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COVID-19 and healthcare workers: a rapid systematic review into risks and preventive measures

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ABSTRACT

Objective The COVID-19 pandemic is demanding for occupational medicine and for public health. As healthcare workers (HCWs) fight impacts of SARS-CoV-2 on front lines, we must create safe work environments through comprehensive risk assessments, evaluation and effective implementation of counter-measures. We ask: 'What does current literature report on health risks at workplaces regarding COVID-19?' and 'What do current studies report on the effectiveness of enacted preventative recommendations?'

Methods As a snapshot of early HCW research, on 26 April 2020, we conducted a rapid systematic literature search in three databases (PubMed, Web of Science and PsycInfo) for COVID-19-related health outcomes and preventive measures in healthcare-associated workplaces.

Results 27 studies were identified as relevant for exploring the risk of infection, 11 studies evaluated preventive measures. The studies described that SARS-CoV-2 impacts significantly on HCW's health and well-being, not only through infections (n=6), but also from a mental health perspective (n=16). 4 studies reported indirect risks such as skin injuries, one study described headaches to result from the use of personal protective equipment. Few studies provided information on the effectiveness of prevention strategies. Overall, most studies on health risks as well as on the effectiveness of preventive measures were of a moderate-to-low quality; this was mainly due to limitations in study design, imprecise exposure and outcome assessments.

Conclusions Due to widespread exposure of HCW to SARS-CoV-2, workplaces in healthcare must be as safe as possible. Information from HCW can provide valuable insights into how infections spread, into direct and indirect health effects and into how effectively counter-measures mitigate adverse health outcomes. However, available research disallows to judge which counter-measure(s) of a current 'mix' should be prioritised for HCW. To arrive at evidence-based cost-effective prevention strategies, more well-conceived studies on the effectiveness of counter-measures are needed.

Strengths and limitations of this study

- ► Empirical information for timely use and decision-making was assessed in an early phase of the COVID-19 pandemic and synthesised in a 'real-time' manner.
- ► The review refers to workplaces of high relevance for individuals and public health.
- ► We developed recommendations for further epidemiological studies that could aid understanding and controlling the pandemic.
- ► The literature focuses on the first phase (until 26 April 2020) of the pandemic.

INTRODUCTION

Challenges due to the SARS-CoV-2/COVID-19 pandemic are unprecedented in scope and scale. After massive 'lockdowns', numerous countries are choosing careful ways back to former life and work. To support this, occupational medicine can play a pivotal role:

Getting back to work is highly relevant for economic prosperity, individual well-being and wealth. Equally clearly, workplaces with countless human contacts bear the risk for case clusters. Therefore, expertise and insights from occupational medicine should be applied to create workplaces that are as safe as possible and to mitigate adverse health effects caused by a recession.[1]

Healthcare workers (HCWs)—as important actors of the critical infrastructure—are under considerable risk of infection and other diseases. Within the first months of the pandemic (until early March), 3300 HCWs in China were described as infected, in Italy about 20% of responding HCW.[2] Because of the risks for HCW, in our review, we ask 'What is reported regarding health risks at workplaces concerning COVID-19?' and 'What do current studies report on the effectiveness of enacted preventative measures?'. We further ask and discuss 'What can we recommend from completed COVID-19 research on workplaces for ongoing and future epidemiology?'

METHODS

On 26 April 2020, we conducted a rapid systematic literature search using three scientific databases (PubMed, Web of Science and

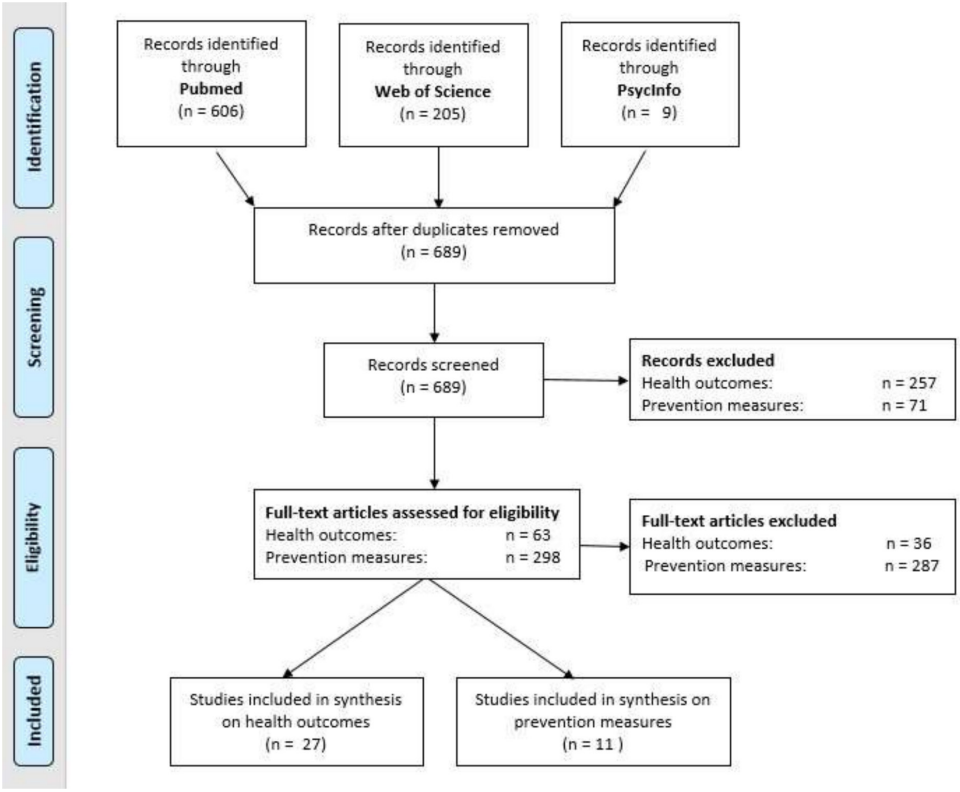

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart of the included studies.

