents any firm conclusions.

One previous umbrella review, conducted on systematic reviews with meta-analyses published until April 2019, aimed to assess the relationship between shift work or long working hours and various chronic health conditions (38). Only three cardiovascular risk factors of interest were considered in this umbrella review. The authors found very low-grade evidence concerning the relationship between shift work and diabetes mellitus (based on two systematic reviews with meta-analysis), obesity (four systematic reviews with meta-analysis) and hypertension (one systematic review with meta-analysis). Another umbrella review conducted on systematic reviews with or without meta-analyses published until April 2020, aimed not only to summarize the evidence but also to assess the validity of the associations of shift work with different health outcomes (39). Diabetes mellitus incidence was the only health outcome in common with our umbrella review. Based only on the results of Li et al. meta-analysis (20), Wu et al. concluded to highly suggestive evidence for association between shift work and diabetes mellitus incidence (39). Our umbrella review specifically focused on cardiovascular risk factors, retained a higher number of systematic reviews with or without meta-analyses, and deeply investigated the specific effect of night-shift work and its different subtypes (permanent or rotating). Thus, considering five systematic reviews (12–16) and four meta-analyses (17–20) reinforced the evidence of the association between night-shift work and diabetes, and provided a more comprehensive and detailed overview of cardiovascular risk profile of night-shift work.

## Assessment of night-shift work

In recent years, the primary studies tended to progress on a homogeneous definition of night-shift work. However, some reviews included in this umbrella highlighted the difficulties to compare results across studies due to inconsistent definitions of night-shift work (mixed rotating, irregular, evening, unspecified) (20, 25, 27, 29). The lack of detailed characteristics of night-shift work was also observed. Few studies assessed exposure parameters such as cumulative duration of exposure of night work alongside working life, average number of night shifts per month, number of consecutive nights per shift period and direction of rotation (clockwise and counter clockwise). Therefore, the dose-response effect cannot be determined.

Information on work schedules were obtained by different sources in the primary studies included in the reviews (14, 17–19). Data of work schedules were reported from the workers through self-administered questionnaires or from other sources such as payment records, employment records, or a list of job titles and workplace characteristics. In the case of self-administered questionnaires, several studies assessed exposure to shift work based on simple questions such as, "do you do shift work?" or "ever worked a night shift?" Other studies sought to distinguish permanent night shift from rotating night shift by asking the following question: "do you normally work (a) day, (b) evening, (c) night or (d) rotating shifts?"

In 2011, the IARC Working Group (cancer research) published recommendations to improve exposure to shift work in a consensus report (40). The authors notably pointed out the need to consider at least 3 h of work between midnight and 5 a.m. as a preliminary criterion in the definition of night work.

To our knowledge, the effects of former night-shift work have not been studied as a specific topic in systematic reviews. It may be worth considering in new synthesis works.

## Assessment of outcomes

As is usually done, the cardiovascular risk factors were reported from self-questionnaires, medical reports or clinical and biological measurements used as continuous values or according to established referenced thresholds.

With regards to diabetes, since all primary studies included in the reviews were conducted in adults, it could be assumed that diabetes was mostly type 2. Apart from two systematic reviews (15, 19), diabetes was not clearly specified as type 2, in particular when self-reports or death certificates were used. Moreover, when biological markers were used, the diagnosis of diabetes was based on several tests including glycaemia, HbA1c, OGTT, and random plasma glucose. The different definitions of the diabetes outcome may have introduced heterogeneity across the studies. However, the relationship was confirmed when Gan et al. conducted a subgroup analysis by restricting to studies that specified the type of outcome as type 2 diabetes (18).

With regards to being overweight/obesity, although this has been little explored in primary studies, the relationships between shift work and waist circumference were consistent with those observed when BMI was used (an increased risk of being overweight/obesity in night-shift workers). Moreover, some authors explored the time-varying weight gain, but this was done insufficiently to be able to determine the exposure duration threshold.

In addition to the 30% excess risk of hypertension observed when considering the referenced thresholds, mean differences of BP were used to explore the effect of night-shift work in Gambao Madeira's meta-analysis (30). A significant increase of a pooled mean difference of SBP was observed among permanent night workers (2.52 mmHg) and workers in rotating shift with nights (0.65 mmHg) compared to day workers. It is well-known that reductions in usual SBP levels of only 2 mmHg result in a 7–10% decrease of cardiovascular mortality in middle-aged people (41). In addition, given the BP nycthemeral cycle, the hour of BP measurement on the 24 h-period is important to mention for shift workers in the systematic reviews.

While significant mean differences were observed for the levels of triglyceride and HDL-C between night-shift workers and day workers, the results about lipid disorders estimated by referenced thresholds, were inconsistent in the systematic reviews.

Some of these cardiovascular risk factors are components of the metabolic syndrome (MetS). Two meta-analyses assessed significant increased risks of MetS, estimated at 57% for those exposed to night shift work, 31% for rotating shift workers and 28% for permanent night workers (42, 43). From a prevention point of view, knowledge on constitutive elements is more informative than the ultimate outcome.

Monnaatsie et al. reported similar levels of total physical activity among shift and day workers. They assumed that shift workers might report higher level of occupational physical activity and day workers higher level of leisure-time physical activity (36). Nevertheless, to clarify in particular the role of occupational physical activity, further research is needed.

In relation to the psychosocial stress pathway, the three systematic reviews selected in this umbrella review aimed to determine the relationship between night-shift work and psychological functioning in nurses (33) or in the working population in general (34, 35). Most of psychological outcomes reported in these systematic reviews were assessed with proxies of stress (i.e., psychological wellbeing, quality of life) or focused on consequences of stress (depression, burnout, job satisfaction), rather than with an assessment of occupational psychosocial stressors. Few authors reported that night workers had less autonomy and more conflict at work than day workers (44), while others observed that permanent night workers were more often satisfied with their co-workers and autonomy at work, although were more often confronted with workplace violence (45). Recently, Tucker et al. suggested that, despite notable differences in psychosocial working conditions between night and day workers, chronic disruption of circadian rhythms and sleep may play a more important role than psychosocial working conditions in explaining the observed significant health effects (symptoms of depression in men and short-term sick leave in women) (46). Thus, the psychosocial stress pathway requires further studies, focusing on occupational psychosocial stressors.

## Mechanisms

The pathophysiological mechanisms to explain the associations between shift work and cardiovascular risk factors are based on several complex and interrelated pathways. One most documented explanatory mechanism concerns a direct effect of the unusual schedule pattern, to which shift workers are subjected, on the internal hypothalamic clock that manages the alternation of periods of wakefulness and sleep and secondary internal clocks (i.e., located in the heart, adipose tissue, kidney, pancreas, and liver). These auto-regulated clocks at central and peripheral levels act through expression of many genetic factors, which determine the circadian rhythm of insulin secretion, carbohydrate, lipid metabolism, and adipogenesis. As well-demonstrated, the consequences of shift work on sleep are well-established, in particular in terms of reduction of sleep duration and quality (47). The misalignment of sleep and awake periods leads to sleep disturbances such as higher frequency of sleepiness, difficulties falling asleep and recovery sleep. More and more evidence is provided on the associations between sleep disorders and hypertension, autonomic dysregulation, metabolic disorders (48). In 2019, the American college of cardiology/American heart association promoted sleep hygiene to prevent cardiovascular diseases (49).

In addition to these internal circadian rhythms, food intake constitutes a well-known external environmental synchroniser. The misalignment induced by eating during the night is a major assumption advanced to explain the metabolism troubles encountered in night-shift or rotating shift workers. As demonstrated, the total 24-h energy intake did not differ significantly between shift, permanent or rotating workers and day workers (50), although any conclusion could be asserted concerning the macronutrient intake. The redistribution of energy intake and the eating behavior changes, pointed out a main effect of shift work on chrono-dietetic.

Psychological stress results from expression of stressors and notably occupational stressors, which can lead to, with an individual variability, mental health problems such as depression. As recognized by the main recent guidelines, preventing chronic psychological stress constitutes an important step to prevent the development of cardiovascular disease and the exacerbation of those (2). Controlled by the axis (hypothalamus-pituitary-adrenal glands), the stress induces an inappropriate secretion of adrenocorticotropic hormones in charge of the development of hypertension and insulin resistance. Through an imbalance of sympathetic and parasympathetic responses, peripheral resistances increase, and the secretion of epinephrine and norepinephrine maintains this mechanism. Moreover, the chronic stress induces an immune dysregulation, which promotes atherosclerosis, by increasing the production of pro-inflammatory biomarkers such as cytokines (51). Suppressing or limiting the progression of these stressors remains a major challenge at the workplace.

## Strength and limitation

Our umbrella review was based on systematic reviews, which used rigorous, high-quality methods leading to a selection of primary articles depending on their inclusion criteria. In counterpart, if the inclusion criteria were too restrictive, the authors may have overlooked some good-quality primary studies. Another limitation of this umbrella review is the possible misclassification of the type of shift work given the lack of detailed exposure characteristics, in particular in the oldest primary studies. To minimize this reporting bias, we provided a quality assessment with a reference tool (AMSTAR 2) and often carefully reviewed the original articles when definitions were unclear. In most systematic reviews undertaken, the healthy worker effect is difficult to assess, leading to a potential underestimation of the risk of night-shift work on cardiovascular factors.

The primary studies included in the selected systematic reviews gave an interesting wide overview of shift work in different occupations: nurses, factory workers (steel plant, semiconductors manufacturing, motor corporation, chemical industry, etc.), white-collar workers such as employees from public administration, but also workers from population-based cohorts gathering a wide range of occupations. Additionally, the results on the effects of night-shift work were obtained for jobs held in Europe, America and Asia, covering a large geographical area.

Given the huge number of studies and reviews undertaken on this topic, this umbrella review provides a summarized and updated overview of knowledge, useful for clinical practitioners and in occupational health. Our umbrella review constitutes a strong base to identify gaps in research and to promote future studies.

## Implication for future research

Some interesting results are provided from clinical trials, such as the rearranging of meal times at night (52), performing exercise sessions (53, 54), or the changes of shift rotation (55). Our umbrella review highlighted the need:

1) to detail the characteristics of night-shift work (working hours, direction of rotation, rotating schedules, etc.).
2) to better define the duration of exposure to night-shift work in working life (continuous or intermittent exposure) in order to assess a dose-response effect.
3) to evaluate the potential reversible health effect in former night-shift workers.
4) to deeply explore some outcomes such as sedentariness, working and leisure-time physical activity, smoking habits and occupational psychosocial stressors.

5) to develop interventional studies on potential mediators (i.e., diet, sleep) but also on the shift-work characteristics in order to counteract the adverse effects of night-shift work.

## Conclusion

This umbrella review reported evidence on the consequences of night-shift work on diabetes, being overweight/obesity and hypertension. In contrast, the links with lipid disorders, sedentariness, smoking habits, and occupational psychosocial stressors are worth being explored further. Monitoring these cardiovascular risk factors for night-shift workers could be implemented by practitioners. Given the widespread use of these working time patterns, it represents a major challenge for public health policies. In upcoming years, research must focus on evaluating the relevance of preventive countermeasures implemented in the workplace.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

## Author contributions

SB, EB, and YE: conception and design and methodology. SB, EB, YE, and JF: review of literature, substantial contributions to interpretation of data and have been involved in revising the manuscript it critically for important intellectual content, and writing and editing. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1034195/full#supplementary-material

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# The influence of corporate social responsibility on safety behavior: The importance of psychological safety and the authentic leadership

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Considering the importance of safety behavior, the current study investigates the relationship between CSR and safety behavior. To be specific, we delve into the underlying mechanism and its contingent factor of the association. This paper proposes that CSR promotes employee safety behavior through the mediation of psychological safety. In addition, authentic leadership may function as a positive moderator that amplifies the positive effect of CSR on psychological safety. Utilizing 3-wave time-lagged survey data from 213 South Korean workers, the current study empirically tests the hypotheses by establishing a moderated mediation model by utilizing structural equation modeling. The results demonstrate that CSR enhances employees' safety behavior by increasing their psychological safety and that authentic leadership positively moderates the relationship between CSR and psychological safety. This research's findings have meaningful theoretical and practical implications.

KEYWORDS

**corporate social responsibility, safety behavior, psychological safety, authentic leadership, moderated mediation model**

## Introduction

In the past few decades, corporate social responsibility (CSR) has emerged as a critical issue for scholars and practitioners. Although the concept has been described in different ways, the majority of researchers have agreed that CSR means various activities and policies that promote economic, social, and environmental benefits *via* satisfying stakeholder requirements (e.g., employees, customers, local communities, governments, and the environment) (1–5). Several works have reported that CSR is an effective strategy to enhance an organization's competitive advantage (3, 6–8) by enhancing its reputation or prestige (9), consumer evaluations of the firm and its products (10), its attractiveness to investors (11), and its financial performance (12, 13).

Specifically, regarding employees' responses toward CSR, extant studies have demonstrated that CSR improves employees' perceptions, attitudes, and behaviors, including organizational commitment and identification, work engagement, job satisfaction, creativity, innovative behavior, and helping behavior (6, 14–20).

As previously mentioned, although various CSR scholars have examined CSR's influence on organizational outcomes, research gaps still exist that must be complemented. First, extant works on CSR have underexplored CSR's influence on employee safety behavior (6, 15). According to Burke et al. (21), employee safety behavior is defined as "actions or behaviors that individuals exhibit in almost all jobs to promote the health and safety of workers, clients, the public, and the environment" (p. 432). Employee safety behavior has been recognized as a critical predictor of accidents and injuries at work (22). Scholars have especially emphasized its importance after the COVID-19 pandemic because it functions as a crucial antecedent of both customer and organizational safety during major health crises (23). Considering the significance of safety behavior in an organization, we need to investigate the influence of CSR on safety behavior.

Second, pertinent to the first research gap, there has been little research on the intermediating processes (i.e., mediators) and the contingent factors (i.e., moderators) of the link between CSR and safety behavior (6, 8, 15). Given that discovering the intermediating mechanisms and their contingent factors can help to systematically understand this relationship (6, 15), it is meaningful to investigate the mediators and moderators of the relationship between CSR and safety behavior.

Third, existing studies on CSR have paid relatively less attention to the important role of leadership, especially the leader's "authenticity" (6, 15, 24). A leader possesses a significant authority to make several critical decisions such as assigning tasks, evaluating performance, and establishing implicit norms in an organization, eventually critically affecting employees' perceptions, attitudes, and behaviors (25–27). In addition, from the point view of a follower, his or her leader is a symbolic figure who represents the organization itself, meaning that the employee is likely to perceive the leaders' purposes or behaviors as those of the organization (28, 29). Therefore, the employees are likely to consider the degree of their leaders' authenticity as their organizations' one. Based on the argument, we suggest that a leader's authenticity may function as a critical moderator in the process of firms' CSR activities, which is why it is important to examine how a leader's authentic behaviors affect and interact with CSR (24).

To fill the research gaps mentioned above, we examine the underlying mechanism and its contextual factors in the relationship between CSR and safety behavior. Although few studies have investigated CSR's influence on safety behavior, based on the social exchange theory, we can infer that CSR promotes employee safety behavior. According to social exchange theory, when one party supplies another party with support and benefits, the beneficiary will likely feel a sense of obligation to repay (30, 31). Employees are both direct and indirect beneficiaries of the organization's CSR activities because they are some of the most important stakeholders (6, 8, 15). Thus, they are likely to feel a sense of duty toward their organization, eventually repaying it through positive behaviors such as safety behavior (6, 32).

***Hypothesis 1:*** CSR may increase employee safety behavior.

Specifically, the current study suggests that employees' psychological safety mediates the association between CSR and their safety behavior. Moreover, authentic leadership functions as a positive moderating factor that amplifies CSR's positive influence on psychological safety.

First, the current paper proposes that CSR enhances employee psychological safety. Psychological safety can be defined as an employee's perception that he or she is safe to take risks or confront tough issues in the organization (33, 34). According to the basic concept of CSR (4, 5), CSR activities contain a variety of charitable acts, investments, and services for internal stakeholders (i.e., employees) as well as external stakeholders (e.g., local communities, the natural environment, and customers) (35). More specifically, CSR for employees includes various training, education, and safety programs for enhancing employees' capabilities, well-being, and safety (35). Through these practices, an employee will likely feel that he or she is supported and treated as a precious member of the organization. These positive experiences directly make the employee feel safe in the organization (26, 34, 36, 37).

In addition, CSR for local community members (e.g., government organizations, nongovernmental organizations, and the socially disadvantaged), the environment, and customers may indirectly influence employees' perceptions and attitudes toward their organization. When a firm proactively conducts its social responsibility for the various external stakeholders, the employees are likely to perceive that the organization is ethical and trustworthy. Then, this morally based trust toward the organization may diminish employees' anxiety about uncomfortable issues pertinent to them, encouraging them to feel less vulnerable (26, 34, 37, 38). Based on the above arguments, this research proposes that CSR activities boost employee psychological safety.

***Hypothesis 2:*** CSR may increase employee psychological safety.

Next, this research suggests that an employee's psychological safety enhances his or her safety behavior. To the best of our knowledge, there have been few studies that investigate the influence of psychological safety on safety behavior (34, 37, 39). However, based on the social exchange theory (30, 31), we expect that psychological safety promotes employee safety behavior (23, 34, 37). According to the social exchange perspective, an

individual or a group tends to maintain balance in relationships, which is called "the rule of reciprocity" (31, 32). Thus, when an individual or a group is given precious things by someone or some group, the beneficiary is likely to feel a sense of obligation to repay it similarly (30, 32).

For instance, from an employee's point of view, experiencing psychological safety at work is likely to be perceived as a psychological reward (30, 34, 37). One of the primary reasons that the employee works in the organization may be for financial reward. However, he or she receives the reward in the form of a wage based on an official contract. In this situation, the employee is likely to perceive that the positive experiences gained *via* psychological safety are an additional reward beyond the contract. Then, the employee may feel a sense of duty to repay the additional reward from the organization. It is reasonable for the employee to repay by demonstrating positive attitudes or behaviors toward the organization, such as safety behavior (23, 32, 34). By increasing safety behaviors which correspond with achieving the organization's goals and success as well as diminishing unsafe behaviors that are incongruent with its direction, the employee may feel a sense of balance in the relationship with the organization (23, 32).

***Hypothesis 3:*** An employee's psychological safety may increase his or her safety behavior.

Then, to integrate the relationships among the research variables as described above (i.e., CSR, psychological safety, and safety behavior), the current paper suggests that employee psychological safety mediates the relationship between CSR and safety behavior. This mediation structure is supported by a context-attitude-behavior framework (38, 40). According to this perspective, an organization possesses several environmental and contextual factors such as systems, practices, rules, and climates, which substantially build members' attitudes and behaviors. CSR is a critical context that influences employees' attitudes, such as psychological safety, eventually building their behaviors, such as safety behaviors. Thus, we suggest that CSR affects employee safety behavior *via* the mediation of psychological safety.

***Hypothesis 4:*** An employee's psychological safety mediates the relationship between CSR and safety behavior.

Moreover, and more critically, we propose that authentic leadership is an important moderator which amplifies CSR's positive impact on psychological safety. As described above, our argument that CSR enhances employee psychological safety is reasonable. However, the link between CSR and psychological safety may not always be valid or applied equally to all situations, organizations, or individual employees, because there may be contextual or contingent variables (e.g., personality, values, motivational characteristics, leadership style, organizational climates, rules, and systems) that moderate the link in a real organization (34, 37).

Among several potential moderating variables, we focus on the role of the "authenticity' of a leader, which is reflected by the degree of authentic leadership from the perspective of followers. Authentic leadership has been defined as a leader's transparent and balanced decision-making patterns based on his or her internalized moral standards and self-awareness. In other words, authentic leadership indicates the degree of "authenticity' of the leader behaviors (41–43). Considering that not only employees are likely to perceive the organization as a "human-like" entity by providing it with humanlike characteristics, including various purposes and intentions (44), the employees may think that the leader symbolizes the organization itself. As a result, they are likely to consider the leaders' intentions or behaviors as those of the organization. Thus, they are likely to regard their leader's authenticity as a criterion to judge whether the activities and systems of the organization are authentic and genuine based on its unique values and philosophy (28, 29). In other words, from the perspective of followers, the degree of authentic leadership significantly represents the level of their organization's authenticity in implementing a variety of activities, practices, policies, and systems. For example, when a leader cannot show sufficient authentic leadership, employees are likely to believe that other hidden intentions or purposes may exist behind the moral acts.

Given that the authenticity of CSR functions as a critical criterion in realizing the positive impacts of the moral acts (45, 46), this doubt about the authenticity of CSR will decrease the positive influence of CSR on psychological safety (28). On the contrary, when authentic leadership is high, employees are likely to consider that the organization makes various decisions and strategies relying on its own value systems and philosophy. Then, the employees feel that the organization's CSR is trustworthy and authentic (28). Therefore, this paper suggests that authentic leadership may positively moderate the link between CSR and psychological safety.

***Hypothesis 5*:** Authentic leadership may function as a positive moderator which amplifies the enhancing effect of CSR on psychological safety.

Taken together, this paper examines CSR's impact on safety behavior *via* the mediating effect of psychological safety. In addition, the current study proposes that authentic leadership may function as a positive moderator which amplifies the positive effect of CSR on psychological safety (see Figure 1). To test our hypotheses, this research established a moderated mediation model with structural equation modeling (SEM) based on 3-wave time-lagged data from 213 Korean employees. The current paper positively contributes to both the CSR and safety behavior literature as follows. First, the current paper aims to reveal CSR's influence on employee safety behavior, considering that the link between CSR and safety behavior has been underexplored despite its importance to an organization.

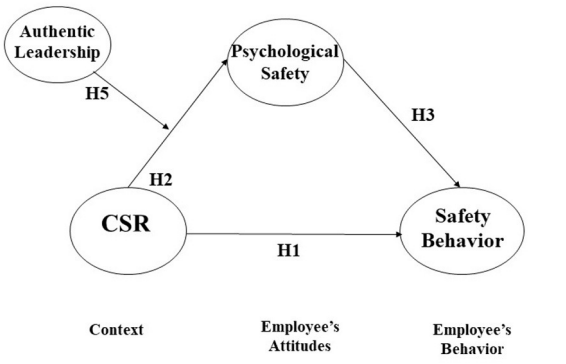


FIGURE 1
Theoretical model.

Second, this research investigates the intermediating mechanism (i.e., a mediator) and its contextual factor (i.e., a moderator) of the relationship between CSR and safety behavior. Third, we emphasize the critical role of leadership by demonstrating that a leader's authenticity functions as a positive moderator which amplifies the enhancing effect of CSR on psychological safety. Lastly, from a methodological perspective, we aim to complement the limitations of cross-sectional research design by applying a longitudinal approach (i.e., a 3-wave time-lagged design).

***Hypothesis 1:*** CSR may increase employee safety behavior.
***Hypothesis 2:*** CSR may increase employee psychological safety.
***Hypothesis 3:*** An employee's psychological safety may increase his or her safety behavior.
***Hypothesis 4:*** An employee's psychological safety mediates the relationship between CSR and safety behavior.
***Hypothesis 5*:** Authentic leadership may function as a positive moderator which amplifies the enhancing effect of CSR on psychological safety.

# Methods

## Participants and procedure

This study's participants consisted of employees over 20 years old who currently work in various organizations in South Korea. We gathered the data across three different time points. We recruited the participants through an online survey company which has an online survey system with the largest population of panelists, totaling about 3,450,000. The participants reported their occupation status when they registered for the system *via* a user authentication function (e.g., a cell phone number or email address). Online survey systems have been recognized as a trustworthy method for accessing various samples (47).

The current study collected data from employees in South Korean firms from three different time points. By collecting data through three different time periods, this study attempts to complement the fundamental issues embedded in cross-sectional research design. The online system's operating functions enabled us to track who responded to our survey, verifying that the participants through the three time points were identical. The time interval between first survey and second one was either 4 or 5 weeks, and the interval between second one and last one was 12 or 13 weeks. The reason why the time intervals in between T1–T2, and T2–T3 are different is that the influence of CSR on an employee's "behaviors" needs more time to be unveiled in compared to the impact of CSR on his or her "attitudes' (6, 15, 20). Our survey system was available for 2 or 3 days at each time point to provide enough time for participants to respond. When the system was available, participants could approach it whenever they wanted. The company monitored the integrity of the data using traps for geo-IP violators and timestamps to flag efficient responding that restricted participants from logging into the survey site and completing the surveys multiple times.

The research company's experts contacted the participants to obtain their permission to participate in the survey, assuring not only that their participation would be voluntary but also that their responses would be confidential and used only for research purposes. Further, the company reported and obtained both the informed consents and compliance with ethical requirements from those who agreed with the participation and reporting. The research firm granted the respondents a financial reward (US $8). This research was approved by the IRB (Institutional Review Board) of one of the representative universities in South Korea.

The research company randomly chose the participants in a stratified way to diminish the possibility of sampling bias. In stratified sampling, a random sample is drawn from each of the strata. Through the stratified random sampling method, the biases from several employee characteristics that were likely to affect the results (e.g., gender, age, position, education, and industry type) were diminished.

During Time Point 1, 407 employees responded to our survey; at Time Point 2, 299 workers responded to the second survey; and at Time Point 3, 217 employees responded to the third survey. After collecting the responses, we eliminated the missing data. Finally, we utilized data from 213 participants who submitted complete responses to all three-wave surveys (response rate: 52.33%). To determine the sample size, we utilized various suggestions from previous research. First, we confirmed whether our sample size was proper by calculating the minimum sample size with G*Power version 3.1.9.7. A power analysis with the program demonstrated that a sample

size of 213 provided sufficient power (≥0.70) to detect a medium effect with an alpha level of $p = 0.05$ (48). In addition, Barclay et al. (49) proposed that one observable variable requires at least 10 cases (i.e., the rule of 10) in conducting a structural equation modeling analysis. Because the research model has 22 observable variables, the final 213 cases are proper. The participants' features are displayed in Table 1.

TABLE 1 Descriptive characteristics of the sample.

| Characteristic | Percent |
|---|---|
| **Gender** | |
| Male | 52.6% |
| Female | 47.4% |
| **Age (years)** | |
| 20–29 | 12.7% |
| 30–39 | 33.8% |
| 40–49 | 32.4% |
| 50–59 | 21.1% |
| **Education** | |
| Below high school | 9.9% |
| Community college | 18.8% |
| Bachelor's degree | 59.6% |
| Master's degree or higher | 11.7% |
| **Occupation** | |
| Office worker | 71.4% |
| Profession (practitioner) | 7.5% |
| Production worker | 5.2% |
| Public official | 4.2% |
| Administrative positions | 4.2% |
| Sales and Service | 2.3% |
| Education | 0.5% |
| Freelance | 0.5% |
| Others | 4.2% |
| **Position** | |
| Staff | 23.0% |
| Assistant manager | 18.3% |
| Manager or deputy general manager | 33.8% |
| Department/general manager or director and above | 24.9% |
| **Tenure (years)** | |
| Below 5 | 49.8% |
| 5–10 | 22.5% |
| 11–15 | 14.6% |
| 16–20 | 6.5% |
| 21–25 | 2.4% |
| Above 26 | 4.2% |
| **Industry type** | |
| Manufacturing | 23.0% |
| Construction | 13.2% |
| Wholesale/Retail business | 11.7% |
| Health and welfare | 10.8% |
| Information service and telecommunications | 8.9% |
| Education | 8.5% |
| Services | 6.6% |
| Financial/insurance | 2.8% |
| Consulting and advertising Others | 0.9% |
| Others | 9.4% |

## Measures

Each time point's survey measured distinct variables of our research model. At Time Point 1, the respondents were asked about the level of CSR and authentic leadership. At Time Point 2, the participants' data were gathered to measure their perceived degree of psychological safety. At Time Point 3, we collected data about participants' safety behavior. These variables were assessed through multi-item scales on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Moreover, through Cronbach alpha values, we computed the internal consistency of each variable.

## CSR (time point 1, collected from employees)

We measured the degree of CSR in each organization using 12 items of Turker's CSR scale. This measure was developed by applying a stakeholder perspective that concentrates on CSR acts for numerous stakeholders. In the current study, we choose four dimensions of CSR practices: environment, community, employee, and customer. The four dimensions include three items. In the case of the environment dimension, the sample item was "our company participates in activities which aim to protect and improve the quality of the natural environment." Regarding the community dimension, the sample item was "our company contributes to campaigns and projects that promote the well-being of the society." Regarding the employee dimension, the sample item was "The management of our company is primarily concerned with the employees' needs and wants." Regarding the customer dimension, the sample item was "our company respects consumer rights beyond the legal requirements." The Cronbach's alpha value is 0.90.

## Authentic leadership (time point 1, collected from employees)

To assess the degree of authentic leadership, we utilized twelve items (Cronbach alpha = 0.96) from the Authentic

Leadership Inventory (ALI) developed and validated by Neider and Schriesheim (42). ALI has been known to possess a high content, convergent, and discriminant validity (42, 50). We asked respondents to measure the authenticity of their immediate leaders at Time Point 1. ALI consists of four dimensions: (1) self-awareness (e.g., "The leader is clearly aware of the impact he/she has on others"), (2) relational transparency (e.g., "The leader expresses his/her ideas and thoughts clearly to others"), (3) internalized moral perspective (e.g., "The leader is guided in his/her actions by internal moral standards"), and (4) balanced processing (e.g., "The leader carefully listens to alternative perspectives before reaching a conclusion"). ALI has been acknowledged as a valid scale, as verified by previous research (50). The Cronbach's alpha value was 0.91.

## Psychological safety (time point 2, collected from employees)

We evaluated the degree of employee psychological safety by utilizing four items from a psychological safety scale developed by Edmondson (33). This scale measures an employee's perception of psychological safety. Sample items were "it is safe to take a risk in this organization," "I am able to bring up problems and tough issues in this organization," "it is easy for me to ask other members of this organization for help," and "no one in this organization would deliberately act in a way that undermines my efforts." These items were used in previous studies with South Korean employees [e.g., 16]. The Cronbach's alpha value was 0.82.

## Safety behavior (time point 3, collected from employees)

To evaluate the degree of employee safety behavior, six items developed by Neal and Griffin (51) were utilized. This measure consists of two sub-dimensions: three items for safety compliance, and three items for safety participation. The sample item for safety compliance is "I use all the necessary safety equipment to do my job." The sample item for safety participation is "I voluntarily carry out tasks or activities that help to improve workplace safety and so on." The Cronbach's alpha value was 0.89.

## Control variables

Considering the suggestions of previous studies (22, 23), this research controlled for safety behavior by utilizing several control variables such as tenure, gender, position, and education. The variables were gathered at Time Point 2.

## Statistical analysis

First, we performed a frequency analysis to check the participants' demographic features. We conducted a Pearson correlation analysis with the SPSS 26 program to compute the relationships among our research variables. Then, according to the suggestion of Anderson and Gerbing (52), we took a two-step approach that consists of (1) the measurement and (2) the structural model. To test the validity of the measurement model, we performed a Confirmatory Factor Analysis (CFA). Next, based on SEM, a moderated mediation model analysis with the maximum likelihood (ML) estimator was performed with the AMOS 23 program to test the structural model.

To test whether the various model fit indices are acceptable, this study utilized a variety of goodness-of-fit indices including the comparative fit index (CFI), the Tucker–Lewis index (TLI), and the root mean square error of approximation (RMSEA). Extant research has reported that CFI and TLI values $>0.90$ as well as an RMSEA value $<0.06$ are proper (53). Next, a bootstrapping analysis was implemented to test whether the indirect effect was significant (54). Lastly, to check whether our mediation hypothesis is supported, we conducted a bootstrapping analysis with a 95% bias-corrected confidence interval (CI). This analysis tests the significance of the indirect mediating effect. If the CI does not include zero (0), this indicates that the indirect effect is statistically significant at a 0.05 level (54).

# Results

## Descriptive statistics

Our research variables, such as CSR, authentic leadership, psychological safety, and safety behavior, are significantly associated. The correlation analysis results are shown in Table 2.

## Measurement model

To test the discriminant validity of the main research variables (CSR, authentic leadership, psychological safety, and safety behavior), we performed a CFA for all items by checking the measurement model's goodness of fit. Specifically, we compared our hypothesized model, a four-factor model (CSR, authentic leadership, psychological safety, and safety behavior), to other alternative models such as three-, two-, and one-factor models by conducting a series of chi-square difference tests.

