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Original Article

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Use of Personal Protective Equipment Among Healthcare Workers During the First and the Second Wave of the COVID-19 Pandemic

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Abstract

Introduction: To treat and properly care for COVID-19 patients it is vital to have healthy healthcare workers to ensure the continued function of the healthcare system and to prevent transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) to patients, co-workers, and the community. Personal protective equipment (PPE) can prevent healthcare workers from being infected with and transmitting SARS-CoV-2. Experience and training are pivotal to ensure optimal protection. This study aims to examine the use and failure of PPE and compliance with PPE guidelines during the first and the second wave of the COVID-19 pandemic among Danish healthcare workers.
Methods: Healthcare workers from the Central Denmark Region and the Capital Region of Denmark were invited to participate April–June 2020 during the first wave and November 2020–April 2021 during the second wave. Day-by-day, participants reported work procedures, use and failure of PPE, and compliance with PPE guidelines. Register-based information on sex, age, department, and profession was available for all participants.

Results: In total, 21 684 and 10 097 healthcare workers participated during the first and the second wave, respectively. During the first wave, 1.7% used filtering face piece-2 or -3 (FFP2 or FFP3) respirators and 8.2% used face masks [fluid resistant (type IIR) masks, masks with visor (typically type IIR), and other unspecified face masks] during physical contact with patients. During the second wave, the corresponding figures increased to 17.8% and 80.7%. During respiratory procedures, the use of FFP2 or FFP3 respirators increased from 5.6 to 24.3%, and the use of face masks from 14.7 to 77.8%. The no PPE use decreased from 21.3% during the first wave to 0.4% in the second wave, during respiratory procedures. Total PPE failures decreased from 0.7 to 0.4% from the first to second wave. The proportion not complying with PPE guidelines declined from 3.6 to 2.2% during physical contact with patients and from 6.5 to 4.6% during respiratory procedures. PPE failure and non-compliance varied by age, sex and type of department. Frequent reasons for non-compliance were *forgetfulness* and *lack of time*, and during the first but not during the second wave, *limited availability of PPE*.
Conclusion: We found a substantial increase in the use of PPE and a substantial decrease in PPE failures from the first to the second wave of COVID-19 in Denmark. However, there is still a need for continuous focus on compliance in use of PPE among healthcare workers.

Keywords: compliance; COVID-19; face masks; healthcare workers; personal protective equipment

What's Important About This Paper?

Personal protective equipment (PPE) is a primary strategy for preventing COVID-19 among healthcare workers. This study surveyed Danish healthcare workers during two waves of the COVID-19 pandemic, and found changes in PPE use and compliance with PPE guidelines. This study demonstrates that healthcare workers' use of PPE and PPE failures can be modified.

Introduction

The number of people infected with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has increased dramatically worldwide since it was first identified and described in China on the 31st of December 2019 (World Health Organization, 2020a). The World Health Organization announced on the 11th of March 2020 that coronavirus disease (COVID-19) had reached the scope of a pandemic (World Health Organization, 2020b). The Danish Government concurrently introduced measures to reduce social contact and increase social distancing as part of the efforts to limit the spread of the COVID-19 (The Danish Government, 2020). Since then, guidelines for hospital hygiene and infection control during the COVID-19 pandemic have been updated several times. Indications for use of respirators as part of COVID-19 supplementary precautions were by large unchanged during the first and the second wave. During the second wave, healthcare workers (HCW) were demanded by the Danish Health Board to use a type II face mask during all patient contact as part of general precautions, to prevent droplet transmission. Current guidelines for the Central Denmark Region (valid since the 26th of November 2020, and concurrently updated to follow national guidelines) can be found in the supplementary material (see Supplementary Document 1 in online edition).

To properly care for and treat patients with COVID-19, healthy HCW are crucial. However, HCW are at greater risk of being infected with SARS-CoV-2 than the general population (Shaman *et al.*, 2020; Jespersen *et al.*, 2021; Verbeeck *et al.*, 2021; Würtz *et al.*, 2021). Four percent of HCW in the Capital Region of Denmark (April 2020) and 3.4% in the Central Denmark Region (May through June 2020) had antibodies against SARS-CoV-2 (Iversen *et al.*, 2020; Jespersen *et al.*, 2021). This was significantly higher than among Danish blood donors, where only 1% had antibodies against SARS-CoV-2 when screened in April 2020 (Erikstrup *et al.*, 2021). As expected, nursing staff, medical doctors, and biomedical laboratory scientists were particularly at risk (Jespersen *et al.*, 2021).

Compliance with personal protective equipment (PPE) donning and doffing guidelines has been shown to reduce and prevent transmission of infections including SARS-CoV-2 (Chu *et al.*, 2020; Liu *et al.*, 2020; Verbeek *et al.*, 2020), but it requires experience

and training to use PPE properly (Verbeek *et al.*, 2020; Piche-Renaud *et al.*, 2021). Furthermore, reduced availability of PPE, widespread in the first wave of the pandemic, may also have been an issue for HCW (Kim *et al.*, 2021; Mantelakis *et al.*, 2021; Rebmann *et al.*, 2021). Breach in the barrier of PPE (e.g. medical gown pulled back from glove exposing skin or HCW sweating and then wiping their face) and damage to PPE (e.g. tear in medical gown) have previously been of concern (Begley *et al.*, 2020; Verbeek *et al.*, 2020), but the combination of breach and damage (failure) of PPE among HCW during the COVID-19 pandemic has to our knowledge not been studied.

Information on mitigating factors for SARS-CoV-2 transmission among HCW such as the (proper) use of PPE and access to appropriate PPE and sufficient training is needed to prevent COVID-19 among HCW (Jespersen *et al.*, 2021). Therefore, this study aims to examine the use and failure of PPE, and compliance with PPE guidelines during the first and the second wave of the COVID-19 pandemic.

Methods

Study population

The COBRA (COVID-19 among Danish healthcare workers) study consists of two waves of daily questionnaires covering the first (spring-early summer 2020) and second (winter 2020–2021) waves of the COVID-19 pandemic in Denmark.

During the first wave, healthcare workers, technical, administrative, and other staff (hereafter, called HCW) of the Central Denmark Region (n = 32 413) and the Capital Region of Denmark (n = 39 520) were invited via work email to participate. Invitations were sent on the 24th of April 2020 in the Central Denmark Region and on the 6th of May 2020 in the Capital Region of Denmark. The first wave of questionnaires ended on the 30th of June 2020.

Prior to the second wave of the questionnaire, the Central Denmark Region cohort was updated; newly hired employees were included and temporary workers were excluded (n = 26 024). The Capital Region of Denmark cohort was restricted to workers participating during the first wave (n = 9569). The first questionnaire in the second wave was sent out on the 17th of November 2020 and 15th of December 2020, for the two Regions, respectively. The questions on work tasks and PPE use concluded on the 30th of April 2021 and the 28th of February 2021.

The first wave of the COVID-19 pandemic in Denmark had a peak in SARS-CoV-2 infection rates on the 4th of April, 2020, with 417 polymerase chain reaction (PCR) verified cases, and a peak in COVID-19 related deaths on the 5th of April 2020, with 22 deaths in a population of 5 771 877 citizens (World Health Organization, 2021). The second wave in Denmark was characterized by a peak in SARS-CoV-2 infection rates on the 17th of December 2020, with 4329 PCR verified cases, and a peak in COVID-19 related deaths on the 15th of January 2020, with 43 deaths (World Health Organization, 2021).

