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Ethnicity and risk of SARS-CoV-2 infection among the healthcare workforce: Results of a retrospective cohort study in rural United Kingdom.

Maxime Inghels*[1,2], Ros Kane[3], Priya Lall[1,4], David Nelson[1], Agnes Nanyonjo[1], Zahid Asghar[3], Derek Ward[5], Tracy McCranor[6], Tony Kavanagh[6], Todd Hogue[7], Jaspreet Phull[6], Frank Tanser[1,8]

Materials & Correspondence:

Dr Maxime Inghels

Lincoln International Institute for Rural Health

University of Lincoln. Brayford Pool, Lincoln, Lincolnshire. LN6 7TS

tel: +44 (0)1522 88 6208

maxime.inghels@gmail.com

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[1] Lincoln International Institute for Rural Health, University of Lincoln, Lincoln, UK.
[2] Centre Population et Développement (UMR 196 Paris Descartes – IRD), SageSud (ERL INSERM 1244), Institut de Recherche pour le Développement, Paris, France.
[3] School of Health and Social Care, University of Lincoln, UK.
[4] London Interdisciplinary School, London, UK.
[5] Lincolnshire County Council, UK.
[6] Lincolnshire Partnership NHS Foundation Trust, Lincolnshire, UK.
[7] School of Psychology, University of Lincoln, UK.
[8] School of Nursing and Public Health, University of KwaZulu-Natal, Durban South Africa.

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Abstract

Background: The reason why Black and South Asian healthcare workers are at a higher risk of SARS-CoV-2 infection remain unclear. We aim to quantify risk of SARS-CoV-2 infection among ethnic minority healthcare staff and elucidate pathways of infection.

Methods: A one-year-follow-up retrospective cohort study has been conducted among NHS employees working at 123 facilities in Lincolnshire, UK.

Results: Overall, 13,366 professionals were included. SARS-CoV-2 incidence per person-year was 5.2% [95%CI: 3.6%–7.6%] during the first COVID-19 wave (Jan-Aug 2020) and 17.2% [13.5%–22.0%] during the second wave (Sep 2020-Feb 2021). Compared to White staff, Black and South Asian employees were at higher risk of SARS-CoV-2 infection during both the first wave (HR, 1.58 [0.91-2.75] and 1.69 [1.07-2.66] respectively) and the second wave (HR 2.09 [1.57-2.76] and 1.46 [1.24-1.71]). Higher risk of SARS-CoV-2 infection persisted even after controlling for age, gender, pay grade, residence environment, type of work and time exposure at work. Higher adjusted risk of SARS-CoV-2 infection were also found among lower-paid health professionals.

Conclusions: Black and South Asian health workers continue to be more at risk of SARS-CoV-2 infection compared to their White counterparts. Urgent interventions are required to reduce SARS-CoV-2 infection in these ethnic groups.

key words: SARS-CoV-2; COVID-19; risk factors; ethnicity; health profession; United Kingdom.

Introduction

To date, nearly 18 million confirmed cases of SARS-CoV-2 infection have been reported in the UK (WHO, n.d.). Because they are at the frontline of the outbreak, healthcare workers are particularly exposed to SARS-CoV-2 infection (Houlihan et al., 2020; Hunter et al., 2020). Despite supply of personal protective equipment and adoption of social distancing and shielding measures, healthcare staff continue to be more affected by COVID-19 compared to the general population (Nguyen et al., 2020; Office for National Statistics, 2021).

Risk of infection varies among healthcare staff. In the UK, studies indicate that professionals in face-to-face contact with patients (e.g. porters, healthcare assistants and nurses) are more likely to be infected by SARS-CoV-2 than those who are not (Eyre et al., 2020; Martin et al., 2020). Furthermore, healthcare professionals from Black and South Asian backgrounds display a high risk of SARS-CoV-2 infection (Nguyen et al., 2020; Eyre et al., 2020; Martin et al., 2020; Shields et al., 2021; Valdes et al., 2021; Ken-Dror et al., 2021; Hanrath et al., 2021; Shields et al., 2020; Shorten et al., 2021; Patel et al., 2021; Kua et al., 2021). However, many studies investigating risk factors for SARS-CoV-2 infection have limitations; the primary being that they adopt cross-sectional designs, so are unable to demonstrate causality. These studies also collect data from a limited number of health facilities inhibiting it representativeness and present unadjusted results or omit important confounding variables (e.g., occupational exposure, residential environment).

A key outstanding question in this area is "to what extent are the observed differences in ethnicity risk explained by differences in job profile and other socio-economic and environmental conditions?". In high income countries, Ethnic minorities are more likely to work in high-risk public-facing jobs including frontline medical positions (Hayward et al.,

2021). They are also more likely to have a lower economic status which has been shown to be associated with higher COVID-19 prevalence in the general population (Chaudhuri et al., 2021; Ho et al., 2020). Yet, the association between socio-economic deprivation of the home environment and SARS-CoV-2 infection in health care workers differs among studies (Hanrath et al., 2021; Martin et al., 2020; Shields et al., 2020; Valdes et al., 2021). Furthermore, the socioeconomic factors that are considered are mainly area based and other individual-based characteristics, such as professional grade or salary, are rarely considered. In addition, SARS-CoV-2 infection risks in rural environments remained poorly described in UK (Asghar et al., 2021).

To quantify changing patterns of infection risk, one needs to go beyond the first wave of the pandemic. However, to date, few studies examine the impact of the second wave of the outbreak on healthcare professionals in the UK (Ken-Dror et al., 2021; Shields et al., 2021). Understanding the evolution of SARS-CoV-2 infection risk factors across the different waves of the pandemic is important to observe if the generalisation and adoption of mitigation measures (e.g. provision of personal protective equipment, vaccination roll-out) have reduced sociodemographic and economic risk inequalities between healthcare staff. The aim of this study is to quantify risk of COVID-19 infection among ethnic minority healthcare workers and elucidate pathway of infection by considering underlying differences in demographics, socioeconomic status, residential environment and occupational exposure.

