Work 79 (2024) 503–521
DOI:10.3233/WOR-230005
IOS Press

The evolution of new and emerging occupational health and safety risks: A qualitative review

Maria Lindholm[a,*], Arto Reiman[b] and Sari Tappura[c]
[a]*Tampere University, Tampere, Finland*
[b]*University of Oulu, Oulu, Finland*
[c]*Finnish Safety and Chemicals Agency (Tukes), Helsinki, Finland*

Received 3 January 2023
Accepted 8 April 2024

Abstract.
BACKGROUND: Work itself and occupational health and safety (OHS) have evolved through industrial revolutions and will also continue to evolve in the future.
OBJECTIVE: The aim of this qualitative literature review was to examine how the scientific discussion on new and emerging risks (NERs) related to OHS has evolved in recent decades in developed and newly industrialized countries.
METHODS: A search of the Scopus database yielded 34 articles published before 2000 and from 2020 onwards.
RESULTS: A review of the articles identified NERs themes related to changes in work patterns, changing workforce and growth in some sectors, climate change, new materials or increased use of materials, new technology and technological development, and viruses. In both article collection periods, possible adverse OHS effects discussed included musculoskeletal disorders, exposure to toxic agents, chemical compounds and hazardous materials, increased stress, increased likelihood of errors and accidents, psychosocial problems, mental fatigue, and increases in work-related illnesses and accidents.
CONCLUSIONS: The articles published during both periods discussed similar themes. The main differences were regarding specific time-related cases, such as climate change and COVID-19. Based on the findings of this review, points to consider in OHS management and future studies are discussed.

Keywords: Change, climate change, human factors and ergonomics, materials, technology, viruses

1. Introduction

Human work has evolved parallel with the general trends on industrialization [1, 2]. During the first and second industrial revolutions (from circa 1760 to 1870 and from the late 1800s to the early 1900s), technological development led to mechanized, yet labor-intensive factories and in the beginning in the latter half of the 20th century, the third industrial revolution led to breakthroughs in information and communication technologies (ICT) [3–5]. Now, in the first part of the 21st century, we are witnessing a shift towards the fourth industrial revolution that is characterized with the introduction of digitalized new technologies [1, 2, 6, 7]. Simultaneously with the technological development, globally experienced changes in demographic structures [8], climate change and related willingness for a shift towards the use of renewable energy sources [9], and the growth of the work arrangements related to the different forms of work [10, 11] have affected how we see and discuss the working life. It is of utmost importance to understand that above revolutions will not

*Address for correspondence: Maria Lindholm, Tampere University, Tampere, Finland. E-mail: maria.lindholm@tuni.fi.

stop, but they will continue in the future [6, 12]. Regarding occupational health and safety (OHS), it is expected that the future brings both development and challenges [11, 13, 14].

While working life has evolved, so has the understanding of OHS [15, 16]. Monotonous work, accident-proneness, and working conditions were addressed in studies in the early to mid-1900s [17]. After the mid-1900s, the complexity of accidents was the focus of research and it was understood that human errors were not the causes of accidents [18]. In the late 1900s, theories and models emphasized organizational aspects in accident prevention [19]. Since 2000, according to Swuste et al. [20], there has been, however, relatively little progress in OHS and OHS management models. In a sense our OHS management thinking has not been fully able to transform itself along the general shift from the third industrial revolution to the fourth revolution [21]. To make use of the new technologies development has brought along, we should understand how they make it possible to exclude humans from dangerous places, ease human work and provide new possibilities to monitor workplace conditions and employees' health [22, 23]. Technological development is, however, accompanied by new and emerging risks (NERs). In the literature these have been associated for instance to the hazardous nature of maintenance work [22], increased psychosocial risks, stress, and mental fatigue [22, 23], risks in interactions between humans and robots [23], and occupational accidents [22, 23].

The aim of our study is to identify and analyze OHS NERs, as presented in the scientific literature before 2000 and from 2020 onwards. Especial interest is paid to those publications discussing NERs in the contexts of developed and newly industrialized countries [24, 25]. Within our temporal comparison approach, we aim to bring new insights to the discussion by Hoffmann et al. [17] and Swuste et al. [20] who have expressed their concerns of the general OHS development having slowed since 2000. Because NERs are time-dependent, in the analysis of current NERs, only the last two years are considered. The following research questions are addressed:

1. What similarities and differences in the OHS NERs are identified in the research literature published before 2000 and from 2020 onwards?
2. What kinds of OHS management suggestions related to the identified NERs have been proposed?

The term emerging risks refers to new and increasing risks. New risks were previously unknown and were caused by new processes, technologies, workplace types, and social and organizational changes. Known issues can be new risks due to new scientific knowledge and changes in social and public perceptions. Risks increase when the number of hazards leading to risk or the probability of exposure to increase and health effects worsen [26, 27].

2. Materials and methods

The phases of this qualitative literature review study are illustrated in Fig. 1. Searches of the cross-disciplinary international research literature database Scopus [28] were conducted on November 1, 2021 and March 29, 2022. Appendix A presents the search strategy and results for publications published before 2000 (search A), and from 2020 onwards (search B). The text fields sought included the titles, abstracts, and keywords of publications. This was a type of a non-interventional study for which an ethical review is not required as per the guidelines outlined by the Finnish National Board on Research Integrity.

After removing duplicates, 1,950 articles remained. The remaining articles were screened based on their titles, abstracts, and keywords. After screening, 173 articles (110 from search A, 63 from search B) were selected for close inspection, of which 85 were retrieved (30 from search A, 55 from search B). Through assessing and determining the eligibility of the full texts of the 85 articles, the following inclusion criteria were set:

1. Types of studies: Qualitative, quantitative, mixed methods studies, literature reviews, and overviews. Articles published in peer-reviewed journals before 2000 and from 2020 onwards. In search A, conference proceedings were accepted to balance the availability of the articles.
2. Types of participants: Any occupational group in developed and newly industrialized countries [24, 25] with no restrictions on field, technology, or employee position.
3. Types of intervention: Articles describing OHS NERs in the future.
4. Types of outcome measures: Identified OHS risks and challenges in the future.

A total of 51 articles did not meet the inclusion criteria; articles briefly mentioning the need for future

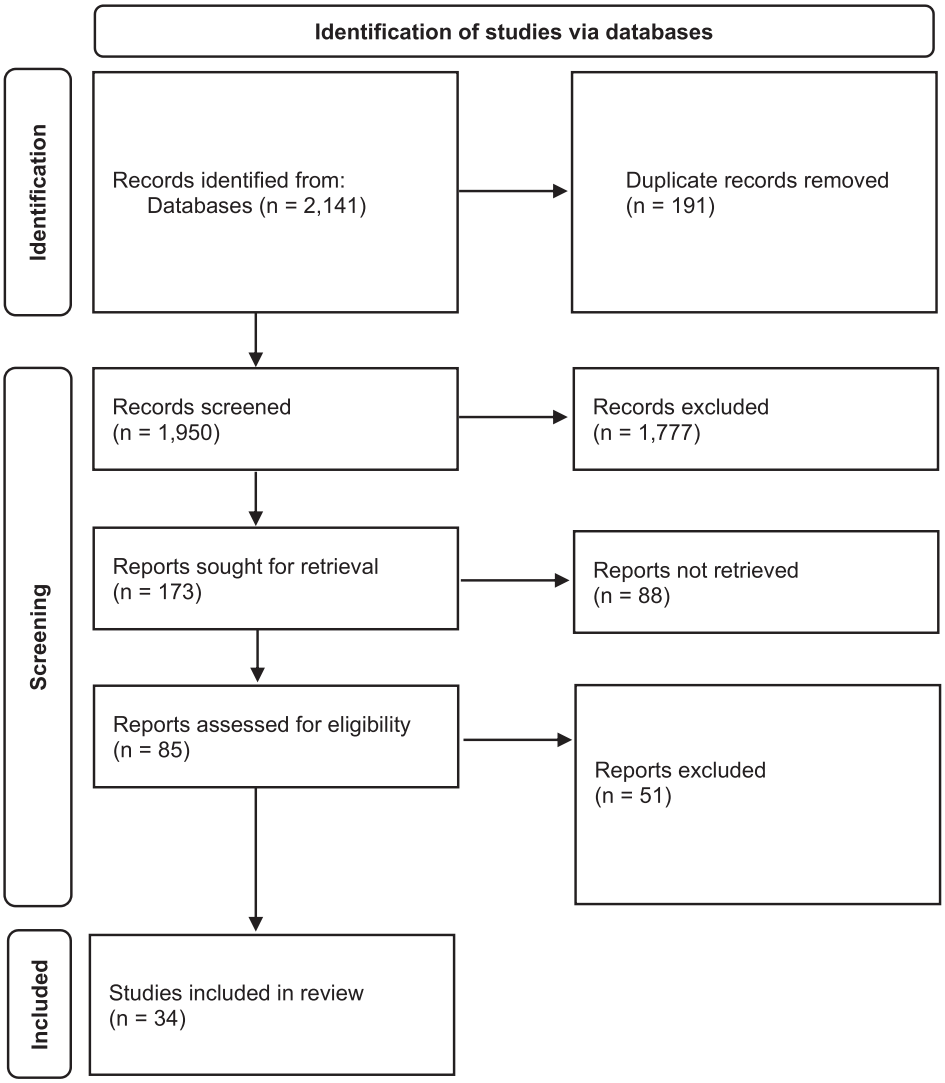

Fig. 1. Phases of the qualitative literature review (adapted from [32]).