The study was registered at the repository of the Central Denmark Region (1-16-02-150-20) and the Capital Region of Denmark (P-2020-455), and the two dataset were merged at the Danish Health Data Authority platform. Both Regional Scientific Ethical Committees approved that ethical approval was not required (1-10-72-1-20 and H-20027931). All participants gave informed consent and could withdraw from the study at any time point.

Questionnaire

Daily questionnaires were sent to participants' smartphones at approximately 3:30 pm. Both waves addressed baseline information such as smoking habits and general health, and furthermore, daily COVID-19 related symptoms, work tasks, contact with SARS-CoV-2 positive individuals, use of PPE, and failure of PPE during work tasks. The questionnaire also addressed whether participants were compliant with PPE guidelines during work tasks.

In the second wave, the questionnaire was expanded to better address why PPE guidelines were not complied with (see Supplementary Document in online edition).

The daily questionnaire typically took between 15 s and 2 min to complete, dependent on whether the participant had been at work with tasks related to patients on that particular day. Most questions allowed multiple answers to accommodate participants with multiple daily tasks and the use of multiple types of PPE. Questions that included a *none* or *no* option had an included mutually exclusive function added to eliminate conflicting answers (e.g. answering that *no PPE* and gloves were used on the same day).

Work tasks were divided into nine categories: (i) consultations with patients or relatives within two meters distance, (ii) physical contact with patients (e.g. treatment, examination, personal care, or patient transfer), (iii) surgical procedures or birth giving, (iv) respiratory procedures (e.g. continuous positive airway pressure (CPAP), positive expiratory pressure (PEP), intubation or resuscitation), (v) transport of patients, (vi) other tasks with a distance less than 2 m, (vii) cleaning of

patient room, (viii) at work but doing none of the mentioned tasks, or (ix) not at work (sick leave, day off, or working from home).

The PPE addressed in the questionnaire were divided into the following eight categories: (i) high isolation suit, (ii) filtering face piece (FFP2 and FFP3) respirator, (iii) face mask (fluid resistant (type IIR) mask, mask with visor (typically type IIR), and other unspecified face masks), (iv) visor, (v) gloves, (vi) medical safety goggles, (vii) medical gown or plastic apron, and (viii) plexiglass/plastic screens (only the second wave).

Failure of PPE was defined as a combination of breach in the barrier of PPE (e.g. mask or visor falling off) and damage to PPE (e.g. punctured glove) during work tasks.

Non-compliance with PPE guidelines was defined as non-use of what participants perceived as the recommended PPE during work tasks.

Registers

Information on sex, age, department, and profession was provided by the two Regions, via the Danish Civil Registration System (Schmidt *et al.*, 2014).

Register information was linked to the study population by use of the unique 10-digit personal identification number given to all individuals in Denmark.

Data management and statistical analysis

All questionnaire data was collected using REDCap (Research Electronic Data Capture) tools (Harris et al., 2009). All subsequent data management and handling were performed in Stata (version 17.0; StataCorp, College Station, TX, USA) and SAS studio (3.8, version 9.04, SAS Institute Inc., Cary, NC, USA.).

When evaluating PPE use, PPE failure, and compliance with PPE guidelines, only a subgroup of the COBRA population was used, namely participants with patient-related work tasks on the given day. When evaluating the reasoning for non-compliance with PPE guidelines, only participants who reported not having complied with PPE guidelines were assessed. Thus, the populations in tables and figures vary accordingly.

Questionnaire responses indicating the use of multiple PPE and only one work task had all the PPE types assigned to that work task and vice versa. To avoid misclassification of PPE use and work tasks, responses with multiple PPE and multiple work tasks were categorized as "multiple work tasks and multiple PPE".

A comparison of the use and failure of PPE and the non-compliance with PPE guidelines was performed by calculating proportions.

Data are presented as *N* (%) unless stated otherwise. Numbers less than 5 are reported as <5 in concordance with the data protection policy.

Odds ratios (OR) for failures of PPE and non-compliance with PPE were estimated by each type of PPE (high isolation suit, FFP2, or FFP3 respirator, face mask, visor, gloves, medical safety goggles, and medical gown or plastic apron) for the two waves by logistic regression. Standard error-based 95% confidence intervals (95% CI) were obtained based on 50 bootstrap samples among the included participants. The logistic regression models were adjusted for sex (female and male), age (<30, 30–39, 40–49, 50–59, and ≥60 years), profession (nursing staff, medical doctors, and biomedical laboratory scientists) and departments (emergency, medical, surgical, and anesthesiology departments), and reported as adjusted odds ratios (AOR).

Results

Participation

During the first wave, 12 115 (37% of invited) participated from the Central Denmark Region and 9569 (24% of invited) from the Capital Region of Denmark. During the second wave, these numbers were 6687 (26% of invited) and 3410 (36% of invited), respectively (Table 1). This corresponded in total to 948 978 responses on daily questionnaires during the first and 928 880 during the second wave. During the first wave, the mean number of days a participant participated was 44 (IQR 35;59), and the mean percentage of possible answered questions 85 (IQR 80;97). The corresponding numbers during the second wave were 93 (IQR 36;156) and 82 (IQR 74;96), respectively. Also, the mean proportion of all participants reporting being in close contact with a COVID-19 patient during the first wave was 0.8%. The corresponding number during the second wave was 2.2%. In both waves, participants were predominantly female and aged 30–59 years. Nurse was the most frequent profession and medical departments supplied the largest percentage of participants.

Comparing the participants with the invited non-participants, participants were generally older and more frequently female. Nursing as profession and employment at a medical department dominated in both populations. A table with the characteristics of participants and non-participants is available as supplementary material (see Supplementary Table 1a in online edition).

Use of personal protective equipment

Only participants who performed patient-related work tasks had their PPE use evaluated (Table 2).

Table 1. Characteristics of participants in the COBRA study.