First, the hypothesized that the four-factor model has a good and acceptable fit [$\chi^2$ (d$f$ = 109) = 172.988; CFI = 0.963; TLI = 0.954; RMSEA = 0.053]. Then, we conducted a series of chi-square difference tests by comparing the four-factor model to a three-factor model [$\chi^2$ (df = 112) = 378.522; CFI = 0.848; TLI

TABLE 2 Correlation between research variables.

| | Mean | S.D. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Gender_T2 | 1.47 | 0.50 | – | | | | | | |
| 2. Education_T2 | 2.73 | 0.79 | −0.18** | - | | | | | |
| 3. Tenure_T2 | 7.91 | 7.57 | −0.32** | −0.06 | - | | | | |
| 4. Position_T2 | 3.04 | 1.62 | −0.46** | 0.24** | 0.26** | - | | | |
| 5. CSR_T1 | 3.20 | 0.62 | −0.22** | 0.08 | 0.18** | 0.14* | - | | |
| 6. AL_T1 | 3.22 | 0.59 | −0.10 | 0.01 | 0.03 | 0.14* | 0.37** | - | |
| 7. PS_T2 | 3.24 | 0.59 | −0.25** | 0.10 | 0.16* | 0.28** | 0.37** | 0.31** | - |
| 9. SB_T3 | 3.71 | 0.56 | −0.20** | 0.05 | 0.12 | 0.14* | 0.30** | 0.22** | 0.31** |

*$p < 0.05$. **$p < 0.01$. S.D. means standard deviation, CSR means corporate social responsibility, AL means authentic leadership, PS means psychological safety, and SB indicates safety behavior. As for gender, males are coded as 1 and females as 2. As for position, general manager or higher are coded as 5, deputy general manager and department manager 4, assistant manager 3, clerk 2, and others below clerk as 1. As for education, "below high school diploma" level is coded as 1, "community college" level as 2, "bachelor's" level as 3, and "master's degree or more" level is coded as 5.

TABLE 3 Results of structural model.

| Hypothesis | Path (relationship) | Estimate | S.E. | Standardized estimate | Supported |
|---|---|---|---|---|---|
| 1 | CSR -> safety behavior | 0.177 | 0.068 | 0.218** | Yes |
| 2 | CSR -> psychological safety | 0.241 | 0.067 | 0.289*** | Yes |
| 3 | Psychological safety -> safety behavior | 0.240 | 0.081 | 0.246** | Yes |
| 5 | CSR × authentic leadership | 0.303 | 0.111 | 0.196** | Yes |

**$p < 0.01$, ***$p < 0.05$. Estimate indicates standardized coefficients. S.E. means standard error.

= 0.815; RMSEA = 0.106], a two-factor model [$\chi^2$ (df = 114) = 802.601; CFI = 0.606; TLI = 0.530; RMSEA = 0.169], and a one-factor model [$\chi^2$ (df = 115) = 876.954; CFI = 0.564; TLI = 0.485; RMSEA = 0.177]. The results of the chi-square difference tests indicated that the four-factor model was better than the others. Thus, this result indicates that our four research variables have a proper degree of discriminant validity.

## Structural model

We constructed a moderated mediation model that includes both mediation and moderation structures in the link between CSR and safety behavior. In the mediation structure, the link between CSR and safety behavior is mediated by the degree of employee psychological safety. In the moderation structure, authentic leadership functions as a positive moderator which amplifies the positive impact of CSR on psychological safety.

Next, in the moderation structure, we multiplied the two variables (i.e., CSR, authentic leadership) to create an interaction term between the variables. Before multiplication, the two variables were centered on their means to decrease the harmful impact of multi-collinearity. Such a centering method increases the validity of the moderation analysis by not only diminishing the degree of multi-collinearity between the variables but also minimizing the loss of correlations (55).

To test the impact of the multi-collinearity bias, we measured the value of the variance inflation factors (VIF) and tolerance (55). The VIF values for CSR and authentic leadership were 1.157 and 1.157, respectively. Moreover, the values of tolerance were 0.864 and 0.864, respectively. These results with VIF values smaller than 10 and tolerance values above 0.2 indicate that CSR and authentic leadership are relatively free from the multi-collinearity issue.

## Results of mediation analysis

To find the best mediation model, we compared a full mediation model to a partial mediation model by performing a chi-square difference test. The full mediation model is identical to the partial mediation model except for the direct path from CSR to safety behavior. The fit indices of both the full mediation model [$\chi^2$ = 215.459 (df = 131), CFI = 0.941, TLI = 0.923, and RMSEA = 0.055] and the partial mediation model [$\chi^2$ = 209.148 (df = 130), CFI = 0.945, TLI = 0.928, and RMSEA = 0.054] were acceptable. However, the chi-square difference test between the models ($\Delta\chi^2$ (1) = 6.311, $p < 0.05$) demonstrated that the partial mediation model was superior, indicating that CSR is likely to directly and indirectly influence (e.g., *via* the mediating effect of psychological safety) safety behavior rather than directly impact it.

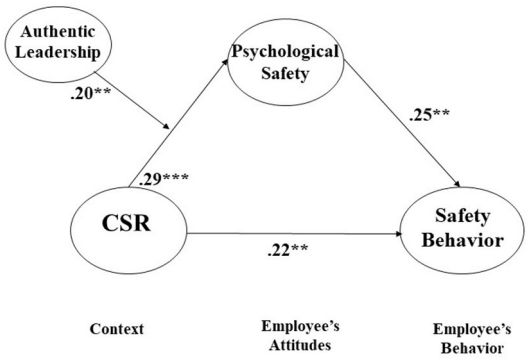


FIGURE 2
Coefficient values of our research model (** $p < 0.01$, *** $p < 0.001$. All values are standardized).

The control variables, such as tenure, gender, education, and position, were included in the research model to control for the dependent variable, safety behavior. The results show that all the control variables were not statistically significant. Including the control variables, our research model demonstrates that CSR is significantly associated with employee safety behavior ($\beta = 0.22$, $p < 0.01$), supporting Hypothesis 1. For Hypothesis 1, the coefficient value of the path from CSR to safety behavior was in the "partial" mediation model (which was superior to the full mediation model) that was finally accepted. This result is consistent with the fact that the model fit indices of partial mediation are better than those of full mediation. Based on the results of the chi-square difference test between the full mediation model and partial mediation model as well as the significant value of the path coefficient, we conclude that Hypothesis 1 is supported. In other words, CSR is likely to influence safety behavior in a both direct and indirect way through the mediating effects of various mediators (e.g., psychological safety).

Further, CSR is significantly and positively associated with the employees' psychological safety ($\beta = 0.29$, $p < 0.001$), supporting Hypothesis 2, and psychological safety is significantly and positively associated with their safety behavior ($\beta = 0.25$, $p < 0.01$), supporting Hypothesis 3 (see Table 3 and Figure 2).

## Bootstrapping

To test psychological safety's mediating effect on the link between CSR and safety behavior (Hypothesis 4), we conducted a bootstrapping analysis with a sample size of 10,000 (54). The indirect mediation effect is significant at the 5% level if the 95% bias-corrected confidence interval (CI) for the effect of mean indirect mediation excludes 0 (54). The results indicate that the bias-corrected CI for the mean indirect effect did not include 0 (95% CI = [0.015, 0.162]), meaning that psychological safety's indirect mediation effect was statistically significant, supporting Hypothesis 4. The direct, indirect, and total effects of the paths from CSR to safety behavior are shown in Table 4.

TABLE 4 Direct, indirect, and total effects of the final research model.

| Model (Hypothesis 5) | Direct effect | Indirect effect | Total effect |
|---|---|---|---|
| CSR -> Psychological Safety -> Safety Behavior | 0.218 | 0.071 | 0.289 |

All values are standardized.

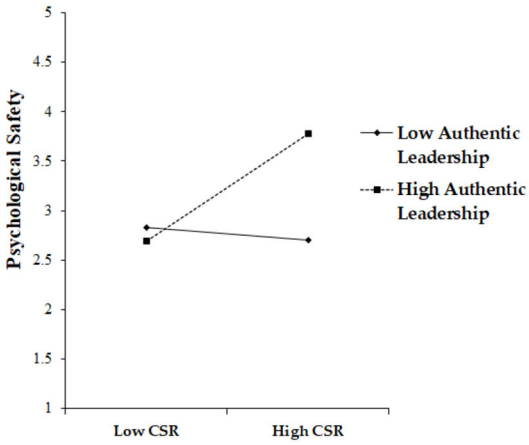


FIGURE 3
Moderating effect of authentic leadership in the CSR–psychological safety link.

## Result of moderation analysis

We tested the moderating effect of authentic leadership on the relationship between CSR and psychological safety, which included conducting a mean-centering process by creating an interaction term. The coefficient value of the interaction term ($\beta = 0.20$, $p < 0.01$) was statistically significant. This result means that authentic leadership positively moderates the relationship between CSR and psychological safety by playing an amplifying role, indicating that when authentic leadership is high, CSR's enhancing impact on psychological safety can increase, supporting Hypothesis 5 (see Figure 3).

# Discussion

Utilizing 3-wave time-lagged data, this paper unveils that an employee's psychological safety is an underlying mechanism (i.e., mediator) in the relationship between CSR and safety behavior. The current paper also finds that authentic leadership positively moderates the relationship between CSR

and psychological safety. The results are consistent with the previous literature on CSR, psychological safety, safety behavior, and authentic leadership. To be specific, CSR increased employee psychological safety (26, 34), and psychological safety promotes employee safety behavior (23, 26, 34). And this mediation structure is supported by a context-attitude-behavior framework (38, 40). Moreover, authentic leadership may function as a positive moderator which amplifies the enhancing effect of CSR on psychological safety (28, 29). Based on the results, we can conclude that our arguments can be supported from the theoretical and empirical perspectives.

The current paper can contribute to expanding the CSR and safety behavior literature by identifying a mediator and moderator that explain why and when CSR increases employee safety behavior. In the following part, we discuss the theoretical and practical implications and limitations and suggestions for future works.

## Theoretical implications

The current research positively contributes to the CSR literature from a theoretical perspective. First, by theoretically and empirically validating the underlying mechanism and its contextual factors in the link between CSR and safety behavior, we demonstrate why and when CSR significantly influences employee safety behavior. The importance of safety behavior has been increasingly emphasized after the COVID-19 pandemic because it is a critical antecedent of both customer and organizational safety during major health crises (23). However, there have been few studies on safety behavior despite its significance. Thus, this paper is helpful for scholars and practitioners to thoroughly understand CSR's influence on safety behavior (6, 15).

Second, we demonstrate that leadership is a crucial contextual variable that positively moderates the relationship between CSR and psychological safety. A leader tends to have substantial power to make several crucial decisions including assigning tasks, evaluating performance, and establishing implicit and explicit norms in an organization. Thus, the leader can significantly affect employees' perceptions, attitudes, and behaviors (25–27). Further, from an employee perspective, the leader is a symbolic actor of the organization itself, meaning that the employee may consider the intentions or behaviors of the leader as those of the organization (28, 29). Thus, our attempt to reveal the importance of leadership in the context of CSR is theoretically meaningful.

Third, this paper demonstrated the significance of authenticity, which is unveiled by a leader's behaviors, based on the empirical result that a leader's authentic behaviors positively moderate the link between CSR and psychological safety. No matter how proactively an organization conducts CSR activities, the positive influence of CSR on employee psychological safety is likely to diminish when there is not sufficient authenticity in the organization's moral acts (28, 45, 46). From the perspective of the employees, the organization's real intention in implementing the moral acts is critical to evaluate whether the moral behaviors of the organization are authentic. Considering the crucial role of a leader in evaluating the authenticity of CSR activities, the degree of authentic leadership can be the criterion to evaluate the degree of authenticity of CSR (28, 46).

## Practical implications

Our research provides practically meaningful implications to top management teams. First, this paper suggests that top management teams should consider CSR activities as an effective investment instead of merely a cost. Our results demonstrate that CSR activities increase employee safety behavior by enhancing their sense of psychological safety. Considering that both employees' sense of psychological safety and their safety behavior positively contribute to improving organizational outcomes, sincere and authentic attempts to implement CSR practices can be helpful to achieve the organization's goals and success.

Second, our results propose that top management teams should understand the essential role of leaders in conducting CSR activities. From the point of view of employees, the leader is a symbolic actor of the organization itself as well as a powerful authority to make several critical decisions within an organization. Thus, they are likely to consider the intentions or behaviors of the leader as those of the organization (28, 29). Top management teams should monitor and manage whether leaders properly affect in implementing CSR activities.

Lastly, top management teams need to understand the significance of authenticity that is reflected through authentic leadership. The positive influence of CSR activities on employees' psychological safety is amplified when they feel that the organization's CSR is authentic. However, on the contrary, when the degree of authenticity that is reflected in the level of authentic leadership is low, employees are less likely to feel psychological safety, indicating that authentic leadership substantially affects the positive influence of CSR activities on employees' attitudes (28, 45, 46). From the perspective of employees, the degree of authentic leadership is an important criterion to evaluate whether the organization's moral activities are genuine. Thus, because of the significance of authentic leadership, top management teams should cultivate authentic leadership in an organization (28).

## Study limitations and directions for future research

This paper has limitations that should be complemented. First, this paper could not adequately accommodate the cultural differences between Eastern and Western societies pertinent

to how members perceive CSR in an organization. According to previous studies, Western cultures tend to emphasize the significance of socially imposed duties including CSR activities; therefore, the members are likely to be more sensitive to social obligations (56, 57). Because this paper gathered data only from employees in South Korea, we should cautiously interpret the results when applying them to other cultural contexts (56, 58). Although the spirit of CSR has been found to be universal (56), South Korean workers may respond to the call for CSR differently compared to Western workers. Therefore, further studies should properly consider this issue.

Second, this paper could not utilize an objective measure in evaluating the degree of CSR activities, as it only used subjective measures from employees. Although extant works on CSR have reported that subjective measures, including an employee's perception of CSR, can properly evaluate the real phenomena of CSR practices [e.g., (59)], future studies are required to utilize both types of measures and compare the different effects of each measure.

Third, this study could not sufficiently accommodate the discriminatory influence of the several sub-factors of CSR activities. As described above, the targets of CSR activities vary widely, including CSR for employees, consumers, local communities, and the environment. However, the current paper measured only four sub-constructs of CSR practices (i.e., CSR for employees, customers, society, and the environment). Thus, respondents may respond differently to the different targets (28, 60). For instance, Farooq et al. (35) demonstrated the differential influences of CSR on employees' perceptions by differentiating the CSR practices into internal CSR and external CSR. This issue must be adequately complemented in future research.

Fourth, the current paper could not adequately consider that utilizing control variables such age and gender as categorical variables, may have very little likely that it gets significant level. Thus, to complement the limitation, future studies should conduct other thorough analysis techniques such as multi-group analysis or Mann–Whitney U test that might offer different perspectives.

Fifth, although we utilized 3-wave time-lagged data, this research cannot be free from the issue of common method bias (CMB). To decrease this concern, we additionally conducted the Harman's single-factor test, that is the most widely utilized technique to evaluate CMB (61). The result demonstrated that merely 26.79% of covariance is explained by a single factor, meaning that the CMB issue was not serious. Nevertheless, future studies should validate the findings by utilizing multiple data sources.

## Conclusion

The current paper delves into CSR's impact on employee safety behavior. According to the results, CSR promotes employee safety behavior *via* the mediating role of psychological safety. Furthermore, authentic leadership functions as a positive moderator in the link between CSR and psychological safety. The results indicate that employee psychological safety is an underlying mechanism in translating CSR into safety behavior. Moreover, authentic leadership functions as an amplifying factor that enhances CSR's positive influence. Although this research has some limitations, we anticipate that these findings positively contribute to expanding the CSR literature.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human/animal participants were reviewed and approved by Macromill Embrain Group of Ethics Committee. Macromill Embrain Group is the company providing market research service and their approval is sufficient according to the local requirements. The patients/participants provided their written informed consent to participate in this study.

## Author contributions

B-JK contributed by writing the original draft of the manuscript and in the conceptualization, data collection, formal analysis, and methodology. JL and M-JK contributed in the conceptualization, analysis, revision, and in editing the manuscript. All authors have read and agreed to the published version of the manuscript.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



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# Anti-violence measures developed by ILO and WHO: Analysis of the prevalence of workplace violence and the effects of implementation in a general hospital in China

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**Objective:** Workplace violence (WPV) not only affects workers' physical and mental health but also increases turnover rates and social costs. There are no studies that have consistently followed the prevalence of WPV and the effectiveness of anti-violence measures in cross-sectional studies of the same hospital. The main aim of this study was to understand the prevalence of WPV among medical staff in a hospital in China and the effectiveness of implemented anti-violence measures.

**Methods:** A cross-sectional survey, which was conducted by using a questionnaire developed by the International Labor Organization and the World Health Organization, was administered in a tertiary hospital in China in 2022 to investigate the occurrence of violence in the past year. Valid data were collected from 1,195 respondents *via* cell phone. WPV was compared between this survey and a baseline survey conducted at the same hospital in 2017 using the same questionnaire. The relationship between years and gender and occupation was explored using the Cochran–Armitage trend test. Descriptive statistics and chi-square tests were used to respond to the effects of the anti-violence interventions.

**Results:** After the implementation of anti-violence measures, the prevalence of WPV decreased from 48.47 in 2017 to 33.95% in 2021. The recognition of safety measures increased from 80.16 in 2017 to 87.70% in 2021($P < 0.001$), improvement of the work environment increased from 56.57 in 2017 to 65.10% in 2021($P < 0.001$), restricted of public access increased from 34.36 in 2017 to 55.60% in 2021($P < 0.001$), the patient protocols increased from 37.42 in 2017 to 38.40% in 2021, patient screening increased from 32.11 in 2017 to 41.90% in 2021($P < 0.001$), and strict restrictions on workplace cash activities from 29.65% in 2017 to 36.00% in 2021($P < 0.05$). The percentage of health workers who felt that anti-violence measures were not at all helpful to their current work decreased from 2017 to 2021.

**Conclusions:** The prevalence of workplace violence has decreased, recognition of interventions has increased, and the proportion of interventions that are perceived by HWs as not helpful at all has decreased. This study demonstrates that the 12 anti-violence measures recommended by the International Labor Organization are applicable in China. Based on this, hospitals should focus on the improvement of the intervention effect of the following measures to further prevent violence.

KEYWORDS

**workplace violence (WPV), hospital, health workers (HWs), anti-violence measures, occupational health**

## Introduction

Workplace violence (WPV) has become a global social problem, affecting health workers (HWs) at a higher rate than other occupations (1, 2). WPV affects the physical and mental health of HWs, and increases the turnover rates and economic burden on society (2–4). Previous studies evaluating workplace aggression have shown that 7–82.9% of HWs are targets of violence (5–11). In China, the prevalence of WPV among HWs ranges from 14.26–69.24% (12–15). However, there are still gaps in the mid-term and long-term descriptions of WPV in healthcare, especially with reference to the effectiveness of mid-term and long-term WPV interventions (16–19). These studies identified several influencing factors that can inform subsequent refinement of interventions to improve the safety of HWs.

WPV has been classified into four types based on the correlation between the perpetrator and the workplace. Type II WPV in hospitals refers to verbal or physical attacks on HWs by patients and visitors. In fact, hospital settings are more likely to trigger Type II WPV than other environments (11, 20, 21). The follow-up on anti-violence measures should elaborate on their lasting effects, as these are not addressed by short-term and or single surveys. Currently, in China, there is a shortage of medium- and long-term sustained follow-up surveys of the improvement measures.

There are different tools for the assessment of WPV among HWs. Current research instruments on WPV in HWs mostly use the self-report questionnaire, a self-administered questionnaire, a short-term assessment tool, the Crisis Monitor, the Brøset Violence Checklist (BVC), the Brief Psychiatric Rating Scale (BPRS), the Perception of Aggression Scale (POAS), and the Perception of Patient Initiated Aggression Tool (POPAS) (22–27). Currently, most of the questionnaires that are used within China are homemade, or only a part of the questionnaire is utilized (13, 28, 29), which indicates a lack of sufficient studies using internationally recognized survey instruments.

Many countries have developed prevention and control guidelines and technical tools to assess WPV. E.g., The Italian Ministry of Health issued recommendations in 2007 for the prevention and management of violence among healthcare workers (30). Australia has developed a risk assessment system for patients, which helps to identify patients as "at risk" when they exhibit one or more of the "at risk" signs in the assessment system. Also, this system involves making a special note in the medical record to alert other patients, departments, and staff and promptly notify the relevant security department (31). The U.S. Occupational Safety and Health Administration (OSHA) issued the "Guidelines for preventing workplace violence for health care social service workers" in 2004 (32), which consists of several specific provisions aimed at creating a safe healthcare environment. Besides HWs' own prevention skills, these measures include the establishment of a comprehensive self-prevention system at the hospital level, such as metal detectors, alarm buttons, 24-h monitoring systems, emergency evacuation, and access control systems. The International Council of Nurses, Public Services International, the World Health Organization (WHO), and the International Labor Organization jointly developed and published "Framework guidelines for addressing workplace violence in the health sector: the training manual" (33). Interim guidance issued by the International Labor Organization and WHO during Coronavirus Disease 2019 (COVID-19) highlights the need to strengthen the prevention and control of violence, harassment, and discrimination experienced by HWs.

About 25% of WPV incidents have been reported to occur in the health sector (2). The International Labor Office (ILO), the International Council of Nurses (ICN), the WHO, and Public Services International (PSI) co-sponsored a program that conducted case studies in Brazil, Bulgaria, Lebanon, Portugal, South Africa, Australia, Thailand in 2000 aiming to prevent and eliminate violence in the health sector. The 12 measures provided in the questionnaire "Workplace violence in the health sector country case studies research instruments: survey questionnaire" (hereafter referred to as the "Questionnaire"), which were jointly developed by these four organizations, are widely recognized as comprehensive anti-violence measures (34).

The present study was based on the ILO/PSI/WHO/ICN definition of WPV (33). This retrospective cross-sectional survey was conducted at the third People's Hospital of Zhengzhou (Zhengzhou, Henan, China) in 2022 using an international survey instrument to investigate the WPV, which occurred from May 31, 2021 to May 31, 2022 and for an accurate description of our survey based on this article on the 2021 survey), and after the 2018 survey (to investigate the occurrence of violence from May 31, 2017–2018. For an accurate description of our survey, we referred to the 2017 survey or the baseline survey), we took steps to address the occurrence of WPV according to the guidelines and compared changes from the 2018 survey results based on the corresponding measures (35). To assess the current prevalence of WPV amongst the HWs at a tertiary care hospital in China in comparison to a previous prevalence of WPV in the same institution. Moreover, the study aimed to identify the effectiveness of the implemented anti-violence measures in our hospital.

# Methods

## Design

The third People's Hospital of Zhengzhou is the pilot hospital of HealthWISE application which organized by Min Zhang's team in Peking Union Medical College (PUMC). As part of the pilot study, the cross-sectional survey was conducted in 2018, 2019 and 2021 with the same questionnaire and methodology, respectively, the methodology and results of those surveys were published previously elsewhere (33–35).

Based on previous results and methodology, a cross-sectional survey was focused on twelve anti-violence measures by distributing an online questionnaire. Our members of the research team visited the hospital for the survey and over 7 days in June 2022.

In June 2018, a retrospective cross-sectional survey was conducted in the same hospital using the same survey questionnaire and the same survey population (35), which in the present study was defined as a baseline survey.

The overall study leading by Min Zhang on nationwide occupational health protection for health workers in 2022 was approved by PUMC ethics committee (number CAMS&PUMC-IEC-2022-044). The study has been reviewed and approved by the Third People's Hospital of Zhengzhou ethics committee (approval number 2022-04-019-K01).

## Participants

This survey was conducted at the third People's Hospital of Zhengzhou (Central China tertiary general hospital that provides healthcare services across regions, provinces, cities, and nationwide, hereinafter referred to as "the hospital") with 1,100 beds and 2,030 employees. The target population included all hospital healthcare workers, i.e., doctors, nurses, medical technicians, and administrative staff. We included clinical managers in our study as part of our administrative staff because they not only have extensive contact with HWs, but also play an important role in the development of anti-violence policies and are implementers and beneficiaries of anti-violence measures. The inclusion criteria were as follows: (1) professionally certified HWs; (2) voluntary participation in the survey with informed consent; and (3) employed by the hospital as a regular employee for >1 year. Exclusion criteria were the following: (1) those failing to answer the questionnaire in the opening hours; (2) those exceeding the time limit for the questionnaire.

## Questionnaire

The original language of the questionnaire was English (34). The pretest and retest reliability and validity were assessed by Prof. Min Zhang's team in Beijing and Shenzhen, with Cronbach's alpha (α) coefficient 0.83 (35). And we have obtained the authorization letter of the questionnaire from the team. Cronbach's α for a summary score of 0.70∼0.80 is considered satisfactory for a reliable comparison between groups, and > 0.90 is required for the clinical usefulness of the instrument (36). In this study, the validity factor of the questionnaire was 0.854. This questionnaire included: (1) participants' demographic information (department, title, education level, age, salary, and gender); (2) experience of physical violence and post-event intervention in the past 12 months; (3) psychological violence in the past 12 months (including verbal abuse, bullying/mobbing, racial and sexual harassment), and post-event intervention experiences in the past 12 months; (4) hospital violence prevention measures and opinions on the causes of violence consisting of three open-ended questions.

## Data collection

In June 2022, members of the research team visited the relevant departments, and for more than 7 days, they kept inviting HWs on duty to fill out an online questionnaire using their cell phones. The online questionnaire included a consent statement on the first page regarding the anonymity, confidentiality, and voluntary participation. The Chinese version of the questionnaire is available online (https://www.wjx.cn/vm/emTu2I4.aspx). An online version of our questionnaire was distributed through WeChat, which allowed HWs to access and participate in our survey by scanning a specific quick response code from their own phone or tablet. WeChat is the most widely used mobile social application in China, with over 1.2 billion active users in 2022 (37). HWs participated in our

TABLE 1 Overview and description of HWs included by gender and occupation.

| Characteristic | | 2017 ($n = 978$) | | 2021 ($n = 913$) | | $\chi 2$ | $p$-value for trend |
|---|---|---|---|---|---|---|---|
| | | $n$ | % | $n$ | % | | |
| Gender | | | | | | 3.757 | 0.053 |
| | Male | 177 | 18.10 | 135 | 14.79 | | |
| | Female | 801 | 81.90 | 778 | 85.21 | | |
| Occupation | | | | | | 193.481 | <0.001 |
| | Technical support and administrative staff | 171 | 17.48 | 129 | 14.13 | | |
| | Doctors | 255 | 26.07 | 227 | 24.86 | | |
| | Nurse | 552 | 56.44 | 557 | 61.01 | | |

survey as WeChat users and in different WeChat groupings according to different department names. Therefore, this was an effective way to implement surveys and communication.

The target sample size was set to 1600 HWs for the whole hospital in order to include every department of medical workers in our research scope. At the same time, this survey method was consistent with the baseline survey, which is more conducive to comparing the research effect of our anti-violence measures. A total of 1,195 individuals fulfilled the inclusion criteria. The data management platform showed that 917 questionnaires were completed by respondents who met the inclusion criteria, 913 of which were valid (total response rate 76.74%; total valid response rate 76.40%).

## Quality control

Before the survey, the team members explained the concept, purpose, and importance of the survey. After collecting the questionnaire from the online platform, two team members validated the data and removed or corrected the logical errors with mutual consent.

## Statistics

The database was coded, and SPSS V.26.0 (SPSS Inc., Chicago, IL, USA) and Excel were used to perform data analysis.

The independent variable is the year, and the dependent variables are gender and occupation. Categorical variables were statistically described by frequency (percentage). The relationship between different years and gender and occupation was explored using the Cochran–Armitage trend test.

First, the gender and occupation of the participants in both surveys were examined using the Cochran-Armitage (CA) trend test.

Second, workplace violence responses were described and evaluated. The descriptive statistics of the total prevalence of violence, the prevalence of various types of violence, responses, medical staff approval of anti-violence measures, and the extent to which medical staff found anti-violence measures helpful were compared between the two surveys using Excel and SPSS V.26.0. $P < 0.05$ indicated statistical significance. We evaluated the effectiveness of the violence measures by comparing the results of the baseline survey with those of the current survey, it included prevalence of workplace violence, prevalence of various types of workplace violence, recognition of anti-violence measures, extent to which health care workers find anti-violence measures helpful. The trend chi-square test was used to compare changes in attitude medical workers had toward various measures between this survey and the annual baseline survey.

# Results

## Changes in the prevalence of WPV

For gender, using the trend test, i.e. Cochran-Armitage (CA) trend test, the $p$-value of the trend test is $< 0.05$, indicating that the change in gender over time is not statistically significant for the trend($\chi 2_{trend} = 3.757$, $P = 0.053$)For occupation, using the trend test, i.e., Cochran-Armitage (CA) trend test, the $p$-value of the trend test is $< 0.05$($\chi 2_{trend} = 193.481$, $P < 0.001$), indicating that the change in occupation has a trend statistical significance over time, with the proportion of nurses increasing year by year and the number of doctors and technical support and administrative staff decreasing year by year (Table 1). The total prevalence of violence decreased from 48.47 in 2017 to 33.95% in 2021 (Figure 1). Physical violence decreased from 8.79 to 2.63%. Verbal abuse decreased from 45.71 to 32.90%, while bullying/mobbing decreased from 12.78 to 5.50%, racial harassment decreased from 2.15 to 0.11%, and sexual harassment decreased from 2.35 to 0.11% (Figure 2).

## Changes in recognition of anti-violence measures in the workplace

The comparison of the results of this and the baseline surveys revealed that the percentage of approval of public

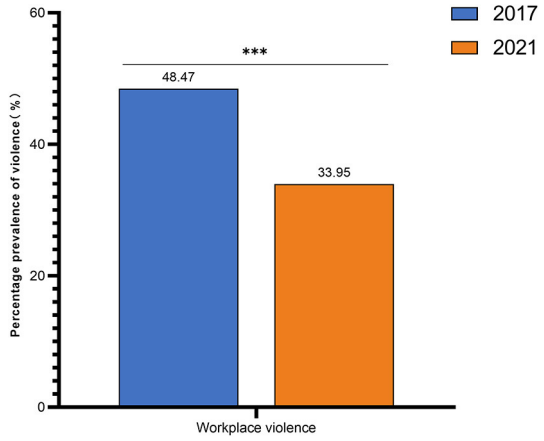


FIGURE 1
Statistical chart of the change in the total prevalence of violence. Both 2017 and 2021 in the figure refer to the year. The prevalence of WPV in hospitals decreased from 48.47 in 2017 to 33.95% in 2021. ***indicates that $P < 0.001$. Total workplace violence prevalence, Pearson's Chi square = 40.974, $P < 0.001$.

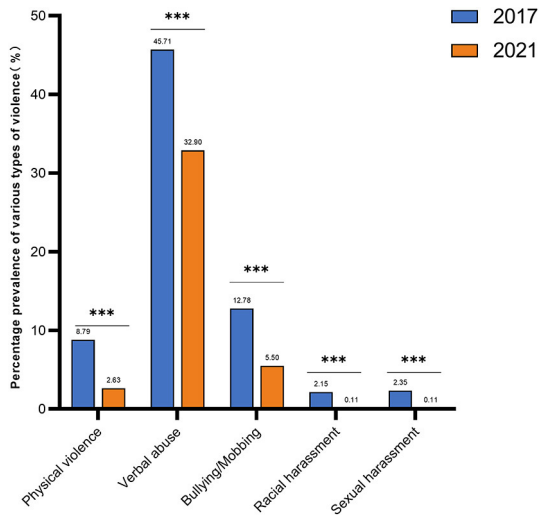


FIGURE 2
Graph of changes in the prevalence of various types of violence among HWs. Both 2017 and 2021 in the figure refer to the year. From 2017 to 2021, all types of violence decreased. The prevalence of verbal abuse has been the highest. Also, the statistical analysis of the two surveys showed the largest decrease in verbal abuse. ***indicates that $P < 0.001$. Physical violence, Pearson's Chi square = 32.775, $P < 0.001$; Verbal abuse; Pearson's Chi square = 32.610, $P < 0.001$; Bullying/Mobbing, Pearson's Chi square = 30.002, $P < 0.001$; Racial harassment, Pearson's Chi square = 17.051, $P < 0.001$; Sexual harassment, Pearson's Chi square = 18.945, $P < 0.001$.

access control is increased maximally from 34.36 in 2017 to 55.60% in 2021, followed by the percentage of approval of patient screening from 32.11 to 41.90%, the percentage of approval of improvement of surrounding from 55.67 to 65.10%, the percentage of recognition for safety measures from 80.16 to 87.70%, the percentage of recognition for restricting the exchange of money in the workplace from 29.65 to 36.00%, the percentage of recognition for patient protocol from 37.42 to 38.40%. The percentage of recognition for training percentage of recognition increased to 36.90% in 2021 from 33.44% in 2017, and the recognition of changing shifts or rotas increased to 29.50% in 2021 from 28.43% in 2017. Increasing staff numbers or reducing the periods of working alone, special equipment or clothing showed a flat percentage increase in recognition at 0.13 and 0.12%, respectively. Among these, the check-in procedures for staff and investment in human resource development are new measures added after the baseline survey, with percent approval of 26.10 and 25.4%, respectively, in this survey (Figure 3).