studies or discussing new technologies but not focusing on OHS NERs were eliminated. A total of 31 journal articles and three conference proceedings met the inclusion criteria and were included in the analysis (see Appendix B). One author of this study extracted data from the included articles. The extracted data included the main findings, results, and conclusions, i.e., identified NERs. No additional information was requested from the authors of the included articles.

The articles were analyzed qualitatively within an inductive analysis approach [29]. In the first phase (open coding), each article was separately read through to identify possible NERs (see Appendix B). In the second phase, the NERs were then categorized into thematic groups. All in all, the following seven categories were formed: *changes in work patterns, changing workforce, growth in certain sectors, climate change, new materials or increased use of materials, new technology and technological development,* and *viruses*.

In the following part of the analysis, the identified NERs from searches A and B were qualitatively compared to examine whether there were certain similarities or differences between those discussed before 2000 or after 2020 [30]. A Word Cloud analysis [31] was applied to the abstracts using ATLAS.ti 22 for an overview comparison. The default settings were used and unnecessary words, such as "may," "can," and "need," were excluded manually from that analysis part. A word threshold of three was

obtained. Finally, the identified NERs from search A and B were compared theme by theme. The qualitative results are presented narratively in the Results -section.

3. Results

3.1. NERs before 2000 and from 2020 onwards

Figures 2 and 3 show the distribution of terms in searches A and B, respectively, based on their frequency of use in the abstracts. The most frequent words in search A were as follows: exposure ($n = 20$), coal ($n = 15$), plants ($n = 13$), waste ($n = 13$), and cancer ($n = 12$). In the articles published before 2000, the sectors receiving attention included coal production, waste recycling, and information services. Technology was often seen as affecting the physical and mental well-being of employees (e.g. [33, 34]) and causing new demands [35]. The three most frequently identified new and emerging OHS risks and challenges were related to *changes in work patterns*, *growth in certain sectors*, and *new technology and technical development*. Technology development was linked to exposure to toxic components (e.g. [34, 36]), need to develop ergonomics [37] and new demands for competence, work ability, and learning [35].

In search B, the most frequent words were as follows: heat ($n = 44$), covid ($n = 20$), pandemic ($n = 16$), exposure ($n = 15$), and stress ($n = 15$). Some words denoted factors that influenced and contributed to OHS, some were OHS effects, and some referred to the sector under study. In the articles published from 2020 onwards, for example, social and health care, outdoor work, and manufacturing received attention. Technological development and COVID-19 pandemic were the most frequently mentioned as affecting the physical and mental well-being of employees (e.g. [38, 39]) and causing new demands for employees [40, 41]. The three most frequently identified new and emerging OHS risks and challenges were related to *climate change*, *new technology and technical development*, and *viruses* (COVID-19), followed by *changes in work patterns* and *growth in certain sectors*. Development was linked to exposure to harmful substances [38, 42], human–machine interactions [41], robotization, and AI [43].

Table 1 shows the main NERs themes in the articles published before 2000 and from 2020 onwards. One article could have discussed multiple NERs and themes. The main differences between searches A and B were related to global topical themes, such as climate change, but also to topical point of discussion at that time, like human immunodeficiency virus (HIV) or the COVID-19 pandemic. *Changes in work patterns*, *changing workforce,* and *growth in certain sectors* were the main themes in 13 articles published before 2000 and in 8 articles published from 2020 onwards. *New materials or increased use of materials* and *new technology and technological development* were the main themes in nine articles published before 2000 and in 10 articles published from 2020 onwards. Similar possible OHS effects included, for example, musculoskeletal disorders [37, 41, 44, 45], exposure to toxic agents, chemical compounds, and hazardous materials [41, 46–49], increased stress [35, 37, 50], increased likelihood of errors or accidents [33, 43, 49, 50], and psychosocial problems [44, 51].

Table 1. Main NERs themes in articles before 2000 and from 2020 onwards, as well as the number of articles in which they were mentioned

Changes in work patterns in search A included shiftwork [33, 52] and changes in the nature of work in the information services [37], while in search B working from home [44] and integrating Industry 4.0 in production environment [41] were discussed. In both searches, generic mentions of changing work environment, demands, organizational forms or patterns of work were mentioned [34, 45, 48, 51]. Härmä and Ilmarinen [52] (search A) and Hauke et al. [45] (search B) examined the aging workforce, while Swanson et al. [46] (search A) discussed women who entered work life. Musculoskeletal disorders [37, 41, 44, 45] (searches A and B), exposure to toxic agents or unknown particles [41, 46, 48, 53] (searches A and B), psychosocial problems [44, 51] (searches A and B), mental fatigue [41] (search A) and possible increases in work-related illnesses and accidents [33] (search A) were found, among others, as possible safety and health effects related to changes in work patterns.

Growth in certain sectors included coal industry [33, 36] and office work [51, 54] which were mentioned in articles published before 2000, while growth in the healthcare sector [48] and wind farm sector [42] were mentioned in articles published from 2020 onwards. Increases in the service sector [48, 51] and waste recycling [49, 55] were found during both data collection periods in this current review study. The articles mentioned discussed NERs related to these developments; the growth of a certain sector is not a NER itself but rather bringing NERs alongside. Increases in these sectors were predicted to cause

Fig. 2. Distribution of terms found in search A based on their frequency of use in the articles' abstracts.

Fig. 3. Distribution of terms found in search B based on their frequency of use in the articles' abstracts.

Table 1
Main NERs themes in articles before 2000 and from 2020 onwards, as well as the number of articles in which they were mentioned

Main NERs themes	Before 2000	From 2020 onwards
Changes in work patterns, changing workforce, growth in certain sectors	13	8
Climate change	–	6
New materials or increased use of materials, new technology and technological development	9	10
Viruses	1	7

OHS challenges, such as those caused by new technology [33, 36, 42, 54] and potentially dangerous agents [42, 48, 49, 55] (searches A and B).

Increased use of chemical compounds [47, 48] and new materials [34, 38, 42, 56] were found in both data collection periods and, for example, unknown health risks [47], fully evaluated risks [34, 56], and re-emerging diseases [48] were discussed. Bridbord et al. [33] and Guidotti [36] discussed *new technology and technological developments* in the coal industry (search A). They focused on exposure to toxic components, dust, and ergonomics issues, among others. In addition to the coal industry, Brooks et al. [54] focused on electronic products in the information revolution, Rantanen [35] and Thibodeau et al. [37] focused on ICT (search A), Belobrajdic et al. [57] focused on space technology, Jarota [43] focused on robotization and AI, Naidu [38] focused on nan-

otechnology, and Svertoka [50] focused on wearable technology (search B). There were also general references to the digitalization [45, 49] (search B) and technological developments in new and old industries [34, 42] (searches A and B). Related to *new materials or increased use of materials* and *new technology and technological development*, there was a large number of possible OHS effects, including but not limited to increased stress [35, 37, 50] (searches A and B), increased likelihood of errors or accidents [43, 49, 50] (search B), exposure to hazardous materials [49] (search B), MSDs [37] (search A), and generic influences on physical and mental well-being [34, 45] (searches A and B).

Related to *viruses*, in search B, the COVID-19 pandemic was identified as bringing multiple new changes and challenges to OHS. It accelerated remote work [39, 44, 58], had combined the effects of heat [59], forced changes in roles and protocols [39, 40, 60], reduced workforces, and caused changes in work loads [40, 58, 60, 61]. Healthcare employees experienced issues in obtaining adequate PPEs [58, 60, 61], and they encountered insufficient communication and management [58]. Such changes and challenges caused anxiety [40, 58] and stress [39, 58], and they negatively affected overall physical and mental health [60, 61]. In search A, HIV was discussed in one article [62].