	First wave						Second wave					
	Central Denmark Region			Capital Region of Denmark			Central Denmark Region			Capital Region of Denmark		
	N	%	% of invited	*N*	%	% of invited	*N*	%	% of invited [a]	*N*	%	% of invited
Participants	12 115	100.0%	37.4%	9569	100.0%	24.4%	6687	100.0%	25.7%	3410	100.0%	35.6%
Sex												
Female	10 232	84.5%	40.1%	8087	84.5%	26.2%	5899	88.2%	27.4%	2943	86.3%	36.4%
Male	1883	15.5%	27.3%	1482	15.5%	17.1%	788	11.8%	17.4%	467	13.7%	31.5%
Age												
<30	1221	10.1%	20.9%	872	9.1%	12.8%	627	9.4%	15.7%	169	5.0%	18.7%
30–39	2551	21.1%	35.0%	1927	20.1%	19.7%	1356	20.3%	20.5%	480	14.1%	24.7%
40–49	3445	28.4%	44.0%	2594	27.1%	28.0%	1875	28.0%	29.7%	970	28.4%	37.5%
50–59	3355	27.7%	45.3%	2771	29.0%	31.8%	1984	29.7%	33.2%	1205	35.3%	43.3%
≥60	1543	12.7%	37.9%	1405	14.7%	28.2%	845	12.6%	26.9%	586	17.2%	43.2%
Profession												
Nursing staff[b]	4735	39.1%	41.0%	4586	47.9%	25.7%	2564	38.3%	23.8%	1527	44.8%	33.3%
Medical doctors	1328	11.0%	28.8%	1264	13.2%	19.6%	640	9.6%	15.8%	396	11.6%	31.6%
Biomedical Laboratory Scientists	661	5.5%	57.3%	509	5.3%	23.7%	413	6.2%	34.3%	234	6.9%	45.8%
Medical secretaries	1015	8.4%	53.3%	745	7.8%	35.6%	616	9.2%	31.4%	341	10.0%	45.8%
Other[c]	4376	36.1%	33.2%	2465	25.8%	22.4%	1813	27.1%	22.5%	912	26.7%	36.8%
Department												
Emergency	443	3.7%	35.6%	287	3.0%	24.7%	229	3.4%	17.6%	99	2.9%	34.1%
Medical[d]	2676	22.1%	41.3%	2301	24.0%	26.0%	1542	23.1%	23.5%	812	23.8%	35.9%
Surgical[e]	1729	14.3%	39.0%	1664	17.4%	25.1%	945	14.1%	19.6%	614	18.0%	37.1%
Biochemistry	725	6.0%	52.6%	531	5.5%	22.7%	448	6.7%	32.3%	229	6.7%	44.0%
Service section[f]	280	2.3%	18.6%	284	3.0%	11.4%	150	2.2%	17.4%	91	2.7%	33.3%
Anesthesiology	1140	9.4%	48.2%	789	8.2%	25.6%	593	8.9%	45.3%	264	7.7%	32.4%
Radiology and nuclear medicine	457	3.8%	44.4%	446	4.7%	27.0%	268	4.0%	26.3%	154	4.5%	34.5%
Psychiatry	1806	14.9%	29.0%	1697	17.7%	24.6%	690	10.3%	22.6%	515	15.1%	30.4%
Departments with limited patient contact[g]	2396	19.8%	44.7%	1330	13.9%	27.7%	954	14.3%	28.8%	548	16.1%	40.2%
Other[h]	463	3.8%	19.3%	240	2.5%	14.8%	227	3.4%	9.4%	84	2.5%	33.5%

[a]For all estimates except *Total (% of invited)* 65 individuals have been removed since no data on sex, age, profession or department was available.

[b]Nurses, social- and healthcare assistants, and radiographers.

[c]Primarily administrative, technical and educational staff.

[d]Internal medicine, paediatrics, oncology, and neurology.

[e]All surgical departments, including: obstetrics and gynaecology; otorhinolaryngology and head and neck surgery; and ophthalmology.

[f]Cleaning services; hospital porters; clothing and waste management; depot and archive; telephone switchboard; and guidance for patients, relatives, and staff.

[g]Occupational and social medicine; physio- and occupational therapy; administration; department of technical services; and kitchen.

[h]Participants without affiliation, e.g. students and participants on call, wage subsidy, and hourly waged.

Table 2. Daily reports on use of personal protective equipment (PPE) during different work tasks during the first and the second wave of the COVID-19 pandemic.

	Consultations		Procedures with physical contact		Respiratory procedures		Surgical procedures or births		Transportation of patients		Other tasks <2 m		Cleaning of patient room		Multiple work tasks and multiple PPE[a]	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
First wave																
No PPE	62552	54.1	35900	34.1	1602	21.3	584	8.7	1391	29.4%	23806	46.5	3070	19.9	0	0.0
High isolation suit	13	0.0	79	0.1	21	0.3	18	0.3	0	0.0%	22	0.0	6	0.0	500	0.7
FFP2 or FFP3 respirator	528	0.5	1783	1.7	423	5.6	324	4.8	50	1.1%	508	1.0	159	1.0	10455	14.4
Face mask[b]	2764	2.4	8683	8.2	1106	14.7	3862	57.5	104	2.2%	2422	4.7	528	3.4	43754	60.3
Visor	1889	1.6	5607	5.3	448	5.9	476	7.1	23	0.5%	1960	3.8	278	1.8	16691	23.0
Gloves	49431	42.7	65260	61.9	5512	73.2	5488	81.7	3255	68.8%	25022	48.9	12130	78.6	71150	98.1
Medical safety goggles	411	0.4	2786	2.6	506	6.7	869	12.9	15	0.3%	546	1.1	133	0.9	17283	23.8
Medical gown or plastic apron	1495	1.3	10345	9.8	691	9.2	3188	47.4	69	1.5%	1632	3.2	1979	12.8	54565	75.2
Second wave																
No PPE	685	1.7	168	0.4	6	0.4	8	0.3	28	3.9%	196	1.4	57	1.0	0	0.0
High isolation suit	17	0.0	81	0.2	25	1.5	22	0.7	<5	<5	10	0.1	11	0.2	787	0.8
FFP2 or FFP3 respirator	7332	18.2	7531	17.8	398	24.3	342	10.7	163	22.6%	2865	20.6	1163	19.4	22514	22.0
Face mask[b]	29890	74.4	34085	80.7	1273	77.8	2876	90.0	459	63.7%	9982	71.8	4129	68.9	86190	84.1
Visor	4645	11.6	9026	21.4	362	22.1	434	13.6	122	16.9%	3125	22.5	1567	26.1	32743	31.9
Gloves	5155	12.8	18859	44.7	892	54.5	2787	87.2	254	35.2%	3318	23.9	4249	70.9	97134	94.8
Medical safety goggles	285	0.7	1373	3.3	214	13.1	490	15.3	15	2.1%	229	1.6	110	1.8	12717	12.4
Medical gown or plastic apron	1222	3.0	9698	23.0	478	29.2	2208	69.1	90	12.5%	1563	11.2	2566	42.8	51419	50.2
Plexiglass/plastic screen[c]	1321	3.3	303	0.7	21	1.3	7	0.2	<5	<5	889	6.4	29	0.5	2351	2.3

Presented as percent of total number of times the specific task was conducted.

[a]Responses containing multiple work tasks and multiple PPE on the same day.

[b]Face mask include the following: type IIR mask, mask with visor (typically type IIR) and other unspecified face masks.

[c]Plexiglass/plastic screen was only an available option during the second wave.

Characteristics of this population are available as supplementary material (see Supplementary Table 1b in online edition).

Apart from gloves (see below), the use of PPE increased markedly from the first to the second wave (Table 2). During consultations, 54.1% reported not using any PPE in the first wave. This number decreased to 1.7% in the second wave. The decrease in no PPE use was seen for all tasks: procedures with physical contact (34.1–0.4%), respiratory procedures (21.3–0.4%), surgical procedures or births (8.7–0.3%), transportation of patients (29.4–3.9%), other tasks performed less than 2 m from the patient (46.5–1.4%), and cleaning of patient room (19.9–1.0%).

The use of both FFP2/FFP3 respirators and face masks increased markedly for all tasks from the first to the second wave. The increase in use of FFP2/FFP3 respirators for the different tasks was substantial: consultations (0.5–18.2%), procedures with physical contact (1.7–17.8%), respiratory procedures (5.6–24.3%), surgical procedures, or births (4.8–10.7%), transportation of patients (1.1–22.6%), other tasks with a distance less than 2 m (1.0–20.6%), and cleaning of patient room (1.0–19.4%). The corresponding numbers for face masks were: consultations (2.4–74.4%), procedures with physical contact (8.2–80.7%), respiratory procedures (14.7–77.8%), surgical procedures or births (57.5–90.0%), transportation of patients (2.2–63.7%), other tasks with a distance less than 2 m (4.7–71.8%), and cleaning of patient room (3.4–68.9%).

