Clinical Infectious Diseases

MAJOR ARTICLE

The Socio-Economic and Demographic Risk Factors for SARS-cov-2 Seropositivity Among Healthcare Workers in a UK Hospital: A Prospective Cohort Study

Tanya Lam[1], Anja Saso[1,2,3], Arturo Torres Ortiz[4,5], James Hatcher[6], Marc Woodman[5], Shruthi Chandran[5], Rosie Thistlethwayte[7], Timothy Best[6], Marina Johnson[5], Helen Wagstaffe[5], Annabelle Mai[8], Matthew Buckland[8], Kimberly Gilmour[8], David Goldblatt[5], Louis Grandjean[5*] and the Co-STARs study team[†]

[1]Department of Infectious Diseases, Great Ormond Street Hospital, Great Ormond Street, London, WC1N 3JH [2]Department of Tropical and Infectious diseases, LSHTM, Keppel St, Bloomsbury, London WC1E 7HT [3]MRC Gambia at LSHTM, Atlantic Boulevard, PO Box 273, Fajara, The Gambia [4]Department of Infectious Diseases, Imperial College London, London, W2 1NY [5]Department of Infection, Immunity and Inflammation, Institute of Child Health, UCL, WC1N 1EH [6]Department of Microbiology, Great Ormond Street Hospital, Great Ormond Street, London WC1N 3JH [7]Management, Great Ormond Street Hospital, London, United Kingdom [8]Clinical Immunology, Camelia Botnar Laboratories, Great Ormond Street Hospital, London, United Kingdom, WC1N 3JH

Background: In order to protect healthcare workers from the consequences of disease due to SARS-CoV-2 it is necessary to understand the risk factors that drive exposure and infection within hospitals. Insufficient consideration of key socio-economic variables is a limitation of existing studies that can lead to bias and residual confounding of proposed risk factors for infection.

Corresponding author details: Dr Louis Grandjean, Department of Infection, Inflammation and Immunity, Institute of Child Health, 30 Guilford Street, London, WC1N. l.grandjean@ucl.ac.uk

Alternate corresponding author details: Arturo Torres Ortiz, Department of Infection, Inflammation and Immunity, Institute of Child Health, 30 Guilford Street, London, WC1N. a.ortiz@ucl.ac.uk

DOI: 10.1093/cid/ciad522

Methods: The Co-STARS study prospectively enrolled 3679 HCWs between April 2020 and September 2020. We used multivariate logistic regression to comprehensively characterise the demographic, occupational, socio-economic and environmental risk factors for SARS-CoV-2 seropositivity.

Results: After adjusting for key confounders relative household overcrowding (OR 1.4 [CI 1.1-1.9] p=0.006), Black, Black British, Caribbean or African ethnicity (OR 1.7 [CI 1.2-2.3] p=0.003), increasing age (50-60 age group OR 1.8 [CI 1.3-2.4] p=<0.001), lack of access to sick pay (OR 1.8 [CI 1.3-2.4] p=<0.001) and out of hospital contact with COVID-19; staff contact (OR 1.8 [CI 1.4-2.4] p=<0.001), travel contact (OR 1.9 [CI 1.2-3.0] p=0.008), household contact (OR 1.6 [CI 1.2-2.2] p=0.002), other contact (OR 1.9 [CI 1.3-3.3] p=0.029) were significantly associated with SARS-CoV-2 seropositivity. In this paediatric tertiary hospital setting, contact with known infected patients was not significantly associated with seropositivity (OR 1.2 [CI 0.6-2.1] p=0.651).

Conclusions: Socio-economic and demographic factors outside the hospital were the main drivers of infection and exposure to SARS-CoV-2 during the first wave of the pandemic in an urban paediatric referral hospital. Overcrowding and out of hospital SARS-CoV-2 contact are less amenable to intervention. However, lack of access to sick pay among externally contracted staff is more easily rectifiable. Our findings suggest that, if addressed, providing easier access to sick pay would lead to a decrease in SARS-CoV-2 transmission and potentially that of other infectious diseases in hospital settings.

Keywords: SARS-CoV-2/COVID-19, risk factors, health care workers, sick-pay/leave, overcrowding, socio-economic status, BAME/ethnicity

Trial Registration Number: NCT04380896.

INTRODUCTION

The COVID-19 pandemic placed unprecedented pressure on healthcare systems globally. Healthcare workers (HCWs) remained at the forefront of the pandemic during the first wave of infections, whilst non-essential workers were placed under stringent lockdown measures. Infection rates of COVID-19 in HCWs were higher than in the general population during this period, both in the UK and internationally [12–15]. Numerous studies have attempted to identify risk factors for HCW acquisition of COVID-19 with a view to creating safer working environments for staff and limiting the spread of healthcare-associated COVID-19 [1,2].