Methods

Design and Settings

An occupational and retrospective cohort study has been conducted among all employees (both clinical and non-clinical) working at 123 facilities in Lincolnshire, a predominantly rural

region in the UK. Staff are employed at one of three hospital trusts namely: Lincolnshire Partnership NHS Foundation Trust, Lincolnshire Community Health Services and United Lincolnshire Hospitals NHS Trusts. These facilities include 11 hospitals, 44 GP medical practices or health centres, 47 other medical facilities (e.g. hospices) and 21 non-medical health facilities (e.g. NHS headquarters, county offices). Majority of staff are hospital-based (72.3%).

Population included

From 1ˢᵗ January 2020 to 10ᵗʰ February 2021, all employees working in the three trusts were retrospectively followed using data routinely collected by human resources departments. Students working in these facilities were excluded from our analysis because their staff group assignment was not reported. Healthcare staff documented as working in different facilities or those not assigned to a specific facility during the same period were also excluded from the study. Individuals belonging to more than one staff group during a given period were assigned to the staff group where the individual spent most of their time.

Data collected

Data collected included demographics (i.e. age, sex, ethnic group), economic status (i.e. NHS pay grade), occupational exposure (i.e. staff group, number of hours worked each weekend, number of NHS staff working in the facility, self or house isolation periods and leaving absence periods), clinical factors (i.e. number of non-COVID-19 related diseases occurring prior SARS-CoV-2 infection during the observation period) and home environment (i.e. UK Index of multiple deprivation—IMD, UK urban-rural classification, household size mean). Ethnic group reported by each employee were categorised as White–British, other White minorities (e.g., Europeans), Southern Asian (i.e. Pakistanis, Indians and Bangladeshis), other

Asian minorities, Black (including Black African and Caribbean) and Mixed group or other. NHS pay grade varies according to NHS body band 1 to 9, with band 1 indicating lower salaries (starting at around 24,830 US dollars per year) while the highest band indicates a higher salary (starting at around 125,483 US dollars per year). The rural-urban classification and the household size mean from 2010 and the IMD from 2019 were linked for each individual by merging the lower layer super output area associated to their home postcode with UK census data. Leaving absences (excluding infection precaution or isolation) and self or house isolation periods (including COVID-19 shielding or infection precaution reasons) were measured through the start and end date of these periods. Any change in the situation of the employee (e.g., staff group, isolation period) during the observation period were collected.

SARS-CoV-2 positive test were routinely collected through the human resources departments of each trust. Following UK National Health Service (NHS) recommendations, before November 2020, NHS staff were tested using PCR-based SARS-CoV-2 tests in the case of COVID-19 related symptoms or contact with COVID-19 cases (Public Health England, 2021). Since November 2020, the NHS provided lateral Flow antigen self-test kits and recommended that staff performed regular SARS-CoV-2 tests (at least twice a week) even in the absence of symptoms, and performed a PCR confirmation test in case of positive lateral flow antigen test results. PCR tests were implemented in dedicated testing centres or health services during the study period. In the case of a positive PCR test result, individuals were legally required to report the result to their human resources department and self-isolate.

Statistical analysis

Bivariate analysis of SARS-CoV-2 positive test prevalence by the collected variables was conducted. SARS-CoV-2 positive test incidence rates per person-year were documented and cluster-adjusted on the place of work.

Survival analysis was conducted to measure the hazard risk ratio of positive SARS-CoV-2 test occurrence. For each individual, observation period was left truncated by the start date of the study observation or the start date of employment contract if that date occurred after the beginning of the study observation. The observation period was also right truncated by the study observation period end date, the end of the contract date or the date of occurrence of the first positive SARS-CoV-2 test.

Bivariate analysis between a SARS-CoV-2 positive test and other variables of interest was conducted using the log-rank test on Kaplan-Meier estimators (Kaplan and Meier, 1958). Then, we ran bivariate and multivariate cox regression models depending on the period of observation: all the study period, first and second COVID-19 wave (Cox, 1972). The first wave (i.e. wave 1) was defined as the period from 1st of January 2020 - 31st August 2020 and the second wave, the period between 1st September 2020 - 10th February 2021 (Mathur et al., 2021). All initial variables of interest were included in the multivariate model. Because data on leaving absence (other than COVID-19 related) was not available for a trust representing 13.7% of our sample, we assumed this value to be zero in the Cox models to avoid sample attrition.

Robust variances were computed to consider repeat measured were at individual level and the cluster effect on the place of work in the survival analysis. Intra group comparisons were conducted using pairwise comparison tests with adjusted p-values for multiple hypothesis

testing using Holm correction (Holm, 1979). Analysis were conducted using the package "survival" from the software R version 4.0.2. (R Core Team, 2021; Therneau, 2021).

Sensitivity Analyses

Complete case analysis for bivariate and multivariate cox models (i.e. exclusion of the individuals with missing values for the number of leaving absence days) has been conducted for sensibility analysis.

Results

Baseline characteristics

Overall, we collected data from 13,880 healthcare professionals. Among them, 56 were documented as working in more than one medical facility and 44 were not based in any facilities and were thus excluded from the analysis. Additionally, we removed 58 students as their staff group were not mentioned. An additional 356 individuals with missing values have been removed leading to 13,366 individuals included in our final sample. The selection process led to the exclusion of 4 of the initial 123 health facilities. The mean average follow-up by individual was 356 days; only 24% of the individuals included were followed less than 407 days (the maximum follow-up).