The use of gloves decreased between the first and the second wave. The decrease was most prominent for consultations (42.7–12.8%) and transportation of patients (68.8–35.2%). However, a decrease was seen in almost all tasks: procedures with physical contact (61.9–44.7%), respiratory procedures (73.2–54.5%), other tasks with a distance less than two meters (48.9–23.9%), and cleaning of patient room (78.6–70.9%). The only task for which the use of gloves increased was surgical procedures or births (81.7–87.2%).

Two most frequent combinations of work tasks in the "multiple work tasks and multiple PPE" category were *consultations and procedures with physical contact* and *consultations, procedures with physical contact, and other tasks <2 m* in both the first and second wave. The two most frequent combinations of PPE were *gloves and medical gown or plastic apron* and *gloves, face mask, and medical gown or* plastic apron in the first wave, and *gloves and* face mask and *gloves, face mask, and medical gown or* plastic apron in the second wave. The 10 most frequent combinations are available as supplementary material (see Supplementary Table 2a in online edition).

Failure of personal protective equipment

During the first wave, 1344 participants reported failures of PPE, and of these only 0.4% reported repetitive failures of PPE (10 or more times), mean 1.16 times, inter quartile range (IQR) 1;1. The same pattern was seen during the second wave, where 877 participants reported failures, and of these 1.3% reported failures of PPE 10 or more times (mean 1.22 times, IQR 1;1).

During the second wave, fewer failures were experienced by the participants for all types of PPE compared to the first wave (4.1‰ and 6.8‰ of PPE used, respectively) as shown in Fig. 1. Face masks had the greatest reduction in failures (from 4.8‰ during the first wave to 1.8‰ during the second wave). Gloves were the PPE with which most participants reported failures (9.9‰ during the first wave and 8.2‰ during the second wave). During both waves, procedures with physical contact were the task in which most participants reported failure of PPE (7.1‰ during the first wave and 6.6‰ during the second wave) as seen in Fig. 2.

Compliance with personal protective equipment guidelines

During the first wave, 4158 participants reported not having complied with PPE guidelines, and of these 4.9% reported not having complied with PPE guidelines 10 or more times (mean 1.38 time, IQR 1;2). The same pattern was seen during the second wave, where 1878 participants reported not having complied with PPE guidelines, and of these 8.0% reported not having complied with PPE guidelines 10 or more times (mean 1.46 times, IQR 1;2).

Fewer tasks were performed without complying with PPE guidelines during the second wave, compared to the first wave, as seen in Fig. 3. Respiratory procedures were the most frequent task where participants reported not having complied with PPE guidelines (6.5 % during the first wave and 4.6 % during the second wave). The corresponding numbers for the other work tasks were: consultations (2.5–1.7%), procedures with physical contact (3.6–2.2%), surgical procedures or births (3.2–1.9%), transportation of patients (2.7–0.8%), other tasks with a distance less than 2 m (2.8–1.7%), and cleaning of patient room (1.9–0.6%).

During the first wave, face masks, and gloves were the PPE with which most participants reported non-compliance with PPE guidelines, 7.1% and 2.8% respectively, Fig. 4. During the second wave, apart from face masks (1.4%) most participants reported non-compliance with PPE guidelines for visors (4.2%).

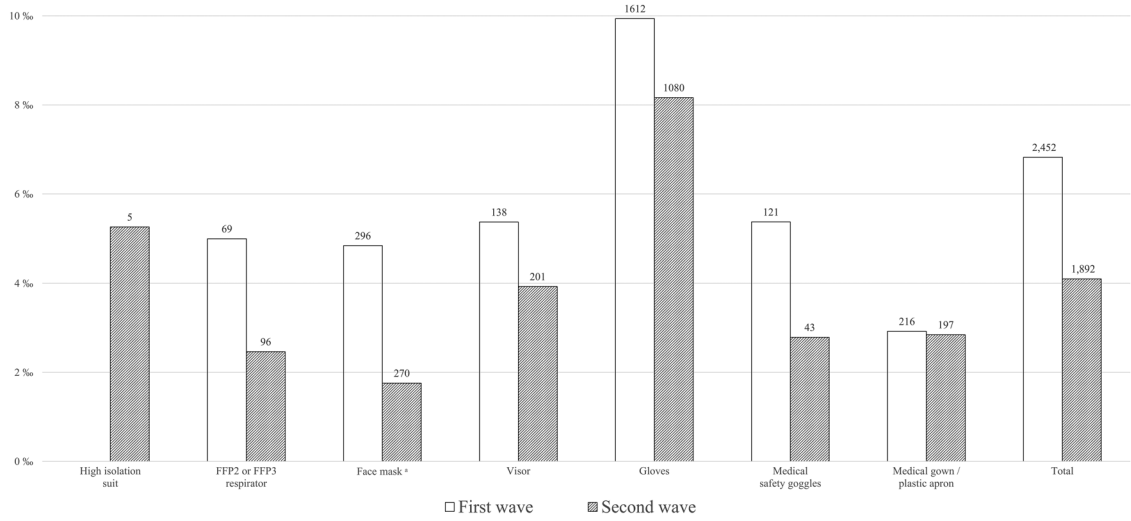

Figure 1. Failure of personal protective equipment (PPE) by type of PPE during the first and the second wave of the COVID-19 pandemic. Presented as per mille of personal protective equipment used (y-axis) as well as total number of events (top of columns). [a]Face mask include the following: type IIR mask, mask with visor (typically type IIR) and other unspecified face masks.

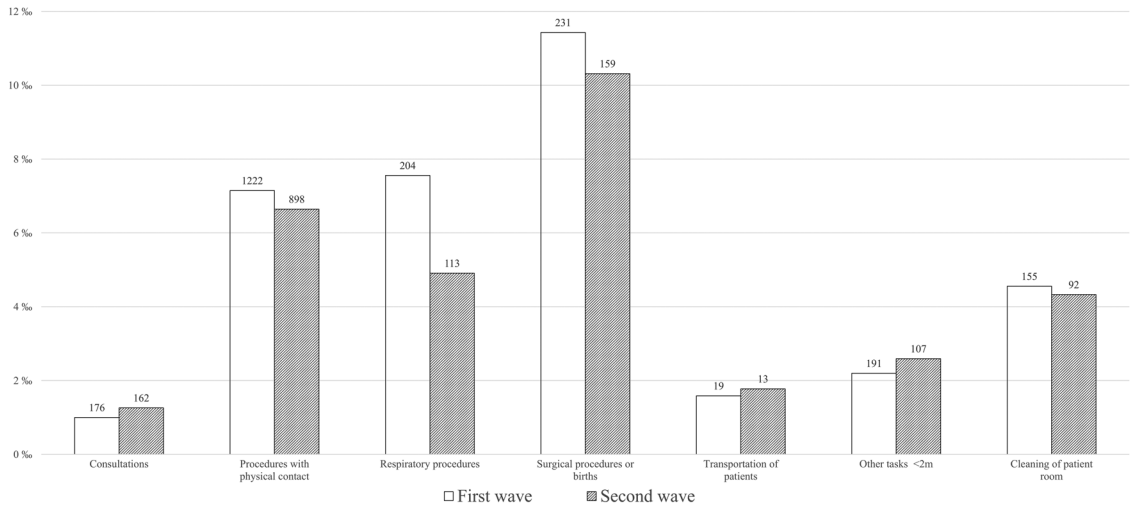

Figure 2. Failure of personal protective equipment (PPE) by task during the first and the second wave of the COVID-19 pandemic. Presented as per mille of personal protective equipment used (y-axis) as well as total number of events (top of columns).