Existing published risk factors for HCW exposure and infection vary widely[1–6]. There is considerable heterogeneity in clinical, demographic, occupational and environmental variables recorded between studies[1,7], limiting our understanding of specific risks and key confounders. For example, several international studies have identified that cleaners and hospital porters are those most at risk of exposure and infection[2,3,8,9], but most studies have failed to include potential socio-economic confounders of this association. SARS-CoV-2 has been detected in air samples in hospital rooms, on surfaces and on shared staff equipment[10,11], potentially exposing non-patient-facing staff —particularly cleaners and porters— to SARS-CoV-2. However, the Office for National Statistics (ONS) does not classify cleaners and hospital porters amongst the highest exposure occupations[12]. This divergence suggests that local variability and residual confounding for SARS-CoV-2 acquisition may explain the association rather than the occupation itself. There are several published studies of SARS-CoV-2 seroprevalence in paediatric hospitals, none have investigated ethnicity or socioeconomic variables as risk factors for SARS-CoV-2 exposure and infection[13–18].

In order to improve our understanding of the underlying socio-economic and demographic determinants of SARS-CoV-2 infection and exposure, we undertook a prospective cohort study of risk factors for SARS-CoV-2 seropositivity in a tertiary London paediatric hospital during the first wave of the pandemic.

Methods

Study setting, design and participants

The Co-STARs project was a single-centre prospective cohort study evaluating antibody responses to COVID-19 in healthcare workers (HCWs) at Great Ormond Street Hospital (GOSH). It was conducted between April 2020 and September 2020 during the first wave of the COVID pandemic[19,20]. Both clinical and non-clinical hospital staff ≥18 years were invited to participate. In order to ensure equity of access to the study, face-to-face active recruitment was used for hospital staff on external contracts without NHS trust email addresses who were more difficult to contact. These staff members included cleaners, porters and catering staff. Participants were excluded if they had significant immunosuppression, recent administration of blood products (including immunoglobulins or convalescent sera) since September 2019 and persistent symptoms of SARS-CoV-2 infection at the time or within 21 days of recruitment. All participants signed an informed consent form and the study was approved by the UK National Health Service Health Research Authority and registered on ClinicalTrials.gov (NCT04380896)[20].

Data collection

Blood samples were taken at baseline and at each follow-up visit for anti-SARS-CoV-2 IgGserology using previously published methods[19,20]. At the recruitment visit, participants also undertook a comprehensive, standardised online questionnaire (Supplementary material, appendix C). This included sociodemographic factors including self-assigned ethnicity [21]; details of previous exposure to SARS-CoV-2; symptomatic episodes consistent with COVID-19 with any subsequent complications; previous SARS-CoV-2 diagnostic test results; occupation and medical history; and a comprehensive assessment of risk factors for exposure, susceptibility to infection, and severe disease[20].

Follow-up appointments

All seropositive participants attended monthly follow-up visits for repeat antibody testing up to 250 days after the date of infection. Seronegative participants were followed up every 6-months.At each follow-up appointment, participants completed a shortened version of the baseline questionnaire, focusing on any significant changes since the last visit, including recurrent SARS-CoV-2 exposure and/or COVID-19 symptoms.

Statistical analysis

The risk of SARS-CoV-2 exposure or infection was estimated by fitting a logistic regression model using seropositivity for SARS-CoV-2 as the binary dependent outcome variable. Demographic (age, sex, and ethnicity), occupational (occupation, income and working conditions), socio-economic, environmental and SARS-Cov-2 exposure factors were included as model predictors. Variables were chosen due to clinical and epidemiological relevance. As no statistical difference in seropositivity was estimated between ethnicities White British, White Other and White Irish, these variables were merged into a single variable White. Univariate and multivariate logistic regression models were used to estimate Odds Ratios (OR). Univariate models were fitted for each variable independently, while a multivariate regression was performed excluding variables that had a proportion of missing values higher than 30%. Similarly, univariate and multivariate logistic regression models were performed to estimate the relationship between SARS-CoV-2 seropositivity and self-reported symptoms. Collinearity was assessed by calculating the VIF (variance inflation factor) for all variables selected in the multivariate model. All VIF values ranged between 1 and 2, suggesting that no collinearity is detected in our model, and therefore no variable was removed.

The impact of socioeconomic deprivation on the risk of SARS-CoV-2 seropositivity was included in the model by linking the postcode metadata to area deprivation using the Index of Multiple Deprivation (IMD) as reported by the UK Ministry of Housing, Communities & Local Government[22].

All analyses were performed using the R project for statistical computing [23].

Supplementary Material includes the study protocol, power calculations, detailed laboratory methodology, and the questionnaires used for data collection.

RESULTS

A total of 3646 staff members were recruited out of a total 5755 employees at Great Ormond Street Hospital (63.3%). Of the total number of staff approached for recruitment, <1% declined to participate. There were 53 confirmed inpatient cases with COVID-19 diagnosed by PCR on nasopharyngeal swabs during the study period. As shown in Table 1, 24% (712/3646) of the participants were categorised as seropositive, defined as presenting a SARS-CoV-2 positive test at any point during the study period. The majority of the participants were female (77%, 2801/3646) and white (54%, 1951/3646). Most participants self-reported symptoms (64%), but 1.3% (48/3646) sought medical attention and only 11 of them (0.3%) required hospitalisation (Table 1).