Climate change, mainly heat-related challenges, was studied by Bitencourt et al. [63], Ebi et al. [64], Kim and Lee [65] and Paterson and Godsmark [66] (search B). In addition, Bose-O'Reilly et al. [59] discussed the combined challenges of heat threat and COVID-19, and Madsen et al. [49] focused on waste sorting and collection and mentioned that global warming was one factor in the possible increase in exposure to biological agents by waste collection employees (search B). It was expected that heat and heat-related issues would increase and directly or indirectly cause concentration lapses, increases in accidents, loss of productivity, increases in the risk of hyperthermia and cardiovascular failure or collapse, vector-borne diseases, and increased vulnerability to heat-related diseases [59, 63, 64, 66].

3.2. *Suggested measures to control the identified NERs*

In both data collection periods, there were similar recommendations concerning the need to develop OHS management. Regarding legislation development, Bridbord et al. [33] pointed out that the enacted Federal Mine Safety and Health Act provided impetus for increased control over hazards in coal mining (search A). Naidu [38] suggested that regulatory bodies should implement a strict, explicit checklist in the fields of nanomedicine and nanotoxicology (search B). Jarota [43] identified the need to expand EU legislation to include robotics and AI in the work environment (search B). Regarding policies, formulating policy within the national plan [36] (search A), adopting a "health and climate change in all policies" approach and developing a heat-health plan [66] (search B), adaptation policy related to work capacity [65] (search B), and a review of public policies [63] (search B) were recommended.

Bridbord et al. [33] pointed out that necessary and technically feasible and available control measures need to be implemented in coal production (search A). Adem et al. [41] suggested that eye fatigue should be reduced by increased employee breaks, and job rotation approaches should be applied to prevent disorders caused by static working positions (search B). Thibodeau and Melamut [37] emphasized that ergonomics should be considered in designing workstations and work areas, while training would further decrease ergonomic problems (search A). Rantanen [35] recommended some key measures to control psychological stress: better organization of work, prevention of unreasonable time pressure, provision of technical help in technology breakdown or other disturbances, improving the competence of employees, and improving the ergonomics of the work site (search A). Procedures were also recommended for communicating with AI [43] (search B). The effects of COVID-19 revealed that workplaces need to have better preparedness [58], such as risk response plans and workplace-specific plans [60] (search B).

Selikoff [56] recognized that identifying and evaluating the carcinogenicity of new and recently introduced materials is difficult because of their long-term effects, such as asbestos-induced cancers, which indicates a need to develop identification and evaluation techniques (search A). Similarly, Naidu [38] pointed out that identifying the exposure sources and pathways of ENPs in work settings, studying their mechanisms, and measuring their concentrations are crucial in order to minimize their damaging effects (search B). Poulsen et al. [55] suggested conducting analytical epidemiological studies and surveillance programs to clarify the links between exposure and OHS problems and to establish exposure limits (search A).

Guidotti [36] called for a major research effort to assess the potential OHS risks of coal processing technologies (search A). Härmä and Ilmarinen [52] recognized new research areas, such as age-specific shift scheduling and worktime models, information ergonomics, visual fatigue, and psychophysiological factors related to new information-intense tasks (search A). Karanikas et al. [42] found a need for further research on all life cycle stages of wind energy production (search B). Hauke et al. [45] noted that research is required to increase physical activity in sedentary workplaces and data security (search B). Adem et al. [41] suggested that psychological pressure in the workplace needs further investigation (search B).

Other measures included training and the development of health professionals to deliver optimal occupational health care [51] (search A). Similarly, Guidotti [36] saw the need for more trained professionals to guide development and provide epidemiologic and environmental analyses and for medical and health professionals to be involved in planning processes (search A). Training was also needed in coal production [33] (search A) and AI [43] (search B). Wegman and Fine [34] pointed out that OHS experts, managers, engineers, and government officials all need training to identify and implement solutions to emerging problems (search A).

4. Discussion

The results of this study show that the articles discussed similar themes in both time periods. Multiple sectors, such as coal industry [33, 36], office work [51, 54], service sector [48, 51] and waste recycling [49, 55] were discussed. Possible OHS effects included, but were not limited to, musculoskeletal disorders [37, 41, 44, 45], exposure to toxic agents, chemical compounds, and hazardous materials [41, 46–49], increased stress [35, 37, 50], increased likelihood of errors or accidents [43, 49, 50] and psychosocial problems [44, 51].

The results indicate that changes in work have been a topic of discussion for a long time, and that differences are due to specific time-related cases, like climate change and COVID-19 now and like for instance HIV in the past. This makes one wonder whether and how research on NERs evolves, or does it eventually rotate in a cycle over time? Although the overlapping themes found in this study were to a certain extent similar, workplaces have still become more complex, which has led to challenges in managing OHS. As we are expecting the technological development to continue along with other relevant megatrends, like climate change, it is of utmost importance to consider how OHS can keep pace with the development. Taking a historical development perspective on the development of humans and human work, de Winter and Hancock [67] argued that the complexity of new technologies has exceeded human evolution during the last centuries. Accordingly, the cognitive demands for humans have diversified, as the need for supervisory control has introduced a new set of demands that humans are not biologically naturally able to perform. We propose as a topic for future research to consider this development from the OHS NERs perspective.

In the future, we are expecting to see how a fifth industrial revolution complements the fourth industrial revolution with a more sustainable, resilient, and human-centric approach as outlined in the research literature [6, 12] and by influencers like the European Union [68]. From the employees' viewpoint this development should be considered positive in principle; technology is expected to be adapted to the needs of employees instead of the need for them to continuously adapt to new technology [68]. That might, however, introduce new NERs to be considered from the OHS management perspective. To promote human-centricity in this context, we suggest paying more attention to the design-oriented principles of human factors and ergonomics (HF/E) and consider how to apply those in use in practice. As outlined in its' globally agreed definition, HF/E aims to understand the interactions among humans and other elements of a system, and to optimize human well-being and overall system performance [69–72]. We argue for the flexibility of HF/E in this regard. HF/E is holistically interested in all kinds of hazards for human health and safety, and it allows considering the system performance from an individual centric micro-level to complex macro-level entities. It has been even proposed how HF/E could—in principle—help to understand and meet the most complex human-nature challenges of a time, like climate change [73, 74]. Concerning the desired and expected human-centric future world of work, we see a great potential for HF/E as a design-oriented discipline to enable identifying new NERs and on designing sustainable solutions to mitigate or remove them [75]. In this regard, we recommend focusing on the theory on balanced work systems that is in core of HF/E. Accordingly, balanced work system think-

ing can be used for identifying and understanding human-related success factors, challenges, discomfort, and load factors as conditions that affect both performance and risk for accidents (e.g., [70, 76, 77]).

The work system model, that considers human interactions with their work tasks, tools and technologies and work environments, allows a systematic categorization of OHS risks and challenges based on their origins. As an example, related to NERs, we have seen how COVID-19 increased home office work (change in work environment), which in turn accelerated digitalization (how work is done), that in turn introduced new negative effects on the individual, such as stress and reduction in job satisfaction. Likewise, we are expecting to see how the climate change initiates new hazards for OHS for instance through extreme weather conditions, increased UV ration and pollution levels and by introducing new infectious diseases [78, 79]. The integration of AI applications and tools in workplaces (changes in work tools and tasks) exacerbates psychosocial OHS risks, as it may lead to increased monitoring and tracking (organizational changes). However, it should be noted that it is not only the technology that creates risks but also deficiencies in the implementation phase. Further studies are needed to see how the work system theory suits, for example, categorizing the NERs and developing suitable OHS management methods.

This study supports the view that changes in work are constant and that there are some issues irrespective of time that should be considered from the OHS management perspective. When considering OHS management and practices, how much importance should be placed on new matters, such as computers [37] or robots [41], itself? Instead, how much focus should be placed on, for example, methods of HF/E, resilience and change management [80, 81] to answer the challenges and to successfully manage OHS when facing changes? HF/E places the focus on human [69] and resilient organizations have the "ability to absorb and adapt in a changing environment" [82] which are required features in the fifth industrial revolution [68]. In addition to the authors' previous suggestions [14], how to best utilize HF/E frameworks, organizational resilience, and change management in OHS when facing NERs should be studied.