Reasons for non-compliance with personal protective equipment guidelines

The reasons most frequently reported by the participants for non-compliance were *forgetfulness* (25.9% during the first wave and 27.2% during the second wave), *lack of time* (21.6% during the first wave and 13.3% during the second wave), *maintaining good patient contact* (7.1% during the second wave) and *considered it to be unnecessary* (17.7% during the second wave) as seen in Fig. 5. During the first wave, participants also reported *limited availability of PPE* as an issue (10.0% during the first wave and 3.0% during the second wave).

Healthcare workers' characteristics associated with failures of personal protective equipment and non-compliance with personal protective equipment guidelines

During both waves and across all PPE, older HCW tended to less often experience failure compared to

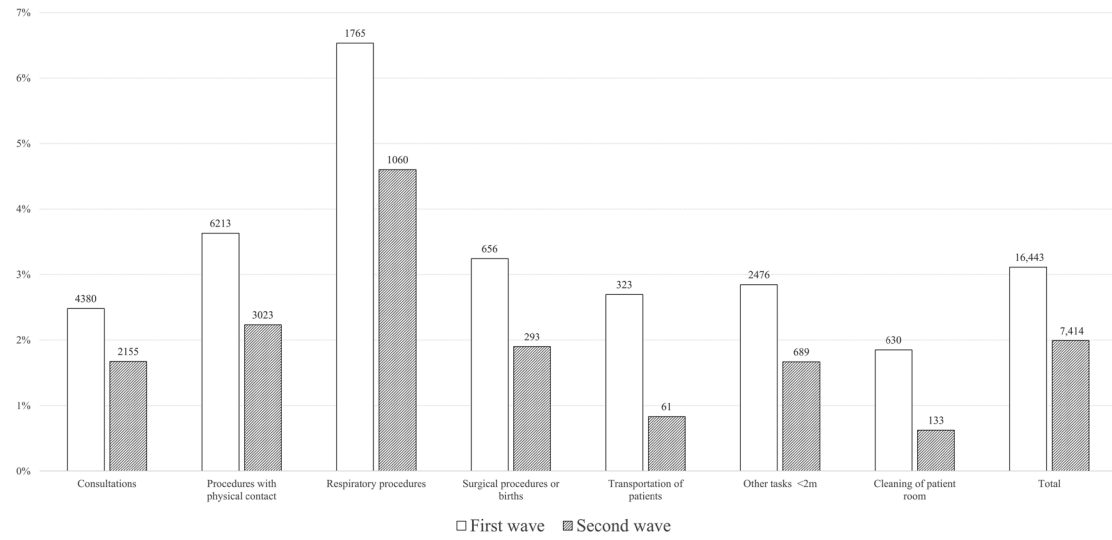

Figure 3. Non-compliance with personal protective equipment (PPE) guidelines by task during the first and the second wave of the COVID-19 pandemic. Presented as percent of total number of times the specific task was conducted (y-axis) as well as the total number of events (top of columns).

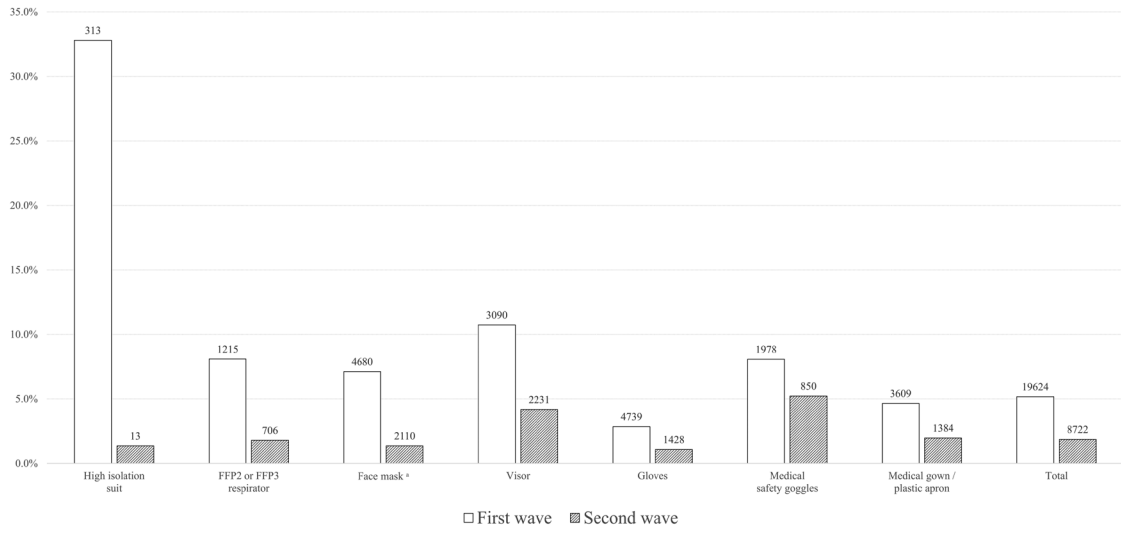

Figure 4. Non-compliance with personal protective equipment (PPE) guidelines by PPE during the first and the second wave of the COVID-19. Presented as percent of total number of times the specific PPE was used (y-axis) as well as the total number of events (top of columns). [a]Face mask include the following: type IIR mask, mask with visor (typically type IIR) and other unspecified face masks.

younger HCW. The greatest difference was seen for FFP2 and FFP3 respirators, where the adjusted odds ratio (AOR) for reporting a failure was 0.2 (0.0;0.8) for participants aged 60< compared to participants aged <30 during the first wave, and the corresponding number for the second wave was 0.1 (0.0;0.4), as seen in Table 3. During both waves and across all PPE, there was a tendency towards the surgical departments less often experiencing failure of PPE compared to the emergency departments. The greatest difference was seen for FFP2 or FFP3 respirators, where the AOR for reporting a failure was 0.1 (0.0;0.5) for surgical departments compared to emergency departments during the first wave, and the corresponding number for the second wave was