SARS-cov-2 Risk Factors for Healthcare Workers

Demographic Risks of SARS-cov-2 infection or exposure

No difference in SARS-CoV-2 seropositivity was observed between male or female staff. Higher rates of seropositivity were seen in the age groups between 40 and 60, which remained significant in multivariate analysis. On univariate analysis, Black and South Asian ethnicity were associated with higher rates of seropositivity (40.0% and 26.4% respectively). However, on multivariate analysis, South Asian ethnicity was no longer significant, whereas Black ethnicity remained significant (OR 1.7 [95%CI 1.2-2.3] p=0.003) (Table 2).

Occupational Risks of SARS-cov-2 infection or exposure

Seropositivity varied by specialty, however occupations with known exposure to aerosolising procedures (Anaesthetics, PICU, CICU) did not have increased risk of seropositivity relative to staff working on other inpatient or outpatient wards.

Univariate analysis identified cleaners, porters and catering staff as having the highest risk of seropositivity at 42.1% (OR 2.2 [95% CI 1.5-3.3], p<0.001). The second highest occupational rate was in the Information Computing Technology (ICT) department at 35.7%, though this was not statistically significant on univariate analysis (OR 1.7 [95% CI 0.7-3.7] p=0.512). One potential explanation for this finding is that ICT is a small department.

Overall, on multivariate analysis, no occupation was found to have a statistically significant risk of seropositivity. Clinical staff did not have higher rates of seropositivity than non-clinical staff and working from home did not impact rates of seropositivity.

Contact with COVID-19/ Symptoms of COVID-19

In total, 34.4% of staff had a known contact with COVID-19 at the time of the survey. Compared to those that did not have a known contact with COVID-19, those with a known contact had an increased risk of seropositivity (30% compared to 21.9%), except if the known contact was a patient. Contact involving travel to Italy, China, Iran or South Korea between the months of December 2019 and February 2020 (OR 1.9 [95% CI 1.2-3.0] p=0.008), other staff members (OR 1.8 [95% CI 1.4-2.4], p<0.001), household members (OR 1.6 [95% CI 1.2-2.2] p=0.002) and other SARS-CoV-2 contact (OR 1.9 [95% CI 1.1-3.3] p=0.029) all remained statistically significant on the multivariate analysis. Thirty eight percent (347/911) of those staff who reported symptoms consistent with SARS-CoV-2 infection were seropositive, compared to 13%(365/ 2735) of asymptomatic staff.

Socio-Economic Risks of SARS-cov-2 Infection or Exposure

Staff that lived in households in which one or more household members did not have access to adequate sick leave, had a statistically significant increased risk of COVID-19 (OR 1.8 [95%CI 1.3-2.4] p<0.001). Staff who self-reported their income was not always enough to cover basic needs of housing, transport and food had higher rates of COVID-19, 33% compared with 15.7% in those who did not (OR 2.2 [95%CI 1.4-3.4], p =0.001). However, this was not included in the multivariate analysis as more than 30% of the entries contained missing values. Moreover, entries with missing data regarding income were not missing at random, with seropositive individuals characterised by a higher odds ratio of income missing values and some ethnicities such as Black or Asian presenting lower odds ratios of income missing values when compared to White (Table 3). Areas of social deprivation based on post codes were analysed for COVID-19 risk. The quartiles of lowest to highest rates of deprivation did not show significant increased risk on multivariate analysis.

Environmental Risks of SARS-cov-2 Infection or Exposure

Presence of children under the age of five in the household did not change seropositivity rates of COVID-19. Neither did households which had more than two generations of family members. An increasing number of household members marginally increased the risk of COVID-19 on univariate analysis (OR 1.1 [95% CI 1.1-1.2] p<0.001). More notable was that an increased ratio of household members relative to rooms in the house increased the risk of COVID-19, which remained significant on multivariate analysis (OR 1.4 [95% CI 1.1-1.9], p=0.006).

DISCUSSION

This large prospective study of healthcare workers in a paediatric tertiary referral hospital demonstrated that lack of access to sick pay, relative household overcrowding, black ethnicity and increasing age were independently associated with SARS-CoV-2 seropositivity.