The cohort comprised mainly women (79.8%, Table 1). White individuals represented 87.9% of the cohort while South Asian and Black employees represented 5.3% and 1.9%, respectively. Employees included at the first COVID-19 wave have similar demographic characteristics to those included in the second wave (Supplementary material, Table S1)

There were 1,258 individuals (9.4%) with a documented SARS-CoV-2 positive test with 397 and 861 cases occurring during the first and the second waves respectively (Table 1,

Figure 1). Overall, the number of documented positive tests for SARS-CoV-2 increased during the second wave, with some heterogeneity between sub-groups (Table S2).

The two largest health facilities accounted for 65.4% of the total cases. Incidence of SARS-CoV-2 positive test during the observation period were highly heterogenous between health facilities (Supplementary materials, Figure S1).

SARS-CoV-2 infection incidence

The overall SARS-CoV-2 infection incidence per person-year was 10.0% [cluster adjusted 95% confidence interval (CI): 8.8%–11.4%]. During the first wave, the incidence was 5.2% [3.6%–7.6%], whilst it was 17.2% [13.5%–22.0%] during the second wave. Incidence was higher for Black employees (18.6% [13.7%–25.3%]) and South Asian (14.7% [11.9%–18.1%]) compared to White staff (9.5% [8.3%–11.0%]). Higher SARS-CoV-2 incidence was also found among additional clinical service staff (14.8% [11.7%–18.7%]) and nurses (12.4% [11.0%–14.1%]).

Probability of SARS-CoV-2 infection

Using Kaplan-Meyer curves, we found that Black employees had significantly higher probability to test positive for SARS-CoV-2 infection compared to White staff at 6 months of follow-up (7.1% [2.6%–11.4%] vs 3.4% [2.3%–4.5%], Holm-corrected p-value=0.018) and at the end of the observation period (20.9% [14.5%–26.8%] vs 10.5% [9.0%–12.0%], p<0.001) (Figure 2.A.). Similar results were found for South Asian employees (6.8% [3.9%–9.5%] vs 3.4% [2.3%–4.5%], p<0.001, at 6 months and, 15.8% [13.5%–18.0%] vs 10.5% [9.0%–12.0%], p<0.001, at the end of the observation period). Women and employees with lower NHS pay grades were also found with a significantly higher probability for SARS-CoV-2 infection (Figure 2.C. and 2.D.).

Adjusted and unadjusted hazard risks for SARS-CoV-2 infection

Compared to White staff, Black and South Asian employees were at higher risk of SARS-CoV-2 positive test but above the significance threshold of 0.05 during the first wave (Clustered adjusted Hazard Ratio, HR 1.58 [0.91-2.75], Holm-corrected p-value=0.311, and 1.69 [1.07-2.66], p=0.119, respectively) and below that significance threshold during the second wave (HR 2.09 [1.57-2.76], p<0.001, and 1.46 [1.24-1.71], p<0.001) (Figure 3, associated tables can be found in supplement material, Tables S3 and S4). Higher significant risks of SARS-CoV-2 infection were still found among Black during the second wave (wave 1: aHR 1.80 [1.07-3.02], p=0.109; wave 2: aHR 2.12 [1.70-2.64], p<0.001) and among South Asian employees during both waves (wave 1: aHR 2.05 [1.33-3.15], p=0.005; wave 2: aHR 1.50 [1.10-2.03], p=0.038) after adjusting for demographics, economic situation, occupational exposure, clinical factors and home environment.

Overall, women (aHR 1.27 [1.06-1.52], p=0.009) and employees with the lowest paygrade (vs highest, aHR 2.93 [2.00-4.35], p<0.001) were at higher risk of SARS-CoV-2 infection. Residential characteristics such as rural-urban classification, IMD and household size mean were not found to be significantly associated with SARS-CoV-2 infection in both adjusted and unadjusted models.

Experiencing a number of isolation days for two weeks or less was significantly associated with a higher risk of positive SARS-CoV-2 test (vs none, aHR 2.17 $CI_{95\%}$[1.79-2.63], p<0.001), but not when that number exceeded two weeks (vs none, aHR 0.97 $CI_{95\%}$[0.82-1.15], p=0.764).

Sensitivity analysis

In the complete case analysis, results from the Cox multivariate models were similar to those previously presented except for IMD of the healthcare workers residence which was significantly associated with SARS-CoV-2 infection in the complete case analysis, although the effects remained small (Figure S2).

Discussion

Our results demonstrated a 110% excess risk of SARS-CoV-2 infection among Black healthcare workers (relative to their white counterparts) in a large occupational cohort in the predominantly rural English county of Lincolnshire. The corresponding figures for South Asian healthcare workers was more than 60%. These excess risks were not fully explained by demographics, economic situation, occupational exposure, clinical factors or home environment. Whilst SARS-CoV-2 infection incidence increased during the second wave of the pandemic, risk groups remained similar between the first and second COVID-19 outbreak waves.

One of the major contributions of our study is to rigorously quantify the higher risk of being infected by the SARS-CoV-2 virus among ethnic minorities in the healthcare workforce during both outbreak waves of the pandemic. Our results support previous findings showing higher risk of SARS-CoV-2 infection among Black and South Asian healthcare workers in the UK (Nguyen et al., 2020; Eyre et al., 2020; Martin et al., 2020; Shields et al., 2021; Valdes et al., 2021; Ken-Dror et al., 2021; Hanrath et al., 2021; Shields et al., 2020; Shorten et al., 2021; Patel et al., 2021; Kua et al., 2021). Yet, our research is one of the first to have considered more than 1 year of follow-up and found no differential changes in SARS-CoV-2 exposure by

ethnic group between waves. Similar results have been found in general population in another high income country (Coyer et al., 2022). While Black and Asian communities were considered to be at higher risk for SARS-CoV-2 infections during the first wave of the pandemic, their persistent higher risk during the second wave suggests that interventions aimed at protecting them were either absent or failed in reducing their occupational risk (Public Health England, 2020; Iacobucci, 2020). Considering the fact that these communities tend to have worse clinical outcomes when tested positive for COVID-19 (Chaudhuri et al., 2021; Mathur et al., 2021), tailored interventions, as well as, improved access to vaccination are urgently needed to protect ethnic minority essential workers (Iacobucci, 2020; Race Disparity Unit, Cabinet Office, 2021).