Although this qualitative literature review adhered the principles of a systematic review with a predefined search strategy and inclusion criteria [83], some sources for potential biases may be identified. The article selection process introduced a potential bias. The search resulted in 1,950 articles, but only a small portion (2%) was included in the final analysis. This does not mean that OHS was not studied in the excluded articles, but that their focus was on the present, and there was little research on future scenarios. Not all interested articles from search A could have been analyzed because they were not available anymore, possibly because of the publication year. Wider searches, including terms such as "hazard," could have resulted in greater number of relevant articles. Because the cross-disciplinary database Scopus was the only database, some articles may have fallen outside the analysis. Furthermore, the researcher's interpretations may have affected the article selection and analysis.

The risk of bias increased because many of the journal articles included were literature reviews or overviews with little information about their methodological choices and study processes. Moreover, only 10 of 34 articles were based on empirical data, as shown in Appendix B. Braun and Tsiatis [53] had 47 respondents and 42 participants, Swanson and Burns [46] had 5,714 cases and 1,972 control cases, Adem et al. [41] used the Hesitant Fuzzy Analytic Hierarchy Process with two experts, Bitencourt et al. [63] used projections, Crotty et al. [40] had 38 participants, Ekpanyaskul and Padungtod [44] had 869 respondents, Hauke et al. [45] had 398 participants, Kim and Lee [65] used projections, Magruder et al. [60] had 531 participants, and Willis et al. [58] had 6,679 responses. The limited amount of empirical material may have decreased the reliability of the results of this review study. Moreover, because this review study was conducted in English, relevant articles, such as those published in German, French, Spanish, Japanese, and the Nordic language, were not searched or included.

5. Conclusions

This review study found that articles published before 2000 and from 2020 onwards shared many similarities concerning the new and emerging OHS risks and challenges. However, it seems that in the current literature, OHS was to a certain extent been considered more as a part of wider entities, such as climate change and COVID-19, while in the literature published before 2000 it was considered slightly more limited. Changes in work patterns, changing workforces and growth in certain sectors, new materials or increased use of materials, and new technology and technological development were the main themes

in multiple articles. In the articles published before 2000, technology was seen as affecting the physical and mental well-being of employees and causing new demands. Technology development was linked to exposure to toxic components, ergonomics, and new demands for competence, work ability, and learning. In the articles published from 2020 onwards, technology, and COVID-19 were mentioned the most frequently as having affected the physical and mental well-being of employees and causing new demands. Development was tied not only to exposure to harmful substances but also to human–machine interactions, robotization, and AI. In both periods, possible OHS effects included musculoskeletal disorders, exposure to toxic agents, chemical compounds, hazardous materials, increased stress, increased likelihood of errors or accidents, psychosocial problems, mental fatigue, and increases in work-related illnesses and accidents. In order to prevent the negative OHS effects, it is necessary to recognize the NERs and manage them. The OHS management suggestions included, for example, policy and legislation changes, control measures, ergonomic improvements, training and more research. Because the future of work and OHS risks are global concerns, this review study may provide an incentive for future research on new and emerging OHS risks.

The authors have no acknowledgments.

The authors declare that they have no conflict of interest.

The authors report no funding.

Ethical approval and informed consent – not applicable.

References

[1] Badri A, Boudreau-Trudel B, Souissi AS. Occupational health and safety in the industry 4.0 era: A cause for major concern? Safety Science. 2018;109:403-11.

[2] Chia G, Lim SM, Sng GKJ, Hwang YFJ, Chia KS. Need for a new workplace safety and health (WSH) strategy for the fourth Industrial Revolution. American Journal of Industrial Medicine. 2019;62(4):275-81.

[3] von Tunzelmann N. Historical coevolution of governance and technology in the industrial revolutions. Structural Change and Economic Dynamics. 2003;14(4):365-84.

[4] Coluccia D. The Second Industrial Revolution (late 1800s and early 1900s). In: Zanda G, editor. Corporate Management in a Knowledge-Based Economy. London: Palgrave Macmillan UK; 2012. pp. 52-64.

[5] Coluccia D. The First Industrial Revolution (c1760–c1870). In: Zanda G, editor. Corporate Management in a Knowledge-Based Economy. London: Palgrave Macmillan UK; 2012. pp. 41-51.

[6] Duggal AS, Malik PK, Gehlot A, Singh R, Gaba GS, Masud M, Al-Amri JF. A sequential roadmap to Industry 6.0: Exploring future manufacturing trends. IET Communications. 2022;16(5):521-31.

[7] Culot G, Nassimbeni G, Orzes G, Sartor M. Behind the definition of Industry 4.0: Analysis and open questions. International Journal of Production Economics. 2020;226:107617.

[8] Gagliardi D, Marinaccio A, Valenti A, Iavicoli S. Occupational Safety and Health in Europe: Lessons from the Past, Challenges and Opportunities for the Future. Industrial Health. 2012;50(1):7-11.

[9] Siemieniuch CE, Sinclair MA, Henshaw MJC. Global drivers, sustainable manufacturing and systems ergonomics. Applied Ergonomics. 2015;51:104-19.

[10] Eichengreen B, Gupta P. The two waves of service-sector growth. Oxford Economic Papers. 2013;65(1):96-123.

[11] Tamers SL, Streit J, Pana-Cryan R, Ray T, Syron L, Flynn MA, Castillo D, Roth G, Geraci C, Guerin R, Schulte P, Henn S, Chang CC, Felknor S, Howard J. Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. American Journal of Industrial Medicine. 2020;63(12): 1065-84.

[12] Xu X, Lu Y, Vogel-Heuser B, Wang L. Industry 4.0 and Industry 5.0—Inception, conception and perception. Journal of Manufacturing Systems. 2021;61:530-5.

[13] Schulte PA, Streit JMK, Sheriff F, Delclos G, Felknor SA, Tamers SL, Fendinger S, Grosch J, Sala R. Potential scenarios and hazards in the work of the future: A systematic review of the peer-reviewed and gray literatures. Annals of Work Exposures and Health. 2020;64(8):786-816.

[14] Lindholm M, Reiman A, Väyrynen S. On Future Occupational Safety and Health Challenges. International Journal of Occupational and Environmental Safety. 2020;4(1):108-27.

[15] Henshaw JL, Gaffney SH, Madl AK, Paustenbach DJ. The employer's responsibility to maintain a safe and healthful work environment: An historical review of societal expectations and industrial practices. Employee Responsibilities and Rights Journal. 2007;19(3):173-92.

[16] Swuste P, Groeneweg J, Guldenmund FW, van Gulijk C, Lemkowitz S, Oostendorp Y, Zwaard W. From Safety to Safety Science: The Evolution of Thinking and Practice. 1st ed. Routledge; 2021.

[17] Hofmann DA, Burke MJ, Zohar D. 100 years of occupational safety research: From basic protections and work analysis to a multilevel view of workplace safety and risk. Journal of Applied Psychology. 2017;102(3):375-88.

[18] Swuste P, Groeneweg J, van Gulijk C, Zwaard W, Lemkowitz S. Safety management systems from Three Mile Island to Piper Alpha, a review in English and Dutch literature for the period 1979 to 1988. Safety Science. 2018;107:224-44.

[19] Swuste P, van Gulijk C, Groeneweg J, Zwaard W, Lemkowitz S, Guldenmund F. From clapham junction to macondo, deepwater horizon: Risk and safety management in high-tech-high-hazard sectors: A review of English and Dutch literature: 1988–2010. Safety Science. 2020;121:249-82.

[20] Swuste P, van Gulijk C, Groeneweg J, Guldenmund F, Zwaard W, Lemkowitz S. Occupational safety and safety management between 1988 and 2010: Review of safety literature in English and Dutch language scientific literature. Safety Science. 2020;121:303-18.