## Changes in the extent to which anti-violence measures are perceived by HWs as helpful to existing efforts

A comparison of this survey with the baseline survey revealed that the largest percentage decrease in measures was valuable for restricting the exchange of money (decreased by 5.77%), followed by restricting public access at the workplace (decreased by 5.51%), security measures (decreased by 5.32%). The special equipment or clothing (decreased by 5.12%), changing shifts or rotas (decreased by 4.74%), patient protocols (decreased by 4.73%), patient screening (decreased by 4.49%), surrounding improvements (decreased by 4.46%), increased staff numbers or reduced periods of working alone (decreased by 4.37%), and the smallest decrease in training among the above ten items (decreased by 3.04%). Investment in human resource development and check-in procedures for staff are new measures added after the baseline survey, and the proportion of individuals considered not helpful at all in this survey is 5.7 and 7.3%, respectively. However, in both surveys, the percentage of security measures was consistently the minimum. With the exception of two measures, the investment in human resource development and the check-in procedures for staff, the percentage of the remaining ten measures that were perceived by HWs as not at all helpful decreased, and all were statistically different (Figure 4).

# Discussion

Between 2000 and 2002, ILO/ICN/WHO/PSI studied all the healthcare providers in 7 countries (Brazil, Bulgaria, Lebanon, Portugal, Thailand, South Africa, and Australia) using the same questionnaire as was used in the present study, finding that the majority of the healthcare workers had experienced at least one prevalence of physical or psychological violence,

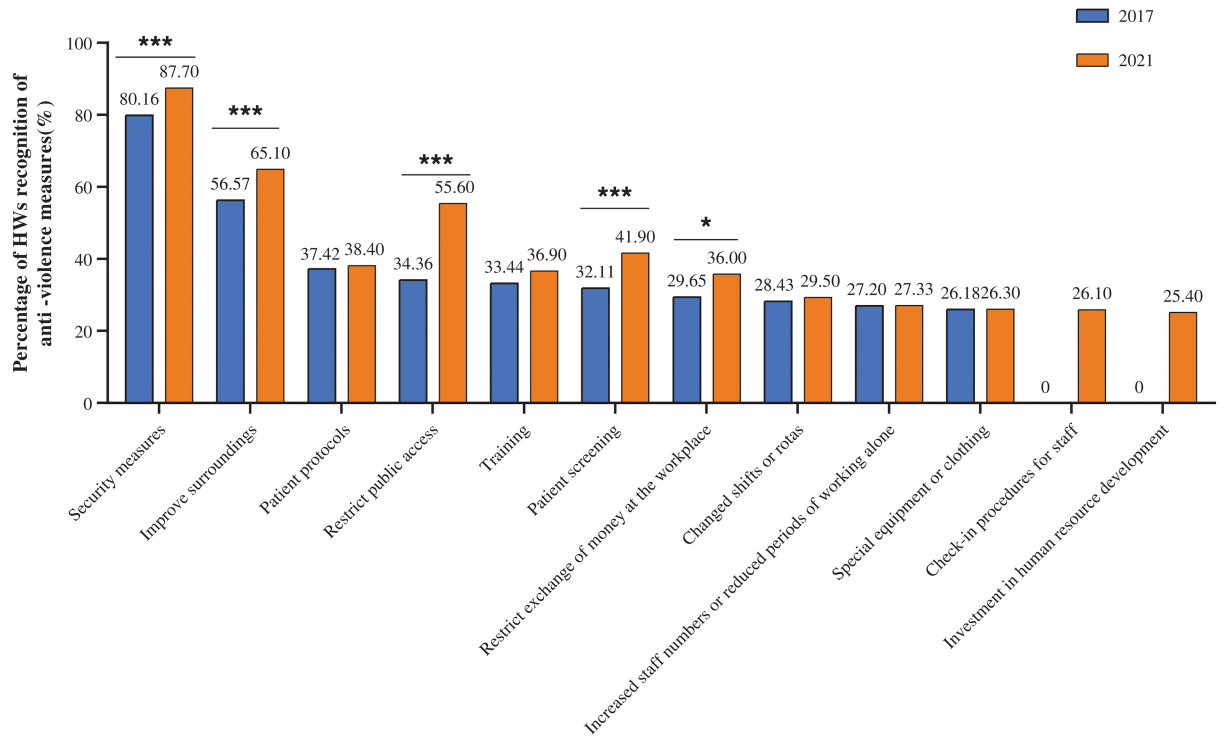


FIGURE 3
Statistical chart of the percentage of recognition of anti-violence measures in the workplace. Both 2017 and 2021 in the figure refer to the year. In both surveys, security measures ranked first in terms of recognition. The recognition of restricting public access showed the largest increase. ***indicates that $P < 0.001$. *indicates that $P < 0.05$. Security measures, Pearson's Chi square = 20.434, $P < 0.001$; Improve surroundings, Pearson's Chi square = 13.682, $P < 0.001$; Restrict public access, Pearson's Chi square = 86.568, $P < 0.001$; Patient screening, Pearson's Chi square = 19.658, $P < 0.001$; Patient protocols, Pearson's Chi square = 0.209, $P = 0.647$; Restrict exchange of money at the workplace, Pearson's Chi square = 8.736, $P < 0.05$; Increased staff numbers or reduced periods of working alone, Pearson's Chi square = 0.001, $P = 0.971$; Special equipment or clothing, Pearson's Chi square = 0.003, $P = 0.956$; Changed shifts or rotas, Pearson's Chi square = 0.247, $P = 0.619$; Training, Pearson's Chi square = 2.504, $P = 0.114$.

amounting to following rates: 75.8% in Bulgaria, 67.2% in Australia, 61% in South Africa, 60% in a medical center and 37% in a hospital in Portugal, 54% in Thailand, and 46.7% in Brazil (2). After the baseline survey, the 12 violence risk prevention measures of the questionnaire served as a guide for the implementation of appropriate violence risk prevention measures in our hospital, resulting in an obvious decrease in the prevalence of violence, going from 48.47 in 2017 to 33.95% in 2021 (33, 38).

## Security measures

Security is one of the major anti-violence measures, which consistently had the highest HWs' endorsement (80.16 in 2017 and 87.7% in 2021) and was consistently considered the most helpful anti-violence measure (48.47 in 2017 and 53.80% in 2021). We also improved the WPV early warning system by installing security cameras and providing the HWs with walkie-talkies to allow timely contact with security staff in dangerous situations, improved the departmental WPV reporting process and added a WPV self-reporting checklist, and revised the hospital's WPV risk contingency plan. Next, the number of guards (55.6% increase from the baseline survey), guard rooms (an additional new room), and patrols were increased, the security guards were provided electric batons, and the hospital infrastructure was strengthened. A cross-sectional study on the security measures for WPV in hospitals (39). However, the necessity of metal detectors for hospital admission and their effectiveness still remains controversial. Since the hospital is a public place, it is difficult to control the source of metals. Patients can also get hold of such objects from the hospital or bypass the security system by entering the hospital premises in an ambulance. Thus, how to control the source of forbidden items to enhance security (for example, some patients or visitors themselves carry items that could be used as weapons at any time, such as lighters, sharp jewelry, etc. Moreover, emergency patients coming in through the ambulance corridor may also carry some dangerous items) which should be further explored.

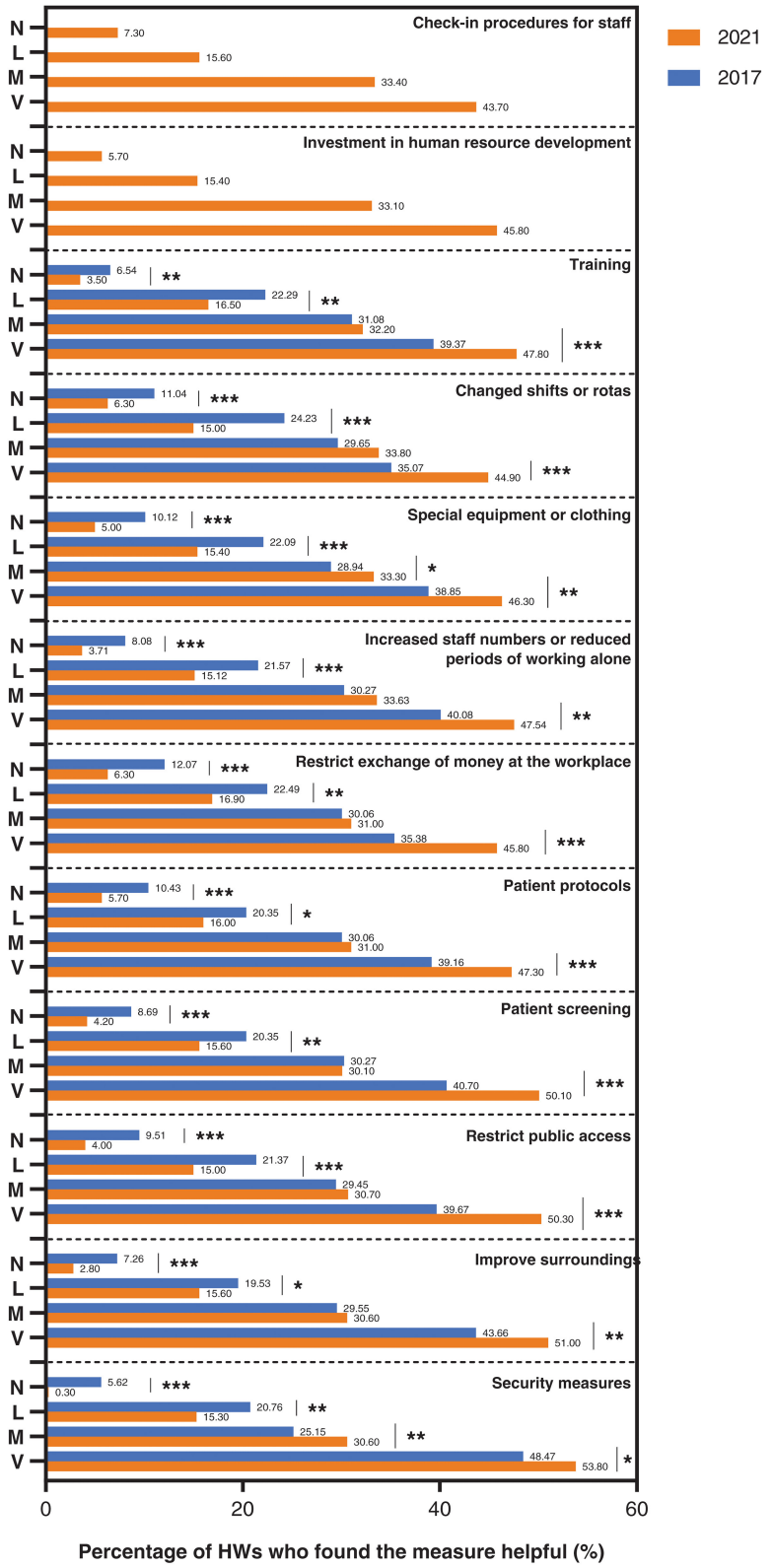


FIGURE 4
The extent to which healthcare workers find various types of measures useful in their existing work. Both 2017 and 2021 in the figure refer to the year. V, M, L, and N stand for very, moderate, little, and not at all, indicating very helpful, moderate, slightly helpful, and not helpful, respectively. ***indicates that $P < 0.001$. **indicates that $P < 0.01$. *indicates that $P < 0.05$. Security measures(not at all): Pearson's Chi square = 44.531,

*(Continued)*

FIGURE 4 (Continued)
$P < 0.001$. Improve surroundings (not at all): Pearson's Chi square = 18.887, $P < 0.001$Restrict public access (not at all): Pearson's Chi square = 21.961, $P < 0.001$. Patient screening (not at all), Pearson's Chi square = 15.052, $P < 0.001$; Patient protocols (not at all), Pearson's Chi square = 14.146, $P < 0.001$; Restrict exchange of money at the workplace (not at all), Pearson's Chi square = 18.256, $P < 0.001$; Increased staff numbers or reduced periods of working alone (not at all), Pearson's Chi square = 15.930, $P < 0.001$; Special equipment or clothing (not at all), Pearson's Chi square = 18.106, $P < 0.001$; Changed shifts or rotas (not at all), Pearson's Chi square = 13.659, $P < 0.001$; Training (not at all), Pearson's Chi square = 9.050, $P < 0.01$.

## Restricted public access

Among our measures implemented to reduce the prevalence of WPV, the increase in the percentage of acceptance of public access control ranked first (34.36 in 2017 and 55.60% in 2021). As visitors are one of the major sources of violence in healthcare settings (40), we adopted the following measures to limit public access. Previous studies also confirmed the validity of the present study's results (41). Similarly, controlling public access was shown to reduce the prevalence of WPV in an intervention study in China (42). We also noted that this measure might increase the risk of WPV among security personnel while reducing the prevalence of WPV in HWs. Therefore, how to reduce the overall prevalence of violence in hospitals requires further comprehensive investigation.

## Increased staff number or reduced periods of working alone

Increasing the staff or reducing independent work hours led to a modest increase in approval (0.13%) of the measures across two surveys. With a rate of 4.37%, the percentage decrease for this measure was considered the least helpful. The presence of coworkers can diminish a potential assault threat (43). The same recommendation was made in a proposal for an action plan to organize emergency services in Norwegian primary healthcare (44). Therefore, it is worrying that most HWs work alone in some cases. Since the baseline survey, the number of in-ward caregivers has increased by 45% based on the third-party professional in-hospital companions contracted by the hospital, which has improved the quality of in-hospital care while reducing violence and lowering economic costs. Concurrently, the hospital increased the recruitment of HWs and implemented an in-hospital talent pool strategy, assigned medical interns to departments with high rates of WPV, and had at least two individuals working together during times of high violence, thus effectively reducing the prevalence of WPV. Also, the interventions to increase staff or reduce independent work time had a positive effect.

## Check-in procedures for staff

With the launch of the "Ubiquitous Medical" model (45), we have developed a series of systems and operational procedures for home care services, including timely positioning and clocking in according to the operational procedures as a critical measure to ensure the safety of home care workers. The importance of this measure was also recognized by another study on risk control strategies for home care in China (46) and was further confirmed by the present survey. However, the current assurance measures and evaluation indicators for operational and provider safety need further improvement. Thus, we suggested developing systematic and scientific evaluation indexes and assessment tools to evaluate the quality of nurses' home care services at three levels, i.e., structure, process, and outcome, which could help further exploit the role of intelligent telemedicine devices in safety assurance.

## Patient screening

Unlike measures such as patient violence medical records in other countries (47), our understanding of the occurrence of violence in the department was mainly based on the information shared during the morning meeting of the department or mentioned in the handover process. For example, patients and family members with a history of violence in medical settings, the occurrence of violence in the department on the previous day, patients or family members who were emotionally unstable during treatment, and the work logs of doctors and nurses. Following the end of the baseline survey, we added a new departmental violence handover register, which includes time, place, type of violence, the way the violence occurred, departmental treatment, and treatment outcomes. Currently, this measure is not considered very useful, as in our survey from 2017, it was 8.69% declining to 4.20% in 2021.

## Improve surroundings

In the present study, working surroundings consisted of light wood furniture without sharp corners that were attached to the floor in parlors or places prone to violence. We also replaced the damaged lamps to maintain bright indoor and

outdoor lighting. For some departments with a high prevalence of WPV, HWs should administer dedicated disposal or operating rooms to manage patients. A third-party cleaning company is contracted in the hospital to take charge of the wards, outpatient clinics, and dining restaurants in separate areas to improve the neatness and comfort of the hospital environment. Since the building structure of our old hospital area could not be changed, we set up screen partitions, while in the new hospital area, we set up two consultation rooms before the opening of the wings. The HWs' approval increased by 8.53% for these measures. A German study showed that improvements in the work environment could reduce the prevalence of WPV (48). Thus, we supposed that even if the structure of the building cannot be changed, it is still possible to decrease the WPV rate. Since the measures related to counseling rooms are difficult to implement without changes to the building structure, the above measures must be included in the initial planning phase of violence interventions. Barriers or glass partitions in the reception area are common and can usually be implemented without major structural modifications.

## Restrict exchange of money at the workplace

According to the FIS 2022 Global Payments Report data, digital wallets, such as Alipay and WeChat Pay, are the leading payment options for Chinese consumers, accounting for about 83% of total e-commerce transactions in 2021 (49). With the merging of the health insurance cost settlement platform with the e-Health service platform and the increase in health insurance reimbursement rates, the process of paperless in-hospital payments was further advanced. However, unlike the pay-as-you-go health insurance system outside of China (50), payment before seeing a doctor is still a predominant modality within the country. Currently, payment for medical expenses in Europe and USA is mainly achieved by credit card, and the use of digital wallets is still relatively low (51). However, there is increasing use of third-party payments in Chinese hospitals. Although we have a slightly different approach to restricting the use of cash, the efficiency of this approach has been well-proven.

## Training

We encouraged our staff to attend HealthWise courses and also provide training for HWs (52). In addition, a social media group on WPV prevention and control has been set up, occupational safety information is dispensed, and a quiz on related knowledge was set up (https://weixin.qq.com/g/AwYAAIOgcnYzDwtv0JB1JauhzBOhojD9FzN6sqVLkKcmtA3ib0ERPDtmJEvglITa). A virtual simulation of the intelligent classroom in the workplace for emergency violence response process simulation training was also conducted. The public security departments of the streets and lawyers from local law firms were invited to impart judicial knowledge land to train the hospital employees on laws and regulations in health care, respectively. The training methods for WPV are mainly based on face-to-face or online courses, which are consistent with the measures taken in this study (16, 19, 53). The effectiveness of the training has been proven by the satisfactory intervention results observed in several studies (13). The 5-year interval between surveys in this study provides evidence of the effectiveness of adherence training; however, there is a lack of long-term research on this measure, which needs to be further explored in future studies.

## Patient protocols

Upon admission, patients or their families are required to sign an informed consent form for some expensive medications and medical services that are not covered by medical insurance. The informed consent form is signed after admission to the hospital, and the nurse on duty is informed when leaving the room during the hospital stay, especially for some patients who need to reduce their activities. This is not the same as the patient privacy confidentiality agreement referred to in most U.S. state patient agreements (54). China's Nine Guidelines for the Integrity of Health Care Facility Staff clearly state that the principle of confidentiality should be observed and patient information should not be disclosed (55). This is both a legal and ethical requirement for HWs.

## Special equipment or clothing

Hospitals are equipped with batons, body shields, walkie-talkies for security guards, and walkie-talkies for departments with a high prevalence of violence (such as emergency departments). Several studies have confirmed the necessity and effectiveness of metal detectors (56–58). However, this study did not adopt metal detectors due to the uncertainty of the security source and to avoid unnecessary tension and panic.

## Changed shifts or rotas

Since the baseline survey, our hospital has initiated a system to update the schedules of doctors and nurses every 2–4 weeks to avoid repeatedly working with the same individual at a time with a high prevalence of violence in a short period. This helps reduce the prevalence of violence and burnout among healthcare workers, thereby enhancing the safety of healthcare workers and patients (59).

## Investment in human resource development

The hospital's pay and performance reform, which added quality control of the staff and linked the service quality to pay and performance, was well received within the hospital, with only 5.7% of the participants reporting it as not helpful in 2021 in the present survey. These results were confirmed in a prospective study on the cross-sectional association between social capital and low rates of WPV (60).

Currently, the main international measures are safety measures, environmental improvements, training, and organizational interventions, of which training and organizational interventions have been proven to be safe and effective. This study's measures, work environment improvement, and restricted public access reached >50% success. Therefore, the next step is to further improve the effectiveness of implementing anti-violence measures.

The current international concentration on organizational intervention research, which emphasizes how the intervention process is conducted and implemented to ensure quality, would provide a new perspective for our study. In addition, the training measure is the most studied worldwide. Although this measure made a difference in both surveys, the observed improvement was small, which is consistent with the results of a previous meta-study on education and training (13). Therefore, improving the effectiveness of medium- and long-term education and training also provides new research directions on how to ensure the effectiveness of training.

Both surveys were conducted in the same hospital to reflect the continuity and effectiveness of the measures on the occurrence of violence in the past 12 months: a baseline survey was conducted from May 31, 2017 to May 31, 2018, and a second survey was conducted from May 31, 2021 to May 31, 2022, with the two datasets independent of each other. For both surveys, we calculated the total violence prevalence according to the number of people, and also each type of violence was calculated according to the number of people, which was based on the possibility of a single person experiencing multiple types of violence.

In the national reports of seven countries, safety measures were introduced first, followed by improvements in the working environment (2). In our 2021 study, safety measures had an 87.7% approval rating, which was the highest compared to other countries (2). In Brazil, when asked, "To what extent do you think these measures contribute to your work environment?," the respondents ranked security measures as very helpful, ranking third in that study but first in our study (2). The recognition of the improvement in the surroundings has been more obvious than in Bulgaria (48.8%) but lower than in Thailand (77%) (2). Of these, the recognition of public access control has increased the most in both our surveys (21.24% increase) and was higher in this survey (55.6%) than in Bulgaria (27.3%), but a higher percentage of Bulgarian survey participants (58.9%) than in ours (2021, 50.30%) believe that limiting public access is the most effective measure (2). In the current study, compared to the baseline survey, we have a breakthrough in terms of investment in human resource development and increased punch card systems in the workflow, which is closely related to the continuous improvement of the anti-violence measures. However, direct comparisons across countries require careful consideration, especially regarding the intrinsic validity and reliability of each questionnaire. The comparison of the two surveys revealed an increase in the percentage of recognition of our measures among survey participants who found each measure very useful. Due to the diversity of health institutions, and economic and sociocultural contexts across survey years, the validity of the measures could be cross-referenced across countries. With the advancement in the laws and rules of civilization in society, the increase in positive image promotion videos of HWs has also increased the public awareness and tolerance of the work content and environment of HWs, which in turn has contributed to the implementation process of anti-violence measures in the workplace.

Regarding the effectiveness of the implementation of the above 12 anti-violence measures, the significant reductions in total workplace violence, physical violence, verbal abuse, and bullying/mobbing, racial harassment, sexual harassment, the increase in recognition of countermeasures, and the decrease in the percentage of measures considered not at all helpful in the level of help after the baseline survey suggest that these measures are effective but still need further improvement. For example, the prevalence of verbal violence continues to have the highest of all violence rates, and increasing staff numbers or reducing the periods of working alone, special equipment, or clothing showed a flat percentage increase in recognition. Based on the results of the baseline survey, we formulated the Regulations on the Management of Violence Prevention Measures according to the above guidelines and guidelines, which mainly included the three-level reporting process of workplace violence risk (individual, department and medical Administration and management department), relevant countermeasures and implementation rules. Through our research, the effectiveness of our measures has been proven to some extent. Based on this, our hospital will improve our violence risk management, emergency response mechanism, violence prevention, and response measures so as to better improve the effectiveness of our anti-violence measures. The hospital's measures to prevent and control workplace violence have had certain effects, but there are still areas to be improved from the comprehensive measures proposed after the previous survey. Based on the results of this survey, the following improvement measures are suggested:

Hospital should further improve the risk assessment system, and to direct contact with the patient/family/strangers in risk assessment, risk identification of special situation (such as shift, work alone, etc.), in a reasonable analysis on the basis of the characteristics of the environment, according to

the level of risk classification management measures, make a targeted prevention programs, change passive response to active prevention and control, To prevent violence. Workplace policies and plans to combat workplace violence should be developed, with the necessary monitoring mechanisms and scope for sanctions; Improve reporting and recording systems and encourage the reporting of all incidents involving physical and psychological violence, as well as minor and potential incidents that do not result in actual harm (recommendations can also be made to reduce the risk of violence or improve working conditions); Reports of such incidents are regularly reviewed as indicators of improved workplace safety measures. The union should regularly assess the risk of workplace violence with hospital leaders and make improvements based on the results.

## Limitations and strengths

This study used a retrospective approach to investigate the occurrence of violence over 12 months with a recall bias. Hence, we considered the pre-survey training on the knowledge and re-explanation at the time of the survey, and allowed the HWs to review their work logs for records of violence. As a cross-sectional study, it was not possible to analyze the causal relationships between variables.

We implemented our online questionnaire through a scannable quick-response code developed by social media, which is available and is currently used in several medical-related survey studies (33, 34, 61–64). The survey used an internationally accepted questionnaire to develop corresponding comprehensive measures using internationally accepted anti-violence measures as a guide, and the increase in recognition of these measures and the decrease in the percentage of measures that were considered unhelpful both enhance international comparability and support the adoption of similar or further comprehensive interventions or policies in Chinese hospitals. Moreover, at present, our team is among the few in China that have used an internationally recognized tool to validate the effectiveness of workplace violence measures.

## Conclusion

As in most countries around the world, there is a constant risk of violence in Chinese hospitals, which can affect the physical and mental health of medical workers, their productivity, and possibly increase their sense of job burnout. This study demonstrated that the 12 violence risk prevention measures recommended by the ILO questionnaire are effective in Chinese tertiary care hospitals, especially in terms of security measures, improvement in the work environment, public access control, and patient screening. However, we still need more measures to improve the effectiveness of our interventions. Although these measures can be replicated, their implementation needs to be integrated with the country's cultural, economic, and social environment.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by the PUMC and the Third People's Hospital of Zhengzhou of the Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

## Author contributions

MZ designed and organized the pilot study in Third People's Hospital of Zhengzhou since 2017. MZ, RL, and NC conducted the survey in 2018. MZ, RL, NC, YLiu, and YHua conducted the survey in 2019. RL, MZ, YW, QL, and YHu contributed to design of the study in 2022. YHu organized the database and wrote the first draft of the manuscript. YHu and PS performed the statistical analysis. JS and YLi wrote sections of the manuscript. MZ, QL, YLiu, YHua, and NC made the final revision of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships

that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1049832/full#supplementary-material

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# Quality of therapy and mental health among occupational therapists during the COVID-19 pandemic

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**Introduction:** The coronavirus disease of 2019 (COVID-19) has had a severe psychological impact on occupational therapists. Clarifying the mental health status of occupational therapists and its relationship with therapy quality is essential for maintaining the quality of care and patients' quality of life. Therefore, the present study aimed to investigate whether and how mental health problems are related to the quality of occupational therapy.

**Methods:** A nationwide cross-sectional online survey was conducted during Japan's second national state of emergency (January 2021). A total of 4,418 registered occupational therapists who were members of the Japanese Association of Occupational Therapists participated in this study. After screening for the exclusion criteria, data from 1,966 participants were analyzed.

**Results:** Path analysis showed that insufficient information provision by the workplace and increased workload were associated with depression, anxiety, and insomnia. Specifically, depression was associated with decreased therapy quality. Furthermore, one's therapy quality showed a strong positive correlation with colleagues' therapy quality.

**Discussion:** These results demonstrated a direct link between therapists' mental health conditions and therapy quality and suggested that decreased therapy quality might occur at the institutional rather than individual level. A reassessment of the support system and prompt detection and support for professionals with psychological symptoms may be the key to enhancing therapy quality and patients' quality of life. The present results contribute to the understanding of these relationships, considering the current pandemic context for occupational therapists.

KEYWORDS

**COVID-19, occupational therapy, anxiety, depression, insomnia**

## Introduction

The coronavirus disease 2019 (COVID-19) pandemic has had an unprecedented impact on society and is viewed as a global stressor induced by widespread voluntary restrictions and social distancing (1). The psychological effects of the COVID-19 outbreak on medical workers who have been fighting on the frontlines and on the general population have recently been documented (2, 3). The importance of physical and psychological support, such as the provision of precautionary items and information, has been emphasized (4). In this critical situation, medical workers who are directly or indirectly involved in diagnosis or treatment are at risk of developing psychological problems due to changes in workloads and/or work contents (3, 5).

Psychological impacts of COVID-19 on second-line healthcare professionals have been documented (5–8). Occupational therapists are classified as second-line medical professionals who do not directly care for patients with COVID-19 during the early stages (9). However, the work environment has changed due to the current pandemic, and this has had a negative impact on their mental health (6, 9). Although such psychological stress can negatively affect therapy quality and lead to client dissatisfaction (10), little is known about the relationship between mental health problems and the therapy quality of occupational therapists. Previous studies identified the relationship between mental health problems and job performance (11–19). For example, Shirom et al. (17) revealed that emotional exhaustion caused by overload is a critical factor in decreasing care quality, suggesting the importance of caring for the mental health of medical professionals to maintain the quality of care. Thus, the purpose of the present study was to clarify the psychological impact of the COVID-19 outbreak on occupational therapists and examine whether their mental health problems are related to decreased quality of therapy. By conducting a cross-sectional web-based survey targeted at registered occupational therapists in Japan, we investigated the relationships among the changes in work and life due to COVID-19, mental health problems, and quality of therapy. As mentioned below, we focused on the following four factors that can affect mental health conditions: efforts to avoid being infected, information provision from the workplace, workload, and working hours.

Previous studies investigating the effects of quarantine on mental health conditions have documented that healthcare workers, compared with the general public, exhibited concerns about being infected by others and reported substantially more negative feelings, such as anger and loneliness, after quarantine (20). A previous report showed that 98.3% of occupational therapists showed more significant efforts to avoid infection, and 94.7% of them refrained from unnecessary outings (6). As a decrease in social connectedness is related to perceived stress (1), these results raise the possibility that efforts to avoid being infected would be related to adverse psychological effects. Information provision from the workplace also has a critical role in addressing mental health conditions. A recent report suggested that sufficient information from the workplace significantly reduced the risk of mental health problems (6, 21), and this finding is consistent with previous evidence that showed the effectiveness of information provision for mental support during previous infectious outbreaks such as H1N1 and SARS (22–24). Other recent reports suggested that social connectedness was associated with a lower level of perceived stress and COVID-19-related burnout (1, 25). Thus, the information provided may improve mental health conditions by enhancing the sense of social connectedness.

The increased workload and working hours negatively impact mental health conditions (6, 26–30). For example, previous literature showed that workload is positively related to depression and that its relationship was mediated by emotional distress (29), and long working hours are also associated with depression (31) and further associated with poor patient safety and decreased care quality (30). In addition to this physical overload, the present pandemic forces medical professionals to work in high-pressure environments (26).

To replicate these findings (i.e., the link between environmental factors and mental health) and further examine whether these mental health problems negatively affect the quality of therapy, we used path analysis in the present study. Because of the close relationships among mental health problems, including depression, anxiety, and insomnia (32, 33), in our hypothesized model, we assume that the four factors (i.e., efforts to avoid being infected, information provision from the workplace, workload, and working hours) are linked to each psychological symptom, and all three psychological symptoms would be related to therapy quality. Based on previous findings, which showed relationships among workload, mental health, and job performance (11, 17, 18), we designed a hypothesized path model (Figure 1A). This model focused on the relationships between (1) the changes in work and life due to COVID-19, (2) mental health problems, including depression, anxiety, and insomnia, and (3) the quality of therapy. Based on recent literature that has documented (perceived) social isolation (20, 23), we proposed "efforts to avoid being infected" and "less information provision from the workplace" as candidates that may increase mental health problems. Second, based on literature that focused on the relationship between mental health and job performance (11, 17, 18, 27, 30), we hypothesized that the increase in mental health problems would be related to a decrease in therapy quality. Based on previous reports that showed a close link between perceptions of caregiver and client (34, 35), in the present study, we employed self-report of one's therapy quality as an index of therapy quality. Further, to examine whether one's therapy quality is closely related to colleagues' therapy quality (i.e., to determine if the change in

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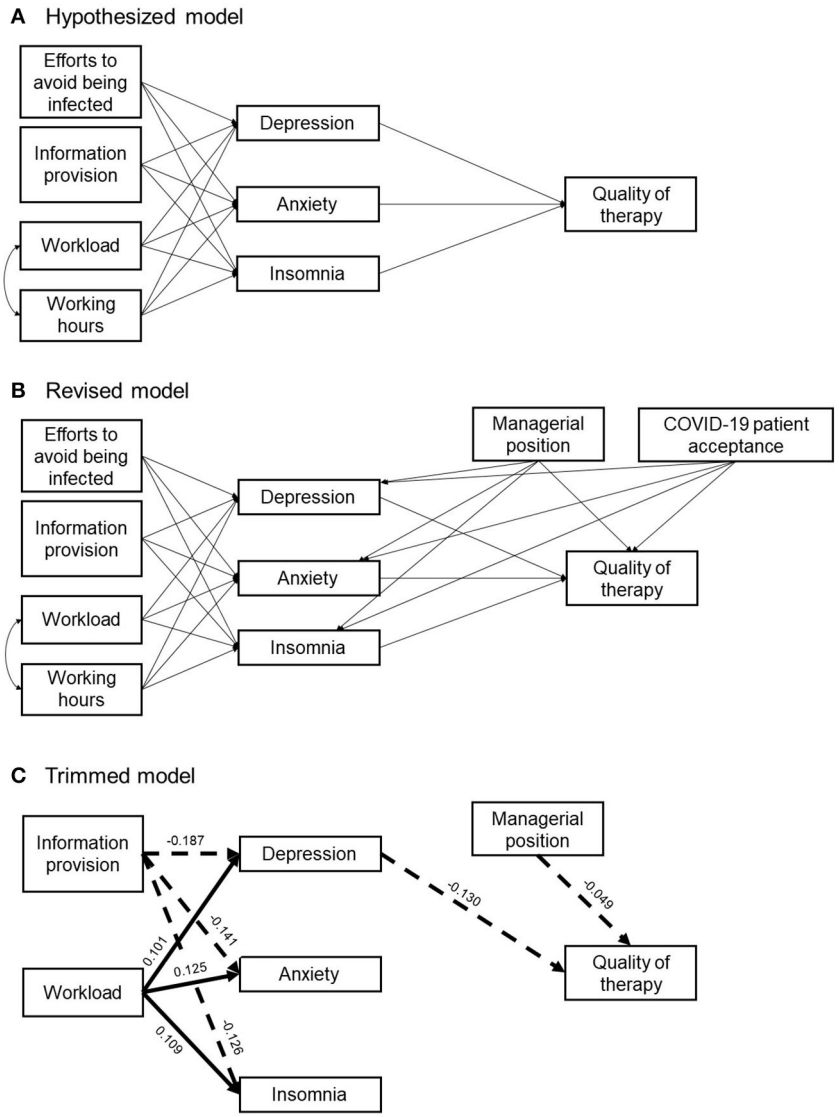


FIGURE 1
A hypothesized path model **(A)**, revised model **(B)**, and trimmed model **(C)**. In the trimmed model, the straight line depicts a significantly positive relationship, and the dashed line depicts a significantly negative relationship.

quality is beyond personal problems), we performed a simple correlation analysis.