A second contribution of this paper is to show persistent infection risk among Black and South Asian communities even after adjusting on demographics, economic situation, occupational exposure, clinical factors or home environment. In other words, the occupational, socio-economic and environmental conditions do not fully explain the persistent higher risk among Black and South Asian NHS staff in our study. This persistent higher risk may suggest other potentials risk factors that were not collected or partially collected in our analysis. For example, this persistent risk could be explained by the non-access to or inadequate use of personal protective equipment found in other studies (Nguyen et al., 2020; Valdes et al., 2021). In addition, while economic and social home environment through IMD and rural-urban classification of home residence were considered in our analysis, some important factors such as household composition or use of public transport have not been included (Katikireddi et al., 2021). It is also possible that other occupational exposures such as working location (e.g., intensive care) explain the higher exposure in several ethnic minorities (Eyre et al., 2020).

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Our findings reinforce the results from other studies showing the limited effect of the index of multiple deprivation among healthcare professionals (Shields et al., 2020; Valdes et al., 2021). The index of multiple deprivation is an area-level indicator rather than individual level socioeconomic-position which may not be representative of every individual, especially those currently working and who may be less likely to be affected by the environment in which they live. However, after adjusting on other individual characteristics and staff group, we did find that having a lower salary was associated with the risk of being tested positive for SARS-CoV-2. This last result could actually reflect other social inequalities such as public transport dependence to go to work or overcrowded housing that are liked to higher SARS-CoV-2 exposure (Hayward et al., 2021).

Another strength of our analysis is to have considered exposure time at work. As expected, those spending more time at work and those who did not take any leave days were those more likely to be tested positive for SARS-CoV-2, which suggests that these professionals were mainly infected at work and not outside of their workplace. Alternatively this result could be explained by the fact that exposed health staff (e.g., intensive care or emergency department workers) may have taken less time off work because of the increased demand for care caused by the pandemic. Regarding isolation periods, our result showed higher risk of SARS-CoV-2 infection among those self-isolating for less than two weeks compared to those isolating more time. Staff required to self-isolated for two weeks were often those who have been exposed to COVID-19 cases while those required to self-isolated for a long period were mainly vulnerable staff (e.g., pregnant women, older employee) asked to shield from a potential SARS-CoV-2 infection.

Our results show that staff groups such as nurses, doctors, and additional clinical services (i.e., healthcare assistants, support workers) were found to be at higher risk of SARS-CoV-2-infection. This result is expected as these staff groups are in close contact with patients and are such more likely to be exposed to SARS-CoV-2-infection (Hayward et al., 2021).

Our study has several limitations. First, SARS-CoV-2 tests were mostly targeted to symptomatic or contact cases during the first wave which may have underestimate SARS-CoV-2 incidence in our results. Second, we were not able to access data on the number of tests performed by individuals and specifically, the negative ones, as only the positive results were collected. Thus, it was not possible to control our results on the number of tests done by individuals. However, ethnic differences in testing are shown to be small during the first two waves of the pandemic (Mathur et al., 2021). Therefore, the higher risk of a positive SARS-CoV-2 test among ethnic minorities is unlikely to be a result of a higher number of tests performed. Vaccination status was not collected at the time of the study, although vaccination roll out began for frontline healthcare professionals in mi-December 2020, 60 days before the end of our study follow-up which may have limited the effect of vaccination on our result (Medicines and Healthcare products Regulatory Agency (MHRA), 2020). The reason for sick leave was not available for more of our population, thus we were not able to consider specific conditions (e.g. diabetes, cardiovascular disease, other infections), although most of these conditions are more associated with a higher risk of COVID-19 related mortality than with a higher risk of infection (de Lusignan et al., 2020; Piroth et al., 2021; Shields et al., 2021).

Nevertheless, our survey is one of the first to document SARS-CoV-2 exposure across one year of follow-up among a large population of healthcare professionals at a regional level. The fact that we included the three NHS trusts operating within the region has facilitated a comprehensive sample. Yet it is possible that private sector structures as well as several GP surgeries may not have been included in our study. Because most of these structures were doing online consultation or referring people to the hospital in case of severe symptoms of COVID-19, professionals working in these structures could have been less exposed to SARS-CoV-2 infections than those working in a hospital setting.

Evidence indicates low vaccine coverage among healthcare workers especially with Black and south Asian groups (Martin et al., 2021). Vaccine hesitancy has been shown to be higher in ethnic minority groups as well as in the most socio-economic deprived areas (Razai et al., 2021). This disparity in vaccination uptake could lead to the increasing risk of SARS-CoV-2 infection in these communities during future waves of the outbreak. Reducing access inequalities to protective intervention and measures is urgently needed.

Conclusion

Black and South Asian healthcare workers were consistency at risk of SARS-CoV-2 infection independent of the period considered. Risk exposure inequalities based on pay grades and gender were also found in our results. Research on interventions aiming to reduce socio-economic and occupational based SARS-CoV-2 exposure with these vulnerable groups are urgently needed.

Ethical approval: Data sharing agreements were signed with each trust who provided their data. Given that we were working with a routinely collected existing NHS staff dataset, there was no active recruitment of participants. In addition, the dataset was provided anonymised, therefore there was no direct approach from the research team for informed consent. The study received a favourable ethical opinion from the Human Ethics Committee at the University of Lincoln on the 28 May 2020 (REC Ref: 2020-3511).