PsycInfo). For PubMed we used the following search term: ((“Workforce”[Mesh] OR worker* OR employee* OR staff OR workforce OR labourer OR “Occupational Medicine”[Mesh] OR “Occupational Health” [Mesh] OR “Occupational Diseases”[Mesh] OR “Workplace”[Mesh] OR “occupational medicine“ OR “occupational health” OR workplace OR “occupational disease” OR “occupation“) AND (“COVID-19” OR “COVID-19” OR “severe acute respiratory syndrome coronavirus 2” OR “novel coronavirus” OR “new coronavirus” OR “COVID-19 pandemic” OR “wuhan coronavirus” OR SARS-CoV-2 OR “2019-nCoV disease”)). This search term was adapted for the other databases.

Inclusion and exclusion criteria

We screened identified relevant studies according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (see figure 1). We included publications focusing on COVID-19-related physical and psychological health outcomes in HCW or studies that investigated prevention measures regarding the risk through COVID-19. Studies focusing on other occupations, not presenting original data, focusing on coronaviruses other than SARS-CoV-2 or on diagnostics, therapies only were excluded. We further excluded articles exploring virus characteristics or transmissibility and those not published in English or German.

Quality appraisal

We critically appraised all original studies fulfilling the review’s criteria. To assess quality of quantitative studies, we used the Appraisal Tool for Cross-Sectional Studies (AXIS), the Critical Appraisal Skilss Programm checklist (CASP) for cohort studies, the Joana Briggs Institute (JBI) Critical Appraisal Checklist for case reports and case series and GRADE (Grading of Recommendations, Assessment, Development and Evaluations) for ecological studies. Qualitative studies were appraised by the CASP qualitative checklist. To identify the appropriate checklist, the study designs were evaluated in regards to our study questions. As several studies included various approaches to assess data in addition to investigating staff, our identification process may result in different study designs than stated by the authors. Where possible, overall scores were calculated or categorical scores were presented (see tables 1 and 2).

Patient and public involvement

No patient involved.

RESULTS

Our literature search identified 820 publications; after removing duplicates, 689 were screened for title and abstract. According to our research questions, JM reviewed studies on workplace-associated health outcomes associated with SARS-CoV-2. JVG reviewed studies on implemented prevention measures in healthcare settings and their implications for HCW’s health (see PRISMA flowchart, figure 1).

Table 1 Studies included for risk of infection, mental health, skin injuries and headaches

Author and year	Study design	Country	Exposure	Outcome/ evaluation tool	Main findings	Quality assessment
Infection						
Centers for Disease Control and Prevention, USA, 2020[3]	Cross-sectional, quantitative	USA	Laboratory confirmed contact with patients with COVID-19, n=9289 (Healthcare personnel)	Infection prevalence among HCW, (assessed through laboratory testing)	As of 9 April, 19% of all infected COVID-19 cases in the USA were HCW, median age was 42 years, death occurred more often among HCW aged ≥65, hospitalisation rate among HCW 8%–10%	AXIS: 12/20 (some items not applicable due to descriptive census-like study)
Chu *et al*, 2020[4]	Retrospective case series, quantitative	China	Working in emergency departments versus low-risk departments (non-emergency and technology departments), n=54	Infection and severity of disease (assessed through laboratory testing and clinical diagnosis)	Much lower incidence of infection among HCW from emergency departments than from other departments (emergency department 3.7% versus other department 72.2%); severe cases were significantly younger than common cases	JBI: 8-9/10
Li *et al*, 2020[5]	Report, Editorial (retrospective fatality analysis based on official report data)	China	No information on exposure assessment, n=24	Mortality among HCW with COVID-19	As of 16 March, 13 out of 24 (54.2%) HCW died from COVID-19, other causes for death were traffic injuries and sudden death	N/A
McMichael *et al*, 2020[6]	Case report, quantitative	USA	Contact to patients with COVID-19 in a long-term care facility, n=167	Infection and hospitalisation rates among staff members, residents and visitors (assessed through laboratory testing)	As of 18 March, 50 out of 167 confirmed cases were HCW, of whom 6% were hospitalised; indicated lacking PPE adherence and unfamiliarity with infection control measures	JBI: 7/8
Ran *et al*, 2020[7]	Retrospective cohort study, quantitative	China	Working in a high-risk department versus low-risk department in one hospital, n=72	Infection risk (assessed through laboratory testing)	HCW in high-risk departments are at higher risk for COVID-19 than those of low-risk departments due to longer duty hours and suboptimal hand hygiene	CASP: 5/13
Zhan *et al* 2020[8]	Report, Editorial	China	–	–	As of 24 February, 4.4% of confirmed COVID-19 cases were HCW. As of 3 April, 23 out of 3387 HCW in China had died from COVID-19	N/A
Mental health						
Cao *et al*, 2020[9]	Qualitative study, Editorial	China	Direct exposure to COVID-19 through work in a fever clinic (doctors, nurses, clinical technicians), n=37	Assessment of physical and psychological burden through interviews	HCW indicated high stress load, overworking, sleep problems and nervousness over own and family members' infection risk, concerns over shortage of medical supplies, overall mild bodily discomfort such as tiredness, throat pain, back pain headaches	CASP (no: n=7, yes: n=2)
Chen *et al*, 2020[10]	Cross-sectional, quantitative, Editorial	China	High exposure versus non or low exposure to patients with COVID-19, n=105	Depression, anxiety (assessed through SDS, SAS)	Symptoms of depression accompanied by anxiety was significantly higher in high-exposure group; no difference when depression or anxiety were considered separately	AXIS: 10/20