# Materials and methods

## Research protocol

This cross-sectional online survey was conducted in Japan from 20 to 25 January 2021. The data were collected through Google Forms (https://www.google.com/forms/about/). All the respondents were registered occupational therapists who were members of the Japanese Association of Occupational Therapists. A request for participation was sent to all registered members *via* email on 20 January 2021. The study protocol was approved by the ethical committee at Saitama Prefectural University (acceptance number: 20003). All participants provided written, informed consent. Email addresses were collected to ensure that the same respondent did not take the questionnaire multiple times.

## Online questionnaire

Participants were asked to report their sociodemographic characteristics: age, gender, academic background, marital status

(married or unmarried), history of psychiatric disorders (yes or no), employment type (full-time/part-time), managerial position (yes or no), and years of service. As the participants had to answer each question before proceeding, no missing data existed. Participants who reported a history of psychiatric disorders were excluded from the analysis. Based on previous findings (5, 6, 23), we focused on loneliness, depression, anxiety, and insomnia. Three validated questionnaires were used: the Japanese version of the three-item loneliness scale (36), the Zung Self-Rating Anxiety Scale (SAS) (37), the Zung Self-Rating Depression Scale (SDS) (38), and the Japanese version of the Insomnia Severity Index (ISI-J) (39). The three-item loneliness scale measures overall with three items ("I feel that I lack companionship," "I feel left out," and "I feel isolated from others") and is known to identify loneliness quite well (40). The total score ranged from 3 to 9, and higher scores reflected greater loneliness (40). The SAS and SDS had 20 items each that measured anxiety and depression, respectively. The SAS included negative statements such as "I get upset easily or feel panicky" (37). The SDS contained 10 negative statements, such as "I feel down-hearted and blue," and 10 reverse-scored positive statements, such as "My life is pretty full" (38). The ISI-J contained seven questions assessing the nature, severity, and impact of insomnia, rated on a five-point Likert scale (0 = no problem; 4 = very severe problem) (6, 41). These questionnaires have been widely used for non-clinical samples, and the cutoffs for detecting the presence or absence of loneliness, anxiety, depression, and insomnia were $\geq 6$ for the three-item loneliness scale (42–44), $\geq 40$ for the SAS (45), $\geq 50$ for the SDS (46), and $\geq 10$ for the ISI-J (39, 47).

Participants were also asked to answer the following items concerning the work environment: acceptance of patients with COVID-19 at their workplace (yes or no), provision of information on COVID-19 by the workplace (7-point rating scale ranging from 1 = *insufficient* to 7 = *sufficient*), changes in one's therapy quality compared to the period before COVID-19 (decreased, unchanged, or increased), colleagues' therapy quality compared with the period before COVID-19 (worse, unchanged, or better), changes in working hours compared to the period before COVID-19 (increase, decrease, or no change), changes in workload with the period before COVID-19 (increase, decrease, or no change), work from home (yes or no), and free description (fill-in-the-blank question).

Concerning daily life, participants were asked to respond to the following items concerning everyday life: efforts to avoid being infected (7-point rating scale ranging from 1 = *never* to 7 = *frequent*), efforts to not transmit the virus to others (7-point rating scale), frequency of contact with family (7-point rating), frequency of contact with friends (7-point rating), changes in daily step count compared to the period before COVID-19 (which was evaluated using records automatically logged in healthcare applications implemented in the respondents' phones), fewer outings (yes or no), attempts to avoid face-to-face conversations (yes or no), increased standard precautions at home (handwashing and gargling) (yes or no), increased frequency of mask-wearing (yes or no), increased social networking site usage (yes or no), and free description (fill-in-the-blank question).

## Path model

Based on previous findings, which showed relationships among workload, mental health, and job performance (11, 17, 18), we designed a hypothesized path model (Figure 1A). This model focused on the relationships between the changes in work and life due to COVID-19, mental health problems including depression, anxiety, and insomnia, and the quality of therapy. Based on recent literature that has documented (perceived) social isolation and loneliness (20, 23), we chose "efforts to avoid being infected" and "less information provision from the workplace" as candidates that can exacerbate mental health problems. Second, based on literature that focused on the relationship between mental health and job performance (11, 17, 18, 27, 30), we hypothesized that the exacerbation of mental health problems would be related to a decrease in therapy quality. Based on previous reports that showed a close link between the perceptions of caregiver and client (34, 35), in the present study, we employed self-report of one's therapy quality as an index of therapy quality. Further, to examine whether one's therapy quality was closely related to colleagues' therapy quality (i.e., check if the change in quality is beyond personal problems), we performed a simple correlation analysis. Path analyses were performed using AMOS 28 (48). To assess the goodness of fit, we employed the chi-square value, the comparative fit index (CFI), and the root-mean-squared error of approximation (RMSEA). The chi-square value of $< 0.05$, the CFI value of $\geq 0.95$, and the RMSEA value of $< 0.06$ are considered to indicate good model fit (49–52). The data were evaluated for estimation methods that assume multivariate normality using Bollen-Stine bootstrapping. Skewness and kurtosis were also examined (Supplementary Table 1).

# Results

## Sample characteristics and questionnaire results

Sample characteristics and questionnaire results are shown in Table 1. Cutoff scores for the four questionnaires were determined based on previous literature (39, 42, 45, 46). The total number of respondents was 4,418. Data from

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TABLE 1 Sample characteristics and questionnaire results.

| Survey item | No./total No. (%) |
|---|---|
| | All 47 Prefectures ($n$ = 1,966) |
| **Sample characteristics** | |
| Age, M (SD) | 36.8 (8.8) |
| **Gender** | |
| Women | 1,106 (56.3) |
| Men | 860 (43.7) |
| **Academic background** | |
| <Bachelor's | 1,115 (56.7) |
| ≧ Bachelor's | 851(43.3) |
| **Marital status** | |
| Married | 1,229 (62.5) |
| Unmarried | 737 (37.5) |
| **Employment type** | |
| Full time | 1,875 (95.4) |
| Part time | 91 (4.6) |
| **Managerial position** | |
| Yes | 651 (33.1) |
| No | 1,315 (66.9) |
| Service years, M (SD) | 12.8 (8.0) |
| **Questionnaire results** | |
| **Presence of anxiety, depression, insomnia, and loneliness (cutoff score)** | |
| Loneliness (≧6) | 480 (24.4) |
| SDS (≧50) | 325 (16.5) |
| SAS (≧40) | 297 (15.1) |
| ISI (≧10) | 286 (14.5) |
| **Median score on each questionnaire (IQR)** | |
| Loneliness | 4 (3–5) |
| SDS | 40 (34–47) |
| SAS | 33 (29–37) |
| ISI | 5 (2–8) |
| **Accepting patients with COVID-19** | |
| Yes | 536 (27.3) |
| No | 1,430 (72.7) |
| **Items related to work** | |
| **Provision of information on COVID-19 by workplace (1 = never, 7 = sufficient)** | |
| 5–7 (above average level) | 1,463 (74.4) |
| 1–3 (below average level) | 185 (9.4) |
| 4 (average) | 318 (16.2) |
| **Changes in one's therapy quality compared with early 2019 (before COVID-19)** | |
| Increased | 123 (6.3) |
| Decreased | 423 (21.5) |
| Unchanged | 1,420 (72.2) |

*(Continued)*

TABLE 1 (Continued)

| Survey item | No./total No. (%) |
|---|---|
| | All 47 Prefectures ($n$ = 1,966) |
| **Changes in colleagues' therapy quality compared with early 2019 (before COVID-19)** | |
| Increased | 110 (5.6) |
| Decreased | 399 (20.3) |
| Unchanged | 1,457 (74.1) |
| **Changes in working hours compared with early 2019 (before COVID-19)** | |
| Increased | 165 (8.4) |
| Decreased | 173 (8.8) |
| Unchanged | 1,628 (82.8) |
| **Changes in workload compared with early 2019 (before COVID-19)** | |
| Increased | 990 (50.4) |
| Decreased | 336 (17.0) |
| Unchanged | 640 (32.6) |
| **Work from home** | |
| Yes | 147 (7.5) |
| No | 1,819 (92.5) |
| **Free description about changes in work style (fill-in-the-blank question)** | |
| Yes | 345 (17.5) |
| No | 1,621 (82.5) |
| **Items related to private life** | |
| **Efforts to avoid being infected (1 = *never*, 7 = *frequent*)** | |
| 5–7 | 1,951 (99.2) |
| 1–3 | 1 (0.05) |
| 4 | 14 (0.7) |
| **Efforts to not transmit the virus to others (1 = *never*, 7 = *frequent*)** | |
| 5–7 | 1,943 (98.8) |
| 1–3 | 6 (0.3) |
| 4 | 17 (0.9) |
| **Frequency of contact with family (1 = *never*, 7 = *frequent*)** | |
| 5–7 | 1,342 (68.3) |
| 1–3 | 260 (13.2) |
| 4 | 364 (18.5) |
| **Frequency of contact with friends (1 = *never*, 7 = *frequent*)** | |
| 5–7 | 499 (25.4) |
| 1–3 | 942 (47.9) |
| 4 | 525 (26.7) |

*(Continued)*

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TABLE 1 (Continued)

| Survey item | No./total No. (%) |
|---|---|
| | All 47 Prefectures ($n$ = 1,966) |
| **Changes in daily step count compared with early 2019** | |
| Increased | 163 (8.3) |
| Decreased | 339 (17.2) |
| Unchanged | 1,386 (70.5) |
| Unknown | 78 (4.0) |
| **Fewer outings** | |
| Yes | 1,938 (98.6) |
| No | 28 (1.4) |
| **Avoidance of face-to-face conversations** | |
| Yes | 1,808 (92.0) |
| No | 158 (8.0) |
| **Increased precautions at home** | |
| Yes | 1,893 (96.3) |
| No | 73 (3.7) |
| **Increased mask-wearing** | |
| Yes | 1,954 (99.4) |
| No | 12 (0.6) |
| **Increased SNS usage** | |
| Yes | 1,003 (51.0) |
| No | 963 (49.0) |
| **Free description about changes in life (fill-in-the-blank question)** | |
| Yes | 329 (16.7) |
| No | 1,637 (83.3) |

SAS, Self-rating Anxiety Scale, SDS, Self-rating Depression Scale, ISI, Insomnia Severity Index, IQR, interquartile range, COVID-19, coronavirus disease 2019. Percentages may not total 100 because of rounding.

respondents with a history of psychiatric disorders ($n$ = 481), inconsistent answers between yes or no questions and rating (e.g., "yes" to the change in outing frequency but rated the frequency as unchanged) ($n$ = 1,336), a declaration that they do not actively see clients ($n$ = 475), and inconsistent answers to working hours ($n$ = 160) were excluded. The remaining respondents were 1,966 (1,106 women and 860 men).

The results of bivariate correlations among study variables are shown in Table 2. Information provision is negatively associated with the three psychological symptoms, supporting previous evidence that insufficient information provision is related to mental health problems. Information provision and the three psychological symptoms were significantly related to one's quality of therapy (all $p$-values $< 0.01$). In other words, an increase in information provision is positively related to the quality of therapy, whereas a decrease in psychological symptoms is positively related to the quality of therapy. Efforts to avoid being infected, workload, and working hours did not show a significant relationship with the quality of therapy.

Furthermore, efforts to avoid being infected and working hours were not significantly associated with any psychological symptoms. We also performed correlation analysis using the data of one's therapy quality and colleagues' therapy quality. This analysis showed a strong positive correlation (Pearson's r = 0.79, $p < 0.01$, 95% confidence interval [0.78, 0.81]), suggesting that changes in therapy quality during the pandemic mainly occur at the institutional rather than the individual level.

## Path analysis

First, we examined whether the demographic variables, including gender, managerial position, marital status, and acceptance of patients with COVID-19, needed to be considered as control variables using multigroup analysis. The four types of multigroup analysis revealed that managerial position and acceptance of patients with COVID-19 needed to be considered as control variables, whereas gender and marital status did not make significant group differences (Supplementary Figures 1–8). Therefore, we revised the model to include managerial position and acceptance of patients with COVID-19 as control variables and performed the path analysis (Figure 1B). The path analysis for the revised model (Table 3, Figure 1B) showed a significant chi-square value ($\chi 2 = 117.22$, df = 9, $p < 0.001$) and a discrepancy between the model and data (Bollen-Stine bootstrapping, $p < 0.05$), but the other goodness-of-fit indicators showed that this model had a good fit (CFI = 0.96, RMSEA = 0.078). Next, we designed a trimmed model based on the results of the revised model. In this trimmed model, exogenous variables, "efforts to avoid being infected" and "working hours," and a control variable, "acceptance of patients with COVID-19," which was not related to any other variables and had insignificant paths, were removed (Figure 1C). Although, this model showed a significant chi-square value ($\chi 2 = 42.48$, df = 7, $p < 0.05$), and the discrepancy between the model and data (Bollen-Stine bootstrapping, $p < 0.05$), the other goodness-of-fit indices showed that this model had a better fit (CFI = 0.99, RMSEA = 0.05). These results suggested that insufficient information provision by the workplace and that increased workload are critically associated with mental health problems, and therapists in managerial positions tend to feel that the quality of their therapy has decreased during the COVID-19 pandemic. Furthermore, although the bivariate correlation revealed that all mental health problems were significantly associated with the quality of therapy, depression

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TABLE 2 Correlations among study variables.

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. Care not to be infected | | | | | | | |
| 2. Information provision | **0.22**$^{***}$ | | | | | | |
| 3. Workload | 0.07$^{**}$ | 0.04 | | | | | |
| 4. Working hours | −0.004 | −0.01 | **0.27**$^{***}$ | | | | |
| 5. Depression | −0.03 | **−0.18**$^{***}$ | 0.09$^{***}$ | 0.01 | | | |
| 6. Anxiety | 0.003 | **−0.13**$^{***}$ | **0.12**$^{***}$ | 0.04 | **0.73**$^{***}$ | | |
| 7. Insomnia | −0.03 | **−0.12**$^{***}$ | **0.10**$^{***}$ | 0.04 | **0.52**$^{***}$ | **0.53**$^{***}$ | |
| 8. Quality of therapy | 0.01 | 0.08$^{***}$ | 0.02 | 0.02 | **−0.13**$^{***}$ | **−0.10**$^{***}$ | −0.06$^{**}$ |

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*} < 0.05$. Absolute values of correlation coefficients >0.1 are shown in bold.

may be especially important in maintaining the quality of therapy.

## Discussion

Using data from an online questionnaire from registered occupational therapists, we investigated the relationships among work life, mental health conditions, and quality of therapy. The results from the path analysis showed that insufficient information provision at the workplace and increased workload were related to depression, anxiety, and insomnia. Depression was associated with decreased self-evaluation of one's quality of therapy. Furthermore, the evaluation of one's quality of therapy showed a strong positive correlation with the evaluation of a colleague's quality of therapy, suggesting the possibility that changes in therapy quality occur on an institutional basis rather than on an individual basis. However, the majority of participants thought that they obtained information from the workplace at a higher level than average; it is considered that qualitatively novel supporting systems and reassessment of workload are important.

A total of 50.4% of the respondents reported an increased workload due to the pandemic, and the increase in workload was significantly related to an increase in depression, anxiety, and insomnia. These findings are consistent with a recent meta-analysis focusing on burnout and the mental health of medical professionals (53). The path analysis showed a specific link between depression and therapy quality. Although depression showed a strong positive correlation with the other two symptoms ($r = 0.73$ with anxiety and $r = 0.52$ with insomnia), anxiety and insomnia showed relatively smaller correlations with therapy quality, which could be negligible ($r = -0.1$ for anxiety and $r = -0.06$ for insomnia) (54). Depression showed a relatively larger correlation with therapy quality ($r = -0.13$), highlighting the relationship between depression and the quality of therapy. Contrary to our hypothesis, efforts to avoid being infected did not show a significant link with other variables and were excluded from our trimmed model. This may be because there is an extremely high number of therapists who do not want to be infected. In fact, 99.2% of the respondents said that their efforts to avoid being infected were above average. The data might indicate the professionalism of occupational therapists.

During the second state of emergency, 24.4, 16.5, 15.1, and 14.5% of occupational therapists presented symptoms of loneliness, depression, anxiety, and insomnia, respectively. Although the prevalence of psychological symptoms varies across countries, especially due to the pandemic (55), the ratio of respondents who showed depression and anxiety increased, and the ratio of insomnia decreased in comparison with the previous online survey, which was conducted during the initial state of emergency (10.9 to 16.5% for depression, 11.3 to 15.1% for anxiety, and 16.8 to 14.5% for insomnia) (6). Although the number of people with insomnia decreased, mental health condition among therapists seems to be getting worse, and additional mental support is needed. Taken together with the finding of the bivariate correlation, which showed a negative relationship between the increase in psychological symptoms and therapy quality, there is a possibility that therapy quality has decreased throughout the pandemic in some institutions. Although additional direct and causal evidence is needed, insufficient information provision and overload might negatively affect therapy quality, resulting in decreased quality of life of patients.

It should be noted that 74.4% of respondents answered that the information provided was above average, and only 9.4% answered that the information provided was below average. Thus, most workplaces seem to have been trying to support therapists, and therapists acknowledge the effort. However, in addition to typical support for workers, such as providing personal protective equipment and information, individual psychological support would be needed. For example, one possible way is to identify therapists with psychological symptoms using validated questionnaires (9) and monitor and care for them (26). Burnout among healthcare professionals has been a severe problem for a

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TABLE 3 Path coefficients of the revised model and trimmed model.

| | Unstandardized estimate | Standard error | *p*-value | Standardized estimate |
|---|---|---|---|---|
| **Revised model** | | | | |
| Care not to be infected → Depression | 0.006 | 0.296 | 0.984 | 0.000 |
| Care not to be infected → Anxiety | 0.265 | 0.222 | 0.234 | 0.026 |
| Care not to be infected → Insomnia | −0.04 | 0.136 | 0.772 | −0.006 |
| Information provision → Depression | −1,208 | 0.151 | **<0.001***** | −0.176 |
| Information provision → Anxiety | −0.705 | 0.113 | **<0.001***** | −0.138 |
| Information provision → Insomnia | −0.374 | 0.069 | **<0.001***** | −0.121 |
| Workload → Depression | 0.843 | 0.163 | **<0.001***** | 0.119 |
| Workload → Anxiety | 0.689 | 0.122 | **<0.001***** | 0.131 |
| Workload → Insomnia | 0.352 | 0.075 | **<0.001***** | 0.110 |
| Working hours → Depression | 0.005 | 0.021 | 0.806 | 0.006 |
| Working hours → Anxiety | −0.03 | 0.045 | 0.513 | −0.015 |
| Working hours → Insomnia | 0.005 | 0.034 | 0.888 | 0.003 |
| Depression → Quality of care | −0.007 | 0.002 | **<0.001***** | −0.115 |
| Anxiety → Quality of care | −0.002 | 0.003 | 0.429 | −0.027 |
| Insomnia → Quality of care | 0.001 | 0.003 | 0.791 | 0.007 |
| Managerial position → Depression | −2,103 | 0.41 | **<0.001***** | −0.114 |
| Managerial position → Anxiety | −0.804 | 0.307 | **0.009*** | −0.059 |
| Managerial position → Insomnia | −0.346 | 0.188 | 0.066 | −0.041 |
| Managerial position → Quality of care | −0.053 | 0.024 | **0.028*** | −0.049 |
| Acceptance of COVID-19 patient → Depression | 0.038 | 0.429 | 0.93 | 0.002 |
| Acceptance of COVID-19 patient → Anxiety | −0.206 | 0.322 | 0.522 | −0.014 |
| Acceptance of COVID-19 patient → Insomnia | −0.305 | 0.197 | 0.122 | −0.035 |
| Acceptance of COVID-19 patient → Quality of care | −0.047 | 0.025 | 0.065 | −0.041 |
| **Trimmed model** | | | | |
| Information provision → Depression | −1.283 | 0.151 | **<0.001***** | −0.187 |
| Information provision → Anxiety | −0.718 | 0.113 | **<0.001***** | −0.141 |
| Information provision → Insomnia | −0.393 | 0.069 | **<0.001***** | −0.126 |
| Workload → Depression | 0.716 | 0.156 | **<0.001***** | 0.101 |
| Workload → Anxiety | 0.657 | 0.117 | **<0.001***** | 0.125 |
| Workload → Insomnia | 0.350 | 0.071 | **<0.001***** | 0.109 |
| Depression → Quality of care | −0.008 | 0.001 | **<0.001***** | −0.130 |
| Managerial position → Anxiety | 0.295 | 0.206 | 0.153 | 0.021 |
| Managerial position → Quality of care | −0.053 | 0.024 | **0.028*** | −0.049 |

***$p < 0.001$, *$< 0.05$. Significant *p*-values are shown in bold.

long time (10, 30), and it is becoming more serious in these challenging times. As burnout is linked to decreased therapy quality, such an approach is essential for therapists and patients.

Another possible idea to support therapists can be drawn from a recent randomized clinical trial that demonstrated the effectiveness of a layperson-delivered, empathy-focused program (56). In this study, callers who were briefly trained in empathetic conversational techniques using a 1-h videoconference talked to participants over the telephone for 4 weeks, and this intervention improved depression, loneliness, and anxiety in at-risk adults (56). If managers are trained to have empathetic conversations using short material, such an intervention can be implemented in each workplace, and it would have the potential to support therapists and further maintain therapy quality during pandemics. However, it should be noted that the managerial position has a negative relationship with therapy quality, and care for the managers is also essential. The findings of this study revealed that one's therapy quality showed a strong positive correlation with colleagues' therapy quality. Thus, it is plausible that therapy quality can change at the institutional level. As a first step, it is crucial to reassess the

work and mental health conditions of each professional and the supporting system in each institution. Then, it might be helpful to consider employing such additional approaches.

The current findings have limitations. First, as the present results were based on a cross-sectional online questionnaire and data were gathered only from occupational therapists in Japan, further studies are needed to examine whether these results can be applied to other populations (e.g., physiotherapists) and across borders. Second, the evaluation of one's own and colleagues' therapy quality in the present study was based on the participants' self-reports. Thus, there is a possibility that those self-evaluations are biased to some extent based on social desirability (a tendency to present oneself as socially desirable or acceptable rather than to present one's true thoughts or feelings) or by decreased self-esteem, which might be related to a personal mental health condition. Although the evaluation between one's therapy quality and that of colleagues' were correlated, and it is plausible that a decrease in therapy quality happens to some extent, these results are reported with caution. Future studies are needed to collect patient data relating to the quality of therapy and personality assessment, which may yield greater objectivity than self-reports. Finally, and most importantly, studies are required that directly examine whether interventions to support therapists' mental health, such as an empathy-focused program, are effective in terms of improving the quality of therapy and patients' quality of life. Nevertheless, we believe the findings from this study would be the cornerstone of a novel support system for therapists.

In conclusion, a nationwide cross-sectional online survey was conducted to investigate whether and how mental health problems are related to the therapy quality of occupational therapists. The results showed that insufficient information provision at the workplace and increased workload were positively related to psychological symptoms. Only depression was associated with decreased self-evaluation of one's quality of therapy. Evaluations of one's own quality and a colleague's quality of therapy showed a strong positive correlation, suggesting that improvements in therapy quality may occur at the institutional rather than the individual level.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by the Ethical Committee in Saitama Prefectural University. The patients/participants provided their written informed consent to participate in this study.

## Author contributions

AI, DS, HM, HN, and TI: study conception, design, and data acquisition. AI, DS, SK, and TI: analysis, interpretation of data, and writing—review and editing. AI: writing—original draft. All authors approved final version of the article.

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## Conflict of interest

Author HN was employed by the Japanese Association of Occupational Therapists.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1053703/full#supplementary-material

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# Work-related disease symptoms and occupational injuries among coffee processing industry workers in Bench-Sheko and Kaffa Zones Southwest, Ethiopia: A mixed-method study

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**Background:** Occupational injuries have become one of the most critical rooting causes paying to infirmities and life-threatening conditions in developed and developing countries. Workers in the coffee industry face some occupational health and safety issues. However, there is limited evidence on this important public health issue. Hence, this research was conducted to assess work-related disease symptoms and occupational injuries among coffee processing workers in Southwest, Ethiopia.

**Methods:** A cross-sectional study supplemented with a qualitative method was done. A total of 721 workers were involved in the study for quantitative information. In addition, we performed a total of 22 in-depth and five key informant interviews for generating qualitative evidence. Quantitative data was collected by an interview-based questionnaire which is adapted from similar studies. We conducted descriptive, binary logistic, and multivariable regression analysis as necessary, to ascertain the factors affecting occupational injuries. We collected qualitative data guided by an interview guide, transcribed verbatim, and analyzed using ATLAS ti version-8 by applying a content analysis approach. Finally, quotes from participants that had exemplary ideas were triangulated along with quantitative findings.

**Result:** The overall prevalence rate of work-related symptoms and occupational injuries among coffee processing workers were 21.7 and 13.4% respectively. Age group 30–39 and 40–49 (Adjusted odds ratio (AOR) 1.95, 95% CI 1.37, 2.79, (AOR 3.28, 95% CI 1.89, 5.69, respectively, income level (AOR 0.24, 95% CI 0.16, 0.36, $p = 0.000$), experience (AOR 1.64, 95% CI 1.04, 2.60, $p = 0.034$), and smoking cigarette (AOR 5.59, 95% CI 2.78, 11.26, $p = 0.000$) were significantly associated with the work-related symptom. In addition, training related to the job (AOR 11.88, 95% CI1.34, 105.57, $p = 0.026$) was significantly associated with occupational injuries among coffee processing industry workers.

**Conclusion:** The prevalence of work-related symptoms and occupational injuries was high among coffee processing industry workers in southwest Ethiopia. Therefore, there is a need for regulations for both government and industry owners to advance the occupational conditions and ergonomic structure of coffee processing industries.

KEYWORDS

work-related disease symptoms, occupational injuries, coffee processing industries, Southwest Ethiopia, work-related symptoms

# 1. Introduction

Job-related injuries are one of the largest reasons contributing to disabilities and life-threatening conditions in developed and developing countries (1–4). Occupational diseases existing a main public health issue resulting in serious social and economic problem that could be prevented if appropriate measures are taken (5, 6). Globally, an estimated 271 million people suffer from occupational injuries, and 2 million die each year as a result of these work-related injuries (7–9).

The estimated economic loss triggered by occupational accidents and disease was equivalent to 4% of the world's gross national product (10). According to International Labor Organization, 2.3 million workers die each year from unintended job-related accidents and diseases. Individuals belonging to all economic groups hurt fatal injuries, but death rates due to injury tend to be higher in those from developing countries where there is an insecure working environment and less awareness (11, 12).

In Ethiopia, the manufacturing sector and working areas are growing alarmingly. As a result, the problem of injury is severe due to the lack of a healthy working environment in the rate of industrial expansion (1, 13, 14). Moreover, only 5–10% of the workforce in Ethiopia have access to some kind of work-related health services and trained workers, limited/no job-related services and psychosocial stress are exist (15, 16).

Currently, 335/1,000 workers are exposed to occupational injury per year in small and medium-scale industries. Of these, 17.1% of them were hospitalized, 40% of them for greater than 24 h, 53.9% were absent from work, and 191 days were lost due to work-related injuries [10. 16]. Another study in Afar prevailed that the overall prevalence rate was 783 per 1,000 workers with 11% being hospitalized and 153 days lost due to injuries (17).

Studies in primary coffee processing factories in Uganda and Sri Lanka have indicated a higher prevalence of acute respiratory symptoms than among controls. Similarly, an increased prevalence of chronic respiratory symptoms has been reported among primary coffee factory workers in Papua New Guinea and Tanzania (18–20).

Ethiopia is a major producer of coffee in Africa producing about 500,000 tones every year (21). Ethiopia is the birthplace of Coffea arabica, which obtained its name from Kaffa where coffee was first discovered in the southwestern highlands of Ethiopia. Coffee contributes to about 10% of the Ethiopian gross domestic product and accounts for more than 25% of the foreign currency income (20, 22). In Ethiopia, about 15 million people depend on coffee production directly or indirectly for their living (23).

Ethiopia is one of the 10 top coffee producers in the world. According to the International coffee organization (ICO), Ethiopia was the fifth largest coffee producer after Brazil, Vietnam, Indonesia, and Colombia, with a total production of 498,780 tones; and the seventh largest coffee exporter in the world (20, 22, 24).

According to the Ethiopian Government figures, in 2019/2020 the total volume and value of Ethiopian's coffee export were 196,117 tones and 841.65 million American Dollars respectively. This volume and value of coffee export when compared to the 2018/19 export performance shows increment was increased by 13.9 and 59.3%, respectively (25).

Despite all these facts; in Ethiopia, there is a lack of wide-ranging data and nationwide research on the rate of work-related disease symptoms and occupational injuries and its factors in coffee processing industry workers. Thus, this study aimed to assess work-related disease symptoms, occupational injuries, and associated factors among coffee processing workers in the Bench-Sheko and Kaffa Zones, in southwest Ethiopia.

# 2. Methods

## 2.1. Study area and period

The study was conducted in the Bench-Sheko and Kaffa Zones from February 15 up to June 30, 2021 (Figure 1). These two zones are among the high coffee-producing districts in Ethiopia. Their capital towns (Mizan-Aman and Bonga) are at 585 km and 469 km respectively from Addis Ababa, the capital of Ethiopia, to the southwest direction.

According to reports from the zones' industry offices; there are a total of 175 functional coffee processing industries in these zones. Of these 82 (53 for wet coffee and 29 for dry coffee) are

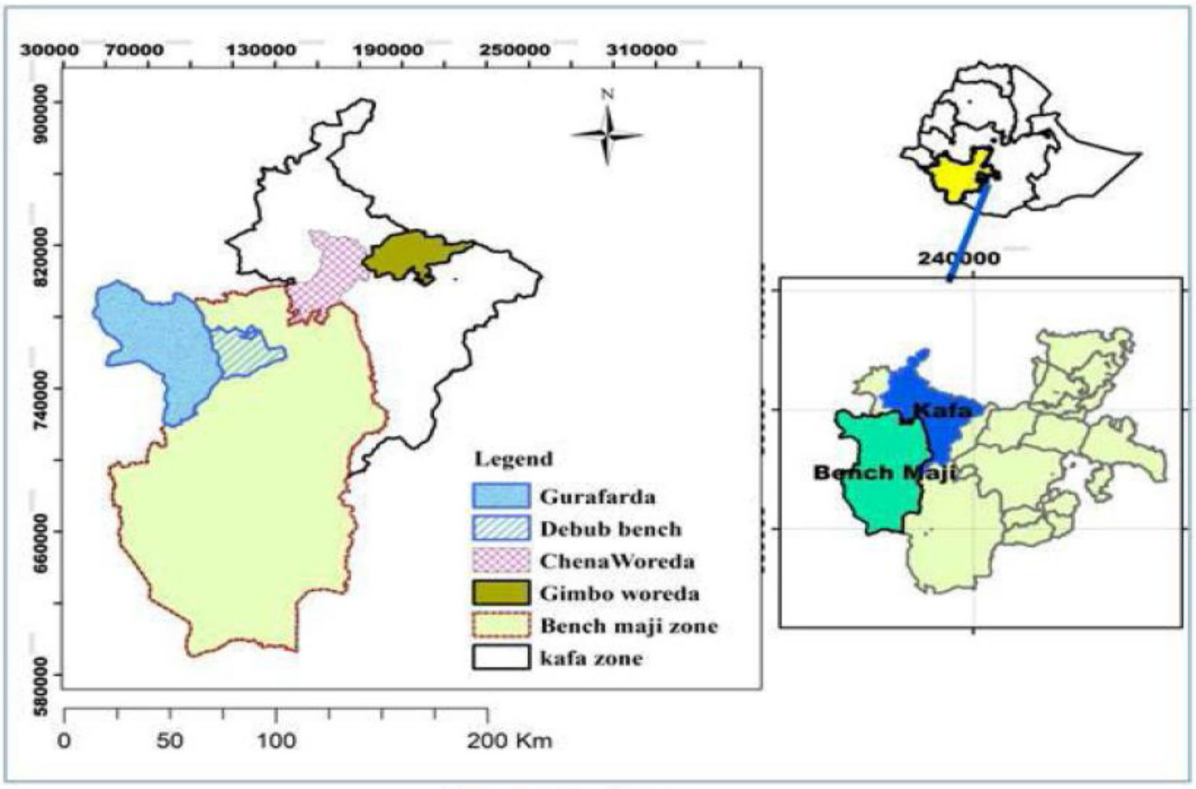


FIGURE 1
Map of study area.