References

Asghar ZB, Ward D, Huntly P, Inghels M, Tanser F. COVID-19 (SARS-CoV-2) Outbreaks in Rural United Kingdom: Patterns of Spread and Empirical Evidence for the "Rule of Six." Rochester, NY: Social Science Research Network; 2021. https://doi.org/10.2139/ssrn.3807267.

Chaudhuri K, Chakrabarti A, Lima JM, Chandan JS, Bandyopadhyay S. The interaction of ethnicity and deprivation on COVID-19 mortality risk: a retrospective ecological study. Sci Rep 2021;11:11555. https://doi.org/10.1038/s41598-021-91076-8.

Cox DR. Regression Models and Life-Tables. J R Stat Soc Ser B Methodol 1972;34:187–202. https://doi.org/10.1111/j.2517-6161.1972.tb00899.x.

Coyer L, Boyd A, Schinkel J, Agyemang C, Galenkamp H, Koopman ADM, et al. Differences in SARS-CoV-2 infections during the first and second wave of SARS-CoV-2 between six ethnic groups in Amsterdam, the Netherlands: A population-based longitudinal serological study. Lancet Reg Health Eur 2022;13:100284. https://doi.org/10.1016/j.lanepe.2021.100284.

Eyre DW, Lumley SF, O'Donnell D, Campbell M, Sims E, Lawson E, et al. Differential occupational risks to healthcare workers from SARS-CoV-2 observed during a prospective observational study. ELife 2020;9:e60675. https://doi.org/10.7554/eLife.60675.

Hanrath AT, Schim van der Loeff I, Lendrem DW, Baker KF, Price DA, McDowall P, et al. SARS-CoV-2 Testing of 11,884 Healthcare Workers at an Acute NHS Hospital Trust in England: A Retrospective Analysis. Front Med 2021;8:636160. https://doi.org/10.3389/fmed.2021.636160.

Hayward SE, Deal A, Cheng C, Crawshaw A, Orcutt M, Vandrevala TF, et al. Clinical outcomes and risk factors for COVID-19 among migrant populations in high-income countries: A systematic review. J Migr Health 2021;3:100041. https://doi.org/10.1016/j.jmh.2021.100041.

Ho FK, Celis-Morales CA, Gray SR, Katikireddi SV, Niedzwiedz CL, Hastie C, et al. Modifiable and non-modifiable risk factors for COVID-19, and comparison to risk factors for influenza and pneumonia: results from a UK Biobank prospective cohort study. BMJ Open 2020;10:e040402. https://doi.org/10.1136/bmjopen-2020-040402.

Holm S. A Simple Sequentially Rejective Multiple Test Procedure. Scand J Stat 1979;6:65–70.

Houlihan CF, Vora N, Byrne T, Lewer D, Kelly G, Heaney J, et al. Pandemic peak SARS-CoV-2 infection and seroconversion rates in London frontline health-care workers. The Lancet 2020;396:e6–7. https://doi.org/10.1016/S0140-6736(20)31484-7.

Hunter E, Price DA, Murphy E, Loeff IS van der, Baker KF, Lendrem D, et al. First experience of COVID-19 screening of health-care workers in England. The Lancet 2020;395:e77–8. https://doi.org/10.1016/S0140-6736(20)30970-3.

Iacobucci G. Covid-19: PHE review has failed ethnic minorities, leaders tell BMJ. BMJ 2020;369:m2264. https://doi.org/10.1136/bmj.m2264.

Kaplan EL, Meier P. Nonparametric Estimation from Incomplete Observations. J Am Stat Assoc 1958;53:457–81. https://doi.org/10.1080/01621459.1958.10501452.

Katikireddi SV, Lal S, Carrol ED, Niedzwiedz CL, Khunti K, Dundas R, et al. Unequal impact of the COVID-19 crisis on minority ethnic groups: a framework for understanding and addressing inequalities. J Epidemiol Community Health 2021;75:970–4. https://doi.org/10.1136/jech-2020-216061.

Ken-Dror G, Wade C, Sharma SS, Irvin-Sellers M, Robin J, Fluck D, et al. SARS-CoV-2 antibody seroprevalence in NHS healthcare workers in a large double-sited UK hospital. Clin Med 2021;21:e290–4. https://doi.org/10.7861/clinmed.2020-1096.

Kua J, Patel R, Nurmi E, Tian S, Gill H, Wong DJN, et al. healthcareCOVID: a national cross-sectional observational study identifying risk factors for developing suspected or confirmed COVID-19 in UK healthcare workers. PeerJ 2021;9:e10891. https://doi.org/10.7717/peerj.10891.

de Lusignan S, Dorward J, Correa A, Jones N, Akinyemi O, Amirthalingam G, et al. Risk factors for SARS-CoV-2 among patients in the Oxford Royal College of General Practitioners Research and Surveillance Centre primary care network: a cross-sectional study. Lancet Infect Dis 2020;20:1034–42. https://doi.org/10.1016/S1473-3099(20)30371-6.

Martin CA, Marshall C, Patel P, Goss C, Jenkins DR, Ellwood C, et al. SARS-CoV-2 vaccine uptake in a multi-ethnic UK healthcare workforce: A cross-sectional study. PLOS Med 2021;18:e1003823. https://doi.org/10.1371/journal.pmed.1003823.

Martin CA, Patel P, Goss C, Jenkins DR, Price A, Barton L, et al. Demographic and occupational determinants of anti-SARS-CoV-2 IgG seropositivity in hospital staff. J Public Health Oxf Engl 2020:fdaa199. https://doi.org/10.1093/pubmed/fdaa199.