Continued

Table 1 Continued

Author and year	Study design	Country	Exposure	Outcome/ evaluation tool	Main findings	Quality assessment
Chew *et al*, 2020[11]	Cross-sectional, quantitative	Singapore and India	Exposure to SARS-CoV-2 not directly assessed, correlation between physical and psychological symptoms during COVID-19 outbreak, n=906	Depression, anxiety and distress, PTSD (assessed through DASS-21, IES-R) and physical symptoms	Headache most commonly reported, participants who had experienced physical symptoms in the preceding month were more likely to screen positive for depression, anxiety and stress, PTSD	AXIS: 13/20
Huang and Zhao, 2020[12]	Cross-sectional, quantitative	China	Comparison between several occupational groups, n=7236	Depression, anxiety, sleep quality (assessed through CES-D, GAD-7, PSQI)	Compared with other occupational groups, HCW had a higher prevalence of sleep disturbances, no difference in depression and anxiety	AXIS: 14/20
Kang *et al*, 2020[13]	Cross-sectional, quantitative	China	High-risk versus low-risk hospital departments, n=994	Depression, anxiety, insomnia, distress (assessed through PHQ-9, GAD-7, ISI, IES-R)	Staff with fewer contact to patients with COVID-19 showed less severe mental health issues, a higher degree of distress was associated with a more extensive exposure to the virus	AXIS: 13/20
Lai *et al*, 2020[14]	Cross-sectional, quantitative	China	Inside versus outside Wuhan and Hubei (high-risk region vs low-risk region), n=1257	Depression, anxiety, insomnia, distress (assessed through PHQ-9, GAD-7, ISI, IES-R)	Those working in Wuhan reported more severe mental health outcomes than other HCW	AXIS: 15/20
Li *et al*, 2020[15]	Cross-sectional, quantitative	China	Front line versus non-front line (high risk vs low risk), n=1266	Vicarious traumatisation (assessed through vicarious traumatisation scale)	Non-front-line nurses had significantly higher scores in vicarious traumatisation than front-line nurses	AXIS: 11/20
Liu, *et al*, 2020[16]	Cross-sectional, quantitative	China	Front-line versus non front-line nurses and doctors (high risk vs low risk), n=4679	Psychological stress, anxiety, depression (assessed through SRQ-20, SAS, SDS)	Doctors and nurses from high-risk departments, those who live mostly without family members, those who had previous experience in treatment of infectious disease have higher scores for all mental health outcomes; younger age and higher professional degree (doctors) had lower risk of mental health problems	AXIS: 16/20
Lu *et al*, 2020[17]	Cross-sectional, quantitative	China	Medical workers versus administrative staff and subgroup analysis of clinical staff (high-risk vs low-risk clinical staff), n=2299	Fear, anxiety, depression (assessed through NRS, HAMA, HAMD)	No significant difference in depression in medical staff compared with administrative staff, subgroup analysis: staff in high-risk department showed significantly greater fear, depressive symptoms, and anxiety compared with low-risk groups	AXIS: 14/20
Mo *et al*, 2020[18]	Cross-sectional, quantitative	China	Exposure to SARS-CoV-2 not directly assessed, correlation between stress and anxiety, n=180	Stress and anxiety (assessed through SOS, SAS)	The higher the stress load, the higher the anxiety among nurses; working long hours, being an only child, anxiety were main factors affecting nurse stress	AXIS: 10/20