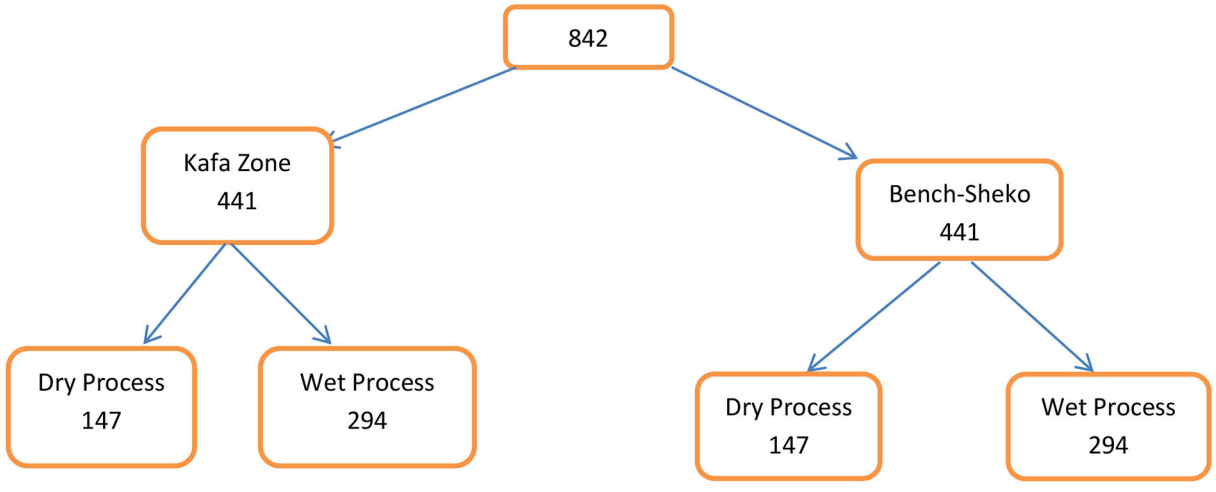


FIGURE 2
The schematic presentation of the sampling process.

found in the Bench-Sheko zone and 93 (58 for spike coffee and 35 for dry coffee) are found in the Kaffa zone. The number of workers in these coffee processing industries varies depending on the season of coffee harvesting. The number of workers in these industries varies with time. It increases in the harvesting season particularly from September to May; since temporary

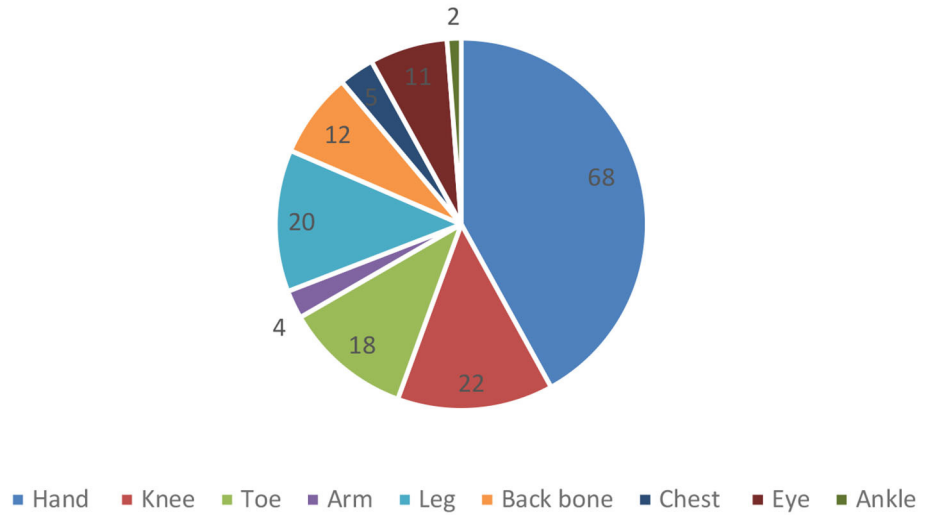


FIGURE 3
Body part injured among coffee industry workers, Bench-Sheko and Kafa zones, May/2021.

employees are involved in coffee processing. And it decreases in the other seasons.

## 2.2. Study design

An institution-based cross-sectional study design supplemented by a qualitative study was conducted.

## 2.3. Populations

### 2.3.1. Source population

All of the workers in coffee processing industries found in the Bench-Sheko and Kaffa zones were the source population.

### 2.3.2. Study population

All workers in the selected coffee processing industries found in the Bench-Sheko and Kaffa zones were the study population.

## 2.4. Eligibility criteria

### 2.4.1. Inclusion criteria

Workers who are employed and being on job for at least 6 months were included.

### 2.4.2. Exclusion criteria

Administrative workers were not included (for the quantitative study) because they may not be involved directly in tasks that put them at risk for occupational injuries. Besides, workers who had chronic illnesses and who had a previous history of musculoskeletal health problems not related to their occupation were excluded from the study.

## 2.5. Sampling size and sampling techniques

### 2.5.1. Sampling size determination

#### 2.5.1.1. For quantitative study

The sample size was calculated using a single population proportion formula taking the prevalence of cough among coffee processing industries workers in Ethiopia which were 46.4% (25). In addition to this, taking a confidence level of 95%, a margin of error of 5%, and a design effect of 2, the sample size became 765. But considering a non-response rate of 10%, about 842 workers were considered (Figure 2) to be included in the study, even though we received a response from only 721 workers.

#### 2.5.1.2. For qualitative study

In-depth interviews with 22 purposively selected workers and five key informant interviews were conducted based on the saturation of the information.

### 2.5.2. Sampling technique

#### 2.5.2.1. For quantitative study

First, among the total coffee processing industries found in both zones, 30% of each type of coffee processing industry were selected randomly from each zone. Then, allocating proportionally, the final sample was selected by a systematic random sampling technique using the list of workers, which was obtained from the registries of industries, as a sampling frame.

#### 2.5.2.2. For qualitative study

A purposive sampling technique was employed and an in-depth interview was conducted with a total of 22 individuals who are assumed to have better information on the issue, and a total of five key informants who were from the administrative unit were involved in the study.

## 2.6. Operational definition

- Occupational injury– any physical injury condition sustained by a worker in connection with the performance of their work in coffee processing industries.
- Work-related disease symptoms– symptoms of diseases that the workers developed during their stay in the coffee processing industries. In this study we have assessed the diseases' symptoms which include respiratory symptoms (cough, wheezing, and breathlessness) and musculoskeletal symptoms (lower back pain, shoulder and neck pains).
- Shoulder and neck pains–ache, pain, or discomfort felt at a time in the shoulder and neck (cervico-brachial region) in the last 6 months.
- Lower back pain–perceived self-reported pain and/or discomfort, localized between the coastal margin (bottom of the ribs) and above the inferior gluteal folds (top of the legs) which have lasted for days or weeks during the last 6 months.
- Respiratory symptoms–having at least one of cough, shortness of breath, or wheezing.
- Cough–participants were considered to have a cough at least if they cough first thing in the morning, cough during the day or night, cough as much as four to six times a day for a week, or cough on most days for as much as three consecutive months of the year.
- Work-related shortness of breath–participants were considered to be experiencing work-related shortness of breath if they usually experienced chest tightness while at work or just after work.
- Wheezing–participants were considered to be experiencing wheezing if their chest ever sounded wheezy (whistling sound).
- Hazards–a physical situation with a potential for human injury, damage to property, damage to the environment, or some combination of these.

## 2.7. Data collection and quality controls

### 2.7.1. For quantitative study

The interviewer-administered structured questionnaire, which was adapted from similar studies was used (11, 19, 25–28). The disease symptoms mainly respiratory symptoms were assessed using the standardized questionnaire adopted from the American Thoracic Society (ATS) (29). In addition, musculoskeletal symptoms were assessed using the standardized Nordic questionnaire for the analysis of musculoskeletal symptoms (30). The questionnaire was translated to Amharic, and back-translated to English to ensure consistency. The data were collected by BSc. nurses and public health officers. Two days of training were given to data collectors about the objective of the study, the contents of the questionnaire, ways of interviews, and other related issues. A pretest was conducted on 5% of the samples in coffee processing industries that were not part of the actual study.

### 2.7.2. For qualitative study

In-depth interviews and key informant interviews were conducted by two of the principal investigators using interview guides. The interviews were conducted in quiet places and responses were recorded by audio recorder.

## 2.8. Data entry, processing, and analysis

After checking for errors data were entered into Epi-data manager version 4.6.0.2 and exported to SPSS version 22 for analysis. The descriptive analysis was made using frequencies and proportions (percentages). Binary logistic regression was used to identify the association between the dependent and independent variables (work-related symptoms and occupational injuries). Variables with a $P < 0.25$ at bi-variable analysis were candidates for multivariable analysis. In multivariable logistic regression $p < 0.05$ was used to identify the significant factors affecting the outcome variables. Both the crude and adjusted odds ratios with the respective 95% confidence intervals were used to assess the strength of the association.

# 3. Results

In this study, multiple issues were addressed through a quantitative and qualitative approach. The qualitative study has focused on the experience of workers at coffee processing organizations mainly addressing issues related to awareness of occupational safety, utilization of personal protective equipment, the experience of work-related

injuries, and experience of work-related musculoskeletal and respiratory diseases. Similarly, the quantitative study assessed and presented figurative data on the given issues. Details of the results are presented here below under different sections.

## 3.1. Socio-demographic and other general characteristics of the respondents

Out of a sample size of 842, a total of 721 workers participated in the quantitative studies, which makes a response rate of 85.6%. About half (48.1%) of the respondents were found in the age category of 19–29 years. The majority (60.2%) of the participants were male and about two third (64.9%) had attended primary education (Table 1).

TABLE 1 Socio-demographic and other general characteristics of the respondents, May/2021, Bench-Sheko and Kafa Zone.

| Variables | Categories | Frequency | Percent |
|---|---|---|---|
| Age in years | 19–29 | 347 | 48.1 |
| | 30–39 | 258 | 35.8 |
| | 40–49 | 102 | 14.1 |
| | ≥50 | 14 | 1.9 |
| Sex | Male | 434 | 60.2 |
| | Female | 287 | 39.8 |
| Monthly income in ETB | <1,000 | 152 | 21.1 |
| | ≥1,000 | 569 | 78.9 |
| Educational status | Can't read and write | 81 | 11.2 |
| | Can read and write | 66 | 9.2 |
| | Primary (Grade 1–8) | 468 | 64.9 |
| | Secondary (Grade 9-12) | 106 | 14.7 |
| Marital status | Single | 285 | 39.5 |
| | Married | 399 | 55.3 |
| | Divorced and widowed | 37 | 5.1 |
| Religion | Orthodox | 330 | 45.8 |
| | Protestant | 293 | 40.6 |
| | Muslim | 73 | 10.1 |
| | Others | 25 | 3.5 |
| Ethnicity | Bench | 135 | 18.7 |
| | Sheko | 137 | 19.0 |
| | Amhara | 58 | 8.0 |
| | Oromo | 61 | 8.5 |
| | Kafa | 315 | 43.7 |
| | Other | 15 | 2.1 |
| Employment status | Permanent | 126 | 17.5 |
| | Temporary | 595 | 82.5 |
| Working location | Within the industry | 258 | 35.8 |
| | Out of the industry | 328 | 45.5 |
| | Both | 135 | 18.7 |
| Service years in the industry | ≤3 years | 592 | 82.1 |
| | >3 years | 129 | 17.9 |

*(Continued)*

## 3.2. Occupational safety experience and behavioral characteristics of the respondents

All qualitative study participants were asked to define what occupational safety means and their experience regarding the occupational safety policy and related concepts. Accordingly, they have expressed as it does mean securing safety like protecting from injuries and exposure to risky conditions or reducing the risk of workers during their engagement in different given activities. Of course, they have described that they lack detailed information about the policy that focuses on such issues and can't mention any article or present a document. The key informants have reported as there is different health information dissemination to workers regarding occupational safety, how to preserve, and health and do works safely by following basic health protocols. The coffee processing organizations have clinics that serve the workers and it has also a referral system for advanced health problems.

### 3.2.1. Utilization of personal protective equipment

All study participants have reported as personal protective materials are the most important things for any workers to facilitate activities, and reduce and avoid any risks to health and life. The most common materials reported to be used by workers include clothing, masks, gowns, gloves, and goggles. However, study participants have discussed as there is an interruption of material provision, quality problems, and inadequacy in terms of amount and timely replacement. Multiple things were

TABLE 1 (Continued)

| Variables | Categories | Frequency | Percent |
|---|---|---|---|
| Ever took job related safety and health training | Yes | 81 | 11.2 |
| | No | 640 | 88.8 |
| Ever exposed to pesticide | Yes | 29 | 4.0 |
| | No | 692 | 96.0 |
| Time of pesticide exposure | Within this year | 20 | 2.8 |
| | Before this year | 9 | 1.2 |
| Working hour | Less or equals to 8 | 713 | 98.9 |
| | More than 8 | 8 | 1.1 |
| Location of the kitchen | Inside the living room | 98 | 13.6 |
| | Outside the living room | 623 | 86.4 |
| Fuel type used for cooking | Electric | 1 | 0.1 |
| | Wood | 700 | 97.1 |
| | Charcoal | 20 | 2.8 |
| Body mass index in kg/m$^2$ | <18.5 | 35 | 4.9 |
| | 18.5–24.99 | 593 | 82.2 |
| | >25 | 93 | 12.9 |

TABLE 2 Types of work-related health problems among workers in coffee industries, Bench-Sheko and Kafa Zones, May/2021.

| Types of health problems | Duration category | Frequency | Percent |
|---|---|---|---|
| Respiratory diseases | Less than a month | 70 | 9.7 |
| | At least 1 month | 87 | 12.1 |
| Occupational injury | Less than a month | 6 | 0.8 |
| | At least 1 month | 91 | 12.6 |

mentioned to be the reason for the gaps in the area and mostly it was found to be due to under planning, budget problem, and improper utilization of the available materials.

### 3.2.2. Occupational injury among study participants

The coffee processing workers engage in different activities like lifting heavy loads, cutting different materials and wood, and collecting and packing the coffee. For doing that; they may use different sharp materials, machines, and chemicals and as a result, may face injuries. The following figure indicates the common kinds of bodily injury (Figure 3).

Through a qualitative approach; the most common kinds of injuries and health-related problems reported by participants include: machine hand cutting injury, pole injury, falling, snake bite, and back pain during carrying heavy loads. Many of them have been treated in the clinics and get recovered but sometimes the problem may end in complications, disability, and even death. The reasons for the occurrence of injury could be failing to take necessary care or lack of convenient working space and what makes the outcome poor could be late treatment, lack of adequate treatment, or irreversibility of the damage. It was also reported as there is no or enough compensation.

TABLE 3 Types of work related disease symptoms among workers in coffee industries, Bench-Sheko and Kafa Zones, May/2021.

| Type of symptoms | Frequency | Percent |
|---|---|---|
| Pain around neck and shoulder | 114 | 15.8 |
| Lower back pain | 353 | 49.0 |
| Cough | 186 | 25.80 |
| Shortness of breath | 66 | 9.2 |
| Wheeze | 66 | 9.2 |
| Overall work related symptoms | 398 | 55.2 |

## 3.3. Work-related disease symptoms

Working environment and work conditions are among determining factors of health, and people may face different health problems while they are on their routine work. Workers from coffee processing industries included in this study have reported a history of respiratory diseases, occupational injuries, and different disease symptoms especially related to respiratory and musculoskeletal systems. The following tables indicate the most common types of health problems and disease symptoms (Tables 2, 3).

Through a qualitative approach, the study participants have reported that the coffee processing area has much exposure to dust particles and pollens which may affect the respiratory system. People who are allergic might be sensitive and others could also develop certain health problems related to the breathing system. When asked if they ever have faced respiratory system-related diseases during their working period, some of them have reported repeated cough, sinusitis, wheezing, and breathing difficulty which challenges their life.

TABLE 4 Factors associated with work-related disease symptoms among workers in coffee industries, Bench-Sheko and Kafa Zones, May/2021.

| Variables | Variables' category | Work related symptoms | | COR (95%CI) | AOR (95%CI) | *P* value |
|---|---|---|---|---|---|---|
| | | No | Yes | | | |
| **Age** | 19–29 | 77 | 270 | 1 | 1 | 1 |
| | 30–39 | 39 | 219 | 1.86 (1.34, 2.59) | 1.95 (1.37, 2.79) | 0.000* |
| | 40–49 | 23 | 79 | 2.62 (1.63, 4.19) | 3.28 (1.89, 5.69) | 0.000* |
| | ≥50 | 4 | 10 | 0.63 (0.21, 1.93) | 0.94 (0.27, 0.27) | 3.274 |
| **Sex** | Male | 177 | 257 | 1.50 (1.11, 2.03) | 0.87 (0.60, 1.25) | 0.441 |
| | Female | 146 | 141 | 1 | 1 | 1 |
| **Income in ETB** | <1,000 | 38 | 114 | 1.25 (0.17, 0.37) | 1.24 (0.16, 0.36) | 0.000* |
| | ≥1,000 | 101 | 468 | 1 | 1 | 1 |
| Service year | ≤3 years | 86 | 506 | 1.27 (0.86, 1.85) | 1.64 (1.04, 2.60) | 0.034* |
| | >3 years | 39 | 90 | 1 | 1 | 1 |
| **Working location** | Within the industry | 103 | 419 | 1.42 (0.93, 2.16) | 1.67 (1.00, 2.77) | 0.051 |
| | Out of the industry | 18 | 134 | 1.02 (0.69, 1.53) | 1.40 (0.86, 2.28) | 0.173 |
| | Both | 11 | 36 | 1 | 1 | 1 |
| **PPE use** | Yes | 68 | 127 | 1.76 (1.25, 2.47) | 1.32 (0.88, 1.97) | 0.177 |
| | No | 255 | 271 | 1 | 1 | 1 |
| **Ever smoking cigarette** | Yes | 11 | 70 | 6.05 (3.15, 11.65) | 5.59 (2.78, 11.26) | 0.000* |
| | No | 312 | 328 | 1 | 1 | 1 |

*Significant at $p < 0.05$.

## 3.4. Factors associated with work-related disease symptoms and occupational injuries

During the bi-variable analysis, age, sex, income level, service year, working location, history of ever smoking, and personal protective equipment use were factors associated with work-related symptoms. However, age, income, service year, and history of smoking were independently associated factors. Likewise, age, income, service year, history of job-related training, pesticide exposure, personal protective equipment use, and current smoking status were associated with work-related (occupational) injuries during bi-variable analysis. However, only job-related training was significantly associated with occupational injuries. The details of bivariable and multi-variable analyses for both outcome variables were given in the following two tables (Tables 4, 5).

# 4. Discussion

In our study, the overall prevalence rate of respiratory symptoms among coffee processing workers was 21.7%. The result is consistent with other studies done in Tanzania, Ethiopia, Papua New Guinea, and Uganda (31–33). All of these studies revealed that coffee workers have a high prevalence of respiratory health problems. However, our present study found a higher prevalence of some of the respiratory symptoms (such as cough 25.8%) compared with the studies done among coffee industry workers in Tanzania, Uganda, and Ethiopia (28, 34). This might be due to the higher personal total dust exposure in southwest Ethiopia's coffee processing industries. The different methods of coffee pre-processing might be another reason (4, 28). One of the study participants depicted the issues as follows:

> *"I have repeatedly experienced common cold and breathing problem and I think it is due to the waste around the working area like accumulation of garbage and liquid waste…and sometimes I visit the clinic, take treatment and sometimes use home treatments…"*

Occupational safety and health problems are becoming major challenges in Ethiopia because of low occupational hazard awareness, lack of factory safety and health policy, and inefficient safety management systems (24). In our study, the overall occupational injuries among coffee processing industry workers were 13.4%. Work-related injuries were significant problems for the coffee processing industry workers. A total of 353 (49%) workers experienced low back pain during the last year, and 114 (15.8%) faced pain around the neck and shoulder during their current job. This work-related pain was considered to be severe

TABLE 5 Factors associated with work related injuries, Bench-Sheko and Kafa Zones, May/2021.

| Variables | Variables' category | Occupational injury | | COR (95%CI) | AOR (95%CI) | *P* value |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Age** | 19–29 | 70 | 277 | 1 | 1 | 1 |
| | 30–39 | 49 | 209 | 1.08 (0.72, 1.62) | 1.25 (0.08, 19.45) | 0.871 |
| | 40–49 | 34 | 68 | 0.51 (0.31, 0.82) | 1.90 (0.12, 29.39) | 0.646 |
| | ≥50 | 2 | 12 | 1.52 (0.33, 6.93) | 2.69 (0.15, 49.81) | 0.506 |
| **Income in ETB** | <1,000 | 43 | 109 | 0.62 (0.41, 0.94) | 0.70 (0.11, 4.31) | 0.696 |
| | ≥1,000 | 112 | 457 | 1 | 1 | 1 |
| Service year | ≤3 years | 106 | 486 | 1 | 1 | 1 |
| | >3 years | 49 | 80 | 0.36 (0.24, 0.54) | 0.68 (0.20, 2.35) | 0.543 |
| PPE use | Yes | 74 | 121 | 0.30 (0.21, 0.43) | 0.36 (0.11, 1.23) | 0.102 |
| | No | 81 | 445 | 1 | 1 | 1 |
| Currently smoking cigarette** | Yes | 16 | 36 | 2.60 (1.01, 6.70) | 0.55 (0.17, 1.77) | 0.315 |
| | No | 15 | 13 | 1 | 1 | 1 |
| Training related with job | Yes | 30 | 51 | 1 | 1 | 1 |
| | No | 125 | 515 | 2.42 (1.48, 3.96) | 11.88 (1.34, 105.57 ) | **0.026*** |
| Pesticide exposure | Yes | 13 | 16 | 1 | 1 | 1 |
| | No | 142 | 550 | 3.15 (1.48, 6.69) | 1.05 (0.10, 10.80) | 0.969 |

*Significant at $p < 0.05$.
**Since all the participants were not smoking currently, four cells will not add up to 721.

enough for most workers to seek medical attention or take days off. Moreover, study participants in coffee processing industries substantiate this finding and explained the issues as follows:

> *"My friend was hand broken, His fracture was due to falling by sliding and he was treated traditionally and healed after he got sick leave with pay. But there was no additional support given for him."*

> *"I was fallen earlier when washing coffee during harvesting time, due to sliding and was sick for 6 months having no sick leave without payment, and at that time I was not able to feed my family. The company did even not cover my treatment expense. The reason for my falling is, due to lack of necessary protective equipment and I was unable to overcome the hardship of the heavy work even not eaten well."*

> *"Cutting wounds by sharp equipment and machines up to death rarely, falling, fractures, disability; possible reasons for the accidental injuries are not following the necessary self-care during using long ladders that ends in falling. Lack of sufficient PPE, due to this, there are several workers walk by crutches ad suffer from chronic back pains."*

These findings are lower than other studies conducted in small-scale industries in Nigeria and Ethiopia (4, 12, 28). This might be due to seasonal variation and the working condition of the industries.

In the current study, age, income, service year, and smoking cigarettes were significantly associated with work-related symptoms. Coffee processing industry workers who have age group 30–39 and 40–49 were 1.95 and 3.28 times more likely to have work-related disease symptoms respectively. This could be attributable to workers who have children might spend more time in the routine activities and coffee processing area and face more exposure to occupational hazards (4).

Besides, coffee processing industry workers who have a monthly income of <10,000 ETB were 1.24 times more likely to have occupational-related disease symptoms. This might be due to workers who have less income could be unable to purchase personal protective equipment. As a result, working without using complete body covering PPE could expose the worker's body to different kinds of occupational hazards. This study is comparable with other studies done in Tanzania, Ethiopia, Papua New Guinea, and Uganda on coffee processing industry workers (27, 31, 32).

Coffee processing industry workers who worked less or equal to 3 years were 1.64 times more likely to have work-related

disease symptoms. The reason for being exposed to this level relates directly to the length of time workers spent on coffee processing activities. Similarly, studies done in Uganda and Tanzania (3, 4) showed that working experience was significantly associated with work-related symptoms among coffee processing industry workers. In addition, another study done in Ethiopia showed that work experience was significantly associated with occupational health conditions (11, 13, 25). Another possible reason for exposure to occupational health risks might be staying for a long time as coffee processing workers, which increases exposure to determinant factors.

Furthermore, coffee processing industry workers who smoke cigarettes were 5.59 times more likely to have work-related disease symptoms compared to their counterparts. This result contradicts other studies done in Ethiopia and Tanzania in which smoking cigarettes was not significantly associated with a respiratory infection and work-related symptoms (19, 27, 28, 34). This might be the smoking habit of the study participants. In addition, coffee processing industry workers who did not take training related to jobs were 11.88 times more likely to have occupational injuries compared with their counterparts. This finding was higher than a similar study conducted in Papua New Guinea (35).

## 5. Conclusion

The prevalence of work-related symptoms and occupational injuries is high among coffee processing industry workers in southwest Ethiopia. Some socio-demographic and workplace factors, which include age, income, service year, and smoking cigarettes, were found to be significantly associated with work-related disease symptoms. In addition, training related to the job has also been significantly associated with work-related injuries. Hence, it is important to provide appropriate and full body cover personal protective equipment with adequate training and manage the working hours. Moreover, there is a need for regulations at both government and private (factory owners) levels to improve the working conditions and ergonomic structure of coffee processing industries. Besides, it is important to have further studies to quantify the ergonomic hazards, especially chemical and dust level exposure, are recommended.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by Mizan-Tepi University College of Medicine and Health Sciences Research Ethical Review Committe. The patients/participants provided their written informed consent to participate in this study.

## Author contributions

BM, NS, and WW have analyzed the data and prepared the manuscript. MT and SN have reviewed the manuscript. All authors have participated in writing the protocol and data collection and read and approved the final manuscript.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

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# Occupational injuries and contributing factors among industry park construction workers in Northwest Ethiopia

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**Background:** Construction business is currently the second greatest source of injuries in Ethiopia after automotive accidents, with a risk of fatality that is five times higher than that of other industrial sectors. To establish measures for injury prevention, it is crucial to assess the severity of occupational injuries and identify the variables that contribute to them. Therefore, this study aimed to assess the magnitude and factors associated with occupational injuries among Bure Industrial Park construction workers, Northwest Ethiopia.

**Methods:** An institutional-based cross-sectional study was conducted among 372 construction workers at Bure Industrial Park. The study participants were selected using a simple random sampling method. The data were collected using interviewer-administered structured questionnaire and work environment observation using structured checklist. In the descriptive statistic, frequencies, proportion, and mean were calculated and the results of the analysis were presented in text and tables. The bi-variable and multivariable logistic regression analyses were carried out to identify independent factors having associations with the occurrence of occupational injury.

**Results:** The overall prevalence of occupational injuries among Bure industrial park construction workers was 39.4%, 95%C.I (34.4%-44.4%). Factors such as sex (being male) [AOR = 1.74, 95%CI (1.02–2.97)], being married [AOR = 2.79, 95%CI (1.50–5.17)], no use of personal protective equipment [AOR = 1.67, 95%CI (1.12–2.85)], no training on occupational safety [AOR = 1.45, 95%CI (1.06–2.98)], and not satisfied with the job [AOR = 5.97, 95%CI (3.48–10.2)] were the factors associated with occupational injuries.

**Conclusion and recommendation:** The finding shows the public health importance of occupational injury among construction workers in the study area. Numerous factors have been linked to workplace injuries, including sex, marital status, the usage of personal protection equipment, training in occupational safety, and job satisfaction. As a result, in order to lower the rate of occupational injury, employers should prioritize offering safety training, encouraging the use of personal protective equipment while working, conducting routine workplace inspections, and ensuring that their staff members are happy at work by providing comfortable workspaces.

KEYWORDS

occupational injuries, construction workers, Bure, Amhara region, Ethiopia

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# Introduction

Any accidental physical hurt or harm to body tissue resulting from work exposure is referred to as an occupational injury (1). The construction sector is home to about a quarter of all work-related fatalities, in addition to a large number of other injuries (2). Safety in the workplace is described as preventing incidents that could cause bodily harm to people (3, 4). Safety on construction sites lowers the danger of work-related accidents and injuries as well as harm to the general public (2).

Worldwide, hundreds of millions of individuals are working in unsafe circumstances (5). In both industrialized and developing countries, work injuries have been identified as one of the most important factors that contribute to poor health and life-threatening illnesses (6). Globally, there are approximately 270 million occupational injuries and two million fatalities per year in all productive sectors (6, 7). Occupational illnesses or accidents claim the lives of 6,300 people per day (8). Annually, 55,000 fatal injuries are caused by the construction sector (9). According to estimates, occupational accidents cost the global economy 4% of its GDP (USD 1.25 trillion) (10, 11). The annual projected direct and indirect costs of fatal and nonfatal construction injury are above $10 billion USD (12).

Construction industry is one of the riskiest and most accident-prone industries (6, 13). People working on construction sites are more likely to suffer traumatic injuries, illnesses, and fatalities than people in other occupations in both developed and developing countries (12, 14–16). Compared to manufacturing industry, peoples working in construction have 2.5 and 5 times higher risk of serious injury and death respectively (17).

Construction workers in poor countries experience occupational health and safety risks that are between 10 and 20 times more severe than those in industrialized countries (18). Construction workers have greater occupational health and safety injuries in developing countries than in developed ones; this is more common in Sub-Saharan Africa. This could be because there are less laws and regulations governing workplace health and safety (19).

The magnitude of work injuries among construction employees in Egypt was reported to be 46.2% (20), 74% in Kenya (21), and the magnitude range from 38.3 and 84.7% in Ethiopia (10, 22). Although unsafe work environments are frequently the cause of workplace injuries, other factors are also mentioned as contributing to occupational injuries, including sex, age, workload, lack of safety training, job stress, the absence of safety signs, sleep issues, alcohol consumption, cigarette smoking, chewing khat, and poor exercise habits (10, 13, 21–23).

Construction business is currently the second greatest source of injuries in Ethiopia after automotive accidents, with a risk of fatality that is five times higher than that of other industrial sectors (7). Although evidence-based work health and safety services are essential, studies showing the prevalence and factors of occupational injuries in the Construction Park are scarce in Ethiopia, particularly no study conducted in the study area so far. Accident prevention starts with having a firm awareness of the contributing factors because accident causalities in the construction sector are complicated and multidimensional (24). To establish measures for injury prevention, it is crucial to assess the severity of occupational injuries and identify the variables that contribute to them. Therefore, this study aimed to assess the magnitude and factors associated with occupational injuries among Bure Industrial Park construction workers, Northwest Ethiopia.

# Methods

## Study design, area, and period

An institutional-based cross-sectional study was in Bure industrial park construction workers from January to February 2022. Bure town administration Industry Park is found in the Amhara region, 411 km Northwest of Addis Ababa, the capital city of Ethiopia. The park has created job opportunities for thousands of people in the area. The number of workers fluctuates from time to time from a minimum of 1,500 to a maximum of 2,000. These construction projects cover range of activities such as site clearance, the demolition or dismantling of building structures or plants and equipment, excavations, reinforcement-bar works, concrete works, HCB (Hollow Concrete block) other material fabrication, decoration, cleaning, installation, and the removal and maintenance of services (electricity, water, and telecommunications). It also includes the use of woodworking, painting, and decorating and the use of heavy machinery for site landscaping.

## Populations

All Bure industry park workers were the source population. The study populations were all randomly selected Bure industry park, construction workers. All Bure industrial park construction workers were eligible and included regardless of their job categories whether they working as daily labor, plasterer, carpenter, mason, welder/electrician, painter, driver/operator, and office/site engineers under construction Enterprise. Construction workers who were unable to respond due to illness and workers with hearing or speaking difficulties were excluded.

## Sample size determination and sampling technique

The sample size was calculated using a single population proportion formula by assuming 32.6% the prevalence rate

of occupational injuries among construction workers in Dessie town (11), with a 95% confidence level, 5% desired precision, and adding 10% for non-response rate, the total calculated sample size was 372. First, a list of building construction works with their respective job category was obtained from Bure Industrial park administration. Then, a simple random sampling technique was employed to select the study participants. If the selected participant is not available at the time of data collection, the next participant was considered.

## Study variables

The presence of occupational injuries among construction workers was the outcome variable. The independent variables were socio-demographic and economic factors (age, residence, marital status, economic status, educational level, medical condition, pattern of employment, salary), occupational factors (working section/job category, total work hours/day, availability of safe tools, availability safe machinery, occupational safety training, availability PPE (personal protective equipment's) and behavioral factors (use of PPE (personal protective equipment's), job satisfaction, sleeping disturbance problem, usage of substances).