Great Ormond Street Hospital (GOSH) is a large tertiary paediatric hospital in central London. The hospital faced unprecedented demand as paediatric units across London were closed to increase adult bed capacity. However, thankfully, relative to adult centres, very few inpatients were severely infected with acute respiratory COVID-19 during the first wave of the pandemic. At GOSH, all inpatients were tested for COVID-19 on admission and were admitted to side rooms pending test results. There were only 53 inpatients that were diagnosed with COVID-19 during the period when this study was conducted. It is therefore unsurprising that contact with a patient with COVID-19 was not shown to be a risk factor for seropositivity in this study, while other types of contact with COVID-19 were. This is supported by findings by Goldblatt et al demonstrating low in-hospital transmission rates amongst healthcare workers in paediatric facilities in 8 European countries [24]. Moreover, clinical staff did not have higher rates of seropositivity than non-clinical staff. This suggests that seropositive staff members primarily acquired COVID-19 either from other staff members at work or outside work[25–27].

Structural inequalities related to socio-economic status (SES) and ethnicity have been directly linked with COVID-19 [28–30]. Healthcare workers from a lower socio-economic background are more likely to live in overcrowded housing, which is a risk factor for respiratory illnesses[31]. Many studies use occupation as a surrogate for SES but have not investigated how income, job security, household environment and living in an area of social deprivation may impact SARS-CoV-2 seropositivity[1,2,32]. Studies of healthcare workers in other UK hospitals found that HCWs from minority ethnic groups had a significantly increased risk of seropositivity (OR: 1.92, 95% CI 1.14 to 3.23, p=0.01)[3].

Staff in non-clinical roles such as cleaners, porters and catering staff had the highest risk of acquiring SARS-CoV-2 prior to consideration of confounders in a multivariate analysis. This observed higher risk amongst non-clinical support staff compared to clinical staff has also been reported by other studies from the UK, Norway and the US[8,9,33]. The fact that occupation did not remain a significant risk factor after controlling for confounders suggests that the postulated association between occupational risk and SARS-CoV-2 seropositivity is actually due to underlying demographic and socio-economic factors.

Lack of access to sick pay was independently associated with higher rates of SARS CoV-2 seropositivity. In the UK, 27% of National Health Service (NHS) Estates and Facilities workers (which includes cleaners, porters, catering, security, engineering, capital delivery and maintenance staff) are outsourced to service delivery partners, 7% are employed by NHS wholly owned subsidiaries and 66% are directly employed by the NHS[34]. The Office for National Statistics reports that as of April-June 2022, 20.2% of workers in the field of health and social care are on zero hours contracts, and a Freedom of Information request submitted by the Financial Times found that in 2013, NHS hospitals used almost 100 000 zero hours contracts[35,36]. While zero hours contracts are legal in the UK[37], lower paid staff members that cannot afford to lose income are more likely to work when they are unwell or have had a COVID-19 contact[38]. This economic vulnerability may make self-isolation challenging, and could contribute to the spread of COVID-19 and other infectious diseases amongst non-clinical healthcare staff. The US Center for Disease Control (CDC) has highlighted the importance of avoiding incentives that encourage people to come to work when symptomatic[39].

Overcrowded housing is a recognised risk factor for respiratory and other infectious diseases, and overcrowding affects 3% of households in England, with ethnic minorities disproportionately affected[40,41]. It is therefore unsurprising that there was an increased risk of seropositivity with a higher ratio of household members to rooms (OR 1.4, 95% CI 1.1 - 1.9, p= 0.006). Overcrowded housing is also considered a measure of poverty and further highlights the impact that socioeconomic status has on COVID-19 infection amongst healthcare workers[42].

The role that ethnicity plays in SARS COV-2 seropositivity has been discussed by many preceding studies[43–45]. We found a significant association between seropositivity and both South Asian and Black ethnicity on the univariate analysis. This correlates with findings from other studies in the UK[2,28].Studies in the United States have shown that Black and South Asian workers are more likely to be employed in healthcare, social assistance and other essential industries[46,47]. ONS data has shown that while minority ethnic groups have higher rates of death from COVID-19, much of this difference is attributable to socioeconomic factors, living conditions and occupational exposure[48,49]. In the UK, poverty rates are the highest in the Bangladeshi (65%) community, followed by, Pakistani (55%), Black African (45%), Black Caribbean (30%), Indian (25%) then White British (20%)[31].On multivariate analysis only black ethnicity remained significant, whilst South Asian ethnicity did not. There may be other unmeasured confounding factors that contribute to the black ethnic risk of SARS-CoV-2 infection that we have not identified in our analysis.

This study benefited from a large, diverse, engaged cohort of recruited HCWs. Other strengths included the collection of data on a wide range of demographic, occupational and socioeconomic factors, as well as data on exposure to COVID-19. This allowed a detailed consideration of the influence of socio-economic and environmental variables which are often overlooked. Our study design ensured that our cohort was truly representative of the entirety of HCWs in the hospital by actively recruiting cleaners, porters and catering staff, who were harder to reach due to lack of access to NHS Trust emails – these staff members at the time were employed by external organisations and so may not have had NHS email accounts. This enabled us to achieve similar recruitment levels for all staff groups. Additionally, our data were gathered over a relatively short time period (April to September 2020) and we used the MSD assay to test antibodies against SARS-CoV-2[19,50], meaning that we would not expect antibodies to have waned during this time period. Consequently, seropositivity rates are more likely to be a true reflection of exposure to COVID-19.