Continued

Table 1 Continued

Author and year	Study design	Country	Exposure	Outcome/ evaluation tool	Main findings	Quality assessment
Sun *et al*, 2020[19]	Qualitative study	China	Direct exposure to COVID-19 through work on a negative pressure ward, n=20	Interview about emotions, coping styles, personal growth, positive emotions during the pandemic	At the beginning of the outbreak, the participants were mainly concerned over unknown conditions of patients, severe emergencies and patients' psychological state, a few developed symptoms of depression and isolated themselves. Over time, the nurses developed coping strategies to deal with stress and indicated a feeling of personal growth under pressure. After 1 week positive emotions prevailed in 70% of nurses.	CASP (no: n=2, yes: n=8)
Tan *et al*, 2020[20]	Cross-sectional, quantitative	Singapore	Medical versus non-medical staff (high risk vs low risk), n=470	Depression, anxiety, stress (assessed through DASS-21, IES-R)	Anxiety and stress were higher in non-medical staff	AXIS:12/20
Wu *et al*, 2020[21]	Cross-sectional, quantitative	China	Medical staff versus non-medical staff (college students); inside versus outside Wuhan (high risk vs low risk), n=4268	Psychological stress (assessed via piloted questionnaire)	Positive exposure effect: in all provinces of China, medical staff scored higher in psychological stress than college students; medical staff in Wuhan scored higher than staff outside Wuhan	AXIS: 9/20
Xiao *et al*, 2020[22]	Cross-sectional, quantitative	China	Exposure to SARS-CoV-2 not directly assessed, n=180	Anxiety, Self-efficacy, Stress, Sleep (assessed through SAS, GSES, SASR, PSQI)	During the COVID-19 pandemic, social support reduced stress and anxiety and increased self-efficacy in medical staff, no significant effect on sleep quality	AXIS: 10/20
Xu 2020[23]	Cross-sectional, quantitative, Editorial	China	Outbreak versus non-outbreak period (high vs low exposure), n=120	Depression, anxiety, anxiety dreams (assessed via scoring system and SF-36)	All endpoints were significantly higher in outbreak period compared with non-outbreak period	AXIS: 5-6/20
Zhang *et al*, 2020[24]	Cross-sectional, quantitative	China	Medical versus non-medical staff (high risk vs low risk), n=2182	Insomnia, somatisation, obsessive compulsive disorder, anxiety, anxiety and depression (assessed through ISI, SCL-90R, PHQ-4)	Medical workers had a higher prevalence for all mental health disorders except for phobic anxiety, having an organic disease was independently associated with mental health outcomes	AXIS: 11/20
Headaches						
Ong *et al*, 2020[29]	Cross-sectional, quantitative	Singapore	Frequent use of PPE due to SARS-CoV-2 exposure, n=158	PPE-related headaches (assessed through self-administered questionnaire)	81.0% of respondents developed de novo PPE-associated headaches. A pre-existing primary headache diagnosis and combined PPE usage for >4 hour per day were independently associated with de novo PPE-associated headaches.	AXIS: 15/20

Continued

Table 1 Continued

Author and year	Study design	Country	Exposure	Outcome/ evaluation tool	Main findings	Quality assessment
Skin injuries						
Gheisari *et al*, 2020[25]	Report, Editorial	Iran	Frequent use of PPE due to SARS-CoV-2 exposure	PPE-related skin injuries	Respirator masks were found to provoke occupational dermatoses, acne, skin irritation, contact dermatitis, allergies, pigmentation, pressure damage; goggles were associated with frictional erosions, pressure damage, xerosis, skin reactions on nasal bridge including; gowns were linked to contact dermatitis, itching	N/A
Jiang *et al*, 2020[26]	Cross-sectional, quantitative	China	Frequent use of PPE due to SARS-CoV-2 exposure, n=4308	PPE-related skin injuries (assessed through self-administered questionnaire)	Overall prevalence of skin injuries 42.8% (mostly device-related pressure injuries, moist associated skin damage and skin tear). Daily wearing time of >4 hour, high-grade PPE (PPE 3), sweating and male sex were associated with skin injuries	AXIS: 14-15/20
Lan *et al*, 2020[27]	Cross-sectional, quantitative, Editorial	China	Frequent use of PPE due to SARS-CoV-2 exposure, n=542	PPE-related skin injuries (self-administered questionnaire)	Prevalence of skin injuries among first-line HCW was 97%, most affected areas were nasal bridge, cheeks, hands and forehead, wearing time of N95 respirators>6 hour was positively correlated with skin damages, frequent hand hygiene (>10 times) was associated with hand skin damage	AXIS: 6/20
Lin *et al*, 2020[28]	Cross-sectional, quantitative, Editorial	China	Frequent use of PPE due to SARS-CoV-2 exposure, n=376	PPE-related skin injuries (assessed through self-administered questionnaire)	Skin on hands, cheeks, nasal bridge and auricular areas most affected by dryness, maceration, erythema; duration of wearing PPE, frequency of hand washing significantly associated with adverse skin reactions	AXIS: 8-9/20

AXIS, The Appraisal Tool for Cross-Sectional Studies; CASP, Critical Appraisal Skills Programme; CES-D, Centre for Epidemiology Scale for Depression; DASS-21, Depression Anxiety and Stress Scale; GAD-7, Generalized Anxiety Disorder-7; GRADE, Grading of Recommendations, Assessment, Development and Evaluations; GSES, General Self-Efficacy Scale; HAMA, Hamilton Anxiety Rating Scale; HAMD, Hamilton Rating Scale for Depression; HCW, healthcare worker; IES-R, Impact of Event Scale; ISI, Insomnia severity Index; JBI, Joana Briggs Institute; N/A, not applicable (N/A in quality assessment was used for articles with no clear study design such as reports or editorials); NRS, Numeric rating scale; PHQ, Patient Health Questionnaire; PSQI, Pittsburgh Sleep Quality Index; PTSD, Post-traumatic stress disorder; SAS, Self-rating anxiety scale; SASR, Stanford Acute Stress Reaction Questionnaire; SCL-90-R, Symptom Checklist 90- Standard; SDS, Self-rating depression scale; SF-36, Short Form Health 36; SOS, Stress Overload Scale; SRQ-20, Self Reporting Questionnaire 20-Item.