[21] Liu Z, Xie K, Li L, Chen Y. A paradigm of safety management in Industry 4.0. Systems Research and Behavioral Science. 2020;37(4):632-45.
[22] Min J, Kim Y, Lee S, Jang TW, Kim I, Song J. The Fourth Industrial Revolution and Its Impact on Occupational Health and Safety, Worker's Compensation and Labor Conditions. Safety and Health at Work. 2019;10(4):400-8.
[23] Zorzenon R, Lizarelli FL, Daniel DBA. What is the potential impact of industry 4.0 on health and safety at work? Safety Science. 2022;153:105802.
[24] WorldData.info. List of current emerging markets [Internet]. Available from: https://www.worlddata.info/newly-industrialized-countries.php
[25] United Nations Department for Economic and Social Affairs. World Economic Situation and Prospects 2023. S.l.: United Nations; 2023.
[26] Milczarek M, Schneider E, González ER. OSH in figures: stress at work — facts and figure. Luxembourg: Office for Official Publications of the European Communities: European Agency for Safety and Health at Work; 2009.
[27] Moraru RI, Băbuț GB, Popescu Stelea M. Approaching occupational safety and health emerging risks categories and prevention. Quality - Access to Success. 2014;15(139):104-8.
[28] Elsevier. Scopus [Internet]. 2019 [cited 2019 May 22]. Available from: https://www.elsevier.com/solutions/scopus
[29] Flick U. An introduction to qualitative research. London: SAGE Publications; 2009. pp. 504.
[30] Guest G, MacQueen K, Namey E. Comparing Thematic Data. In: Guest G, MacQueen KM, Namey EE, editors. Applied Thematic Analysis. Thousand Oaks, CA: SAGE Publications, Inc.; 2014. pp. 161-86.
[31] DePaolo CA, Wilkinson K. Get Your Head into the Clouds: Using Word Clouds for Analyzing Qualitative Assessment Data. TechTrends. 2014;58(3):38-44.
[32] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P, Moher D. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.
[33] Bridbord K, Costello J, Gamble J, Groce D, Hutchison M, Jones W, Merchant J, Ortmeyer C, Reger R, Wagner WL. Occupational safety and health implications of increased coal utilization. Environmental Health Perspectives. 1979;33:285-302.
[34] Wegman DH, Fine LJ. Occupational health in the 1990s. Annual Review of Public Health. 1990;11:89-103.
[35] Rantanen J. Challenges for occupational health from work in the information society. American Journal of Industrial Medicine Supplement. 1999;1:1-6.
[36] Guidotti TL. Health implications of increased coal use in the western states (Environmental Health). West J Med. 1979;131:70-6.
[37] Thibodeau PL, Melamut SJ. Ergonomics in the electronic library. Bull Med Libr Assoc. 1995;83(3).
[38] Naidu KSB. Engineered nanoparticles: Hazards and Risk Assessment upon Exposure-A Review. Current Trends in Biotechnology and Pharmacy. 2020;14(1):111-22.
[39] Rosen MP, Norbash A, Kruskal J, Meltzer CC, Yee J, Thrall J. Impact of Coronavirus Disease 2019 (COVID-19) on the Practice of Clinical Radiology. Journal of the American College of Radiology. 2020;17(9):1096-100.
[40] Crotty TJ, Corbett M, Gary S, Davey MG, Hughes JP, Keogh IJ, Patil NP, Doherty E. The psychological impact of COVID-19 on ear, nose and throat (ENT) specialists. Irish Journal of Medical Science (1971 -). 2022;191(1):51-7.
[41] Adem A, Çakit E, Dağdeviren M. Occupational health and safety risk assessment in the domain of Industry 4.0. SN Applied Sciences. 2020;2(5):977.
[42] Karanikas N, Steele S, Bruschi K, Robertson C, Kass J, Popovich A, MacFadyen C. Occupational health hazards and risks in the wind industry. Energy Reports. 2021;7:3750-9.
[43] Jarota M. Artificial intelligence and robotisation in the EU - should we change OHS law? Journal of Occupational Medicine and Toxicology. 2021;16(1):18.
[44] Ekpanyaskul C, Padungtod C. Occupational Health Problems and Lifestyle Changes Among Novice Working-From-Home Workers Amid the COVID-19 Pandemic. Safety and Health at Work. 2021;12(3):384-9.
[45] Hauke A, Flaspöler E, Reinert D. Proactive prevention in occupational safety and health: how to identify tomorrow's prevention priorities and preventive measures. International Journal of Occupational Safety and Ergonomics. 2020;26(1):181-93.
[46] Swanson GM, Burns PB. Cancer Incidence Among Women in the Workplace: A Study of the Association Between Occupation and Industry and 11 Cancer Sites. Journal of Occupational and Environmental Medicine. 1995;37(3):282-7.
[47] Frederick KA, Babish JG. Evaluation of mutagenicity and other adverse effects of occupational exposure to sodium azide. Regulatory Toxicology and Pharmacology. 1982;2(4):308-22.
[48] Fazen LE, Linde B, Redlich CA. Occupational lung diseases in the 21st century. Current Opinion in Pulmonary Medicine. 2020;26(2):142-8.
[49] Madsen AM, Raulf M, Duquenne P, Graff P, Cyprowski M, Beswick A, Laitinen S, Rasmussen PU, Hinker M, Kolk A, Górny RL, Oppliger A, Crook B. Review of biological risks associated with the collection of municipal wastes. Science of The Total Environment. 2021;791:148287.
[50] Svertoka E, Saafi S, Rusu-Casandra A, Burget R, Marghescu I, Hosek J, Ometov A. Wearables for Industrial Work Safety: A Survey. Sensors. 2021;21(11):3844.
[51] Koh D, Jeyaratnam J. Occupational health in Singapore. Int Arch Occup Environ Health. 1998;71:295-301.
[52] Härmä MI, Ilmarinen JE. Towards the 24-hour society - New approaches for aging shift workers? Scandinavian Journal of Work, Environment and Health. 1999;25(6):610-5.
[53] Braun SR, Tsiatis A. Pulmonary abnormalities in art glassblowers. Journal of Occupational Medicine. 1979;21(7):487-9.
[54] Brooks BO, Utter GM, DeBroy JA, Davis WF, Schimke RD. Chemical emissions from electronic products. IEEE International Symposium on Electronics and the Environment. 1993;120-5.
[55] Poulsen OM, Breuma N, Ebbehøj N, Hansen ÅM, Ivens UI, Van Lelieveld D, Malmros P, Matthiasen L, Nielsen BH, Nielsen EM, Schibye B, Skov T, Stenbaek EI, Wilkins KC. Sorting and recycling of domestic waste. Review of occupational health problems and their possible causes. The Science of the Total Environment. 1995;168:33-56.
[56] Selikoff IJ. Recent Perspectives in Occupational Cancer. Ambio. 1975;4(1):14-7.
[57] Belobrajdic B, Melone K, Diaz-Artiles A. Planetary extravehicular activity (EVA) risk mitigation strate-