There are, however, some important limitations. Data including some socioeconomic factors such as difficulty accessing sick leave were self-reported, and could be subject to reporting bias. These data could be useful to elucidate whether this behaviour was driven primarily by a lack of contractual sick leave, or by perceptions about the effects of taking sick leave on their employment – which may be driven by wider socioeconomic and workplace factors. Staff on lower incomes may feel unable to isolate even if they do have access to statutory sick leave, influenced by their overall economic precarity, concern about repercussions or a sense of duty to their work. There were also a small proportion of staff who declined to participate in the study (36 participants or 0.99% of those recruited) and the lack of their demographic and occupational data makes it difficult to determine the extent that this may have influenced transmission.

The COVID-19 pandemic highlighted the effect of structural and ethnic inequality on communicable disease in the UK[48]. This is corroborated in our data demonstrating an increased risk of SARS-CoV-2 seropositivity in staff reporting difficulty accessing sick leave, living in overcrowded housing and those of black ethnicity. These data emphasise the importance of taking economic, ethnic and social factors into account when forming public health policy, and underscore the impacts of social determinants of health in the UK. Since the pandemic, cleaning staff at GOSH have been brought in house, under full hospital employment, and several NHS trusts have done the same[51]. This should be considered around the country to ensure that all staff have equitable access to information, participation in the life of the hospital and a safe place to work.

DOI: 10.1093/cid/ciad522

NOTES

Financial Support: LG was supported by the Wellcome Trust (201470/Z/16/Z) and (226007/Z/22/Z), the National Institute of Allergy and Infectious Diseases of the National Institutes of Health under award number 1R01AI146338, the GOSH Charity (VC0921) and the GOSH/ICH Biomedical Research Centre (www.nihr.ac.uk). AS was supported by the Wellcome Trust (220565/Z/20/Z). The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests Statement: The authors have declared that no competing interests exist.

Ethics Statement: This study was approved by the UK Health Research Authority (www.hra.nhs.uk) and registered with www.clinical-trials.gov (NCT04380896). Written informed consent was obtained from all participants before recruitment to the study.

Acknowledgements: We would like to dedicate this article to the staff members at Great Ormond Street Hospital who died of COVID-19 during the first wave of the pandemic. We would also like to thank all the staff at Great Ormond Street Hospital who have taken part in the study. In addition, we are grateful for all the hard work undertaken by the Great Ormond Street laboratory staff and the staff in the immunology laboratories both in the Camelia Botnar Laboratory and the Great Ormond Street Institute of Child Health who ensured that all the PCR tests and serological assays were completed in a timely manner. Finally, we would like to acknowledge the support of the Great Ormond Street Hospital Research & Development, Governance, Finance, Management, Estates, Operations and Communications departments.

[†] **The Co-Stars Study Team**

Dorcas Mirambe-Korsah	Fernanda Fenn Torrente	Jakub Wyszynski	Victoria Gander
Amy Leonard	Louise Myers	Aimee Vallot	Camille Paillas
Rose Fitzgerald	Adam Twigg	Rabia Manaf	Lois Gibbons
Hollie Powell	Richard Nar-Dorh	Ally Gray	Elias Fernandez
Aline Minja	Emily Beech	Waffa Girshab	Pei Shi Chia
Kate Webb	Malti Nakrani	Kim Gardiner	Valerija Karaluka

Karen Ryan	Dorothy Lee	Katie Groves	Hamad Khan
Shamime Nsubuga	Olivia Rosie-Wilkinson	Julia Spires	Nuria Sanchez-Clemente
Sapriya Kaur	Natasha Carroll	Jemma Efford	Gabriel Bredin
Celma Marisa Dos Santos Domingues	Sophie Foxall	Helen Ashton	Abbey Afzal
Sally Mainland	Kate Crumpler	Lucinda Dawson	Claire Smith
Maria Tabbu	Laura Chiverton	Jade Sugars	Jordan Mooney
Dorothy Chikusu	Fariba Tahami	Baratth Samy	Shomona Begum
Dhimple Patel	Philippa Wiltshire	Annie Susay	Anna Ryan
Luke Lancaster	Kavita Thind	Kate Speller	Rachel Sterling
Connor Tugulu	Sandhya Ghurburrun	Steffi Gray	Joy Mugas
Moe Kishma	Kathleen Akpokomua	Sophie White	Eleana Pieri
Sabina Shamsad	Demi Alexandrou	Odera Aguele	Katherine Miles
Anamika Jain	Subishma Gautam	Oliver Simms	Rachel Goff
Zarif Shams	Tinya Chirinda	Aaliya Nur	Tarekur Rahman