## Operational definitions

Occupational injuries are any physical injuries sustained by a worker in connection with the performance of his or her work (25). Personal Protective Equipment (PPE) was defined as specialized clothing or equipment worn by employees for protection against health and safety hazards. Workers were classified as those who used PPE when they responded to use PPE that was necessary to be worn during a particular activity (10). Substance use was defined as a person who used at least one of the following substances such as cigarette, khat and alcohol in the past 30 days (26).

## Data collection tools, procedures, and quality assurance

The data were collected using a pretested structured questionnaire, which was developed after reviewing relevant literature (11, 14). After preparing the English version it was translated first into Amharic and then back to English to keep its consistency. The local language Amharic was used to collect the data. A face-to-face interview was used to collect the data. The questionnaire was composed of the following variables; socio-demographic and economic factors (age, residence, marital status, economic status, educational level, medical condition, pattern of employment, and salary), occupational factors (working section/job category, total work hours/day, availability of safe tools, availability safe machinery, occupational safety training, availability PPE (personal protective equipment's), behavioral factors [use of PPE (personal protective equipment's), job satisfaction, sleeping disturbance problem, usage of substances], and occupational injury-related variables (the occurrence of injuries, and their types, time of injury happen and causes of injury). The outcome variable was occupational injury. It was measured by asking respondents a question stated as, "Have you encountered any injuries in the past 12 months?" Responses that were "yes" were coded as "1" while responses that were "no" were categorized as "0". In addition to participant self-reports, we confirm the existence and type of injury by looking at the respondent's damaged body part. The health center record also used to confirm such injuries which are documented when an individual's sustain injury and visit for treatment. The availability and use of personal protective equipment (PPE) as well as different workplace hazards (such as whether respondents worked with machines or not and whether they worked in an environment that made them vulnerable to injury) were also determined using a work environment observation checklist. The questionnaire's face validity was examined by professionals in occupational health. In terms of instrument reliability, a test of reliability was conducted on the questionnaire status, and a satisfactory reliability status was obtained (in this study, a Cronbach's alpha of 0.79 was obtained). A pretest of the tool was conducted on 5% of the sample size (not actually part of the study, but had similar characteristics) among construction workers in Finote Selam town before the actual data collection commenced and necessary correction was done. The data collection was done by three BSc nurses, who had previous experience in data collection. The overall data collection process was supervised by two BSc public health officers. Two days of training was given for data collectors along with their supervisors about the questionnaire and data collection procedures.

## Data processing and analysis

The data were coded and entered into Epi Data version 3.1 and then exported to SPSS version 20 for statistical analysis. In the descriptive statistic, frequencies, proportion, and mean were calculated and the results of the analysis were presented in text and tables. Binary logistic regression analysis was carried out to assess the association of different independent variables with the dependent variable. Independent variables having $P < 0.25$ on the binary logistic regression analysis were considered as candidates for the final multivariable logistic regression analysis. The level of significance was declared at a $p < 0.05$.

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## Ethical approval and consent to participate

Ethical approval was obtained from Mizan-Tepi University Ethical Review Committee. Confidentiality and privacy were maintained; only the ID number was used during data collection, analysis, and reporting in which the information obtained from the respondents will not be shared with anyone other than the data collectors and principal investigator. The data collectors provide health education related to occupational injuries to study participants a long side of the data collection process. Taking the current COVID-19 pandemic into account, preventive measures such as the use of personal protective materials and physical distancing were applied during the data collection. First aid kit and other necessary materials were prepared in advance to provide first aid service for the participants if occupation accidents occur at the time of data collection. Written informed consent was obtained from participants who participated in the study.

# Results

## Socio-demographic characteristics

Of the 377 total sample size, 368 study participants have completed the interview, giving a response rate of 97.6%. The mean age of the participants was 27.2 (±8.4 SD) ranging from 16 to 47 years old. Almost all of the respondents, 348 (94.5%) and 348 (94.8) were orthodox religion followers and Amhara by ethnicity respectively (Table 1). The mean monthly salary of the participants was 3,444 (±1,449 SD) ranging from 1,800 to 6,000 Ethiopian birr.

TABLE 1 Socio-demographic characteristics of the Bure industry park construction workersin Northwest Ethiopia.

| Variables | Categories | Frequency | Percent |
|---|---|---|---|
| Sex | Male | 179 | 48.6 |
| | Female | 189 | 51.4 |
| Age | ≤ 25 years | 74 | 20.1 |
| | 26–35 years | 184 | 50 |
| | 36–45 years | 92 | 25 |
| | ≥ 46 years | 18 | 4.9 |
| Religion | Orthodox | 348 | 94.5 |
| | Protestant | 8 | 2.2 |
| | Muslim | 12 | 3.3 |
| Ethnicity | Amhara | 349 | 94.8 |
| | Oromo | 11 | 3 |
| | Others* | 8 | 2.2 |
| Marital status | Out of marriage | 199 | 54.1 |
| | Married | 169 | 45.9 |
| Educational level | Illiterate | 8 | 2.2 |
| | Able to read and write | 4 | 1.1 |
| | Primary school (1–8) | 46 | 12.5 |
| | Secondary (9–12) | 74 | 20.1 |
| | College and above | 236 | 64.1 |
| Previous residence | Urban | 362 | 98.4 |
| | Rural | 6 | 1.6 |
| Monthly salary (ETB) | <3,444 | 196 | 53.3 |
| | ≥3,444 | 172 | 46.7 |

*Others: South and Tigre; ETB, Ethiopian Birr.

## Description of the pattern of occupational injuries

Of the 368 study participants, 41.8% were daily laborers, followed by 29.9% masons and 9.8 carpenters (Figure 1). The commonest type of injury mentioned was laceration (42%) followed by 23.5%. One hundred seventy-six (47.8%) used personal protective equipment (Table 2). The overall prevalence of occupational injuries among workers of Bure industrial park was 39.4%, 95% C.I (34.4–44.4%).

## Common work-related determinants of injuries and behavioral profiles

Fifty-four (14.7%) of the participants had occupational safety training at work. More than three-fourths (80.4%) of the participants had regular workplace supervision. Slightly above half (47.8%) and 36 (9.8%) of the participants were alcohol drinkers and had sleep disturbance, respectively (Table 3).

## Observational finding

After reviewing the records, 112 (30.4%) of the respondents visited the health center for treatment after sustained injury. Of 112 participants visited health center, the majority, 35 (31.3%) for laceration followed by 34 (30.4%), 29 (25.9%) and 14 (12.5%) were for stab, fracture and dislocation injuries respectively. Despite not being full, all participants had at least one PPE. One hundred seventy-six (47.8%) of the participants used personal protective equipment at work (Table 2). Two hundred ninety-eight (91%) of the participants were work with machineries. Of those who work with machineries, 62 (20.8%) were work under risky machineries (Table 3).

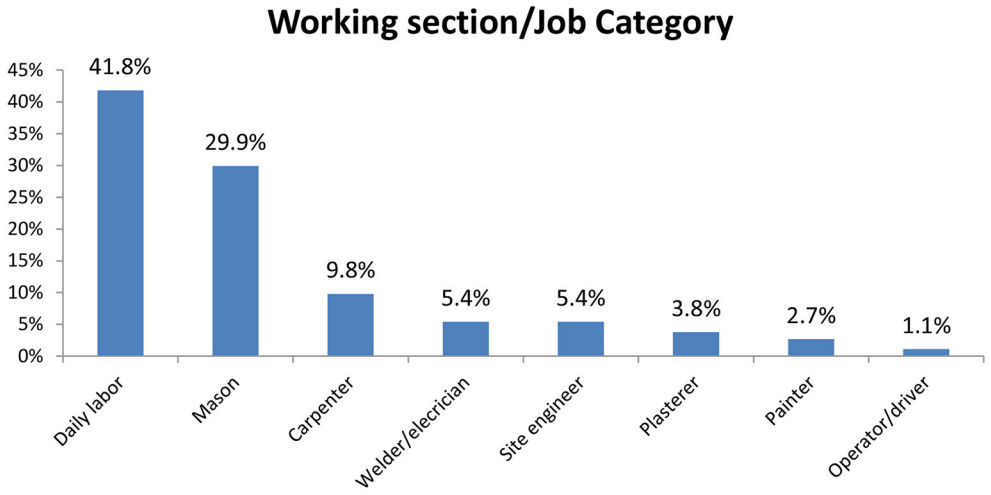


FIGURE 1
The working section/job category of the Bure industry park construction workers in Northwest Ethiopia.

## Factors associated with occupational injuries

After A multi variable logistic regression four variables namely; sex (being male) [AOR = 1.74, 95%CI (1.02–2.97)] being married [AOR = 2.79, 95%CI (1.50–5.17)], no use of personal protective equipment [AOR = 1.67, 95%CI (1.12–2.85)], no training on occupational safety [AOR = 1.45, 95%CI (1.06–2.98)], and not satisfied with the job [AOR = 5.97, 95%CI (3.48–10.2)] were the factors associated with occupational injury (Table 4).

# Discussion

Construction business is one of the most dangerous workplaces (15). It is currently the second greatest source of injuries in Ethiopia after automotive accidents, with a risk of fatality that is five times higher than that of other industrial sectors (7). Although evidence-based work health and safety services are essential, studies showing the prevalence and factors of occupational injuries in the Construction Park are scarce in Ethiopia, particularly no study conducted in the study area so far. Therefore, this study aimed to assess the magnitude and factors associated with occupational injuries among Bure Industrial Park construction workers in Northwest Ethiopia.

The prevalence of occupational injury in the last year among Bure industry park construction workers was 39.4%, 95% C.I (34.4–44.4%). The prevalence stated above was consistent with 39% in Gonder (15), 39.2% in Robe town (27), 38.3% in Addis Ababa (10) studies in Ethiopia, and 39.3% in Nigeria (15). The result of this study is lower than 84.7 and 67.7% in Addis Ababa, Ethiopia (20, 22), 79.8% in Iran (28), and 46.2% in Egypt (20). The result of this study is also higher than 15% in Gondar, Ethiopia (29), 32.4% in Uganda (30), and 34.8% in China (31). The possible discrepancy may be due to study setting differences, working conditions, level of accident prevention strategies, and socio-cultural and regulatory factors (15). Besides, the difference in the level of regular workplace supervision, PPEs utilization, and working hours per day, as well as week, may create a considerable variation across different studies. There was also a discrepancy between the self-reported and observation of the health center records. This could be due to the participants' avoidance of seeking care for laceration by considering it as a mild. Besides, the preference and attendance of traditional healers for joint dislocation also another thing for the variation observed. The incompleteness of documentation due to the above reasons, the discrepancy between self-report and record observation was observed.

Male construction workers were more vulnerable to occupational injury than female construction workers. In this study, the risk of occupational injury was 1.74 times higher among male workers as compared to female workers. This finding was consistent with a studies conducted in Ethiopia (31–33), Ghana (34), and China (35) which reported that male workers are more prone to occupational injury than female workers. The possible explanation for this report is due to the difference in tasks and males are high in risk-taking behavior (36).

The occurrences of occupational injury among married were 2.8 times higher as compared to their counterparts. The finding of this study is supported by another similar study conducted in Gonder, Ethiopia (15) and Iran (37). This may be due to married workers may more engage in works without taking

TABLE 2 Description of the occupational injury-related characteristics among Bure industry park construction workers in Northwest Ethiopia.

| Variables | Categories | Frequency | Percent |
|---|---|---|---|
| Have you ever transferred from one working section to other? ($n = 368$) | Yes | 36 | 9.8 |
| | No | 332 | 90.2 |
| Reason for your transfer ($n = 36$) | Health problem | 4 | 11.1 |
| | Workload | 6 | 16.1 |
| | For better salary | 26 | 72.2 |
| Total working hours per week ($n = 368$) | <48 h | 66 | 17.9 |
| | 48 h | 237 | 64.4 |
| | ≥48 h | 65 | 17.7 |
| Have you encountered any injuries in the past 12 months? ($n = 368$) | Yes | 145 | 39.4 |
| | No | 223 | 60.6 |
| Number of times in the past 12 months ($n = 145$) | Once | 58 | 40 |
| | Two or more | 87 | 60 |
| Time of injury happen ($n = 145$) | Morning | 50 | 34.5 |
| | Afternoon | 95 | 65.5 |
| Kinds of injury ($n = 145$) | Laceration | 62 | 42.8 |
| | Stab | 34 | 23.5 |
| | Fracture | 29 | 20 |
| | Joint dislocation | 20 | 13.7 |
| Causes of injury ($n = 145$) | Personal failure | 41 | 28.3 |
| | Occupational failure | 104 | 71.7 |
| Personal protective equipmentuse ($n = 368$) | Yes | 176 | 47.8 |
| | No | 192 | 52.2 |
| Type of treatment after injury ($n = 145$) | First aid | 63 | 43.5 |
| | General treatment | 82 | 56.5 |

adequate rest to cover a family expenses. Stress and fatigue can be higher among married workers than single ones because of higher responsibilities in life to secure family needs. It may be led to more unsafe acts resulting in an accident (32).

The odds of work-related injuries among workers who did not receive occupational safety training were 1.45 times more likely compared to those who received occupational safety training. This finding was supported by a study done in Bahirdar (1), Dessie (11), and a systematic analysis in Ethiopia (32), which reported that workers who attend safety training programs were less likely to experience work-related injuries. This might be due to training that provides knowledge about the presence of different safety hazards in construction and helps workers how to protect them. In addition, training may have an impact on changing the behaviors of workers to follow the safety precautions.

Personal protective equipment use was another factor significantly associated with the occurrence of occupational injuries. Accordingly, workers who did not engage in the work by wearing personal protective equipment were 1.67 times less likely to develop occupational injuries than those workers who did use PPE. This finding was supported by studies done in Bahrdar, Ethiopia (11), and Addis Ababa, Ethiopia (20), Uganda (30), which indicated that the use of PPE in a working environment reduces the occurrence of occupational injuries. This could be due to personal protective equipment protecting the worker against the hazards to which the worker may be exposed. Worker protection equipment (PPE) shields workers against a range of dangers, including chemical, physical, biological, electrical, mechanical, and radiological dangers (38).

Workers who had no job satisfaction were a 5.6 times higher risk of developing occupational injuries compared to their counterparts. This finding was supported by a study conducted in Addis Ababa, Ethiopia (20), and Nigeria (15). This might be because those workers who had no satisfaction with work did not comply with standard work

TABLE 3 Common occupational and behavioral factors of injuries among Bure industry park construction workers in Northwest Ethiopia.

| Variables | Categories | Frequency | Percent |
|---|---|---|---|
| Training on occupational safety | Yes | 54 | 14.7 |
| | No | 314 | 85.3 |
| Regular workplace supervision | Present | 296 | 80.4 |
| | Absent | 72 | 19.6 |
| Work done by using machinery | Yes | 298 | 91 |
| | No | 70 | 19 |
| Machinery design in a way that does not cause accident and injury (n=298) | Yes | 236 | 79.2 |
| | No | 62 | 20.8 |
| Alcohol drinking | Yes | 176 | 47.8 |
| | No | 192 | 52.2 |
| Cigarette smoking | Yes | 66 | 17.9 |
| | No | 302 | 82.1 |
| Khat chewing | Yes | 40 | 10.9 |
| | No | 328 | 89.1 |
| Do you hand a sleeping disturbance problem? | Yes | 32 | 9.8 |
| | No | 336 | 90.2 |

TABLE 4 Factors associated with occupational injuries among Bure industry park construction workers in Northwest Ethiopia ($n = 368$).

| Variables | Categories | Occupational injuries | | COR (95% CI) | AOR (95% CI) | *P*-value |
|---|---|---|---|---|---|---|
| | | Yes | No | | | |
| Sex | Female | 59 | 130 | 1 | 1 | |
| | Male | 86 | 93 | 2.04(1.48–3.47)** | 1.74(1.02–2.97) | **0.042** |
| Marital status | Out of marriage | 67 | 132 | 1 | 1 | |
| | Married | 78 | 91 | 1.69(1.11–2.58)* | 2.79(1.50–5.17) | **0.001** |
| Income | <3,444 | 62 | 134 | 1 | 1 | |
| | ≥3,444 | 83 | 89 | 2.02(1.32–3.08)** | 0.83(0.43–1.58) | 0.567 |
| Personal protective equipment use | Yes | 55 | 121 | 1 | 1 | |
| | No | 90 | 102 | 1.94(1.27–2.97)** | 1.67 (1.12–2.85) | **0.032** |
| Training on occupational safety | Yes | 29 | 25 | 1.98(1.11–3.54)** | 1.45(1.06–2.98) | **0.017** |
| | No | 116 | 198 | 1 | 1 | |
| Job satisfaction | Yes | 91 | 51 | 1 | 1 | |
| | No | 54 | 172 | 5.68(3.59–8.99)** | 5.97(3.48–10.2) | **< 0.001** |

AOR, adjusted odds ratio; CI, confidence Interval; COR, crude odds ratio.
*p < 0.05, **p < 0.01. The bold values are used to show the level of significance. All bold values are significant variables.

procedures, and safety precautions including proper use of PPEs. Evidence suggests that there is a link between accidents and Job satisfaction (39). Job satisfaction can result in improved performance and a decrease in occupational accidents (40). This means that job dissatisfaction might lead to an increase unsafe acts and result in occupational accidents (41).

## Limitations of the study

One-year prevalence may be underestimated or overestimated due to recall and social desirability bias although much effort was taken to minimize it. Furthermore, the study's cross-sectional design makes it difficult to demonstrate cause-and-effect linkages between the dependent and independent

variables. Therefore, future studies should be consider with better study designs (cohort study) to minimize recall bias and to determine the cause-and-effect relationship between the dependent and independent variables.

## Conclusion and recommendation

The finding shows the public health importance of occupational injury among construction workers in the study area. Numerous factors have been linked to workplace injuries, including sex, marital status, the usage of personal protection equipment, training in occupational safety, and job satisfaction. As a result, in order to lower the rate of occupational injury, employers should prioritize offering safety training, encouraging the use of personal protective equipment while working, conducting routine workplace inspections, and ensuring that their staff members are happy at work by providing comfortable workspaces.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by Mizan-Tepi University Ethical Review Committee. The patients/participants provided their written informed consent to participate in this study.

## Author contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas, took part in drafting, revising, or critically reviewing the article, gave final approval of the version to be published, have agreed on the journal to which the article has been submitted, and agreed to be accountable for all aspects of the work.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



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# Comparison of the risks of occupational diseases, avoidable hospitalization, and all-cause deaths between firefighters and non-firefighters: A cohort study using national health insurance claims data

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**Objectives:** National Health Insurance claims data were used to compare the incidence of occupational diseases, avoidable hospitalization, and all-cause death standardized incidence ratio and hazard ratio between firefighters and non-firefighters.

**Methods:** The observation period of the study was from 2006 to 2015 and a control group (general workers and national and regional government officers/public educational officers) and a firefighter group was established. The dependent variables were occupational diseases, avoidable hospitalization (AH), and all-cause death. The analysis was conducted in three stages. First, the standardized incidence ratios were calculated using the indirect standardization method to compare the prevalence of the disease between the groups (firefighter and non-firefighter groups). Second, propensity score matching was performed for each disease in the control group. Third, the Cox proportional hazards model was applied by matching the participants.

**Results:** The standardized incidence ratio and Cox regression analyses revealed higher rates of noise-induced hearing loss, ischemic heart disease, asthma, chronic obstructive pulmonary disease, cancer, back pain, admission due to injury, mental illness, depression, and AH for firefighters than general workers. Similarly, the rates of noise-induced hearing loss, ischemic heart disease, asthma, chronic obstructive pulmonary disease, back pain, admission due to injury, mental illness, depression, and AH were higher in the firefighter group than in the national and regional government officer/public educational officer group.

**Conclusions:** The standardized incidence ratios and hazard ratios for most diseases were high for firefighters. Therefore, besides the prevention and management of diseases from a preventive medical perspective, management programs, including social support and social prescriptions in the health aspect, are needed.

KEYWORDS

**occupational diseases, ambulatory care sensitivity condition, firefighter, NHI cohort data, propensity score matching, Cox proportional hazard model, average treatment effect on the treated (ATT), avoidable hospitalization**

# 1. Introduction

Firefighters are responsible for various safety activities, such as fire prevention, fire response, 119 (Korean emergency care number) rescue/emergency calls, and 119 related life safety activities in South Korea. Over the last decade, the number of dispatches and rescues has annually increased by 8.5 and 9.7%, respectively. Compared to 10 years ago, the dispatch and rescue numbers in 2019 doubled to 115 and 136%, respectively. Thus, firefighters play a role in ensuring the safety of people through various activities (1). Firefighters are engaged in hazardous tasks, such as fire suppression, emergency, and rescue services. Owing to occupational characteristics, various harmful factors that threaten health, including chemical factors (e.g., harmful gases) and physical factors (e.g., noise and high temperature) may expose firefighters to severe physical and mental danger.

Firefighters with long working hours and shift work are exposed to tension for a long time. Owing to chronic stress and sleep disorders that subsequently develop, a decline in the physical and mental health and quality of life of firefighters occurs (2). The direct and indirect experiences of shocking, traumatic incidents, which are common owing to excessive working hours and the occurrence of repeated disasters, facilitate the development of post-traumatic stress disorders in firefighters (3). In a prior study, firefighters were reported to have greater degrees of hearing loss than the general population, and the degree of hearing loss was found to increase with age (4). Moreover, in the event of a fire, various harmful chemical factors, including carbon monoxide, carbon dioxide, hydrogen cyanide, and nitrogen oxides generated by furniture, insulating materials, plastics, etc., are present, which pose a health risk to firefighters who are exposed to these toxic gases for long and short periods (5–8).

Owing to various adverse health factors, firefighters are at risk of developing occupational diseases, such as noise-induced hearing loss (NIHL), cardiovascular disease, respiratory disease, musculoskeletal disease, occupational cancer, and mental illness. Furthermore, in a study on firefighters in a Busan metropolitan city, 22.8% of firefighters were found to have diabetes while 10.7% had hypertension. Accordingly, the health of firefighters was not ideal (9), especially for those with diabetes and hypertension, which are ambulatory care sensitive conditions (ACSCs) in which unnecessary hospitalization can be avoided through timely and effective outpatient care (10). The experience of avoidable hospitalization (AH) is closely related to the quality of primary care and medical accessibility (10, 11). For firefighters, continuous health management is necessary due to the nature of their work.

This study aimed to highlight the necessity of health management for firefighters by using the National Health Insurance (NHI) claims data from South Korea to compare the incidence of occupational diseases, AH, and all-cause deaths standardized incidence ratios (SIRs) and hazard ratios (HRs) between firefighters and non-firefighters.

Abbreviations: ACSCs, ambulatory care sensitive conditions; AH, avoidable hospitalization; CCI, Charlson comorbidity index; COPD, chronic obstructive pulmonary disease; HR, hazard ratio; ICD-10, International Classification of Diseases 10th revised edition; SIR, standardized incidence ratio; IHD, ischemic heart disease; NHI, national health insurance; NIHL, noise-induced hearing loss; NRG, national and regional government officer; PEO, public educational officer; PSM, propensity score matching.

# 2. Materials and methods

## 2.1. Data

The NHI claims data from South Korea were used as the research data. NHI claims data are data provided by the NHI and include qualifications and premiums for all populations, health examination results, personal medical histories, long-term care insurance data for older adults, the current status of hospitals, and registration information for cancer and rare diseases; national medical care data for 1.3 trillion cases are also included in this database (12).

A cohort of data was collected from 2005 to 2015. The year 2005 was used as the washout period to exclude illnesses. The 10-year data collected from 2006 to 2015 were used for the analysis. Firefighters were placed in one group, general workers formed a control group, and national and regional government officers (NRGs) and public educational officers (PEOs) known to have few occupational risk factors formed another control group. Accordingly, the study participants were divided into firefighters and general workers comparison group and the firefighters and NRGs/PEOs comparison group.

Of the 49,760,223 participants, only age group of 25–64 years in 2006 (when the observation started) were included in the study ($N$ = 20,559,369 excluded). Further, those who were unemployed and female were excluded ($N$ = 22,933,520 excluded). Additionally, men that had used medical services as part of a principal diagnosis for a disease corresponding to the dependent variable one year before the start of the observation period for each disease were excluded from the study. All exclusion criteria were the same for both groups, except that only public officers were studied in the NRG/PEO control group ($N$ = 5,774,503 excluded). The final general worker group included 6,267,334 people between 25 and 64 years, while the NRG/PEO control group consisted of 492,831 people (Figure 1). This study was approved by the Institutional Review Board of Yonsei University (1041849-202203-SB-057-01).

## 2.2. Study variables

### 2.2.1. Dependent variables

The dependent variables were occupational diseases, AH, and all-cause deaths. Only participants with principal diagnoses based on the International Classification of Diseases 10th revised edition (ICD-10) codes were included in the analyses of occupational diseases and AH.

The following occupational diseases were considered: NIHL (H83.3), ischemic heart disease (IHD) (I20–I25), myocardial infarction (I21–I22), cerebral infarction (I63), cerebral hemorrhage (I60–I62), asthma (J45 and J46), chronic obstructive pulmonary disease (COPD) (J43.1, J43.2, J43.8, J43.9, J44), cancer (C00–C97), back pain (M54), admission due to injury (S00–T98), mental illness (F00–F99), and depression (F32–F33). Based on disease prevalence, the participants were classified as "1" (occurred) and "0" (did not occur).

AH is an indicator closely related to the quality of primary care and accessibility to care, with the concept that unnecessary hospitalization can be avoided through proper management of primary care. Therefore, in this study, participants who were hospitalized for the relevant ACSCs in South Korea were classified as "1" and those who were not hospitalized were classified as "0." The variables included those hospitalized (as a principal

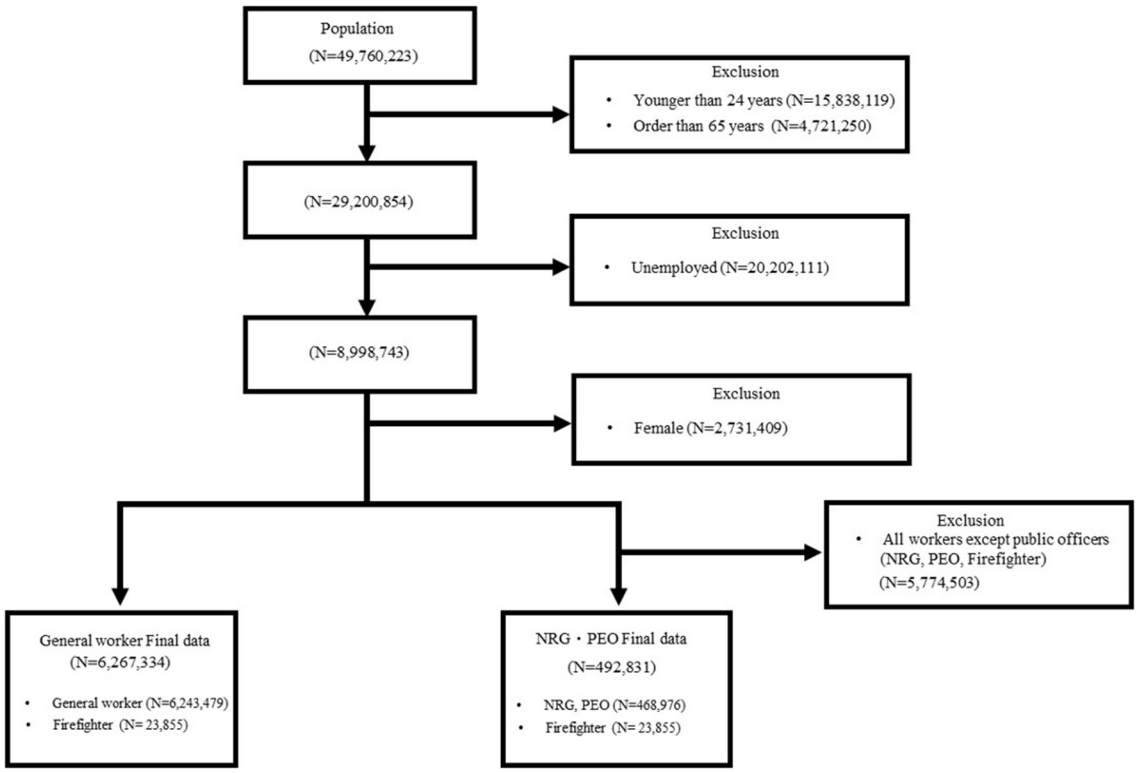


FIGURE 1
Process used to select the study population.

diagnosis) (13) with ICD-10 code-based meningococcal infections (A39); emphysema (J43); meningitis in bacterial diseases classified elsewhere (G01); bacterial meningitis, not elsewhere classified (NEC) (G00); nondiabetic hypoglycemic coma (E15); other disorders of fluid, electrolyte, and acid-base balance (E87); convulsions, NEC (R56); other disorders of pancreatic internal secretion (E16); volume depletion (E86); other acute IHDs (I24); other respiratory disorders (J98); pneumonia (J09–J18); unspecified diabetes mellitus (E14); fever of other and unknown origin (R50); dizziness and giddiness (R42); angina pectoris (I20); essential hypertension (I10); other noninfectious gastroenteritis and colitis (K52); influenza, virus not identified (J11); cutaneous abscess, furuncle, and carbuncle (L02); acute tonsillitis (J03); acute upper respiratory infections (J00, J01, J02, J04, and J05); acute upper respiratory infections of multiple and unspecified sites (J06); and chronic rhinitis, nasopharyngitis, and pharyngitis (J31).

Deaths from all causes were included. Participants who died during the observation period were classified as "1" and survivors were classified as "0."

### 2.2.2. Independent variable

The independent variable was the occupation type. To compose the data set, firefighters were coded as "1" and general workers and NRG/PEOs were coded as "0."

### 2.2.3. Control variables

The control variables were demographic and health-related. The demographic variables included age, income, and region, while the health-related variables included disability, Charlson comorbidity index (CCI) scores, and admission in 2005.

The demographic variable, age, was divided into eight 5-year categories: 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, and 60-64 years. Income was divided into four groups: NHI premiums of 70% or less (quartile 1), 80% or less (quartile 2), 90% or less (quartile 3), and 100% or less (quartile 4). The regions were divided into Seoul, Gyeonggi, metropolitan, and rural. Metropolitan areas, excluding Seoul and Gyeonggi, were classified as large cities, while other areas were classified as rural areas.

The presence or absence of a disability as a health-related variable was classified using the disability grade variable. The allocated disability grades ranged from 1 to 6; the lower the grade, the higher the severity. Grades 1–2 indicated severe disorders while grades 3–6 indicated mild disorders. In this study, participants with grades 1–6 were classified as "1," and participants with no-disability were classified as "0" (14). The CCI score is a typical index for adjusting for the severity of comorbidities. There are several criteria for calculating the CCI score; however, Quan et al. (15) calculation method is typically used. Quan et al. (15) method selects 17 diseases and imposes weights according to the disease by scoring them from 0 to 6 points (15), with a minimum of 0 and a maximum of 24 points (15). In this study, the CCI score was divided into 0, 1, and 2 points or more. In the case of admission in 2005, admissions for all diseases were considered after applying the 1-year washout to the diseases corresponding to each dependent variable. The presence or absence of admission for illness was scored as "1" if admission occurred in 2005 and as "0" if admission did not occur in 2005, considering only the principal diagnosis.

## 2.3. Statistical analysis

The analysis was conducted in three stages. First, the SIR was calculated using the indirect standardization method to compare disease prevalence between the firefighter and control groups. The expected number of cases in the firefighter group was calculated based on the incidence rate by age in the control group. The SIR was calculated from the ratio between the actual and expected numbers of cases. The formula for calculating SIR is as follows:

$$SIR = \frac{observed\ number\ of\ cases}{expected\ number\ of\ cases} \times 100 \quad (formula)$$

$$(where\ expected = person - year\ of\ case\ group \times incidence\ rate\ of\ control\ group)$$

The 95% confidence interval (CI) of the SIR was calculated assuming a Poisson distribution and was judged to be statistically significant when the 95% CI crossed 1. Second, propensity score matching (PSM) was performed for each disease in the control group. The propensity score was calculated using the variables of age, region, income, disability, CCI, and admission in 2005, and 1:3 matching was performed using the greedy matching method. Matching verification was verified by ensuring that the absolute value of the standardized difference was <0.1 (16). Finally, regression analysis using the Cox proportional hazard model was performed by matching the participants. Proportional risk assumptions were confirmed using a Kaplan–Meier survival curve (17), and the model was adjusted for age, region, income, disability, CCI, and admission in 2005. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA). The statistical significance of the hypothesis test was confirmed using a two-sided test.

# 3. Results

Age, income, region, disability, CCI score, and frequency of admission in 2005 were analyzed by group (Table 1). Based on age, 30.4% of the firefighters were 35–39 years old. Further, approximately 83% of firefighters had income in quartile 2 or above, indicating that most had a high income. Most firefighters lived in rural regions, were non-disabled, had CCI scores of 0, and had never been hospitalized in 2005. Most general workers were 35–39 years (19.0%) and had income in quartile 1 (58.3%). The residence, presence or absence of disability, CCI scores, and proportion of admissions in 2005 of general workers were similar to those of firefighters. Finally, 21.1% of the participants in the NRG/PEO group were 45–49 years old, and 80.8% had income in quartile 2 or above. Thus, most of these workers had a high income, similar to firefighters. Other variables for the NRG/PEO participants were found to be similar to those of firefighters.