gies for long-duration space missions. npj Microgravity. 2021;7(1):16.
[58] Willis K, Ezer P, Lewis S, Bismark M, Smallwood N. "Covid Just Amplified the Cracks of the System": Working as a Frontline Health Worker during the COVID-19 Pandemic. International Journal of Environmental Research and Public Health. 2021;18(19):10178.
[59] Bose-O'Reilly S, Daanen H, Deering K, Gerrett N, Huynen MMTE, Lee J, Karrasch S, Matthies-Wiesler F, Mertes H, Schoierer J, Shumake-Guillemot J, van den Hazel P, Frank van Loenhout JA, Nowak D. COVID-19 and heat waves: New challenges for healthcare systems. Environmental Research. 2021;198:111153.
[60] Magruder L, Wilke D, Radey M, Cain M, Yelick A. COVID-19's Social Ecological Impacts on Health and Human Services Worker Well-being. Social Work in Public Health. 2022;37(3):233-43.
[61] Schmitt N, Mattern E, Cignacco E, Seliger G, König-Bachmann M, Striebich S, Ayerle GM. Effects of the Covid-19 pandemic on maternity staff in 2020 – a scoping review. BMC Health Services Research. 2021;21(1):1364.
[62] Turner JG, Fawal HJ, Long MN, Rivers MP. Preventing HIV Transmission in Health Care Settings. AAOHN JOURNAL. 1998;36(7).
[63] Bitencourt DP, Alves L, Shibuya EK, da Cunha I, de Souza JP. Climate change impacts on heat stress in Brazil—Past, present, and future implications for occupational heat exposure. International Journal of Climatology [Internet]. 2021 Feb 1;41(S1). Available from: https://onlinelibrary.wiley.com/doi/10.1002/joc.6877
[64] Ebi KL, Capon A, Berry P, Broderick C, de Dear R, Havenith G, Honda Y, Kovats RS, Ma W, Malik A, Morris NB, Nybo L, Seneviratne SI, Vanos J, Jay O. Hot weather and heat extremes: health risks. The Lancet. 2021;398(10301):698-708.
[65] Kim D, Lee J. Spatial Changes in Work Capacity for Occupations Vulnerable to Heat Stress: Potential Regional Impacts From Global Climate Change. Safety and Health at Work. 2020;11(1):1-9.
[66] Paterson SK, Godsmark CN. Heat-health vulnerability in temperate climates: lessons and response options from Ireland. Globalization and Health. 2020;16(1):29.
[67] de Winter JCF, Hancock PA. Why human factors science is demonstrably necessary: historical and evolutionary foundations. Ergonomics. 2021;64(9):1115-31.
[68] European Commission, Directorate-General for Research and Innovation, Breque M, De Nul L, Petridis A. Industry 5.0: towards a sustainable, human-centric and resilient European industry. Publications Office; 2021.
[69] IEA. Human Factors/Ergonomics (HF/E) [Internet]. International Ergonomics Association. 2020 [cited 2020 Sep 16]. Available from: https://iea.cc/what-is-ergonomics/
[70] Dul J, Bruder R, Buckle P, Carayon P, Falzon P, Marras W, Wilson J, van der Doelen B. A strategy for human factors/ergonomics: Developing the discipline and profession. Ergonomics. 2012;55(4):377-95.
[71] IEA, ILO. Principles and Guidelines for Human Factors/Ergonomics (HF/E) Design and Management of Work Systems [Internet]. Draft Document Jointly Prepared by International Ergonomics Association and International Labour Organization; 2020. pp. 60. Available from: https://www.ilo.org/wcmsp5/groups/public/—ed_dialogue/—lab_admin/documents/publication/wcms_826596.pdf
[72] Read GJM, Salmon PM, Goode N, Lenn MG. A sociotechnical design toolkit for bridging the gap between systems-based analyses and system design. Human Factors and Ergonomics in Manufacturing & Service Industries. 2018;28(6):327-41.
[73] Richardson M, Thatcher A. State of science: refitting the human to nature. Ergonomics. 2023;1-15.
[74] Thatcher A, Nayak R, Waterson P. Human factors and ergonomics systems-based tools for understanding and addressing global problems of the twenty-first century. Ergonomics. 2020;63(3):367-87.
[75] Reiman A, Kaivo-oja J, Parviainen E, Takala EP, Lauraeus T. Human factors and ergonomics in manufacturing in the industry 4.0 context – A scoping review. Technology in Society. 2021;65:101572.
[76] Kleiner BM. Macroergonomics: Analysis and design of work systems. Applied Ergonomics. 2006;37(1 SPEC. ISS.):81-9.
[77] Smith M, Carayon-Sainfort P. A balance theory of job design for stress reduction. International Journal of Industrial Ergonomics. 1989;4(1):67-9.
[78] Rocque RJ, Beaudoin C, Ndjaboue R, Cameron L, Poirier-Bergeron L, Poulin-Rheault RA, Fallon C, Tricco AC, Witteman HO. Health effects of climate change: an overview of systematic reviews. BMJ Open. 2021;11(6):e046333.
[79] Schulte PA, Jacklitsch BL, Bhattacharya A, Chun H, Edwards N, Elliott KC, Flynn MA, Guerin R, Hodson L, Lincoln JM, MacMahon KL, Pendergrass S, Siven J, Vietas J. Updated assessment of occupational safety and health hazards of climate change. Journal of Occupational and Environmental Hygiene. 2023;20(5–6):183-206.
[80] Errida A, Lotfi B. The determinants of organizational change management success: Literature review and case study. International Journal of Engineering Business Management. 2021;13:184797902110162.
[81] Maali O, Lines B, Smithwick J, Hurtado K, Sullivan K. Change management practices for adopting new technologies in the design and construction industry. Journal of Information Technology in Construction. 2020;25(April):325-41.
[82] ISO 22300:2021. Security and resilience. Vocabulary (ISO 22300:2021). EUROPEAN COMMITTEE FOR STANDARDIZATION, CEN-CENELEC Management Centre, Brussels;
[83] Grant MJ, Booth A. A typology of reviews: An analysis of 14 review types and associated methodologies. Health Information and Libraries Journal. 2009;26(2):91-108.

Appendix A
Searches and search results

#	Searches	Search results (A)*	Search results (B)*	Total
1	(“new risks” OR ”emerging risks”) AND (“occupational safety” OR ”work* safety” OR future) AND challenges	2	27	29
2	(“occupational safety” OR “work* safety”) OR (safety AND work) AND (“future challenges” OR “future studies”)	17	156	173
3	(“changing work* environment” OR “new technology”) AND (“work* risk*” OR “occupational risk*”)	13	19	32
4	Future AND (“work* life” OR “occupational safety and health” OR OSH OR “work* environment”) AND risk*	161	287	448
5	(“occupational health” OR ”occupational disease*”) AND risk* AND (trend* OR future)	795	378	1173
6	“risk management” AND (“work* risk*” OR ”occupational safety risk*”)	12	27	39
7	(“new risk*” OR “emerging risk*” OR “new challenge*” OR “emerging challenge*” OR “new problem*” OR “emerging problem*”) AND (work OR occupational) AND safety)	69	178	247
	Total	1069	1072	2141

*Search results (A) are for publications published before 2000, and search results (B) are for publications published from 2020 onwards.

Appendix B
Analyzed articles and their identified NERs themes and research methods

Authors	Research methods	Summary of the NERs	Thematic group
Search results A			
Braun S.R., Tsiatis A. [53]	Questionnaire, 47 respondents. Pulmonary functions, 42 participants. Multiple and logistic regression analyses were performed.	The yet unknown detrimental effects of art glassblowing on pulmonary status and cough prediction suggested a parenchymal change rather than airway impairment.	Changes in work patterns
Bridbord K., Costello J., Gamble J. [33]	Overview**	The increase in production was expected to result in an increased number of employees who performed shift work, which could increase work-related illnesses and accidents. Increased production pressures may result in factors causing fatigue and increases in overall employee stress levels, which may lead to accidents. Increased use of diesel engine-powered equipment caused concern because of exposure to the toxic components of diesel emissions, in addition to substances already present in mining. In addition to toxic components, ergonomic considerations such as increased noise were found to be important factors. In the use of longwalls, potential hazards included exposure to dust-laden air, inefficient ventilation, and noise levels	Changes in work patterns; Growth in certain sectors; New technology and technological development

(*Continued*)

Appendix B
(*Continued*)

Authors	Research methods	Summary of the NERs	Thematic group
Brooks B.O. et al. [54]	Overview**	During the information revolution, offices and raised-floor data processing were the fastest-growing work environments, in which air quality was potentially affected by contaminants from electronic products. Authors' case example indicated that the combination of poor ventilation and volatile organic chemical emissions from new electronic devices can cause transient mucous membrane irritation. The second case demonstrated that a belief in odor-related chemical incidents could cause psychophysiological responses.	Growth in certain sectors; New technology and technological development
Frederick K.A., Babish J.G. [47]	Overview**	Even though not all occupational health risks were known, the use of sodium azide had increased, resulting in prevalent occupational exposure in laboratory and industrial settings.	New materials or increased use of materials
Guidotti T.L. [36]	Overview**	Increased production in the coal industry exposes larger numbers of workers to hazards. The risks of some new coal processing technologies, such as coal liquification, were not yet known. In particular, toxic hazards could not be sufficiently predicted. The processes and products included complex mixtures of substances and varying degrees of physical containment, causing different risks of exposure	Growth in certain sectors; New technology and technological development
Härmä M.I., Ilmarinen J.E. [52]	Overview**	Anticipated developments in working time and demographic changes caused a need for new approaches for aging shift workers. The reviewed research on the relationship of shift work with fatigue, sleep disorders, anxiety, performance, accidents, peptic ulcers, and coronary heart disease indicated that shift work could become a major OHS problem.	Changes in work patterns; Changing workforce
Koh D., Jeyaratnam J. [51]	Overview**	Regarding occupational diseases, the authors suggested that new cases involving work-related illnesses, such as musculoskeletal disorders and psychosomatic illnesses, would appear because of the changing patterns of work in a largely service- and office-based workforce. The findings indicated that psychosocial hazards were more prevalent than physical or chemical ones.	Changes in work patterns; Growth in certain sectors
Poulsen O.M. et al. [55]	Overview**	Planned increased recycling led to the need to build new waste recycling facilities and increase the number of employees. Knowledge of the magnitude of the risks and the causal factors was limited concerning different types of waste recycling plants and work tasks. Employees could be exposed to a mixture of bioaerosols and airborne volatile compounds. The importance of synergistic interactions between agents was considered.	Growth in certain sectors
Rantanen J. * [35]	Overview**	Continuous changes in technology and software and information-intensive work raised new demands for competence and work ability, as well as continuous adaptation and learning for employees and organizations which constituted a major stress factor. Video display terminal work was associated with eye discomfort and musculoskeletal disorders. Job stress and its relationship to increased risk of muscular overload and cardiovascular disorders were mentioned as needing prevention. Authors raised the paradoxical impact of ICT, in which work can be done faster but causes more time pressure at work and leads to less leisure time.	New technology and technological development