References

1. Galanis P, Vraka I, Fragkou D, Bilali A, Kaitelidou D. Seroprevalence of SARS-CoV-2 antibodies and associated factors in healthcare workers: a systematic review and meta-analysis. The Journal of hospital infection **2021**; 108:120–134.
2. Eyre DW, Lumley SF, O'donnell D, et al. Differential occupational risks to healthcare workers from SARS-CoV-2 observed during a prospective observational study. eLife **2020**; 9:1–37.
3. Shields A, Faustini SE, Perez-Toledo M, et al. SARS-CoV-2 seroprevalence and asymptomatic viral carriage in healthcare workers: a cross-sectional study. Thorax **2020**; 75:1089–1094.
4. Steensels D, Oris E, Coninx L, et al. Hospital-Wide SARS-CoV-2 Antibody Screening in 3056 Staff in a Tertiary Center in Belgium. JAMA **2020**; 324:195–197.
5. Self WH, Tenforde MW, Stubblefield WB, et al. Seroprevalence of SARS-CoV-2 Among Frontline Health Care Personnel in a Multistate Hospital Network - 13 Academic Medical Centers, April-June 2020. MMWR Morbidity and mortality weekly report **2020**; 69:1221–1226.
6. Iversen K, Bundgaard H, Hasselbalch RB, et al. Risk of COVID-19 in health-care workers in Denmark: an observational cohort study. The Lancet Infectious diseases **2020**; 20:1401–1408.
7. Gómez-Ochoa SA, Franco OH, Rojas LZ, et al. COVID-19 in Health-Care Workers: A Living Systematic Review and Meta-Analysis of Prevalence, Risk Factors, Clinical Characteristics, and Outcomes. American Journal of Epidemiology **2021**; 190:161–175.
8. Molvik M, Danielsen AS, Grøsland M, Telle KE, Kacelnik O, Eriksen-Volle HM. SARS-CoV-2 in health and care staff in Norway, 2020. Tidsskrift for den Norske laegeforening : tidsskrift for praktisk medicin, ny raekke **2021**; 141.
9. Barrett ES, Horton DB, Roy J, et al. Risk Factors for Severe Acute Respiratory Syndrome Coronavirus 2 Infection in Hospital Workers: Results From a Screening Study in New Jersey, United States in Spring 2020. Open forum infectious diseases **2020**; 7.
10. Moore G, Rickard H, Stevenson D, et al. Detection of SARS-CoV-2 within the healthcare environment: a multi-centre study conducted during the first wave of the COVID-19 outbreak in England. The Journal of hospital infection **2021**; 108:189–196.
11. Ong SWX, Tan YK, Chia PY, et al. Air, Surface Environmental, and Personal Protective Equipment Contamination by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) From a Symptomatic Patient. JAMA **2020**; 323:1610–1612.
12. Which occupations have the highest potential exposure to the coronavirus (COVID-19)? - Office for National Statistics. Available at: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/articles/whichoccupationshavethehighestpotentialexposuretothecoronaviruscovid19/2020-05-11. Accessed 28 October 2022.
13. Oygar PD, Büyükçam A, Bal ZŞ, et al. SARS-CoV-2 seropositivity among pediatric health care personnel after the first peak of the pandemic: nationwide surveillance in Turkey. International Journal of Infectious Diseases **2021**; 113:184.
14. Guarnieri V, Moriondo M, Giovannini M, et al. Surveillance on Healthcare Workers During the First Wave of SARS-CoV-2 Pandemic in Italy: The Experience of a Tertiary Care Pediatric Hospital. Frontiers in Public Health **2021**; 9:1004.