TABLE 1 Characteristics of the general participants.

| Variable | Firefighter ($N$ = 23,855) | Control group | |
|---|---|---|---|
| | | General workers ($N$ = 6,243,479) | NRGs, PEOs ($N$ = 468,976) |
| | ($N$, %) | ($N$, %) | ($N$, %) |
| **Age** | | | |
| 25–29 | 1,464 (6.1) | 858,364 (13.7) | 22,837 (4.9) |
| 30–34 | 4,487 (18.8) | 1,184,656 (19.0) | 49,623 (10.6) |
| 35–39 | 7,242 (30.4) | 1,188,097 (19.0) | 69,644 (14.9) |
| 40–44 | 4,940 (20.7) | 972,827 (15.6) | 83,752 (17.9) |
| 45–49 | 2,970 (12.5) | 870,980 (14.0) | 98,931 (21.1) |
| 50–54 | 2,004 (8.4) | 597,951 (9.6) | 77,939 (16.6) |
| 55–59 | 713 (3.0) | 363,265 (5.8) | 47,768 (10.2) |
| 60–64 | 35 (0.1) | 207,339 (3.3) | 18,482 (3.9) |
| **Income** | | | |
| Quartile 1 | 4,066 (17.0) | 3,639,709 (58.3) | 90,036 (19.2) |
| Quartile 2 | 6,317 (26.5) | 813,219 (13.0) | 73,783 (15.7) |
| Quartile 3 | 11,143 (46.7) | 857,267 (13.7) | 145,197 (31.0) |
| Quartile 4 | 2,329 (9.8) | 933,284 (14.9) | 159,960 (34.1) |
| **Region** | | | |
| Seoul | 2,929 (12.3) | 1,332,494 (21.3) | 87,157 (18.6) |
| Gyeonggi | 5,118 (21.5) | 1,521,675 (24.4) | 84,748 (18.1) |
| Metropolitan | 6,540 (27.4) | 1,608,008 (25.8) | 123,956 (26.4) |
| Rural | 9,268 (38.9) | 1,781,302 (28.5) | 173,115 (36.9) |
| **Disability** | | | |
| Non-disabled | 23,475 (98.4) | 6,051,692 (96.9) | 456,199 (97.3) |
| disabled | 380 (1.6) | 191,787 (3.1) | 12,777 (2.7) |
| **CCI** | | | |
| 0 | 20,829 (87.3) | 5,531,753 (88.6) | 403,282 (86.0) |
| 1 | 1,749 (7.3) | 384,196 (6.2) | 34,070 (7.3) |
| ≥2 | 1,277 (5.4) | 327,530 (5.2) | 31,624 (6.7) |
| **Admission in 2005** | | | |
| No | 22,323 (93.6) | 5,913,171 (94.7) | 442,188 (94.3) |
| Yes | 1,532 (6.4) | 330,308 (5.3) | 26,788 (5.7) |

NRG, national and regional government officer; PEO, public education officer; CCI, Charlson Comorbidity Index.

We determined the frequency of occupational diseases, avoidable hospitalizations, and all-cause deaths in the population (Table 2). The total number of firefighters was 23,855. Based on disease, 89 had NIHL, 1,464 had IHD, 157 had myocardial infarction, 320 had cerebral infarction, 112 had cerebral hemorrhage, 2,745 had asthma, 919 had cancer, 9,791 had back pain, 4,479 were admitted due to injury, 3,078 had mental illnesses, and 857 had depression; a total of 1,169 avoidable hospitalizations and 251 all-cause deaths were recorded. Notably, for firefighters, general workers, and NRG/PEOs, back pain had the highest number of cases, followed by admission due to injury and mental illness.

The SIRs for occupational diseases and AH, and the standardized mortality ratios (SMRs) for all-cause deaths for firefighters were compared to those of non-firefighters (Table 3). Compared to general workers, firefighters had higher rates of NIHL [2.09 (95% CI, 1.68–2.58)], IHD [1.21 (95% CI, 1.15–1.27)], asthma [1.13 (95% CI, 1.09–1.17)], COPD [1.16 (95% CI, 1.05–1.27)], cancer [1.15 (95% CI,

TABLE 2 Disease and person-year data of firefighters, general workers, national regional government officers, and public educational officers.

| Number | Disease | Firefighter | | Control group | | | |
|---|---|---|---|---|---|---|---|
| | | | | General workers | | NRGs, PEOs | |
| | | Cases | PY | Cases | PY | Cases | PY |
| 1 | NIHL | 89 | 236,441 | 11,192 | 61,105,178 | 812 | 4,635,670 |
| 2 | IHD | 1,464 | 226,707 | 351,941 | 58,662,879 | 37,072 | 4,362,700 |
| 3 | Myocardial infarction | 157 | 236,025 | 47,005 | 60,882,490 | 4,207 | 4,613,857 |
| 4 | Cerebral infarction | 320 | 234,820 | 108,893 | 60,454,972 | 10,161 | 4,568,580 |
| 5 | Cerebral hemorrhage | 112 | 236,325 | 33,933 | 60,984,961 | 2,743 | 4,624,136 |
| 6 | Asthma | 2,725 | 215,129 | 657,276 | 56,115,920 | 53,344 | 4,214,524 |
| 7 | COPD | 446 | 234,120 | 127,193 | 60,351,753 | 11,641 | 4,563,050 |
| 8 | Cancer | 919 | 231,728 | 250,137 | 59,860,270 | 26,259 | 4,485,518 |
| 9 | Back pain | 9,791 | 163,993 | 2,191,515 | 45,770,680 | 165,913 | 3,447,576 |
| 10 | Admission due to injury | 4,479 | 210,593 | 756,235 | 56,916,312 | 47,610 | 4,372,331 |
| 11 | Mental illness | 3,078 | 212,454 | 693,428 | 56,100,241 | 61,252 | 4,156,905 |
| 12 | Depression | 857 | 230,659 | 174,393 | 59,929,016 | 16,847 | 4,508,904 |
| 13 | AH | 1,169 | 230,800 | 311,862 | 59,536,633 | 25,299 | 4,504,079 |
| 14 | All cause deaths | 251 | 237,007 | 113,225 | 61,179,099 | 7,417 | 4,641,439 |

PY, person-year; NIHL, noise-induced hearing loss; IHD, ischemic heart disease; COPD, chronic obstructive pulmonary disease; AH, avoidable hospitalization; NRG, national and regional government officer; PEO, public educational officer.

1.08–1.23)], back pain [1.28 (95% CI, 1.25–1.30)], admission due to injury [1.62 (95% CI, 1.58–1.67)], mental illness [1.23 (95% CI, 1.19–1.28)], depression [1.35 (95% CI, 1.26–1.44)], and AH [1.09 (95% CI, 1.03–1.15)]. In the case of death, the SMR of firefighters was lower than that of general workers [0.73 (95% CI, 0.65–0.83)]. Firefighters also had higher rates of NIHL [2.25 (95% CI, 1.81–2.77)], IHD [1.11 (95% CI, 1.05–1.17)], asthma [1.07 (95% CI, 1.03–1.11)], COPD [1.18 (95% CI, 1.07–1.29)], back pain [1.31 (95% CI, 1.29–1.34)], admission due to injury [1.92 (95% CI, 1.87–1.98)], mental illness [1.10 (95% CI, 1.06–1.14)], depression [1.08 (95% CI, 1.01–1.16)], and AH [1.16 (95% CI, 1.09–1.23)] than NRG/PEOs. However, regarding death, a statistical significance could not be confirmed between these groups.

After PSM, the HRs of the occupational diseases, AH, and all-cause deaths for firefighters were compared with those of non-firefighters using regression analysis and the Cox proportional hazard model (Table 4). Firefighters were found to have a higher risk of NIHL [2.15 (95% CI, 1.64–2.82)], IHD [1.16 (95% CI, 1.10–1.24)], asthma [1.08 (95% CI, 1.03–1.12)], COPD [1.13 (95% CI, 1.01–1.26)], back pain [1.21 (95% CI, 1.18–1.24)], admission due to injury [1.74 (95% CI, 1.67–1.80)], mental illness [1.22 (95% CI, 1.17–1.27)], depression [1.34 (95% CI, 1.24–1.45)], and AH [1.09 (95% CI, 1.02–1.17)] than general workers. Compared to NRG/PEOs, firefighters also had a higher risk of NIHL [2.59 (95% CI, 1.95–3.44)], IHD [1.11 (95% CI, 1.04–1.17)], back pain [1.28 (95% CI, 1.25–1.31)], admission due to injury [1.86 (95% CI, 1.79–1.93)], mental illness [1.11 (95% CI, 1.06–1.16)], and AH [1.16 (95% CI, 1.08–1.24)]. Regarding the HR for death, statistical significance could not be confirmed.

# 4. Discussion

## 4.1. Key findings

This study aimed to compare the SIRs, SMRs, and risks of occupational diseases, AH, and all-cause deaths between firefighters and non-firefighters. Based on the key findings of this study, the SIRs and risks of NIHL, IHD, asthma, COPD, cancer, back pain, admission due to injury, mental illness, depression, and AH were higher for firefighters than non-firefighters.

## 4.2. Interpretation

Firefighters had a higher risk of NIHL than non-firefighters. These results were similar to those of a previous study that revealed more significant hearing loss in firefighters than in the general population and a higher probability of experiencing NIHL (4). Firefighters are often exposed to sirens, air horns, and engine noise. According to previous studies, wearing personal protective equipment (PPE) was associated with reduced incidence of NIHL (18) and stated that wearing PPE was necessary to reduce noise exposure (19). In the case of IHD, firefighters had a higher risk of developing cardiovascular disease than general workers; this result is consistent with that of a previous study (20, 21). Firefighters are at increased risk of developing cardiovascular disease due to frequent chemical exposures and inflammatory reactions caused by inhaled toxins (22). In addition, Various psychological stressors and shift

TABLE 3 Standardized incidence ratios of firefighters compared to general workers, national regional government officers, and public educational officers.

| Number | Disease | General workers | | NRGs, PEOs | |
|---|---|---|---|---|---|
| | | SIR | 95% CI | SIR | 95% CI |
| 1 | NIHL | **2.09** | (1.68–2.58) | **2.25** | (1.81–2.77) |
| 2 | IHD | **1.21** | (1.15–1.27) | **1.11** | (1.05–1.17) |
| 3 | Myocardial infarction | 0.98 | (0.83–1.15) | 1.12 | (0.95–1.31) |
| 4 | Cerebral infarction | 1.00 | (0.89–1.11) | 1.08 | (0.96–1.20) |
| 5 | Cerebral hemorrhage | 0.94 | (0.77–1.13) | 1.05 | (0.87–1.27) |
| 6 | Asthma | **1.13** | (1.09–1.17) | **1.07** | (1.03–1.11) |
| 7 | COPD | **1.16** | (1.05–1.27) | **1.18** | (1.07–1.29) |
| 8 | Cancer | **1.15** | (1.08–1.23) | 1.06 | (0.99–1.13) |
| 9 | Back pain | **1.28** | (1.25–1.30) | **1.31** | (1.29–1.34) |
| 10 | Admission due to injury | **1.62** | (1.58–1.67) | **1.92** | (1.87–1.98) |
| 11 | Mental illness | **1.23** | (1.19–1.28) | **1.10** | (1.06–1.14) |
| 12 | Depression | **1.35** | (1.26–1.44) | **1.08** | (1.01–1.16) |
| 13 | AH | **1.09** | (1.03–1.15) | **1.16** | (1.09–1.23) |
| 14 | All cause deaths | 0.73 | (0.65–0.83) | 1.13 | (0.99–1.28) |

NRG, national and regional government officer; PEO, public educational officer; SIR, standardized incidence ratio; CI, confidence interval; NIHL, noise-induced hearing loss; IHD, ischemic heart disease; COPD, chronic obstructive pulmonary disease; AH, avoidable hospitalization. The bold values indicate the statistically significant values.

TABLE 4 Hazard ratios and 95% confidence intervals for the risk of death from all causes and risk of diseases for firefighters compared to general workers, national regional government officers, and public educational officers after propensity score matching.

| Number | Disease* | General workers | | NRGs, PEOs | |
|---|---|---|---|---|---|
| | | HR | 95% CI | HR | 95% CI |
| 1 | NIHL | **2.15** | (1.64–2.82) | **2.59** | (1.95–3.44) |
| 2 | IHD | **1.16** | (1.10–1.24) | **1.11** | (1.04–1.17) |
| 3 | Myocardial infarction | 0.99 | (0.83–1.19) | 1.17 | (0.97–1.40) |
| 4 | Cerebral infarction | 0.98 | (0.86–1.11) | 1.08 | (0.95–1.23) |
| 5 | Cerebral hemorrhage | 1.09 | (0.88–1.35) | 1.09 | (0.87–1.35) |
| 6 | Asthma | **1.08** | (1.03–1.12) | 1.01 | (0.96–1.05) |
| 7 | COPD | **1.13** | (1.01–1.26) | 1.11 | (0.99–1.24) |
| 8 | Cancer | 1.06 | (0.99–1.15) | 1.06 | (0.99–1.15) |
| 9 | Back pain | **1.21** | (1.18–1.24) | **1.28** | (1.25–1.31) |
| 10 | Admission due to injury | **1.74** | (1.67–1.80) | **1.86** | (1.79–1.93) |
| 11 | Mental illness | **1.22** | (1.17–1.27) | **1.11** | (1.06–1.16) |
| 12 | Depression | **1.34** | (1.24–1.45) | 1.07 | (0.99–1.16) |
| 13 | AH | **1.09** | (1.02–1.17) | **1.16** | (1.08–1.24) |
| 14 | All cause deaths | 1.01 | (0.88–1.17) | 1.10 | (0.95–1.27) |

*Adjusted for Age, Income, Region, Disability, CCI, Admission in 2005; HR, hazard ratio; CI, confidence interval; NIHL, noise-induced hearing loss; IHD, Ischemic heart disease; COPD, chronic obstructive pulmonary disease; AH, avoidable hospitalization. The bold values indicate the statistically significant values.

work are also known to contribute to cardiovascular disease (23). Firefighters sometimes do not wear PPE in the presence of harmful inhalants after fire suppression, which contributes to their risk of developing cardiovascular disease (20).

Our results regarding lung disease, such as asthma and COPD, were similar to the following previous studies. The firefighters' standardized admission ratio due to asthma and COPD was higher in the military control group (24). Firefighters had a higher degree of deterioration of lung function than general workers (25). The pulmonary function of firefighters is associated with many factors, including firefighting exposure level, smoke, use of respiratory PPE, and other health behaviors (24, 26, 27). In particular, inconsistent use of respiratory PPE and chronic respiratory diseases have been identified to have interactive effects that reduce one's health-related

quality of life (28). Accordingly, strict guidelines for wearing PPE are required to prevent NIHL and respiratory and heart disease development.

Contrary to the prior (29, 30), the all-cancer SIRs of the firefighters in this study were higher than those of non-firefighters. In previous studies (29, 30), firefighters appeared to be the healthier group due to the healthy worker effect. One prior study, which observed firefighters for a long period from 1985 to 2009, confirmed that firefighters had a significantly higher all-cancer incidence (31). Using Australian data, firefighters showed significantly high overall risk of cancer with data year from 1976 to 2003 (32). However, recent studies reported that there were no statistically significant overall risks of cancer among firefighters (29, 33, 34). The systematic review study reported a high level of heterogeneity of articles (29). These results depend on the cohort design definitions and cohort observation periods applied. Cohort study designs are important in occupational studies as occupational changes may occur depending on the time of turnover or retirement, and job security may change depending on the period of occupational observation. These thing and the incubation period of cancers make it difficult to identify the true effects (35). Studies performed with the fixed cohort method, which considers employment security by occupation, and the dynamic cohort method are necessary. Moreover, a systematic cohort of firefighters must be established and additional research must be conducted.

Our results regarding back pain and admission due to injury were the same as those of a previous study (36), where firefighters had a higher risk of musculoskeletal disorders (lumbar sprain, lumbar disc herniation, shoulder soft tissue disease, among others) and admission due to injury than general public officers. Owing to the intense physical labor performed by firefighters, there is a high possibility of back pain recurrence or admission due to injury. Therefore, the results of this study may have been underestimated. A previous study on injuries in firefighters at fire sites found that overworking and increased tension were the leading causes of injury, accounting for 26% of the total injuries. Other significant causes of injuries included slipping, falling, among others. Sprain was found to account for more than 28% of all injuries, and one-third of such trauma leads to loss of working hours (37). If the work burden of firefighters is increased in such situation, the health of the entire firefighting organization may be threatened.

In the case of mental illness, the firefighters in our study had the same results as those obtained in a previous study, where the risks of mental illnesses and mood disorders in firefighters were higher than those in general public officers (36). For firefighters, stress due to job instability, improper compensation, work culture, among others is significantly associated with depressive symptoms (38). Depression plays a significant role in the relationship between job stress and suicide committed by firefighters (39). Accordingly, the mental illnesses of firefighters should be managed and their work stress should be reduced. The work stress of firefighters is known to affect their quality of life due to a lack of social support (40). Thus, the mental health and stress of firefighters must be managed using social support systems.

AH is an indicator of the accessibility and quality of primary care (10, 11). Our study results are not the results of comparisons by region; thus, it is somewhat difficult to interpret the results according to the geographical accessibility of primary care and the quality of primary care. Therefore, the results can be interpreted as the accessibility level of medical use at the personal level. As a result, the shiftwork system must be reorganized to improve the accessibility of firefighters.

In the case of all-cause death, the SMR of the firefighter group was lower than that of the general worker's control group. When confirming the HR of all-cause death using Cox regression analysis, statistical significance could not be confirmed in any of the results when general workers and NRG/PEOs were employed as controls. The lower risk of all-cause death observed in firefighters compared to general workers might be due to the healthy worker effect resulting from the characteristics of the firefighters' occupation. These results were similar to those of a previous study, in which the SMR of firefighters was lower than that of the general population (41).

## 4.3. Strengths and limitations

This study had some limitations. First, using 2006 as the reference point, we determined the effect of time flow on the outbreak of illness; however, in the case of occupations that were independent variables, we could not consider changes due to period flow and occupational maintenance periods. In the case of public officers, job security differs between temporary public officers and NRG/PEOs, whose regular retirement is fixed. Consequently, dangerous effects may be mixed in the civil service group. However, efforts were made to minimize bias by applying PSM and controlling for covariates in the firefighter and control groups (16). Second, the effects of exposure associated with harmful substances affecting the health of firefighters were not considered. Special health examination data are required to understand the effects of exposure to harmful substances (42); such data could not be obtained from the NHI claim data. Third, the impact of the firefighters' job series was not considered. Firefighters' job series are divided into fire suppression, first aid, rescue, and administration. For administrative and indoor positions, there is a relatively low possibility of exposure to harmful substances compared to other locations. Consequently, if the effects of the series are not distinguished, firefighters may have a mixed risk of health problems. To overcome this limitation, the present study was only performed with male firefighters. A total of 5,299 of the 56,639 firefighters in 2019 were female (9.3%), and most performed administrative or indoor jobs (43). Accordingly, we included only male firefighters in this study and sought to control for the effects of series and sex imbalances. Fourth, Lifestyle-related factors are influential factors that are closely related to individual health, and the occurrence of diseases. However, this study did not control for lifestyle factors, such as smoking, drinking, and exercise. To overcome this limitation, health-related variables were used as surrogate indicators. Efforts were made to reflect the participants' health statuses using the variables of disability, CCI score, and admission in 2005.

Despite these limitations, our study provided a general description of the occupational diseases of firefighters and confirmed the risk of AH as a health management index. Further, the average treatment effect on the treated was estimated using the PSM method, thereby increasing the relevance of the results.

## 5. Conclusion

According to the study results, the lower risk of all-cause death observed in firefighters due to the healthy worker effect. However, the SIRs and HRs of firefighters were high for most diseases. Firefighters are always exposed to disaster risks and fatalities due to industrial disasters that occur every year. Therefore, besides prevention and management of diseases from a preventive medical perspective, management programs, such as social support and social prescriptions in the health aspect, are needed. It is hoped that such a management program will reduce the occurrence of occupational diseases among firefighters and the number of disabilities and deaths caused by such diseases. Therefore, it is necessary to conduct a study to evaluate the effectiveness of firefighters' preventive activities in the future.

## Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://nhiss.nhis.or.kr/bd/ab/bdaba000eng.do;jsessionid=B1rHeZOeazNhRerGsXWUUtdpyGklOnnx1LfuTqIrE1xZjiKQbzcZQIcasZAUuIPf.primrose2_servlet_engine10.

## Ethics statement

The studies involving human participants were reviewed and approved by the Institutional Review Board of Yonsei University (1041849-202203-SB-057-01). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

## Author contributions

Conceptualization and methodology: W-RL, HL, EN, J-WN, J-HY, and K-BY. Formal analysis and writing–original draft: W-RL. Writing–review and editing: W-RL, J-HY, and K-BY. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



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# Association between occupation type and development of type 2 diabetes: A population-based Panasonic cohort study 3

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**Background:** Due to a lack of investigation on the association between the type of occupation and the development of type 2 diabetes among Japanese individuals, we aimed to assess this association in 98,935 Japanese individuals.

**Methods:** This long-term retrospective cohort study included participants selected from medical health checkup programs conducted at the Panasonic Corporation, Osaka, Japan, from 2008 to 2018. Cox regression analyses were used to evaluate the association between occupation type and the incidence of type 2 diabetes.

**Results:** From 2008 to 2018, 5,008 participants developed type 2 diabetes. The proportion of never smokers, those with slow eating speeds, and those working with a flextime system was higher in men with technical jobs than in salespersons, manufacturers, and office workers ($p < 0.0001$). Cox regression analyses revealed that occupation type was associated with an increased probability of type 2 diabetes development in men but not in women. Multivariate analyses showed that the hazard ratios were 1.15 [95% confidence interval (CI), 1.05–1.26], 1.20 (95% CI, 1.10–1.30), and 1.11 (95% CI, 1.02–1.21) in men working as salespersons, manufacturers, and office workers, respectively (reference group: men with technical jobs). On the other hand, the occupation type was not associated with the development of type 2 diabetes in women.

**Conclusions:** This study demonstrated that occupation type might be an independent factor in the development of type 2 diabetes in Japanese men.

KEYWORDS

**type 2 diabetes, occupation type, Japanese, risk factors, cohort study**

## 1. Introduction

The global prevalence of diabetes and its associated medical costs have increased tremendously over the past decade. Therefore, it is essential to prevent the development and progression of diabetes in clinical settings.

Work-related factors, including working hours, socioeconomic status, and job insecurity, have reportedly been associated with cardiovascular disease, mortality, and diabetes development (1–6). As work-related factors are associated with unhealthy lifestyle habits, stress, sleep disturbances, and symptoms of depression, they contribute to the development of diabetes (7, 8). Moreover, Kivimäki et al. (5) reported in their meta-analysis that the correlation between working hours and the development of type 2 diabetes varies by occupation type. Moreover, occupation type is also considered as one of the major work-related factors. However, few studies

have investigated the association between occupation type and the development of diabetes in the Japanese population. Although Osaki et al. (9) reported an association between shift work and the development of type 2 diabetes, they did not consider the occupation of the participants. Nagaya et al. (10) suggested that salespersons had a higher risk of type 2 diabetes than those in other occupations. However, their study included only men and did not include analysis of plasma glucose levels in their multivariate analyses, which is one of the most important factors for the development of type 2 diabetes.

Thus, it is unclear whether occupation type is associated with the development of type 2 diabetes in the Japanese population. Therefore, the aim of the present study was to investigate the association between occupation types and the development of type 2 diabetes among Japanese populations in a large cohort.

# 2. Materials and methods

## 2.1. Study design and data collection

This long-term retrospective cohort study included participants selected from medical health checkup programs conducted at the Panasonic Corporation, Osaka, Japan. All employees participated in this program every year. We used the data collected between 2008 and 2018 from the Panasonic cohort study database. This particular Panasonic cohort study has been described in detail elsewhere (11). We used a questionnaire, which was previously standardized and validated self-administered, to evaluate baseline characteristics. Participants were classified as non-smokers, current smokers, or past smokers. The participants were also categorized into three levels of eating speed: fast, normal, and slow. We also asked the participants of their breakfast habits and habits of snack after dinner. No alcohol consumption was defined as daily alcohol consumption <20 g/day for women and <30 g/day for men. Regular exercisers were defined as participants who regularly exercised for at least 30 min at least 2 days per week for at least 1 year. We also asked the sleeping hours of participants. Here, the participants were questioned about their working style and the details regarding flextime and night shifts. Occupation types present in this study included technical jobs, salespersons, manufacturers, and office workers. The participants were classified in a particular category based on the following criteria: the people who had specific talent/ expertise or engaged in a product development job were classified as those with technical jobs. A salesperson was defined as the person who persuaded people to buy the company's products; manufacturers included individuals who made products for their company, and office workers were those who engaged in paperwork or office work. Type 2 diabetics was defined as having a fasting plasma glucose level of ≥126 mg/dL or, a self-reported history of diabetes, and/or the use of anti-diabetic medication.

## 2.2. Ethics approval

This study was approved by the local ethics committee of the Panasonic Health Insurance Organization (approval number: 2021-001) and conducted in accordance with the principles of the Declaration of Helsinki.

## 2.3. Exclusion criteria

In total, 236,603 employees underwent medical health checkups between 2008 and 2018. Participants who did not undergo a blood examination at baseline (n = 74,827), those with missing data or unknown occupation type ($n$ = 27,464), those with diabetes at baseline ($n$ = 7,096), and those who had undergone a medical health checkup only at baseline ($n$ = 28,281) were excluded from the study.

## 2.4. Statistical analyses

The mean and frequency of the potential confounding variables were calculated. The participants were classified according to sex. The general characteristic differences at baseline were categorized according to occupation type or diabetes development during follow-up and were assessed using analysis of variance, the $t$-test, or the chi-square test as appropriate. Group comparisons were conducted using the Tukey–Kramer (continuous variables) or the Bonferroni method (categorical variables). The association between the occupation type and the development of type 2 diabetes was evaluated using Cox regression analyses and multivariate models. The covariates included in the multivariate model are known to be associated with the development of type 2 diabetes. Additionally, the multivariate model (Model 1) was adjusted for age, body mass index (BMI), systolic blood pressure (SBP), low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, triglyceride, and glucose levels. Model 2 included factors of as model 1 as well as details on smoking status, eating speed, breakfast skipping, snacking after dinner, alcohol consumption, physical exercise, flextime system, night shifts, and hours of sleep. All continuous variables are presented as mean ± SD or absolute number. $P < 0.05$ were considered statistically significant. While using the Bonferroni method, differences were considered statistically significant at $p < 0.008$. The associations were presented as hazard ratios (HR) with 95% confidence intervals. All statistical analyses were performed using JMP software version 10 (SAS Institute, Cary, NC, USA).

# 3. Results

The baseline characteristics of the participants enrolled in this study are presented in Tables 1, 2. Men with technical jobs were younger than the salespersons, manufacturers, and office workers included in this study. SBP was lower in men with technical jobs than in those working as salespersons, manufacturers, and office workers. The proportion of never smokers, those with slow eating speeds, and those working with a flextime system was higher in men with technical jobs than the others. Further, the proportion of alcohol drinkers and those with exercise habits was lower among men with technical jobs than among those working as salespersons, manufacturers, and office workers. In addition, the proportion of never-smokers and those working with a flextime system was higher in women with technical jobs than in those working as salespersons, manufacturers, and office workers.

Abbreviations: BMI, body mass index; SBP, systolic blood pressure; LDL, low-density lipoprotein; HDL, high-density lipoprotein.

TABLE 1 Characteristics of patients at baseline according to occupation type in men.

| | All | Technical jobs | Salesperson | Manufacturer | Office worker | *p* |
|---|---|---|---|---|---|---|
| *n* | 76,092 | 27,038 | 12,303 | 20,965 | 15,786 | |
| Age (y) | 45.0 (8.2) | 44.0 (7.8) | 44.4 (8.9)* | 44.5 (8.3)* | 47.9 (7.6)* | <0.0001 |
| Body mass index (kg/m$^2$) | 23.4 (3.2) | 23.2 (3.1) | 24.1 (3.2)* | 23.1 (3.3)* | 23.7 (3.1)* | <0.0001 |
| Systolic blood pressure (mmHg) | 120.5 (14.0) | 119.3 (13.6) | 121.7 (14.4)* | 120.8 (14.0)* | 121.0 (14.2)* | <0.0001 |
| Diastolic blood pressure (mmHg) | 75.6 (10.6) | 75.0 (10.4) | 76.4 (11.0)* | 75.0 (10.5) | 76.7 (10.5)* | <0.0001 |
| LDL cholesterol (mg/dL) | 126.0 (31.2) | 126.0 (30.7) | 125.7 (31.6) | 124.8 (31.9)* | 127.9 (30.6)* | <0.0001 |
| HDL cholesterol (mg/dL) | 57.7 (14.2) | 57.5 (13.9) | 57.4 (14.2) | 58.3 (14.6)* | 57.4 (14.2) | <0.0001 |
| Triglyceride (mg/dL) | 122.0 (93.1) | 116.2 (84.3) | 136.4 (108.3)* | 118.0 (91.0) | 126.1 (95.8)* | <0.0001 |
| Glucose (mg/dl) | 93.9 (9.3) | 93.8 (8.9) | 93.5 (9.5)* | 93.6 (9.7) | 94.8 (9.2)* | <0.0001 |
| Smoking (none/past/current) | 32,964/13,527/29,601 (43.3/17.8/38.9) | 14,444/4,859/7,735 (53.4/18.0/28.6) | 4,610/2,363/5,330* (37.5/19.2/43.3) | 6,914/2,996/11,055* (33.0/14.3/52.7) | 6,996/3,609/5,481* (44.3/21.0/34.7) | <0.0001 |
| Eating speed (fast/normal/slow) | 26,847/44,212/5,033 (35.3/58.1/6.6) | 9,240/15,760/2,038 (34.2/58.3/7.5) | 5,133/6,480/690* (41.7/52.7/5.6) | 6,651/12,984/1,330* (31.7/61.9/6.3) | 5,823/8,988/975* (36.9/56.9/6.2) | <0.0001 |
| Skipping breakfast (+/−) | 16,983/59,109 (22.3/77.7) | 5,031/22,007 (18.6/81.4) | 3,679/8,624* (29.9/70.1) | 5,627/15,338* (26.8/73.2) | 2,646/13,140* (16.8/83.2) | <0.0001 |
| Snack after dinner (+/−) | 12,707/63,385 (16.7/83.3) | 4,442/22,596 (16.4/83.6) | 1,750/10,553* (14.2/85.8) | 4,230/16,735* (20.2/79.8) | 2,285/13,501* (14.5/85.5) | <0.0001 |
| Alcohol drinker (+/−) | 8,581/67,511 (11.3/88.7) | 2,104/24,934 (7.8/92.2) | 2,190/10,113* (17.8/82.2) | 2,382/18,583* (11.4/88.6) | 1,905/13,881* (12.1/87.9) | <0.0001 |
| Physical exercise (+/−) | 14,242/61,850 (18.7/81.3) | 4,666/22,372 (17.3/82.7) | 2,399/9,904* (19.5/80.5) | 3,981/16,984* (19.0/81.0) | 3,196/12,590* (20.2/79.8) | <0.0001 |
| Flextime system (+/−) | 24,927/51,165 (32.8/67.2) | 15,201/11,837 (56.2/43.8) | 2,819/9,484* (22.9/77.1) | 1,803/19,162* (8.6/91.4) | 5,104/10,682* (32.3/67.7) | <0.0001 |
| Night shift (+/−) | 15,468/83,467 (15.6/84.4) | 2,477/24,561 (9.2/90.8) | 1,478/10,825* (12.0/88.0) | 9,206/11,759* (43.9/56.1) | 1,179/14,607* (7.5/92.5) | <0.0001 |
| Hours of sleep; ≤5 h (+/−) | 16,210/59,882 (21.3/78.7) | 6,157/20,881 (22.8/77.2) | 2,829/9,474 (23.0/77.0) | 4,165/16,800* (19.9/80.1) | 3,059/12,727* (19.4/80.6) | <0.0001 |

Data are expressed as mean (SD) or absolute number. LDL, Low-density lipoprotein; HDL, High-density lipoprotein.
*Significant difference compared to technical jobs.