Mathur R, Rentsch CT, Morton CE, Hulme WJ, Schultze A, MacKenna B, et al. Ethnic differences in SARS-CoV-2 infection and COVID-19-related hospitalisation, intensive care unit admission, and death in 17 million adults in England: an observational cohort study using the OpenSAFELY platform. The Lancet 2021;397:1711–24. https://doi.org/10.1016/S0140-6736(21)00634-6.

Medicines and Healthcare products Regulatory Agency (MHRA). UK medicines regulator gives approval for first UK COVID-19 vaccine. GOVUK 2020. https://www.gov.uk/government/news/uk-medicines-regulator-gives-approval-for-first-uk-covid-19-vaccine.

Nguyen LH, Drew DA, Graham MS, Joshi AD, Guo C-G, Ma W, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. Lancet Public Health 2020;5:e475–83. https://doi.org/10.1016/S2468-2667(20)30164-X.

Office for National Statistics. Coronavirus (COVID-19) related deaths by occupation, England and Wales. Off Natl Stat Website 2021. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/causesofdeath/bulletins/coronaviruscovid19relateddeathsbyoccupationenglandandwales/deathsregisteredbetween9marchand28december2020 (accessed July 22, 2021).

Patel M, Nair M, Pirozzoli E, Cienfuegos MC, Aitken E. Prevalence and socio-demographic factors of SARS-CoV-2 antibody in multi-ethnic healthcare workers. Clin Med 2021;21:e5–8. https://doi.org/10.7861/clinmed.2020-0619.

Piroth L, Cottenet J, Mariet A-S, Bonniaud P, Blot M, Tubert-Bitter P, et al. Comparison of the characteristics, morbidity, and mortality of COVID-19 and seasonal influenza: a nationwide,

population-based retrospective cohort study. Lancet Respir Med 2021;9:251–9. https://doi.org/10.1016/S2213-2600(20)30527-0.

Public Health England. COVID-19: management of staff and exposed patients or residents in health and social care settings. GOVUK 2021. https://www.gov.uk/government/publications/covid-19-management-of-exposed-healthcare-workers-and-patients-in-hospital-settings/covid-19-management-of-exposed-healthcare-workers-and-patients-in-hospital-settings (accessed September 8, 2021).

Public Health England. Disparities in the risk and outcomes of COVID-19. London: Public Health England; 2020.

R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2021.

Race Disparity Unit, Cabinet Office. Third quarterly report on progress to address COVID-19 health inequalities. GOVUK 2021. https://www.gov.uk/government/publications/third-quarterly-report-on-progress-to-address-covid-19-health-inequalities/third-quarterly-report-on-progress-to-address-covid-19-health-inequalities (accessed July 16, 2021).

Razai MS, Osama T, McKechnie DGJ, Majeed A. Covid-19 vaccine hesitancy among ethnic minority groups. BMJ 2021;372:n513. https://doi.org/10.1136/bmj.n513.

Shields A, Faustini SE, Perez-Toledo M, Jossi S, Aldera E, Allen JD, et al. SARS-CoV-2 seroprevalence and asymptomatic viral carriage in healthcare workers: a cross-sectional study. Thorax 2020;75:1089–94. https://doi.org/10.1136/thoraxjnl-2020-215414.

Shields AM, Faustini SE, Kristunas CA, Cook AM, Backhouse C, Dunbar L, et al. COVID-19: Seroprevalence and Vaccine Responses in UK Dental Care Professionals. J Dent Res 2021:00220345211020270. https://doi.org/10.1177/00220345211020270.

Shorten RJ, Haslam S, Hurley MA, Rowbottom A, Myers M, Wilkinson P, et al. Seroprevalence of SARS-CoV-2 infection in healthcare workers in a large teaching hospital in the North West of England: a period prevalence survey. BMJ Open 2021;11:e045384. https://doi.org/10.1136/bmjopen-2020-045384.

Therneau T. A package for survival analysis in R. 2021.

Valdes AM, Moon JC, Vijay A, Chaturvedi N, Norrish A, Ikram A, et al. Longitudinal assessment of symptoms and risk of SARS-CoV-2 infection in healthcare workers across 5 hospitals to understand ethnic differences in infection risk. EClinicalMedicine 2021;34:100835. https://doi.org/10.1016/j.eclinm.2021.100835.

WHO. Coronavirus (COVID-19) Dashboard n.d. https://covid19.who.int (accessed June 23, 2021).

Figure legends

Figure 1. Evolution of the number of positive SARS-CoV-2 test by facility size.

Note1: each rectangle represents a facility. The height of the rectangle is depending on the number of documented SARS-CoV-2 positive tests.