15. Tatsi EB, Dellis C, Petridou E, et al. SARS-CoV-2 seroepidemiological study in healthcare workers and discordant results using seven different diagnostic methods. Infection **2022**; 50:251–256.
16. Morris CR, Sullivan P, Mantus G, et al. Prevalence of SARS-CoV-2 antibodies in pediatric healthcare workers. International journal of infectious diseases : IJID : official publication of the International Society for Infectious Diseases **2021**; 105:474–481.
17. Ceruelo EE, Ruíz MAE, López-Peláez MO, Garoz BF, Antón JA, García RJ. Seroprevalence of antibodies against SARS-CoV-2 among health care workers in a pediatric monographic hospital in Madrid (Spain). Enfermedades Infecciosas Y Microbiologia Clinica (English Ed) **2022**; 40:326.
18. Heyming TW, Sanger T, Tongol A, Schomberg J, Bacon K, Lara B. Provider Antibody Serology Study of Virus in the Emergency Room (PASSOVER) Study: Special Population COVID-19 Seroprevalence. The western journal of emergency medicine **2021**; 22:565–571.
19. Grandjean L, Saso A, Torres Ortiz A, et al. Long-Term Persistence of Spike Protein Antibody and Predictive Modeling of Antibody Dynamics After Infection With Severe Acute Respiratory Syndrome Coronavirus 2. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America **2022**; 74:1220–1229.
20. COVID-19 Staff Testing of Antibody Responses Study (Co-Stars) - Full Text View - ClinicalTrials.gov. Available at: https://clinicaltrials.gov/ct2/show/NCT04380896. Accessed 28 October 2022.
21. Ethnic group, national identity and religion - Office for National Statistics. Available at: https://www.ons.gov.uk/methodology/classificationsandstandards/measuringequality/ethnicgroupnationalidentityandreligion. Accessed 19 July 2023.
22. English indices of deprivation 2019 - GOV.UK. Available at: https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019. Accessed 6 November 2022.
23. R: The R Project for Statistical Computing [Internet]. [cited 2022 Jul 2]. Available from: https://www.r-project.org/. Available at: https://www.r-project.org/. Accessed 28 October 2022.
24. Goldblatt D, Johnson M, Falup-Pecurariu O, et al. Cross-sectional prevalence of SARS-CoV-2 antibodies in healthcare workers in paediatric facilities in eight countries. J Hosp Infect **2021**; 110:60–66.
25. Garcia-Basteiro AL, Moncunill G, Tortajada M, et al. Seroprevalence of antibodies against SARS-CoV-2 among health care workers in a large Spanish reference hospital. medRxiv **2020**; :2020.04.27.20082289.
26. Kluytmans-Van Den Bergh MFQ, Buiting AGM, Pas SD, et al. Prevalence and Clinical Presentation of Health Care Workers With Symptoms of Coronavirus Disease 2019 in 2 Dutch Hospitals During an Early Phase of the Pandemic. JAMA Network Open **2020**; 3.
27. Sikkema RS, Pas SD, Nieuwenhuijse DF, et al. COVID-19 in health-care workers in three hospitals in the south of the Netherlands: a cross-sectional study. The Lancet Infectious diseases **2020**; 20:1273–1280.
28. Mathur R, Rentsch CT, Morton CE, 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. www.thelancet.com **2021**; 397.