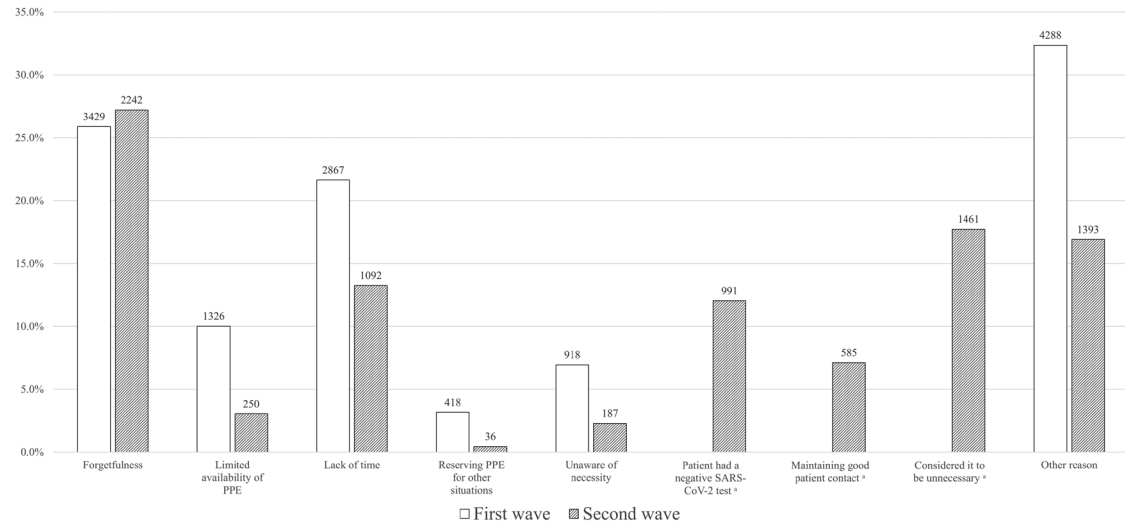

Figure 5. Reasons for non-compliance with personal protective equipment (PPE) guidelines during the first and the second wave of the COVID-19 pandemic. Presented as percent of registered number of times where PPE guidelines were not complied with (y-axis) as well as the total number of events (top of columns). [a]This response was only an available option during the second wave.

0.6 (0.1;2.3). Across all PPE the difference between the two types of departments decreases from the first to the second wave.

During both waves and across all PPE, female HCW tended to report non-compliance with PPE guidelines less often compared to male HCW. The greatest difference was seen for FFP2 or FFP3 respirators, where the AOR for reporting non-compliance with PPE guidelines was 0.6 (0.4;0.8) for females compared to males during the first wave. The corresponding number for the second wave was 0.4 (0.3;0.6), as seen in Table 4. During both waves and across all PPE, there was a tendency that the surgical and medical departments less often reported non-compliance with PPE guidelines compared to emergency departments. The greatest difference was seen for medical safety goggles, where the AOR for reporting non-compliance with PPE guidelines was 0.3 (0.2;0.3) for medical departments compared to emergency departments during the first wave, and the corresponding number for the second wave was 0.9 (0.3;2.2). Across all PPE the difference between the departments decreased from the first to the second wave.

Discussion

Main results

Overall, the proportion of PPE use increased and the proportion of PPE failures decreased from the first wave to the second wave. PPE failure and non-compliance varied by age, sex, and type of department. Reasons for non-compliance with PPE guidelines were predominately *forgetfulness*, *lack of time,* and *maintaining good patient contact*. During the first wave, participants also reported *limited availability of PPE* as an issue.

Interpretations

There were substantial differences in the use of PPE from the first to the second wave. This may be explained by factors such as changes in guidelines over time, more stable PPE deliveries, and awareness of and training in proper use of PPE, both at hospital and at community level. HCW were required to use a type II face mask during all patient contact during the second wave, as part of general precautions. This was not the case during the first wave. During the course of the first wave, infection control units experienced increasing awareness of the use of PPE as part of general precautions (e.g. mask and eye protection when at risk of splashes or sprays) among HCW.

During the second wave, we found a decrease in the use of gloves in almost all tasks compared to the first wave. A reason for this could be that participants were more efficiently trained in good hand hygiene and thus did not consider it necessary to wear gloves. Also, the guidelines for procedures for e.g. transportation of patients changed during the COVID-19 pandemic, where HCW were urged not to be in direct contact with patients or their belongings. Therefore, a HCW could

Table 3 Healthcare workers' characteristics associated with failures of personal protective equipment (PPE) expressed as odds ratios (OR) and adjusted odds ratios (AOR) (95% confidence intervals) for each type of PPE.

	FFP2 or FFP3 respirator		Face mask[a]		Visor		Gloves		Medical safety goggles		Medical gown or plastic apron	
	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]
First wave												
Sex												
Male	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Female	1.4	0.9 (0.2;4.0)	0.7	0.6 (0.3;1.2)	1.6	2.0 (0.7;5.5)	1.0	0.7 (0.5;1.0)	1.1	1.5 (0.7;3.4)	0.8	0.7 (0.3;1.3)
Age												
<30	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
30–39	0.5	0.6 (0.2;1.8)	1.2	1.2 (0.6;2.5)	1.0	1.2 (0.5;3.2)	0.9	1.0 (0.7;1.2)	1.3	1.5 (0.7;3.2)	0.7	0.8 (0.5;1.4)
40–49	0.4	0.4 (0.1;1.2)	1.1	1.1 (0.6;2.0)	0.6	0.7 (0.3;1.7)	0.5	0.6 (0.4;0.7)	0.5	0.5 (0.2;1.4)	0.4	0.5 (0.3;0.8)
50–59	0.6	0.5 (0.1;1.9)	0.9	0.8 (0.4;1.6)	0.3	0.4 (0.1;1.1)	0.5	0.5 (0.4;0.7)	0.5	0.5 (0.2;1.2)	0.2	0.3 (0.1;0.5)
≥60	0.2	0.2 (0.0;0.8)	0.6	0.6 (0.2;1.4)	0.4	0.5 (0.1;1.9)	0.3	0.3 (0.2;0.5)	0.1	0.1 (0.0;0.4)	0.2	0.3 (0.1;0.9)
Profession												
Biomedical Lab Scientists	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Medical doctors	0.3	0.4 (0.1;1.2)	0.9	0.8 (0.4;1.4)	1.1	1.4 (0.7;2.9)	1.7	1.7 (0.7;4.2)	1.4	1.8 (0.9;3.5)	0.9	0.7 (0.4;1.2)
Nursing staff	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	2.7	3.1 (1.2;8.2)	Insufficient data	Insufficient data	Insufficient data	Insufficient data
Department												
Emergency	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Anesthesiology	0.8	0.9 (0.3;2.6)	0.9	1.0 (0.5;2.0)	0.2	0.2 (0.1;0.5)	0.8	0.9 (0.7;1.3)	0.2	0.3 (0.1;0.7)	0.3	0.3 (0.2;0.7)
Surgical[c]	0.1	0.1 (0.0;0.5)	0.4	0.4 (0.2;0.9)	0.3	0.3 (0.1;0.6)	0.8	1.0 (0.7;1.3)	0.2	0.2 (0.1;0.4)	0.3	0.3 (0.1;0.7)
Medical[d]	0.2	0.3 (0.1;0.8)	0.3	0.4 (0.2;0.7)	0.4	0.4 (0.2;0.9)	0.8	0.9 (0.6;1.2)	0.3	0.3 (0.1;0.6)	0.4	0.4 (0.2;0.8)
Second wave												
Sex												
Male	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Female	0.5	0.5 (0.2;1.1)	1.7	1.7 (0.3;9.8)	1.6	1.0 (0.4;2.6)	1.2	0.7 (0.4;1.2)	0.6	0.4 (0.1;1.3)	1.3	1.2 (0.4;3.4)
Age												
<30	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
30–39	0.4	0.4 (0.1;1.6)	1.0	1.1 (0.3;4.2)	0.6	0.7 (0.3;1.5)	0.4	0.4 (0.3;0.7)	1.5	2.0 (0.5;8.7)	2.1	2.4 (0.6;8.8)
40–49	0.3	0.3 (0.1;1.3)	1.4	1.5 (0.5;4.4)	0.5	0.5 (0.2;1.0)	0.5	0.6 (0.4;0.9)	1.8	2.3 (0.6;9.4)	2.7	2.8 (0.8;10.5)
50–59	0.3	0.3 (0.1;1.1)	1.1	1.1 (0.3;3.8)	0.4	0.4 (0.2;0.8)	0.3	0.3 (0.2;0.5)	0.7	0.8 (0.2;3.7)	1.0	1.0 (0.3;3.2)