Table 2 Studies included for preventive measures

Author and year	Study design	Country	Exposure/ prevention measure	Outcome/ evaluation tool	Main findings	Quality assessment
Cao *et al*, 2020[9]	Qualitative interviews	China	HCW (n=37)/ Coping strategies as video chats or telephone calls with family and friends	Interview	Psychological support may help buffer negative impact on stress.	CASP (No: n=7, Yes: n=2)
Chen *et al*, 2020[39]	Qualitative interviews	China	HCW (n=13), stress, influence on mental health/ psychological intervention medical team, hotline	Interview	Not scared to get infected, help for resting, skills to cope with patients' anxiety and PPE shortage needed	CASP (No: n=5, Yes: n=2, can't tell: n=2)
Chen *et al*, 2020[34]	Ecological study	China	Caesarean delivery (n=17)/ appropriate PPE (N95 masks, goggles, protective suits, disposable caps, rubber gloves), if endotracheal intubation air-purifying respirator ; negative operating room,	RT-PCR	No medical staff involved in operation were infected	GRADE: very low
Htun *et al*, 2020[36]	Cross-sectional study	Singapore	Hospital overall (staff n=10583)/ Fever and sickness surveillance for staff; risk-based PPE; enhanced surveillance for unwell staff	Mixed (clinical assessment, swabs for PCR)	No infection with COVID-19	AXIS: positive aspect n=10, negative n=4, don't know n=6
Huang *et al*, 2020[35]	Ecological study	China	Nurses, 35 confirmed, 260 suspected cases/ PPE (hat, respirator, inner gloves, eye mask, protective clothing. Shoe covers, isolation gowns, outer gloves, face shield), hand hygiene, ward disinfection, medical waste management, sterilisation of patient care devices, management of occupational exposure. Teaching. Shift schedule evaluated; psychological counselling	Not specified	Zero infection rate in nurses	GRADE: very low
Huang *et al*, 2020[30]	Ecological study	China	Radiology department, 3083 suspected or confirmed COVID-19 patients/ Reconfiguring of the department, PPE (protective clothing, surgical cap, N95 mask, gloves, face shields, goggles), training, donning and doffing under supervision, strategic planning of examination procedures	Clinical symptoms	None of the staff became infected.	GRADE: very low
Kabesch *et al*, 2020[38]	Ecological study	Germany	Outbreak scenario, midwife → colleagues / Face masks, social distancing in cafeteria and break rooms, on site visits hygiene experts, staff training, transparent, timely and direct communication, testing all symptomatic employees	Laboratory test for symptomatic staff	Successful containment of the outbreak within 3 weeks, 36 staff members tested positive	GRADE: very low
Malik 2020[33]	Ecological study	Pakistan	Admission of a COVID-19 positive patient to the ICU/ HCW with N95 or surgical masks	PCR	All HCW (n=34) tested negative for COVID-19	GRADE: low

Continued

Table 2 Continued

Author and year	Study design	Country	Exposure/ prevention measure	Outcome/ evaluation tool	Main findings	Quality assessment
Ng *et al*, 2020[32]	Ecological study	Singapore	one patient with pneumonia/ HCW (n=41) exposed during aerosol-generating procedures	Clinical monitoring and PCR	No HCW infected	GRADE: low
Wee *et al*, 2020[31]	Ecological study	Singapore	Emergency department, PCR tests for all patients with respiratory syndromes, n=70 patients tested positive/ PPE risk stratified	PCR testing, extensive surveillance	No nosocomial transmission	GRADE: low
Zhu *et al et al*, 2020[37]	Ecological study	China	one patient with endonasal adenoma resection, general care and operation/ no prevention measures initially before confirmed infection	Diagnosis of infection not specified.	four nurses without prevention measures (and 10 persons without contact to the patient) got infected, none of the persons in the operation room or under specific prevention got infected.	GRADE: very low

AXIS, Appraisal Tool for Cross-Sectional Studies; CASP, Critical Appraisal Skills Programme; GRADE, Grading of Recommendations, Assessment, Development and Evaluations; HCW, healthcare worker.

Health risks at healthcare workplaces

Of 27 included studies, 6 provided information on the risk of infection,[3–8] 16 on mental health,[9–24] 4 on skin injuries associated with PPE[25–28] and 1 on resulting headaches[29] (see tables 1 and 2).

Infection

Due to frequent contact with infected people, HCW's own infection and the virus transmission to others is an important concern. Six[3–8] out of twenty-seven included studies on health outcomes reported on the prevalence of SARS-CoV-2 infection as well as on COVID-19-related morbidity and mortality among HCW. In all six studies, exposure was assessed based on known contact with patients with SARS-CoV-2 positive and infection was diagnosed through laboratory tests (reverse transcription PCR).

According to Zhan *et al* who refers to statistics of the National Health Commission of People's Republic of China, as of 24 February, 4.4% of the infected people in China (3387 of 77,262 patients with COVID-19) were HCW.[8] A cross-sectional study conducted by the US Centers for Disease Control and Prevention (CDC) revealed that as of 9 April, HCW accounted for 11% of all reported cases in the USA.[3]

Two studies provided information on hospitalisation rates.[3 6] For instance, in a long-term care facility in the USA, McMichael *et al* observed that 6% of 50 infected nursing staff were hospitalised,[6] which is similar to a prevalence of 8% stated by the CDC.[3] More specifically, in a case series Chu *et al* observed more cases of severe and critical illness among younger HCW than in older colleagues who were hospitalised due to COVID-19.[4]

Two studies provided information on HCW's mortality.[5 8] According to Zhan *et al* as of 3 April, 23 out of 3387 (~0.7%) COVID-19-positive HCW in China had died from the infection.[8] Additionally, in their retrospective fatality analysis Li *et al* reported that as of 16 March, 13 out of 24 fatalities among HCW (54.2 %) were attributable to COVID-19 and most cases were recorded in Hubei province or Wuhan.[5]