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TABLE 2 Characteristics of patients at baseline according to occupation type in women.

| | All | Technical jobs | Salesperson | Manufacturer | Office worker | *p* |
|---|---|---|---|---|---|---|
| *n* | 22,843 | 2,144 | 1,491 | 5,948 | 13,260 | – |
| Age (y) | 41.2 (8.2) | 40.4 (7.9) | 36.6 (9.8)* | 44.4 (7.8)* | 40.4 (7.8) | <0.0001 |
| Body mass index (kg/m$^2$) | 21.4 (3.5) | 21.2 (3.4) | 20.9 (3.0) | 22.2 (3.8)* | 21.1 (3.4) | <0.0001 |
| Systolic blood pressure (mmHg) | 112.0 (14.3) | 110.5 (13.6) | 109.1 (13.6)* | 115.6 (14.9)* | 110.9 (14.0) | <0.0001 |
| Diastolic blood pressure (mmHg) | 68.4 (10.4) | 67.8 (10.3) | 66.5 (9.9)* | 70.1 (10.5)* | 68.0 (10.4) | <0.0001 |
| LDL cholesterol (mg/dL) | 114.3 (30.5) | 111.7 (29.8) | 107.9 (29.3)* | 120.1 (31.8)* | 112.8 (29.8) | <0.0001 |
| HDL cholesterol (mg/dL) | 70.0 (14.9) | 69.7 (14.6) | 70.7 (15.0) | 68.6 (14.9)* | 70.5 (14.9) | <0.0001 |
| Triglyceride (mg/dL) | 71.3 (44.6) | 71.4 (47.0) | 68.2 (39.7) | 75.7 (49.2)* | 69.7 (42.3) | <0.0001 |
| Glucose (mg/dl) | 88.1 (8.2) | 88.3 (7.6) | 86.2 (7.7)* | 89.7 (8.7)* | 87.5 (8.0)* | <0.0001 |
| Smoking (none/past/current) | 18,135/1,660/3,048 (79.4/7.3/13.3) | 1,838/127/179 (85.7/5.9/8.3) | 1,123/139/229* (75.3/9.3/15.4) | 4,534/320/1,094* (76.2/5.4/18.4) | 10,640/1,074/1,546* (80.2/8.1/11.7) | <0.0001 |
| Eating speed (fast/normal/slow) | 5,822/14,636/2,385 (25.5/64.1/10.4) | 530/1,356/258 (24.7/63.2/12.0) | 469/846/176* (31.5/56.7/11.8) | 1,353/4,108/487 (22.7/69.1/8.2) | 3,470/8,326/1,464* (26.2/62.8/11.0) | <0.0001 |
| Skipping breakfast (+/–) | 4,002/18,841 (17.5/82.5) | 370/1,774 (17.3/82.7) | 424/1,067* (28.4/71.6) | 885/5,063 (14.9/85.1) | 2,323/10,937 (17.5/82.5) | <0.0001 |
| Snack after dinner (+/–) | 5,377/17,466 (23.5/76.5) | 445/1,699 (20.8/79.2) | 315/1,176 (21.1/78.9) | 1,555/4,393 (26.1/73.9) | 3,062/10,198* (23.1/76.9) | <0.0001 |
| Alcohol drinker (+/–) | 2,006/20,837 (8.8/91.2) | 194/1,950 (9.0/91.0) | 169/1,322 (11.3/88.7) | 393/5,555 (6.6/93.4) | 1,250/12,010* (9.4/90.6) | <0.0001 |
| Physical exercise (+/–) | 2,599/20,244 (11.4/88.6) | 250/1,894 (11.7/88.3) | 180/1,311 (12.1/87.9) | 596/5,352 (10.0/90.0) | 1,573/11,687 (11.9/88.1) | 0.002 |
| Flextime system (+/–) | 3,628/19,215 (15.9/84.1) | 887/1,257 (41.4/58.6) | 295/1,196* (19.8/80.2) | 253/5,695* (4.3/95.7) | 2,193/11,067* (16.5/83.5) | <0.0001 |
| Night shift (+/–) | 1,128/21,715 (4.9/95.1) | 118/2,026 (5.5/94.5) | 86/1,405 (5.8/94.2) | 665/5,283* (11.2/88.8) | 259/13,001* (2.0/98.0) | <0.0001 |
| Hours of sleep; ≤5 h (+/–) | 5,050/17,793 (22.1/77.9) | 533/1,611 (24.9/75.1) | 343/1,148 (23.0/77.0) | 1,341/4,607* (22.5/77.5) | 2,833/10,427 (21.4/78.6) | 0.002 |

Data are expressed as mean (SD) or absolute number. LDL, Low-density lipoprotein; HDL, High-density lipoprotein.
*Significant difference compared to technical jobs.





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TABLE 3 Characteristics of participants at baseline according to the development of diabetes.

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | The development of diabetes (−) | The development of diabetes (+) | *p* | The development of diabetes (−) | The development of diabetes (+) | *p* |
| *n* | 71,450 | 4,642 | – | 22,477 | 366 | – |
| Age (y) | 44.9 (8.3) | 47.0 (6.5) | <0.0001 | 41.1 (8.2) | 45.5 (6.4) | <0.0001 |
| Body mass index (kg/m$^2$) | 23.3 (3.1) | 25.6 (3.9) | <0.0001 | 21.3 (3.4) | 26.6 (5.8) | <0.0001 |
| Systolic blood pressure (mmHg) | 120.1 (13.8) | 126.1 (15.1) | <0.0001 | 111.7 (14.1) | 126.4 (18.2) | <0.0001 |
| Diastolic blood pressure (mmHg) | 75.3 (10.5) | 79.8 (10.8) | <0.0001 | 68.3 (10.3) | 77.7 (12.3) | <0.0001 |
| LDL cholesterol (mg/dL) | 125.5 (31.0) | 133.6 (32.5) | <0.0001 | 113.9 (30.4) | 137.7 (32.1) | <0.0001 |
| HDL cholesterol (mg/dL) | 58.0 (14.2) | 53.1 (13.8) | <0.0001 | 70.1 (14.8) | 61.1 (14.7) | <0.0001 |
| Triglyceride (mg/dL) | 119.5(90.4) | 160.8 (120.7) | <0.0001 | 70.7 (44.0) | 106.8 (60.5) | <0.0001 |
| Glucose (mg/dl) | 93.1 (8.6) | 106.5 (10.8) | <0.0001 | 87.8 (7.9) | 103.0 (10.8) | <0.0001 |
| Smoking (none/past/current) | 31,303/12,668/27,479 (43.8/17.7/38.5) | 1,661/859/2,122 (35.8/18.5/45.7) | <0.0001 | 17,849/1,635/2,993 (79.4/7.3/13.3) | 286/25/55 (78.1/6.8/15.0) | 0.62 |
| Eating speed (fast/normal/slow) | 24,825/41,767/4,858 (34.7/58.5/6.8) | 2,022/2,445/175 (43.6/52.7/3.8) | <0.0001 | 5,693/14,419/2,365 (25.3/64.2/10.5) | 129/217/20 (35.3/59.3/5.5) | <0.0001 |
| Skipping breakfast (+/−) | 15,849/55,601 (22.2/77.8) | 1,134/3,508 (24.4/75.6) | 0.0004 | 3,930/18,547 (17.5/82.5) | 72/294 (19.7/80.3) | 0.27 |
| Snack after dinner (+/−) | 11,889/59,561 (16.6/83.4) | 818/3,824 (17.6/82.4) | 0.08 | 5,289/17,188 (23.5/76.5) | 88/278 (24.0/76.0) | 0.82 |
| Alcohol drinker (+/−) | 7,922/63,528 (11.1/88.9) | 659/3,983 (14.2/85.8) | <0.0001 | 1,980/20,497 (8.8/91.2) | 26/340 (7.1/92.9) | 0.25 |
| Physical exercise (+/−) | 13,372/58,078 (18.7/81.3) | 870/3,772 (18.7/81.3) | 0.96 | 2,559/19,918 (11.4/88.6) | 40/326 (10.9/89.1) | 0.79 |
| Flextime system (+/−) | 23,455/47,995 (32.8/67.2) | 1,472/3,170 (31.7/68.3) | 0.12 | 3,550/18,927 (15.8/84.2) | 78/288 (21.3/78.7) | 0.004 |
| Night shift (+/−) | 13,496/57,954 (18.9/81.1) | 844/3,798 (18.2/81.8) | 0.23 | 1,108/21,369 (4.9/95.1) | 20/346 (5.5/94.5) | 0.64 |
| Hours of sleep; ≤5 h (+/−) | 15,164/56,286 (21.2.78.8) | 1,046/3,596 (22.5/77.5) | 0.04 | 4,936/17,541 (22.0/78.0) | 114/252 (31.2/68.9) | <0.0001 |
| Occupation type: technical jobs/salesperson/manufacturer/office workers | 25,644/11,451/19,617/14,738 (35.9/16.0/27.5/20.6) | 1,394/852/1,348/1,048 (30.0/18.4/29.0/22.6) | <0.0001 | 2,113/1,491/5,790/13,100 (9.4/6.6/25.8/58.3) | 31/17/158/160 (8.5/4.6/43.2/43.7) | <0.0001 |

Data are expressed as mean (SD) or absolute number. LDL, Low-density lipoprotein; HDL, High-density lipoprotein.





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TABLE 4 Unadjusted and adjusted hazard ratios (95% CI) for development of diabetes according to occupation type.

| | Men | | Women | |
|---|---|---|---|---|
| Unadjusted | HR | *P*-value | HR | *P*-value |
| Technical jobs | 1 | – | 1 | – |
| Salesperson | 1.48 (1.35–1.61) | <0.0001 | 0.87 (0.47–1.56) | 0.65 |
| Manufacturer | 1.45 (1.35–1.57) | <0.0001 | 2.11 (1.46–3.16) | <0.0001 |
| Office workers | 1.48 (1.36–1.60) | <0.0001 | 1.04 (0.72–1.56) | 0.83 |
| Adjusted (model 1) | HR | *P*-value | HR | *P*-value |
| Technical jobs | 1 | – | 1 | – |
| Salesperson | 1.26 (1.16–1.37) | <0.0001 | 1.14 (0.61–2.03) | 0.68 |
| Manufacturer | 1.38 (1.28–1.49) | <0.0001 | 1.44 (0.99–2.17) | 0.06 |
| Office workers | 1.17 (1.08–1.27) | 0.0002 | 1.10 (0.75–1.65) | 0.64 |
| Adjusted (model 2) | HR | *P*-value | HR | *P*-value |
| Technical jobs | 1 | – | 1 | – |
| Salesperson | 1.15 (1.05–1.26) | 0.003 | 1.10 (0.59–1.99) | 0.76 |
| Manufacturer | 1.20 (1.10–1.30) | <0.0001 | 1.41 (0.95–2.17) | 0.09 |
| Office workers | 1.11 (1.02–1.21) | 0.01 | 1.06 (0.72–1.60) | 0.79 |

Model 1, adjustment for age, body mass index, systolic blood pressure, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, triglycerides, and fasting plasma glucose. Model 2, adjusted for model 1 plus smoking status, eating speed, skipping breakfast, snack after dinner, alcohol consumption, exercise habits, flextime system, night shift, and hours of sleep.

Table 3 shows the baseline characteristics of the participants according to the development of type 2 diabetes. In total, 4,642 men and 366 women developed type 2 diabetes between 2008 and 2018. The incidence rate for type 2 diabetes was 1,394 (5.2%), 852 (6.9%), 1,348 (6.4%), and 1,048 (6.6%) in men with technical jobs, salespersons, manufacturers, and office workers, respectively. The incidence rate for type 2 diabetes was 31 (1.5%), 17 (1.1%), 158 (2.7%), and 160 (1.2%) in women with technical jobs, salespersons, manufacturers, and office workers, respectively. We found significant differences between the occupation types according to the development of type 2 diabetes both in men and women.

Table 4 shows the unadjusted and adjusted HR for the development of type 2 diabetes in men and women, respectively. The type of occupation was associated with an increased probability of developing type 2 diabetes in men. When the reference group was defined as men with technical jobs, the HR was 1.26 [95% confidence interval (CI), 1.16–1.37], 1.38 (95% CI, 1.28–1.49), and 1.17 (95% CI, 1.08–1.27) in salespersons, manufacturers, and office workers, respectively, in model 1. The HR was 1.15 (95% CI, 1.05–1.26), 1.20 (95% CI, 1.10–1.30), and 1.11 (95% CI, 1.02–1.21) in salespersons, manufacturers, and office workers, respectively, in model 2. Interestingly, the occupation type was not associated with the development of type 2 diabetes in women.

## 4. Discussion

To the best of our knowledge, this is the first study to investigate the association between occupation type and the development of type 2 diabetes among the Japanese population in such an extensive cohort. The major finding of this study was that occupation type may be an independent factor for the development of type 2 diabetes in Japanese men but not in women. Our results describe that there is a higher risk of type 2 diabetes development among men who are salespersons, manufacturers, or office workers than among men with technical jobs.

However, the reason for this association remains unclear. It has been reported that there is an increased risk of type 2 diabetes in low-income groups with lower educational qualifications (6, 8). We believe that the educational and income levels of the participants in the present study were almost similar for all occupation types because all participants worked in the same corporation. We thus postulated that working hours, sleeping hours, unhealthy behaviors, and psychosocial stress could affect glucose tolerance. Azami et al. (12) reported an association between long working hours and glycemic control in young Japanese male patients with type 2 diabetes. Such long working hours have been suggested to result in poor glycemic control due to higher job-related stress, which can lead to the development of negative behavioral habits, including overeating and neuroendocrinological problems, causing increased levels of counterregulatory hormones (13). Several reports have suggested that short sleep duration is associated with the development of diabetes (14–16). The results of a meta-analysis suggested a *U*-shaped relationship between sleep duration and risk of type 2 diabetes (14). Moreover, it is well-known that unhealthy behaviors, including smoking, fast eating speed, or skipping breakfast, are associated with the development of diabetes (17–19). We identified similar findings after adjusting sleep duration and unhealthy behaviors in this study. Similarly, variations in psychosocial stress have been reported to be associated with different types of occupation (20). Long-term stress affects the entire neuroendocrine system and can lead to diabetes (21, 22). We believe that occupational stress may differ according to occupation type as the required communication skills, demands of the job, and discretionary powers tend to vary between occupations. Moreover, the proportion of participants working with a flextime system was higher in technical jobs than in those working as salespersons, manufacturers, and office workers. Thus, we postulate that adopting a flextime system may have a positive impact on work stress.

We also assessed why an association between occupation type and the development of type 2 diabetes was observed in men but not in women. A previous study reported sex-based differences in the association between occupation type and job stress. Kawaharada et al. (20) reported that there were associations between job requirements and job stress among occupation types in men but not in women. Thus, these findings support the results of the present study.

The main strengths of the present study were its huge cohort size and the time-span of data collection. However, this study has some limitations. First, it has been reported that working hours, psychosocial stress, exposure to chemicals, seniority in the particular job, educational qualification, salary, and marital/family status were associated with the development of diabetes (1, 5–7, 10, 23–25). Moreover, genetic susceptibility was well-known as the important factor of incident diabetes. Unfortunately, we have no data on these

variables. We believe that the educational and income levels of the participants in our study are almost similar for all occupation type because all the participants work in the same corporation. Second, we had no data of quantitative expression of smoking habit and eating speed. Third, the study population comprised only of Japanese men and women with high socioeconomic status; therefore, it is uncertain whether these findings can be generalized to other ethnic groups as well.

## 5. Conclusion

Our study showed that the risk of incident type 2 diabetes was higher in salespersons, manufacturers, and office workers than that in men with technical jobs after adjustment for covariates in Japanese men. In conclusion, occupation type was an independent factor for the development of type 2 diabetes in Japanese men. The findings of this study may be important for the advancement of healthcare in diabetes.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving human participants were reviewed and approved by the local Ethics Committee of the Panasonic Health Insurance Organization (approval number: 2021-001). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

## Author contributions

MHab collected the data and wrote the manuscript. MHam, KK, and HM contributed to the discussion. HO and MI analyzed the data and contributed to the discussion. MF reviewed and edited the manuscript. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

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The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note



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# Mental health of public safety personnel: Developing a model of operational, organizational, and personal factors in public safety organizations

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The work of public safety personnel (PSP) such as police officers, firefighters, correctional officers, and paramedics, as well as other PSP, makes them vulnerable to psychological injuries, which can have profound impacts on their families and the communities they serve. A multitude of complex operational, organizational, and personal factors contribute to the mental health of PSP; however, to date the approach of the research community has been largely to explore the impacts of these factors separately or within single PSP professions. To date, PSP employers have predominantly focused on addressing the personal aspects of PSP mental health through resiliency and stress management interventions. However, the increasing number of psychological injuries among PSPs and the compounding stressors of the COVID-19 pandemic demonstrate a need for a new approach to the study of PSP mental health. The following paper discusses the importance of adopting a broader conceptual approach to the study of PSP mental health and proposes a novel model that highlights the need to consider the combined impacts of operational, organizational, and personal factors on PSP mental health. The **TR**i-**O**perational-**O**rganizational-**P**ersonal Factor Model (TROOP) depicts these key factors as three large pieces of a larger puzzle that is PSP mental health. The TROOP gives working language for public safety organizations, leaders, and researchers to broadly consider the mental health impacts of public safety work.

KEYWORDS

**occupational health, public safety, organizational factors, mental health, public safety personnel**

## 1. Introduction

Public safety personnel (PSP) such as police officers, firefighters, correctional officers, and paramedics, as well as border service officers, rescue personnel, operational intelligence personal, and communications operators/dispatchers work to protect the public (1–9). Individuals working in these careers have greater exposure to psychological trauma than civilians, making their mental wellness particularly relevant (10, 11). Research has revealed that PSP work is associated with higher rates of several mental health conditions including posttraumatic stress disorder (PTSD), anxiety disorders, depression, and substance use disorder as well as increased suicidal ideation, stress, and burnout compared to the general public (10). The mental wellness of PSP workers has significant ripple effects for PSP families and their communities (11).

In 2020, the Government of Canada released a national strategy on PTSD, which is heavily focused on public safety populations, making this a particularly pertinent time for research addressing PSP mental health. In addition, the unprecedented pressures of the COVID-19 pandemic have compounded the occupational stressors faced by PSPs while also highlighting the need for work addressing the mental health needs of this particular population of workers (5). Each individual's mental health is the result of a multitude of factors with the most commonly studied factors falling into the categories of operational, organizational, and personal factors.

## 1.1. Operational factors

Operational factors refer to the content of the work and include demands unique to the job and the specific pressures facing PSPs. For instance, responding to violent situations, feeling fearful of potential injury, or experiencing negative interactions with the public while on duty (12) could all be considered operational factors. Other operational factors include workload and threats to safety and risk of injury or death (12). The COVID-19 pandemic has further revealed the potential negative mental health impact of increased operational risk when performing public safety work (5).

## 1.2. Organizational factors

Organizations that employ PSPs can also contribute to work-related stress and cause negative mental health outcomes (13). Organizational factors include elements of the employment context that impact the mental health of PSPs during their work. These factors are often controlled or highly influenced by the employer and can either contribute to work related stress or act as facilitators to improve mental health outcomes, as well as job satisfaction and work efficiency (13, 14). Inadequate supervisor support or poor workplace culture, for example, can act as barriers to positive mental health outcomes (14–16).

## 1.3. Personal factors

Personal factors are unique to the individual PSP and depend on the circumstances of each person, including their family and social relationships, their overall health status, and their individual interests and activities outside of work. Personal factors can exacerbate stressors already present at work, such as poor familial support or experiencing a mental health condition (16). Personal factors can also interact with the demands of the job (i.e., operational factors) and act as either facilitators or stressors.

## 1.4. Need for more research

To date, most research has adopted a reductive strategy to the study of PSP mental health by exploring the mental health impacts of operational, organizational, and/or personal factors separately or within a single PSP profession [e.g., (4, 12, 14–20)]. However, at any one time, an individual's mental health is influenced by a variety of factors with the balance of impacts changing with different pressures. Consider, for instance, the impact of certain operational factors such as witnessing the traumatic injury of a child when also dealing with the illness of a loved one at home and knowing that organizational demands are so great that you will not be able to take any time off to process the traumatic experience or care for your loved one. Given the dynamic and complex contributions of operational, organizational, and personal factors on the mental health of a population already at an elevated risk of serious psychological injuries, it is important to move beyond the investigation of individual impacts and focus on the interplay between all three factors when exploring and addressing the mental health needs of all PSP.

The need to approach PSP mental health from a broader perspective, one that moves beyond a focus on a single category of factors, was further highlighted by the findings of a recent scoping review that explored the role that operational, organizational, and personal factors play in the mental health of PSPs (2). The review revealed that although organizational factors are most amenable to change, it is also vital to consider the impact of operational and personal factors when addressing the mental health needs of PSP (2). The intent of this paper is to propose a visual model that can serve as a foundation for examining the dynamic and often interconnected roles that operational, organizational, and personal factors play in the mental health of PSPs. The purpose of this model is also to serve not only as a roadmap for future studies and interventions focusing on PSP mental health, which could lead to amendments and further development of the model, but also a guide to help PSP organizations identify factors that can be addressed within their own context to facilitate positive changes for workplace mental health. The aim of this model is not to provide a comprehensive overview of PSP mental health, as many aspects of PSP mental health have yet to be studied, but rather to draw attention to the need to broaden our focus as researchers and employers to better address the needs of a vulnerable population that serves all of our communities.

# 2. A tri-factor model of public safety personnel mental health

This new tri-factor model focuses on the impact of three broad factors (operational, organizational, and personal) known to impact PSP mental health. The factors are depicted as three large pieces of a larger puzzle that is PSP mental health (Figure 1). In the figure, the bottom puzzle piece is left blank to symbolize the larger context, which could include external factors beyond the workplace, home, or community, as well as elements that research may not yet have focused on. No single piece is more or less important than the other; however, the salience of each can vary at any given point in time depending on the individual circumstances of PSPs.

Named the **TR**i-**O**perational-**O**rganizational-**P**ersonal Factor Model (TROOP), this tri-factor model gives visibility to these key factors as well as working language for public safety organizations, leaders, and researchers to broadly consider the mental health impacts of public safety work.

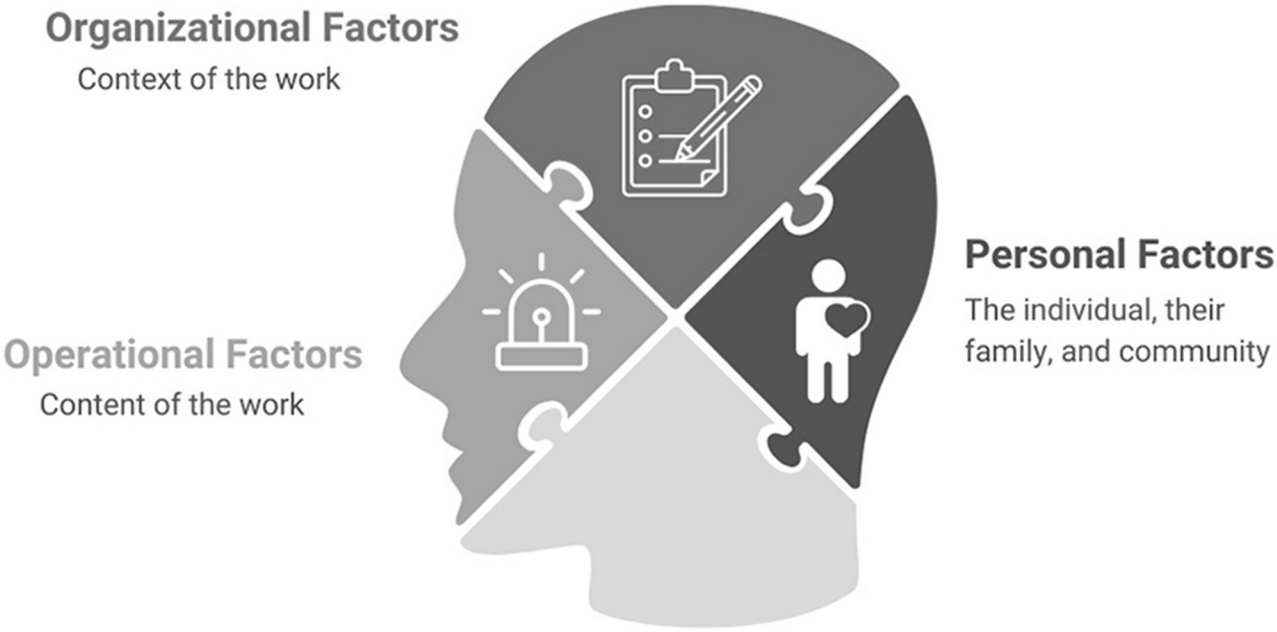


FIGURE 1
**TR**i-**O**perational-**O**rganizational-**P**ersonal Factor Model (TROOP).

## 3. Discussion

Each one of the three factors in the TROOP include a complex network of factors that previous research has found to have an impact on PSP mental health. Using the findings from Edgelow et al.'s scoping review (2), we have created Table 1 to summarize the most common operational, organizational, and personal factors known to impact PSP mental health positively and negatively. This table also includes a representation of the amount of published scholarly work that has, to date, focused on a given factor known to impact PSP mental health. It is important to note that we are just beginning to understand which factors positively or negatively impact PSP mental health and as research progresses, more factors can be added to the table. What the model and tables highlight is that a great deal more work is required to explore the complex interplay between operational, organizational, and personal factors and their joint impacts on PSP mental health (1, 2).

### 3.1. Operational factors known to impact PSP mental health

Operational factors are unavoidable aspects of public safety work. In the Edgelow et al. review (2), factors known to have a positive impact on PSP mental health include work role. For example, police officers working in "operational support" roles (e.g., firearms officers, family liaison, and negotiators) roles had lower odds of developing mental health conditions compared to "investigations officers" (e.g., public protection, counter terrorism, and forensics) (17). Working in suburban, urban, and mixed departments has been associated with a lower risk to mental health compared to rural departments (21). Conversely, exposure to critical incidents (18–20) is a frequently cited negative operational factor as is high workload (22–24). Other operational factors associated with negative impacts on PSP mental health include risk of violence (25–27) and negative interactions with the public (28–30). Longer tenure and higher rank have also been negatively associated with PSP mental health (20, 21). Table 1 depicts the most well-documented factors known to impact PSP mental health positively and negatively.

### 3.2. Organizational factors known to impact PSP mental health

Organizational factors include the context in which public safety work occurs. These organizational factors have the potential to either create added stress or facilitate positive outcomes for the PSP. For instance, support from supervisors (31–33) and co-workers (34–36) can lead to higher job satisfaction and improve mental health, or conversely, a lack of support can contribute to the opposite impacts (12, 37, 38). Other negative factors include negative workplace culture (20, 39, 40), limited resources to perform the work (23, 41, 42), and work-related interpersonal conflict with colleagues (43–45) (Table 1).

### 3.3. Personal factors known to impact PSP mental health

Personal factors are unique to each individual PSP and exist outside of the work context but may interact with it.

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TABLE 1 Summary of the top 10 factors known to impact PSP mental health [as in Edgelow et al. (2)].

| Negative operational factors | # of studies | Negative organizational factors | # of studies | Negative personal factors | # of studies | Total negative factors |
|---|---|---|---|---|---|---|
| Exposure to critical incidents | 21 | Lack of supervisor support | 23 | Health conditions (mental) | 26 | |
| High workload | 20 | Negative workplace environment | 21 | Work/life/family conflict | 19 | |
| Threats or risk of violence | 13 | Lack of co-worker support | 14 | Gender | 12 | |
| Administrative duties | 12 | Limited resources to perform work | 14 | Job satisfaction | 12 | |
| Negative public interactions | 12 | Interpersonal conflict with colleagues | 13 | Poor sleep | 12 | |
| Workplace stress | 12 | Stigma/barriers to seeking help | 13 | Lack of coping skills | 10 | |
| Risk of injury | 12 | Leadership issues | 12 | Fatigue | 9 | |
| Experiencing violence | 9 | Overtime hours | 12 | Health conditions (physical) | 8 | |
| Work overload | 8 | Understaffing | 12 | Substance misuse | 8 | |
| Risk of death | 5 | Shift work | 11 | Burnout | 7 | |
| *Total* | *124* | *Total* | *145* | *Total* | *123* | ***392*** |
| **Positive operational factors** | **# of studies** | **Positive organizational factors** | **# of studies** | **Positive personal factors** | **# of studies** | **Total positive factors** |
| Role | 2 | Co-worker support | 10 | Job satisfaction or meaning | 8 | |
| Tenure | 1 | Supervisor support | 8 | Family support | 8 | |
| Rank | 1 | Autonomy | 4 | Gender | 4 | |
| Department setting | 1 | Positive workplace culture | 3 | Work/life/family balance | 4 | |
| Sense of safety | 1 | Adequate training | 3 | Adequate sleep | 3 | |
| | | Access to mental health specialists | 2 | Positive coping skills | 3 | |
| | | Positive leadership | 2 | Good physical health | 3 | |
| | | Recognition of good work | 2 | Race | 3 | |
| | | Role clarity | 2 | Resilience | 3 | |
| | | Team dynamics | 2 | Social support | 3 | |
| *Total* | *6* | *Total* | *38* | *Total* | *42* | ***86*** |
| *Total operational factors* | *130* | *Total organizational factors* | *183* | *Total personal factors* | *165* | ***TOTAL*** |
| | | | | | | ***478*** |

Edgelow et al. (2) found that family support (25, 46, 47) and job satisfaction (18, 48, 49) most positively impacted PSP mental health. For example, family relationships have been found to have a protective role in preventing correctional officers from attempting suicide (50). Other personal factors known to positively impact PSP mental health include work, life, and family balance (35, 51), good physical health (52, 53), and social support (46, 54). On the other hand, the most common personal factor that worsened work related stress was experiencing a mental health issue (55–57) with PTSD, anxiety, and depression being the most frequently listed diagnoses. Dealing with work, life, and family conflicts also had a negative impact on PSP mental health (47, 55, 58). When considering mental health impacts, it should be noted that there is a bi-directional relationship, in that each factor can cause increased stress on the other. Research also indicates that public safety careers negatively impacted PSPs' social life outside of work (59) due to their "unsociable" working hours and limited availability outside of work (60) (Table 1).

## 3.4. Use of the TROOP and the factors summary table

Factors related to PSP mental health have been grouped into three broad categories: operational, organizational, and personal factors. Each broad category includes several factors known to impact PSP mental health positively or negatively. The goal of this paper was to introduce the TROOP and also provide a summary of existing research on the positive and negative factors that fall within each of these three categories. Table 1 depicts the relative frequency of published scientific work focusing on a given factor (2).

Given the inherent stressors associated with PSP work and PSPs' increased risk of psychological injury, it is possible to use the TROOP (Figure 1) and Table 1 to consider how factors can be attended to within a workplace. Operational risks associated with PSP work are often thought of as inherent to the job, but all jobs with safety risks can be approached with an occupational and public health lens to reduce work-related risk. Personal factors are also not easily modified, but organizations can offer mental health supports to employees and their families and adopt policies that encourage work-life balance. Organizational factors may be the most modifiable. A recent review (1) considered the impact of work stressors on PSPs and found that organizational factors such as supervisor support, leadership styles, shift work models, staffing levels, stigma, and workplace culture are amenable to change within PSP organizations. Using the TROOP (Figure 1) can ensure that organizations consider operational, organizational, and personal factors more holistically in their efforts to improve workplace mental health.

## 4. Conclusion

This paper has proposed that researchers and employers broaden their focus with respect to PSP mental health and offers the **TR**i-**O**perational-**O**rganizational-**P**ersonal Factor Model (TROOP), a model of operational, organizational, and personal factors as a roadmap to explore and address the mental health needs of PSP. The aim of this paper was to provide a model to synthesize and depict the wide breadth of scientific work exploring factors that impact PSP mental health. In addition, the tri-factor table depicts the relative frequency of published scientific work focusing on a given factor (Table 1) (2). The overall aim of this work is to draw attention to the need to broaden our approach to future research exploring the complex factors that impact PSP mental health and to assist public safety organizations in attending to a variety of factors that impact the mental health of PSP within their organizations and our communities.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

## Author contributions

ME and AF contributed to the model conception and design. All authors shared the writing of the manuscript and read and approved the final manuscript.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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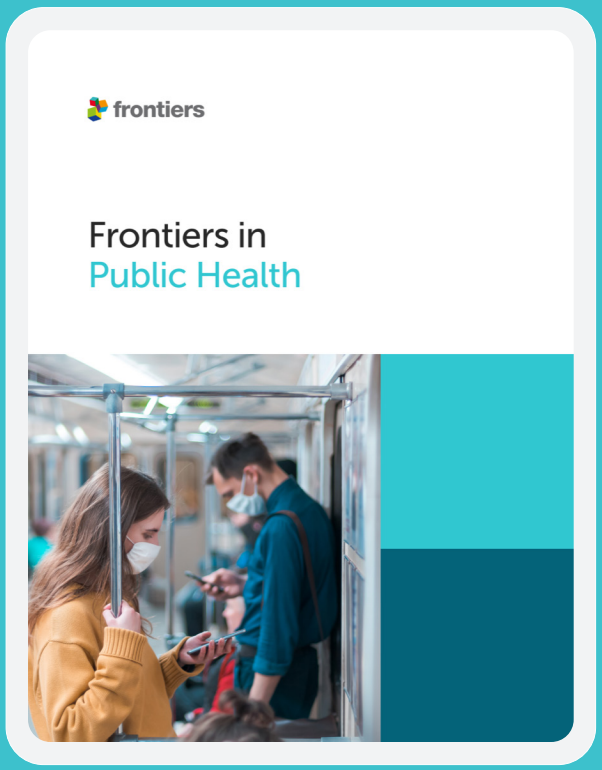


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