(*Continued*)

Appendix B
(*Continued*)

Authors	Research methods	Summary of the NERs	Thematic group
Selikoff I.J. [56]	Overview**	There was a lack of knowledge about the carcinogenic potential of new and recently introduced agents and their health effects, for example, related to materials in the petrochemical industry.	New materials or increased use of materials
Swanson G.M., Burns P.B. [46]	A total of 5714 cancer cases and 1972 population controls among women were included in the analysis. Maximum likelihood estimates of the odds ratio (OR) were performed with unconditional logistic regression.	More women were entering working life. The relationship between occupational exposure and cancer development in women needed assessment. Elevated odds ratio were indicated for women employed in the computer manufacturing industry, hairdressing shops, the beverage manufacturing industry, food stores, bus and truck services, and military service.	Changing workforce
Thibodeau P.L., Melamut S.J. * [37]	Overview**	Changes in work had led to new problems, such as stress, fatigue, and cumulative trauma disorders. Common environmental aspects of workplaces were room lighting, chairs, and workstations with computer monitors. Poor design could lead to eyestrain, headaches, and neck and back problems. Because of the prolonged use of a keyboard, mouse, or trackball, muscles could become fatigued. Ergonomic injuries had been reported increasingly in libraries.	Changes in work patterns; New technology and technological development
Turner J.G. et al. [62]	Overview**	As the number of people being treated for HIV-associated illnesses increased, the number of healthcare workers exposed to HIV increased. Even though the risk of occupational HIV infection was seen as minimal because of safety precautions, healthcare workers were documented to have sustained HIV infections.	Virus
Wegman D.H., Fine L.J. [34]	Overview**	Changes in work environments, organizational forms, and technological advances had possible effects on the physical and mental well-being of employees. For example, cumulative trauma disorders were increasing and needed attention. Electronic monitoring as one aspect of work pacing had implications for employee health. Some materials and processes had not been fully evaluated for their impact on health, but they were associated with potential hazards or were suspected to be carcinogenic in humans. New materials and technological development were found to be problematic in old and established industries that attempted to alter existing technology and materials.	Changes in work patterns; New materials or increased use of materials; New technology and technological development
Search results B			
Adem A., Çakit E., Dağdeviren M. [41]	Hesitant Fuzzy Analytic Hierarchy Process, two experts.	Mental fatigue was found to stem from encounters between humans and machines, while psychological pressure was indicated to be related to the adaptation of duties that require creativity. Eye-related disorders, disorders due to static working positions, and exposure to unknown particles while working with robots were identified as possible OHS risks.	Changes in work patterns

(*Continued*)

Appendix B
(*Continued*)

Authors	Research methods	Summary of the NERs	Thematic group
Belobrajdic B, Melone K, Diaz-Artiles A. [57]	Overview**	Future explorations of planetary extravehicular activity (EVA) missions are more challenging than current international space station requirements. Several risks were discussed, including hypercapnia from accumulated waste gases, temperature, and humidity in space suits, nutrition, and hydration during longer EVAs, waste management, maintaining physical health, decompression sickness, radiation exposure, and lunar dust. Astronaut fatigue and psychological stressors, communication delays, and the use of augmented reality and virtual reality technologies in EVA operational risks were also discussed.	New technology and technological development
Bitencourt D.P. et al. [63]	Projections related to heat stress, estimated by the wet-bulb globe temperature (WBGT) index.	The occurrence of high wet-bulb globe temperature (WBGT) was predicted to increase annually, causing, for example, body weakness, altered psychosensory reactions, fluctuating risk perceptions, concentration lapses, accidents, loss of productivity, increased vulnerability to heat-related diseases, and even chronic kidney disease among outdoor employees.	Climate change
Bose-O'Reilly S. et al. [59]	Literature review. The searches were as follows: –Heat stress: Institutional reports from the World Health Organization, Global Heat Health Information Network, Center for Disease Control, Robert Koch-Institute, and German Environmental Agency, and systematic reviews (PubMed listed). Key words: "Heat Stress Disorders/prevention and control," "COVID-19," "Health Personnel," and "Hot Temperature" COVID-19: Websites of (inter)national institutes and authorities, and the websites of John Hopkins University, Center for Disease Control, European Center for Disease Prevention and Control, EuroMOMO, medRxiv (Preprint Server), and PubMed. Keywords: "Covid-19," "climate," and "change"	New challenges caused by heat threats in the summer, coinciding with the COVID-19 pandemic, were discussed. Health care personnel must wear personal protective equipment (PPE) against COVID-19, which exacerbates heat load and heat-related health problems, such as reducing endurance and cognitive performance and increasing the risk for accidents. An important question concerns whether COVID-19-related health recommendations contradict recommendations for reducing heat stress.	Climate change; Pandemic (COVID-19)
Crotty T.J. et al. [40]	Online survey with SurveyMonkey Inc. Participants: 38 ear, nose and throat specialists. The questionnaire was constructed using a pilot study. Data obtained: sociodemographic and COVID-19-related data. Anxiety was measured using Spitzer's 7-item General Anxiety Disorder scale.	The study focused on ear, nose, and throat specialists who are at high risk for COVID-19. As the level of emotional exhaustion among doctors was already high, the long-term mental health effects of COVID-19 may be significant. Increased vulnerability to infection and a lack of control over the risk of infection were the main sources of anxiety. In addition, a reduced workforce and the need to adopt new roles to meet healthcare demands may exacerbate healthcare workers' anxiety.	Pandemic (COVID-19)

(*Continued*)

Appendix B
(*Continued*)

Authors	Research methods	Summary of the NERs	Thematic group
Ebi K.L. et al. [64]	Overview**	The projections indicate that the temperature extremes will increase substantially by the end of the century and that the duration and intensity of heat extremes are increasing. Heat stress impairs physical work capacity and increases the risk of hyperthermia and cardiovascular failure or collapse, as well as the risk of acute kidney disease, accidents, and sick leave rates.	Climate change
Ekpanyaskul C., Padungtod C. [44]	Online survey. Participants: 869 working-from-home employees. The questionnaire was constructed based on a literature review. Data obtained: demographic data, the characteristics of working from home, physical health and psychosocial effects, and lifestyle changes while working from home. Prevalence rate and Chi-square tests were performed.	Working from home has increased and may increase in the future. Body weight changes, ergonomic problems such as neck, shoulder, and back pain, indoor environmental problems, and psychosocial problems were significantly related to the intensity of working from home. So-called "cabin fever" was the most prevalent psychosocial health problem.	Changes in work patterns; Pandemic (COVID-19)
Fazen L.E., Linde B., Redlich C.A. [48]	Overview**	The emergence of cleaning-related respiratory diseases and the reemergence of silicosis were discussed. The growth in the healthcare and service sectors has contributed to cleaning products being an important cause of work-related asthma. They have also been associated with a higher risk of chronic obstructive pulmonary disease in women. Even though silica is a well-known hazard, there are new patterns of exposure. For example, roofing, demolition work, concrete manufacturing, sandblasting, artificial stone manufacturing, and pottery and ceramic production are common work settings with exposure to silica in the United States.	Changes in work patterns; Growth in certain sectors; New materials or increased use of materials
Hauke A., Flaspöler E., Reinert D. [45]	Online survey. Participants: 398 labor inspectors. Participants were asked to rate the importance of 63 new and emerging developments related to associated OHS risks using a 7-point Likert scale. 95% confidence intervals were obtained.	The aging workforce, a shortage of skilled staff, strain on the musculoskeletal system, and increasing demands for mobility and flexibility were among the greatest concerns discussed. Digitalization, job insecurity, noise, resistance to medicines and disinfectants, physical violence at work, synthetic mineral fibers, epoxy resins, mold spores, diesel engine emissions, and UV radiation were major factors, depending on the field.	Changes in work patterns; Changing workforce; New technology and technological development
Jarota M. [43]	Literature review. Databases used: HeinOnline, PubMed, Scopus, Web of Science, ERIH PLUS, and EBSCO. Search strings not specified	The effects of robotization and artificial intelligence (AI) on employees' health and safety were studied. Among others, damage may be caused by collisions between humans and robots because of defective sensors, software, or connectivity. Further considerations included communication between robots and humans as well as ethical principles involved when a robot performs duties or makes decisions. The development of AI poses threats to privacy and to employees' protection against discrimination, and it may cause employees to be concerned about losing their jobs. There is a need to develop legal solutions at the European Union level.	New technology and technological development