Among the reasons for HCW's infection, shortage of PPE and insufficient knowledge and training in infection control measures were reported to be most relevant.[4 6] Chu *et al* pointed out that normal wards evinced a disproportionally high number of infected HCW compared with first-line departments (3.7% from first-line departments vs 72.2% from non-first-line departments) that were prioritised over second-line departments in terms of PPE allocation.[4] Moreover, McMichael *et al* reported on disease spreading in a US-American long-term care facility, where staff worked while being symptomatic and moved between several facilities indicating lacking knowledge about infection control and containment measures.[6]

The high importance of protective measures was also emphasised in a retrospective cohort study by Ran *et al* who found that unqualified hand washing, suboptimal hand hygiene before and after patient contact and improper

PPE increased the risk of infection by 2.64 (95% CI: 1.04 to 6.71), 3.10 (95% CI: 1.43 to 6.73), 2.43 (95% CI: 1.34 to 4.39) and 2.82 (95% CI: 1.11 to 7.18), respectively.[7] The study also found that longer working hours, that is, longer exposure to SARS-CoV-2, was positively correlated with a higher proportion of infection.[7]

Mental health

Sixteen[9–24] out of the twenty-seven included studies reported on mental health problems, four investigated PPE-related skin injuries[25–28] and one reported on headaches associated with frequent PPE use.[29]

Most studies found that the exposure to SARS-CoV-2 was positively correlated with mental health problems.[10 12–14 16 17 21 23 24] Depression, anxiety and stress were the most commonly assessed disorders showing a significantly higher prevalence in HCW in high-risk departments or high-risk regions (Wuhan, Hubei province) compared with medical staff in low-risk departments, non-clinical staff or staff in low-risk regions.[10 11 13 14 16 17 19 23 24]

Factors contributing to psychical exhaustion and development of mental illness were concerns over self-infection and infection of relatives due to insufficient protection, worry about patients, helplessness, unfamiliarity with infection control measures, overworking and traumatising events at work, to name but a few.[9 15 17 19]

More specifically, Kang *et al* indicated that the severity of psychological disturbances increased with the frequency of contacts to patients with COVID-19.[13] A study by Huang *et al* compared different occupational groups during the pandemic and revealed that HCWs were more likely to develop sleep disturbances than other workers whereas no difference in prevalence of depression or anxiety was found.[12]

In contrast, Tan *et al* reported higher scores of anxiety and stress among non-medical workers (allied HCW, technicians etc) compared with medical workers.[20] Moreover, a similar direction of effect was found by Li *et al* indicating that non-front-line nurses without any patient contact had significantly higher vicarious traumatisation scores than front-line nurses.[15]

Furthermore, a qualitative interview study by Sun *et al* showed that attitudes and feelings changed over time.[19] They observed that front-line nurses experienced a high degree of helplessness and anxiety at the beginning of the pandemic, but could transform their negative emotions into feelings of higher professional identity and responsibility and personal growth. They further indicated that they felt grateful for the support from colleagues and family members.[19]

The importance of social support was demonstrated by Xiao *et al*.[22] The authors highlighted a potentially mitigating effect on anxiety and stress and showed that social support improved HCW's self-efficacy.[22] Likewise, nurses in Sun *et al*.'s study emphasised the importance of support by their families and colleagues.[19] Moreover, Mo *et al* identified that social characteristics such as being the only child could have a predisposing effect for the development of stress.[18]

Furthermore, underlying organic diseases were associated with developing mental health disorders including insomnia, anxiety, depression, obsessive–compulsive disorder, somatisation, stress and post-traumatic stress disorder (PTSD).[11 24]

Health effects through prevention measures

In a cross-sectional study, Ong *et al* explored the prevalence of de novo PPE-related headaches among medical workers from different high-risk areas of a tertiary health centre in Singapore.[29] Data from a self-administered questionnaire revealed that 81% of the 158 respondents suffered from de-novo headaches when wearing N95 respirators or eye protection. The chance of developing PPE-related headaches increased significantly for those with pre-existing headaches (OR 4.20; 95% CI: 1.48 to 15.4) and for those who used PPE for more than 4 hours per day (OR 3.91; 95% CI: 1.35 to 11.31).[29]

Moreover, PPE-related skin damages were evaluated in four studies.[25–28] Lin *et al* showed a positive correlation between self-perceived adverse skin reactions (such as dryness, erythema, maceration mostly on hands, cheeks and the nasal bridge) and the duration of wearing PPE (>6 hour).[28] The prevalence of skin irritation was reported to be 74.5%.[28] Furthermore, Gheisari *et al* pointed out the most common adverse skin effects (dermatoses, acne, skin irritation, frictional and pressure erosions) associated with goggles and respirator masks.[25] Lan *et al* found that 97% of HCW suffered from some sort of skin damages, especially dryness and desquamation on the forehead and nasal bridge as a result of enhanced hygienic and infection control measures.[27] Wearing N95 respirators for a period longer than 6 hour doubled the risk for facial skin lesions (OR 2.02; 95% CI: 1.35 to 3.01). The authors further observed that frequent hand hygiene (>10 times per day) may increase the risk of skin damage twofold, (OR 2.17; 95% CI: 1.38 to 3.43).[27] Similarly, a large multicentre cross-sectional study performed by Jiang *et al* found an overall prevalence of skin injuries of 42.8%, involving pressure-related and moisture-related skin issues as well as skin tear. The prevalence of skin injuries was found to be higher when daily wearing time exceeded 4 hours and when high-grade PPE (ie, PPE3) was used.[26]