Note2: Data were obtained through February 10, 2021.
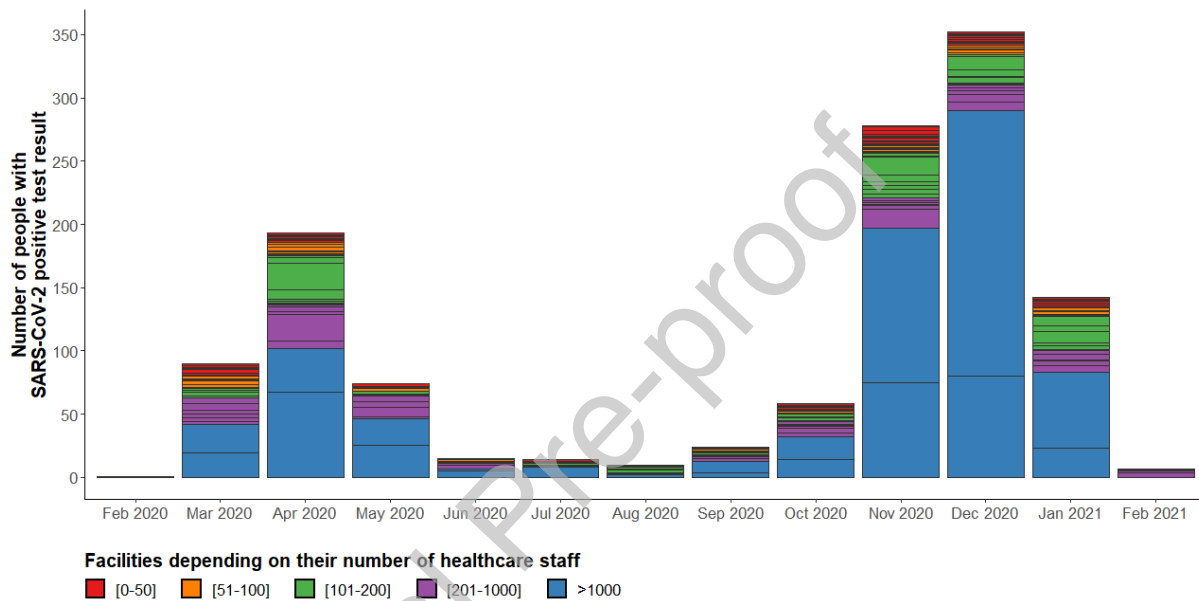
Figure 2. Cumulative event curves, based on Kaplan-Meyer estimates, of COVID-19 positive test among healthcare professional by ethnic background (A), by staff group (B), by sex (C) and NHS salary grade (D).

Note1: two-sided p-values were computed using the logrank test.

Note2: NHS body band 1 is corresponding to the lower salary grade while NHS body band 9 is corresponding to the higher pay grade
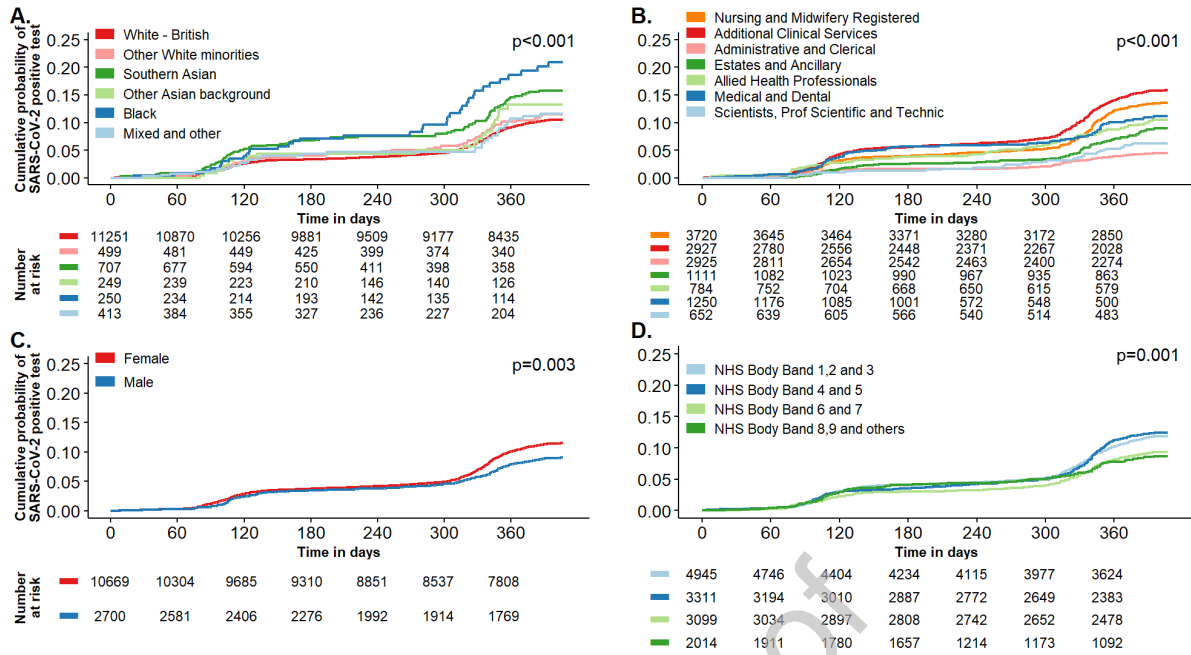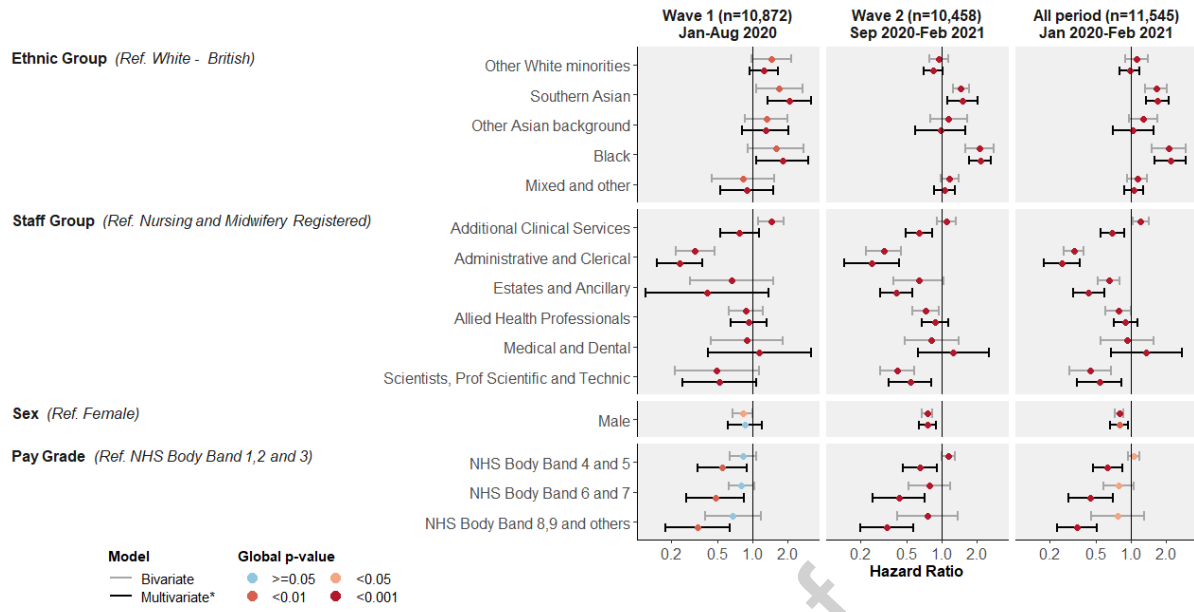
Figure 3. Hazard ratio of COVID-19 positive test among healthcare professional by time period, bivariate and multivariate cox models.