Table 3 Continued

	FFP2 or FFP3 respirator		Face mask[a]		Visor		Gloves		Medical safety goggles		Medical gown or plastic apron	
	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]
60≤	0.1	0.1 (0.0;0.4)	0.7	0.8 (0.2;3.3)	0.3	0.3 (0.1;1.2)	0.2	0.2 (0.1;0.5)	Insufficient data	Insufficient data	0.9	0.9 (0.1;5.5)
Profession												
Biomedical Lab Scientists	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Medical doctors	1.0	0.8 (0.3;1.8)	0.8	1.0 (0.3;3.4)	0.4	0.4 (0.2;1.0)	0.4	0.3 (0.2;0.6)	0.6	0.4 (0.1;1.8)	0.6	0.7 (0.3;1.5)
Nursing staff	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
Department												
Emergency	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Anesthesiology	1.2	1.7 (0.5;5.5)	0.4	0.4 (0.2;0.9)	0.6	0.6 (0.2;1.6)	0.7	0.8 (0.4;1.5)	5.1	5.4 (1.7;17.5)	0.6	0.7 (0.3;1.7)
Surgical[c]	0.4	0.6 (0.1;2.3)	0.3	0.3 (0.1;0.9)	0.3	0.3 (0.1;0.9)	0.7	0.8 (0.4;1.7)	0.6	0.6 (0.1;3.0)	0.3	0.3 (0.1;0.7)
Medical[d]	0.7	1.0 (0.3;3.4)	0.4	0.4 (0.2;0.8)	0.5	0.6 (0.3;1.2)	0.4	0.5 (0.3;1.0)	0.7	0.7 (0.2;3.0)	0.4	0.4 (0.2;0.9)

[a]Face mask include the following: type IIR mask, mask with visor (typically type IIR) and other unspecified face masks.

[b]Adjusted for sex, age, profession, and department.

[c]All surgical departments, including: obstetrics and gynecology; otorhinolaryngology and head and neck surgery; and ophthalmology.

[d]Internal medicine, pediatrics, oncology, and neurology.

Table 4 Healthcare workers' characteristics associated with non-compliance with personal protective equipment (PPE) guidelines expressed as odds ratios (OR) and adjusted odds ratios (AOR) (95% confidence intervals) for each type of PPE.

	FFP2 or FFP3 respirator		Face mask[a]		Visor		Gloves		Medical safety goggles		Medical gown or plastic apron	
	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]
First wave												
Sex												
Male	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Female	0.5	0.6 (0.4;0.8)	0.8	0.9 (0.7;1.2)	0.9)	1.0 (0.7;1.5)	0.7	0.7 (0.5;1.0)	0.8	0.9 (0.6;1.3)	0.9	0.9 (0.6;1.1)
Age												
<30	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
30–39	0.8	0.8 (0.5;1.2)	0.8	0.8 (0.6;1.0)	0.8	0.8 (0.6;1.2)	0.8	0.8 (0.5;1.1)	0.7	0.8 (0.6;1.0)	0.7	0.8 (0.6;1.0)
40–49	0.7	0.7 (0.4;1.1)	0.8	0.7 (0.6;0.9)	0.5	0.5 (0.4;0.8)	0.5	0.5 (0.4;0.7)	0.6	0.5 (0.4;0.7)	0.5	0.5 (0.4;0.6)
50–59	0.7	0.6 (0.4;1.1)	0.7	0.6 (0.5;0.8)	0.5	0.5 (0.4;0.7)	0.4	0.5 (0.3;0.6)	0.4	0.3 (0.2;0.4)	0.4	0.4 (0.3;0.6)
≥60	0.4	0.4 (0.2;0.6)	0.6	0.5 (0.3;0.7)	0.3	0.4 (0.2;0.6)	0.5	0.5 (0.3;0.7)	0.1	0.1 (0.1;0.2)	0.3	0.3 (0.2;0.5)
Profession												
Biomedical Lab Scientists	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Medical doctors	2.8	1.7 (0.7;4.5)	6.0	4.3 (1.3;14.3)	8.1	7.9 (2.7;22.8)	2.7	2.2 (0.7;7.2)	1.1	1.3 (1.0;1.6)	1.5	1.4 (0.2;8.7)
Nursing staff	2.4	1.6 (0.7;3.7)	5.3	3.5 (1.1;11.2)	7.3	7.1 (2.5;20.4)	2.1	2.0 (0.6;6.4)	Insufficient data	Insufficient data	1.7	1.6 (0.2:10.3)
Department												
Emergency	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Anesthesiology	0.8	0.9 (0.6;1.3)	1.1	1.2 (1.0;1.4)	0.4	0.5 (0.3;0.8)	0.6	0.6 (0.5;0.9)	0.8	1.0 (0.7;1.4)	0.3	0.4 (0.3;0.5)
Surgical[c]	0.3	0.3 (0.2;0.5)	0.7	0.7 (0.6;0.9)	0.4	0.4 (0.3;0.7)	0.6	0.6 (0.4;0.8)	0.3	0.3 (0.2;0.5)	0.3	0.3 (0.2;0.4)
Medical[d]	0.3	0.3 (0.2;0.5)	0.4	0.4 (0.3;0.5)	0.5	0.5 (0.3;0.8)	0.6	0.6 (0.4;0.8)	0.2	0.3 (0.2;0.3)	0.4	0.4 (0.3;0.5)
Second wave												
Sex												
Male	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Female	0.3	0.4 (0.3;0.6)	0.7	0.8 (0.4;1.5)	0.7	0.8 (0.4;1.5)	0.4	0.4 (0.2;0.9)	0.6	0.9 (0.3;2.3)	0.6	0.5 (0.3;1.2)
Age												
<30	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
30–39	0.4	0.5 (0.2;1.3)	1.1	1.2 (0.5;2.8)	0.9	1.0 (0.5;2.1)	0.9	1.0 (0.5;1.9)	1.0	0.9 (0.3;3.1)	0.6	0.7 (0.3;1.6)