Effectiveness of enacted preventive measures

Only nine studies[30–38] focused on evaluating the effectiveness of implemented preventive strategies regarding risk of infection, all of which were case reports or case series (see table 2). The studies observed operative procedures[34 37] as well as general care and diagnostics.[30–33] Infection was assessed by laboratory testing or clinical diagnosis of COVID-19.[30] The number of investigated patients ranged from 1[32 33 37] to 308.[30]

Most of the studies reported zero staff infections,[30–36] in one study four nurses who contacted a patient without protection (before quarantine) became infected while

there was no transmission for staff members using PPE (after the patient's confirmed infection).[37] Malik *et al* suggested that surgical masks may be as effective as N95 masks, but further studies were needed to confirm this.[33] However, in most studies the enacted preventive measures were complex and do not allow deducing the effectiveness of single measures.

Kabesch *et al* described how rigorous testing for SARS-CoV-2 and targeted self-isolating of HCWs in addition to improved hygienic measures and consequent use of surgical face masks could stop a COVID-19 outbreak in a large maternity and perinatal centre in Germany. While maintaining the clinical services, the virus was stopped within 3 weeks[38].

Measures concerning mental health were evaluated in two studies.[9 39] Concerning the effectiveness of supporting mental health, in qualitative interviews (n=13) in a tertiary general hospital in Beijing, communication with colleagues, family members or psychologists was described as being most helpful for most workers.[9] Monitoring HCW in a Chinese hospital who received psychological support revealed that they would particularly appreciate designated resting areas and sufficient protection supply as well as the acquisition of necessary skills to manage patients' anxiety.[39]

Quality assessment

Overall, most studies on health risks as well as on the effectiveness of preventive measures were of a moderate-to-low quality mainly due to limitations in study design, imprecise exposure and outcome assessments. Hence, selection, misclassification and information bias need to be taken into account when interpreting the findings (see tables 1 and 2 for the studies' quality scores).

DISCUSSION

Currently, and presumably in the near future, we will have to cope with enormous challenges due to COVID-19. HCW at the front lines are under particular risk. In times when numerous preventative measures are taken for HCW, our review asks two questions, deliberately confining our evidence search to publications until 26 April 2020: 'What is reported regarding health risks at workplaces concerning COVID-19?' and 'What do current studies report on the effectiveness of enacted preventative recommendations?' We focus on a limited time period to identify effective evidence-based responses, on the one hand, or lack of studies into the effects of measures to protect HCW, on the other at an early stage of the pandemic. Answering our study question in 'real time' is important as we need to know—and apply—'what' does protect 'whom' effectively or otherwise instigate much-needed studies seeking such evidence.

Safety at healthcare workplaces

Among workplace-associated risks through SARS-CoV-2, virus transmission seems to be the biggest concern. However, robust data on incidence and prevalence are difficult to obtain due to uncertainty around infection pathways, inconsistent testing modalities within and between countries and varying disease manifestations including the unknown proportions of asymptomatic cases.

In most studies, exposure assessment referred to HCWs' contact to patients with COVID-19 without specifying the exact contact time and duration. Yet, this is important to consider, as we know that viral shedding and infectivity differ over the course of disease.[40] Moreover, a considerable proportion of included studies did not perform a thorough exposure assessment risking biased study findings on infection-related health consequences.

Another aspect to consider is virus transmission through HCW from outside healthcare facilities, which makes containment measures difficult and increases the risk for nosocomial infection.[41] Of note, as protective equipment is usually prioritised to high-risk areas (fever clinics, emergency departments), undersupplied second-line departments could become breeding grounds for new infections.[4]

Beyond infections, the pandemic's impact on mental health can be significant. Apart from the fear of self-infection and infecting others, high work pressure, changing relationships between HCW and patients, and possible stigmatisation in society[42 43] may have detrimental effects on HCW's psychological stability. While front-line HCW seem to be at highest risk, impacts on second line and non-clinical staff should not be underestimated. Since front-line HCW generally have better access to mental health support and protective and infection control measures, their psychological resilience is assumed to be higher than in second-line staff.[15 20]

To understand determinants of mental health disorders, qualitative studies can bring valuable insights. Since recent evidence is predominantly built on cross-sectional studies, it seems to be difficult to quantify the true effect of the 'SARS-CoV-2 challenge' on mental health, particularly with respect to pre-existing psychological and physical issues. For this review, we found great heterogeneity in self-administered outcome assessment (tables 1 and 2), which likely introduces information bias and complicates comparison of studies. Given both complexity and durability of mental health problems, longitudinal studies are warranted to explore HCWs' mental and psychological health over time. Moreover, in future studies, mental health disorders such as PTSD may come on the study radar.

Our observations of COVID-19-related mental health outcomes were consistent with a recent systematic review and meta-analysis on the prevalence of depression, anxiety and insomnia by Pappa *et al*.[44] Our work complements their findings as our broader scope of outcomes and study types adds valuable insight for occupational health research of HCWs in challenging times.

Overall, it becomes clear that healthcare workplaces pose multifaceted challenges to HCWs' health, which

require diligent investigations and a swift implementation of effective precautionary and supportive measures.

Effectiveness of enacted preventive measures

Since the COVID-19 pandemic could last for long(er) and effective medications, improving and developing appropriate protective measures are a must. While many publications describe preventive measures for general and specific healthcare settings, the imbalance regarding—or scarcity of 11—studies into the very effectiveness of a 'mix' of enacted measures is striking and needs to be corrected.