* adjusted on age, contract type, index of multiple deprivation, urban-rural classification, number of Non-COVID diseases, number of isolation days and number of other leaving absence days. The associated result table with all the covariables can be found in Table S2 and Table S3 in supplementary materials

Note1: two-sided p-values were computed using Wald-test adjusted for clustering.

Note2: NHS body band 1 is corresponding to the lower salary grade while NHS body band 9 is corresponding to the higher pay grade

Note3: logarithmic scale has been used for the Hazard ratio axis

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Ethnic Group *(Ref. White - British)*

Staff Group *(Ref. Nursing and Midwifery Registered)*

Sex *(Ref. Female)*

Pay Grade *(Ref. NHS Body Band 1,2 and 3)*

Table 1. Population characteristics and SARS-CoV-2 prevalence during the study period (n=13,366).

	Headcount		Tested positive for SARS-CoV-2		p-value[1]
	N	%	n	% (n/N)	
Sex					<0.001
Female	10 667	**79.8**	1 062	**10.0**	
Male	2 699	**20.2**	196	**7.3**	
Age					0.002
30 and below	2 619	**19.6**	259	**9.9**	
31-40	2 976	**22.3**	290	**9.7**	
41-50	3 000	**22.4**	307	**10.2**	
51-60	3 462	**25.9**	317	**9.2**	
61 and over	1 309	**9.8**	85	**6.5**	
Ethnic group					0.009
White - British	11 248	**84.2**	1 035	**9.2**	
Other White minorities	499	**3.7**	48	**9.6**	
Southern Asian[2]	707	**5.3**	83	**11.7**	
Other Asian background	249	**1.9**	23	**9.2**	
Black[3]	250	**1.9**	36	**14.4**	
Mixed and other	413	**3.1**	33	**8.0**	
Staff group					<0.001
Additional Clinical Services	2 926	**21.9**	399	**13.6**	
Administrative and Clerical	2 925	**21.9**	113	**3.9**	
Allied Health Professionals	784	**5.9**	71	**9.1**	
Estates and Ancillary	1 111	**8.3**	87	**7.8**	
Medical and Dental	1 250	**9.4**	96	**7.7**	
Nursing and Midwifery Registered	3 719	**27.8**	458	**12.3**	
Scientists, Prof Scientific and Technic	654	**4.9**	34	**5.2**	
Pay grade					0.072
NHS Body Band 1, 2 and 3	4 945	**37.0**	509	**10.3**	
NHS Body Band 4 and 5	3 310	**24.8**	355	**10.7**	
NHS Body Band 6 and 7	3 097	**23.2**	263	**8.5**	
NHS Body Band 8, 9 and others[4]	2 014	**15.1**	131	**6.5**	
Contract type					0.179

Part-time	5 809	**43.5**	523	**9.0**	
Full-time	7 557	**56.5**	735	**9.7**	
Number of healthcare staff working in the facility					0.057
[1-50]	927	**6.9**	65	**7.0**	
[51-100]	787	**5.9**	51	**6.5**	
[101-200]	1 126	**8.4**	154	**13.7**	
>200	10 526	**78.8**	988	**9.4**	
Index of multiple deprivation					0.119
lower decile (1-4)	4 396	**32.9**	432	**9.8**	
middle decile (5-7)	4 433	**33.2**	448	**10.1**	
upper decile (8-10)	4 537	**33.9**	378	**8.3**	
Urban-rural classification					0.822
Urban	8 062	**60.3**	763	**9.5**	
Rural	5 304	**39.7**	495	**9.3**	
Household size mean					0.742
[1-2]	739	**5.5**	73	**9.9**	
]2-2.5]	11 107	**83.1**	1 045	**9.4**	
>2.5	1 520	**11.4**	140	**9.2**	
Number of non-COVID diseases					<0.001
0	5 561	**41.6**	404	**7.3**	
1	3 451	**25.8**	309	**9.0**	
2	2 177	**16.3**	244	**11.2**	
3+	2 177	**16.3**	301	**13.8**	
Number of isolation days[5]					<0.001
0	8 671	**64.9**	712	**8.2**	
[1-14]	3 225	**24.1**	455	**14.1**	
>14	1 470	**11.0**	91	**6.2**	
Other leaving absence days[5]	NA = 1821		NA = 262		0.001
0	7789	**67.5**	736	**9.4**	
[1-7]	2 784	**24.1**	203	**7.3**	
>7	972	**8.4**	57	**5.9**	

[1] two-sided global p-values (i.e. both rows and columns comparison for each characteristics) were computed using cluster-adjusted chi-square test of independence

[2] Include Pakistanis, Indians, Bangladeshis

[3] Include Black African and Caribbean

[4] Other pay grades encompass mainly specialty registrar and consultant

[5] Measured during the study period