Table 4 Continued

	FFP2 or FFP3 respirator		Face mask[a]		Visor		Gloves		Medical safety goggles		Medical gown or plastic apron	
	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]	OR	AOR[b]
40–49	0.5	0.6 (0.2;1.6)	1.2	1.2 (0.6;2.4)	0.6	0.6 (0.3;1.3)	0.7	0.8 (0.4;1.7)	1.2	1.0 (0.3;3.3)	0.4	0.5 (0.2;0.9)
50–59	0.3	0.4 (0.2;1.0)	1.1	1.2 (0.6;2.3)	0.4	0.4 (0.2;0.9)	0.8	0.9 (0.4;1.9)	1.0	0.8 (0.2;3.0)	0.4	0.4 (0.2;0.8)
≥60	0.4	0.5 (0.2;1.5)	1.9	2.1 (0.8;5.5)	0.4	0.4 (0.2;1.2)	1.6	1.7 (0.6;4.5)	0.6	0.4 (0.1;2.1)	0.3	0.3 (0.2;0.8)
Profession												
Biomedical Lab Scientists	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Medical doctors	2.2	1.4 (1.0;2.1)	7.5	5.9 (1.5;23.5)	3.3	2.5 (0.4;14.3)	14.7	8.5 (3.0;24.0)	1.1	0.5 (0.1;3.6)	0.6	0.4 (0.1;1.3)
Nursing staff	Insufficient data	Insufficient data	6.9	6.3 (1.8;21.5)	3.2	2.8 (0.5;16.9)	9.0	7.9 (2.6;24.2)	0.7	0.3 (0.1;2.0)	0.7	0.6 (0.2;1.6)
Department												
Emergency	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Anesthesiology	0.4	0.5 (0.2;1.1)	0.5	0.4 (0.2;1.1)	0.6	0.7 (0.4;1.2)	0.5	0.5 (0.2;1.2)	4.7	5.4 (1.915.0)	0.5	0.5 (0.3;1.1)
Surgical[c]	0.2	0.3 (0.1;0.7)	0.8	0.8 (0.3;2.4)	0.4	0.4 (0.3;0.8)	0.6	0.6 (0.2;1.5)	2.8	2.8 (1.1;7.5)	0.4	0.4 (0.2;0.7)
Medical[d]	0.3	0.4 (0.2;0.9)	0.4	0.5 (0.2;1.1)	0.4	0.4 (0.3;0.7)	0.4	0.4 (0.2;0.7)	0.9	0.9 (0.3;2.2)	0.3	0.3 (0.2;0.6)

[a]Face mask include the following: type IIR mask, mask with visor (typically type IIR) and other unspecified face masks.

[b]Adjusted for sex, age, profession, and department.

[c]All surgical departments, including: obstetrics and gynecology; otorhinolaryngology and head and neck surgery; and ophthalmology.

[d]Internal medicine, pediatrics, oncology, and neurology.

perform the same work task, e.g. transportation of patients, during the two waves, but the change in guidelines could reduce the need for wearing gloves. We speculate that gloves might have been used more uncritically during the first wave, including in situations where there was no indication for using gloves, in order to be on the safe side. Also, gloves were the PPE where most participants reported failures. In a review Mischke and colleges found 18.5 gloves perforations per 100 person-operations, but they only investigated perforations and not failures (Mischke *et al.*, 2014). Also, almost 70% of glove perforations are not identified by practitioners (Jahangiri *et al.*, 2022), and therefore, our findings of glove failures may be underestimated.

The decrease in PPE failure could be explained partly by the above-mentioned increase in training in PPE use, but also by the PPE being of varying quality (e.g. some batches of PPE had a falsified certificate) throughout the two waves (Proffitt, 2020; World Health Organization, 2020c).

During the first wave, 18.1% of the participants reported not using PPE during respiratory procedures but only 6.6% performing this task reported not complying with PPE guidelines. At first glance, this seems contradictory and could question the validity of participants' own assessment of compliance with guidelines. However, compliance with PPE guidelines presupposes that HCW know what proper use is and are trained to comply with PPE donning and doffing guidelines. Moreover, our findings are based on self-reported compliance, which is not necessarily the same as actual compliance with guidelines. In addition, the definition of respiratory procedures was partly left to the participant besides the mentioned examples (CPAP, PEP, intubation, or resuscitation), for which e.g. FFP2/FFP3 respirators or face masks were required when caring for patients with suspected or confirmed COVID-19. Importantly, FFP2/FFP3 respirators were only recommended when caring for patients with suspected or confirmed COVID-19. Therefore, we do not know if participants performed (other) respiratory procedures that did not require PPE according to the guidelines.

In this study showed availability of PPE was reported as an issue during the first wave, which is in accordance with the literature from other countries (Kim *et al.*, 2021; Mantelakis *et al.*, 2021; Rebmann *et al.*, 2021). This might only have been the case at the beginning of the first wave, but due to the resolution in the analysis, we cannot elaborate on this. More participants from the first wave reported that they were unaware of the necessity of PPE compared to the second wave. At the beginning of the first wave of the COVID-19 pandemic in Denmark, some hospitals experienced a rapid increase of COVID-19 patients causing lack of time to sufficiently train HCW in PPE guidelines. During the second wave, the training of HCW in PPE guidelines was more sufficient and systematic. Our results could be explained by participants being more experienced and trained in PPE use during the second wave, compared to the first. This is in accordance with the literature (Verbeek *et al.*, 2020; Piche-Renaud *et al.*, 2021).

PPE failure and non-compliance varied by age and sex and type of department, but with a decrease in the difference between the first and the second wave. Being a female and of older age decreased the risk for both failure and non-compliance, and we speculate whether this can be explained by sex based difference in behavior. The difference between emergency departments and the other departments in both failures of PPE and non-compliance with PPE guidelines across all types of PPE also decreased from the first wave to the second wave. Jespersen and colleagues (Jespersen *et al.*, 2021) found that the emergency departments in Denmark during the first wave of COVID-19 had the highest seroprevalence (29.7%) of SARS-CoV-2. Also, many of the Danish emergency departments acted as a gateway for COVID-19 patients into the rest of the hospital. We, therefore, speculate that emergency departments have experienced more awareness of and training in proper use of PPE from the first to the second wave.

Strengths and limitations

Major strengths of this study are the large study population, the prospective study design with day-by-day information, which minimizes the risk of recall issues, and the register-based information on sex, age, department, and profession.

Questionnaire data from the Central Denmark Region and the Capital Region of Denmark were combined even though data were not collected during the exact same periods. However, the periods overlap substantially and cover both the first and the second wave of the COVID-19 pandemic in Denmark. Furthermore, the source population and the study population from the two Regions were similar but not identical. Despite the differences, the answer patterns in the two Regions were almost identical.

It is possible that HCW less likely to use PPE would not participate in the study, but this would be expected to be the case for both waves of questionnaires, and thus, would not explain the differences in PPE usage found between the first and the second wave.

The complexity of the questionnaire was high. Participants were able to give multiple answers to work tasks and PPE use. If a participant had two or more tasks and used two or more PPE it was not possible to differentiate between specific PPE used for a specific work task, but if we should have accommodated this in more detail, the questionnaire would have increased significantly in length, possibly leading to less participation.

Generalisability

Due to differences in age and sex distribution among participants and non-participants, our study population is not entirely representative of the source population (HCW at hospitals in Denmark), but still, we anticipate the external validity to be reasonably good.

This study indicates that the focus on prevention of SARS-CoV-2 transmission should be on PPE guideline compliance, but that good quality of PPE to avoid PPE failure is also of importance.

Conclusion

In this study, we observed a substantial increase in use of PPE and a substantial decrease in PPE failure among healthcare workers from the first to the second wave of the COVID-19 pandemic in Denmark. PPE failure and non-compliance varied by age, sex, and type of department. There is still a need for continued focus on compliance with PPE guidelines.

SUPPLEMENTARY DATA

Supplementary data are available at *Annals of Work Exposures and Health* online.

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Conflict of interest

All authors declare no conflicts of interest.

Data availability

The data underlying this paper cannot be shared publicly due to the privacy of the individuals who participated in the study, but data can be shared in an anonymized form on reasonable request to the corresponding author.

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