Indeed, the dynamic pandemic necessitates flexible adaptation of precautionary measures to take note of rapidly changing recommendations.[45] With so many people under risk worldwide, one main objective must be to protect as many of those most under risk as possible. This does certainly not imply to use a maximum prevention in a 'mix' of available counter-measures. To the contrary, recommending highest standards of protection can be(come) overuse which has been described as a form of misuse.[46] To exemplify, during the last months we all experienced that shortage of prevention measures, especially for PPE[47] or laboratory tests,[48] can occur. Therefore, when creating effective prevention measures, we also have to consider whether or how long they are available.

Given the obvious need of studies into which counter-measure(s)—alone or in combination—is/are effective, it is unfortunate that only very few studies focus on measuring effectiveness. Moreover, since most studies describe complex prevention concepts, effects of individual measures could hardly be investigated. Finally, the identified case and cross-sectional studies clearly complicate a generalisation of results. Moreover, as the virus is not specific for workplaces, studies should assess the risk of infection in private life, too. Unfortunately, non-workplace associated risks were not explicitly considered.

Cost–Benefit ratio

When discussing prevention measures, possible negative effects have to be considered and investigated. As described above, the PPE's use can have negative impact on health and well-being. Additionally, the inappropriate use of preventive measures could be a danger[49] resulting from a false sense of security due to unawareness which can have a negative impact on workers' actions and the protective effect of instigated measures. Preferably, before implementing preventive strategies, the effectiveness of the specific measure (the benefit) has to be weighed up against possible risks and inconveniences (the costs).

Acceptance and appropriate use

When interpreting the epidemiological studies, it seems misleading to assume the effectivity of PPE tested under laboratory conditions to be equal to real workplace situations as the PPE's effectivity depends on the acceptance and actual use by the individual worker. For instance, in a Chinese hospital the use of PPE was investigated, revealing that 100% of the staff used masks, with an accuracy rate of 73.79% only, but the compliance rate of hand hygiene of all staff was limited to 40.78%.[50] Reasons for HCWs' ability and willingness to follow guidelines regarding respiratory infections were investigated in a Cochrane review[51]: Insecurity on how to handle guidelines, frequently changing guidelines, the resulting additional workload and fatigue, little support, uncomfortable PPE and unwanted effects on the patients (for instance through covering parts of the face by a mask) were described as negative factors. On the other hand, a clear communication, training on how to use PPE and seeing the value of the recommended measures were deemed positive.

It is astonishing that even in hospital settings, PPE is often used inappropriately: In 2019, Herron *et al* found that only 18% of theatre staff (n=1034) used face masks according to the CDC standard.[52] During the current pandemic, Wennmann *et al* described that HCW in an emergency department of a German University hospital required more PPE training than expected.[53]

Overall, ignoring the acceptance and appropriate use of preventive measures in epidemiological studies can result in severe information and misclassification bias. As inadequate knowledge is a risk for inappropriate PPE use,[54] information and transparent communication is important to improve the acceptance and correct use of prevention measures. Moreover, exaggerated and untargeted measures might decrease workers' acceptance and willingness to wear PPE as intended with far-reaching consequences for individual and public health.

Suggestions for ongoing research

What could be viewed as a limitation of this review, viz that we are still at an early stage of the pandemic and that our review covers a short period of time only, can be judged as a strength as well: Empirically, we identified lack of evidence for which counter-measure(s) of a current 'mix' provides the necessary protection of HCW and should be prioritised in what setting. Material regarding our review questions may now be considered to shape much-needed studies seeking such evidence. Clearly, (some) data for currently missing 'effect studies' may be collected now or never.[55]

Indeed, this review about HCW allows a first 'real-time' insight into current research and highlights challenges we face when investigating COVID-19. Due to high exposure to SARS-CoV-2, healthcare workplaces provide ideal conditions to study virus transmission, the effectiveness of prevention measures and findings may be transferred, at least partially, to other workplaces. Against the background of emerging disease clusters in other essential services, as recently observed in military service or in slaughterhouses, lessons learnt in the healthcare sector can be critical for occupational research to prevent further disruptions of everyday life.

However, as demonstrated in this review, high-quality studies from different parts of the world are lacking. Therefore, we do agree with Glasziou that the current phase of the pandemic has generated replicative studies

of low methodological quality highlighting the need for well-defined study questions and robust study designs in order to reduce waste in COVID-19 research.[56] Moreover, studies from different countries and economical settings are needed to avoid 'geographical bias'. To achieve this end, multifaceted studies investigating the risk through COVID-19 at healthcare—and other—workplaces should include and consider:

1. The risk of infection.
2. The effectiveness of prevention measures.
3. The availability of prevention measures.
4. The risks of prevention measures.
5. The cost–benefit ratio of prevention measures.
6. The acceptance and appropriate use of prevention measures among workers.

CONCLUSION

COVID-19 poses severe risks for HCWs' physical and mental health. While a plethora of prevention measures is currently enacted, we lack informative evaluations of their effectiveness and possible negative consequences. Taken together, available research disallows to judge which counter-measure(s) of a current 'mix' should be prioritised at healthcare workplaces. After reviewing hitherto scarce COVID-19-HCW-associated literature, recommendations for effect-based epidemiology to arrive at evidence-based cost-effective counter-measures should be considered when shaping ongoing and future research.

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