(*Continued*)

Appendix B
(*Continued*)

Authors	Research methods	Summary of the NERs	Thematic group
Karanikas N. et al. [42]	Literature review. Databases used: Scopus, Web of Science, PubMed, Medline, and Embase. Search strings, e.g., ('wind farm' OR 'wind turbine') AND health AND work* Internet search engines. Limited to publications in English until 31-08-2020.	Because the wind farm sector is growing, its employees are exposed to occupational risks from working with new materials, technologies, and processes. Noise, electromagnetic fields, shadow flicker, epoxy, styrene, and physical stress were among the risks that had been previously researched. Vibrations, welding fumes, other potentially harmful substances, weather conditions, and biological hazards have not yet been studied in relation to wind farms, even though they could be relevant. The decommissioning of wind farms may have some unknown risk factors, which requires further research.	Growth in certain sectors; New materials or increased use of materials; New technology and technological development
Kim D., Lee J. [65]	Projections related to occupations vulnerable to heat stress and work capacity. The main data used were WBGT from the Korea Meteorological Administration and information from the Korean Working Condition Survey from the Occupational Safety and Health Research Institute of Korea.	Exposure to heat stress is increasing in multiple occupations, such as machine operators and elementary laborers working in the construction, welding, metal, and mining industries. Climate adaptation policies and measures were called for to protect employees from disadvantageous employment conditions, wage reductions owing to lowered productivity, and unsafe working conditions without scheduled breaks.	Climate Change
Madsen A.M. et al. [49]	Structured literature review. Databases used: CAB abstract, PubMed (incl. Medline), Biosis, Embase, Google Scholar, Web of Science, Proquest Environmental Science Collection, Health, and Safety Science Abstracts, British Library Inside Conferences and OSHA updates. Search strings are provided as supplementary material. Literature limited to publications published between January 1995 and October 2019.	Infrequent waste collection with the effects of global warming may lead to increased growth of microorganisms and greater human exposure to biological agents when the waste is collected. The influence of different waste types on occupational exposure levels is not yet clear. Gastrointestinal problems, irritations of the eyes and skin, symptoms of organic dust toxic syndrome, and a correlation between bioaerosol exposure levels and reduced lung function have been reported. Technological development and the implementation of digital technologies need further consideration. Personnel can reduce their frequency of getting in and out of trucks and instead walk alongside autonomous trucks while emptying bins, which may increase the risk of exposure and accidents.	Climate change; Growth in certain sectors; New technology and technological development
Magruder L. et al. [60]	Survey. Participants: 531 child welfare and other health and human services workers. Open-ended responses about the impacts of COVID-19 on their well-being were analyzed by thematic analysis.	The results suggested that having to stay at home due to COVID-19 negatively affected the physical and mental health of health and human services employees. Remote working, roles, and responsibilities adjustments, frequently changing policies or protocols, and closed agencies received attention. Technical difficulties and logistical challenges were described by remote workers, while a lack of adequate PPEs was mentioned by field workers. Changes in workload and caseload size, reduced in-person client capacity, and on-the-job mileage reimbursement negatively affected workers' health and finances.	Pandemic (COVID-19)

(*Continued*)

Appendix B
(*Continued*)

Authors	Research methods	Summary of the NERs	Thematic group
Naidu KSB. [38]	Overview**	Emerging nanoscience is among the new technologies projected to impact the industrial revolution and may simultaneously cause risks. The risks of engineered nanoparticles (ENPs) fall into the potential risk category. Compared with bulk alternatives, it is anticipated that ENPs will affect living organisms in different ways. Regarding toxicity, ENPs also differ greatly from one another.	New materials or increased use of materials; New technology and technological development
Paterson S.K., Godsmark C.N. [66]	Scoping literature review. Databases used: PubMed, Web of Science, and Google Scholar. Main search terms: heat, health, Ireland. Literature limited to publications published in English pertaining to Ireland, with the primary aim of exploring the impact of climate-related heat on human health, and studies involving humans. If no literature was available in the Irish context, the search was broadened to similar countries.	Outdoor workers are at risk of increased ambient temperature, air pollution, ultraviolet (UV) radiation, extreme weather, and biological hazards, such as vector-borne diseases. Employees required to wear PPE are at an elevated risk of suffering heat-related illness. Physiological thermal tolerance limits, pest, and contaminant control with chemicals, and mental distress were found to affect employees' health. The health and social care sector is vulnerable to rising temperatures. For example, the projected increases in the number of hot days and heatwaves will probably increase morbidity and mortality in vulnerable populations, which will then likely increase service demands and the need for extra capacity.	Climate change
Rosen M.P. et al. [39]	Overview**	Remote work in radiology practice because of COVID-19 may result in increased stress, distance, discord, or tension between staff members, as well as within the radiology department. This risk was due to class division, as higher socioeconomic groups had more opportunities to stay at home compared with lower socioeconomic groups. Because of the pandemic, some radiologists have been relocated for direct patient care, which has potentially exposed them to infectious risks that did not occur in their previous work environments.	Pandemic (COVID-19)
Schmitt N. et al. [61]	Scoping literature review. Databases used: CINAHL, MEDLINE (via Ovid, Web of Science), Cochrane Library, and PubMed. Search string used: (midwi* OR nurse-midwi* OR certifed midwi* OR obstetric nurses OR obstetric* OR perinatal care OR maternity care) AND (burden OR workload OR barriers OR challenges OR safety OR stress OR mental health OR resources OR potential OR anxi* OR depression OR psych*) AND (covid OR pandemic OR coronavirus). Additional literature was identified outside the main searches. Literature limited to publications in German and English originated in China or OECD countries, published between January 2020 and January 2021, discussing the effects of the Covid-19 on maternity staff, scientific studies, case reports, reports, editorials, letters to the editor, interviews, commentaries, and newspaper articles with quantifiable evidence. Analyzed by organizing the literature topically.	In maternity staff, the changes and challenges caused by COVID-19 included staff shortages and restructuring, PPE, tests, virtual communication, handling women with a positive infection, and excluding accompanying persons. The mental health of the employees was strongly affected. They were afraid of infection, suffered from increased workloads and exhaustion, and experienced ethical–moral dilemmas. The results demonstrated increased depression, anxiety, stress levels, and risk of post-traumatic stress symptoms among employees. There were reported cases of medical staff being violently attacked, as they were presumed to have spread the disease.	Pandemic (COVID-19)

(*Continued*)

Appendix B
(*Continued*)

Authors	Research methods	Summary of the NERs	Thematic group
Svertoka E. et al. [50]	Systematic literature review. Databases used: g IEEE Xplore, ACM Digital Library, ScienceDirect, SAGE Journals Online, and Springer Link. Search string: (Wearable OR "Body Area") AND (Safety OR Industr* OR Injury) Literature limited to publications published in the last five years and in the fields of electrical engineering, applied physics, telecommunications, biomedical engineering, and computer information systems. Analyzed by organizing the literature topically.	The role of wearable technology in occupational safety was discussed. Regarding data privacy and confidentiality, employees may be afraid that their collected information could be used as a reason for dismissal or fines. They may feel nervous about being tracked and pressured because of monitoring, which could increase their stress levels and the likelihood of errors.	New technology and technological development
Willis K. et al. [58]	Online survey, part of an Australian COVID-19 Frontline Health Workers Study. Participants: "frontline" health workers. This article focused on an open-ended question about the challenges caused by COVID-19. The responses ($N = 6{,}679$) were analyzed by coding and thematization. Data gathering was described in detail in a previous article.	The frontline health workers had increased workloads and work–life imbalances because of, among other factors, stretched staff resources, tensions in working from home and using telehealth, and the need for more flexibility. They had concerns about patient care, felt they were misunderstood, ignored, and devalued by management. The employees encountered insufficient communication about guidelines and communication overload, confusion about conflicting messages, and unpredictability in their roles and practices. They sometimes had insufficient protection and experienced delays accessing PPEs and rationing PPE. The employees experienced stress and anxiety because they did not feel safe at work. Actions and decisions were more reactive than proactive, and there was a need for preplanning and preparation.	Pandemic (COVID-19)

*Conference paper. **Data collection and analysis methods are not specified.