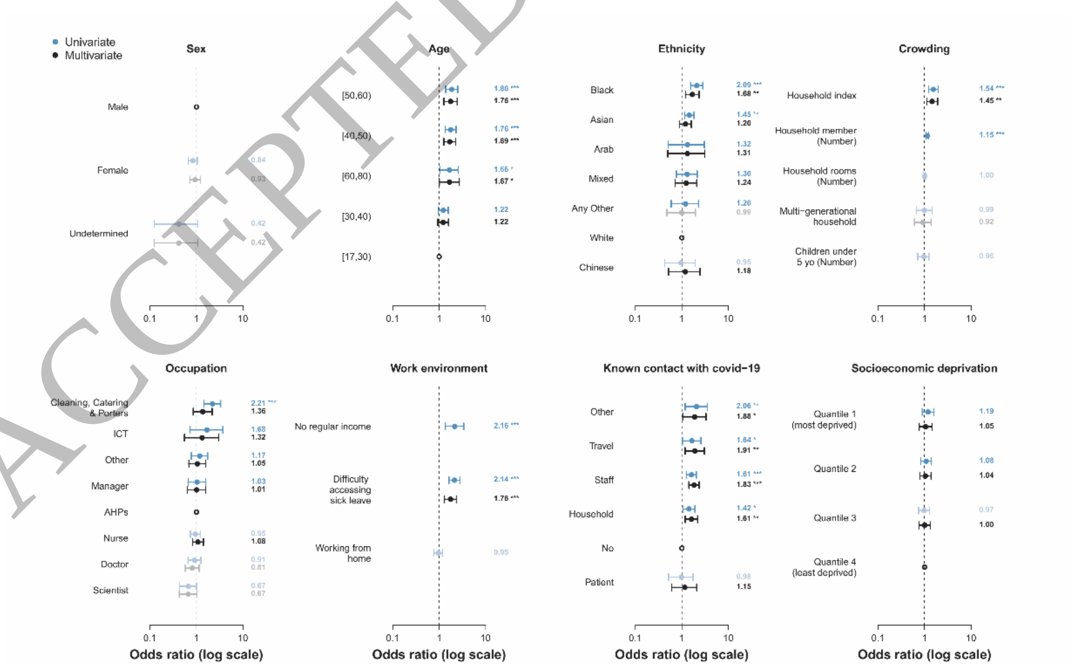
DOI: 10.1093/cid/ciad522

29. Patel JA, Nielsen FBH, Badiani AA, et al. Poverty, inequality and COVID-19: the forgotten vulnerable. Public Health **2020**; 183:110.
30. Abuelgasim E, Saw LJ, Shirke M, Zeinah M, Harky A. COVID-19: Unique public health issues facing Black, Asian and minority ethnic communities. Current problems in cardiology **2020**; 45.
31. Poverty rates among ethnic groups in Great Britain | JRF. Available at: https://www.jrf.org.uk/report/poverty-rates-among-ethnic-groups-great-britain. Accessed 28 October 2022.
32. Alishaq M, Jeremijenko A, Al-Kanaani Z, et al. Prevalence and risk factors for SARS-CoV-2 infection and seroprevalence among clinical and non-clinical staff in a national healthcare system. PloS one **2021**; 16.
33. Moscola J, Sembajwe G, Jarrett M, et al. Prevalence of SARS-CoV-2 Antibodies in Health Care Personnel in the New York City Area. JAMA **2020**; 324:893–895.
34. Estates and Facilities Workforce Action Plan Building, developing and engaging our people. **2022**;
35. Employers increase zero hours contracts | Financial Times. Available at: https://www.ft.com/content/04a86a6c-9f8a-11e2-b4b6-00144feabdc0. Accessed 28 October 2022.
36. EMP17: People in employment on zero hours contracts - Office for National Statistics. Available at: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/emp17peopleinemploymentonzerohourscontracts. Accessed 28 October 2022.
37. Zero hours contracts: guidance for employers. Available at: https://www.gov.uk/government/publications/zero-hours-contracts-guidance-for-employers/zero-hours-contracts-guidance-for-employers. Accessed 19 July 2023.
38. Himmelstein DU, Woolhandler S. Health Insurance Status and Risk Factors for Poor Outcomes With COVID-19 Among U.S. Health Care Workers: A Cross-Sectional Study. Annals of internal medicine **2020**; 173:410–412.
39. Dyal JW, Grant MP, Broadwater K, et al. COVID-19 Among Workers in Meat and Poultry Processing Facilities - 19 States, April 2020. MMWR Morbidity and mortality weekly report **2020**; 69.
40. Overcrowded households - GOV.UK Ethnicity facts and figures. Available at: https://www.ethnicity-facts-figures.service.gov.uk/housing/housing-conditions/overcrowded-households/latest. Accessed 28 October 2022.
41. Krieger J, Higgins DL. Housing and Health: Time Again for Public Health Action. American Journal of Public Health **2002**; 92:758.
42. Stroud P. A new measure of poverty for the UK.
43. Apea VJ, Wan YI, Dhairyawan R, et al. Ethnicity and outcomes in patients hospitalised with COVID-19 infection in East London: an observational cohort study. BMJ open **2021**; 11.
44. Mackey K, Ayers CK, Kondo KK, et al. Racial and Ethnic Disparities in COVID-19-Related Infections, Hospitalizations, and Deaths : A Systematic Review. Annals of internal medicine **2021**; 174:362–373.
45. Tai DBG, Shah A, Doubeni CA, Sia IG, Wieland ML. The Disproportionate Impact of COVID-19 on Racial and Ethnic Minorities in the United States. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America **2021**; 72:703–706.
46. Hawkins D. Differential occupational risk for COVID-19 and other infection exposure according to race and ethnicity. American journal of industrial medicine **2020**; 63:817–820.

47. Roberts JD, Dickinson KL, Koebele E, et al. Clinicians, cooks, and cashiers: Examining health equity and the COVID-19 risks to essential workers. Toxicology and industrial health **2020**; 36:689–702.
48. Marmot M, Allen J. COVID-19: exposing and amplifying inequalities. Journal of Epidemiology and Community Health **2020**; 74:681.
49. Coronavirus (COVID-19) related deaths by ethnic group, England and Wales - Office for National Statistics. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/coronavirusrelateddeathsbyethnicgroupenglandandwales/2march2020to10april2020. Accessed 28 October 2022.
50. Torres Ortiz A, Fenn Torrente F, Twigg A, et al. The influence of time on the sensitivity of SARS-CoV-2 serological testing. Sci Rep **2022**; 12:10517.
51. NHS trust brings workers in-house after industrial action | Financial Times. Available at: https://www.ft.com/content/d2cabb4a-4373-11ea-a43a-c4b328d9061c. Accessed 28 October 2022.

FIGURE LEGEND:

Figure 1: Risk factors for SARS-CoV-2 seropositivity among health care workers Risk of SARS-CoV-2 seropositivity among health care workers estimated using Univariate and Multivariate logistic regression model. Points show the best estimate of the odds ratio (OR), while error bars represent the 95% Confidence interval for the estimate OR. Bold indicates whether the OR is higher than the reference group (bold) or lower (grey). Statistical significance of the estimated ORs is presented next to the CI bars (*p < 0.001)



TABLES

Table 1: Demographics of study participants

	Total number	**Seropositive**
Total participants	2378 (100%)	593 (24.94%)
Demographic		
Age		
[17,30)	719 (30.24%)	142 (19.75%)
[30,40)	752 (31.62%)	174 (23.14%)
[40,50)	469 (19.72%)	142 (30.28%)
[50,60)	331 (13.92%)	104 (31.42%)
[60,80)	107 (4.5%)	31 (28.97%)
Sex		
Male	496 (20.86%)	138 (27.82%)
Female	1865 (78.43%)	455 (24.4%)
Undetermined	17 (0.71%)	0 (0%)
Ethnicity		
White	1639 (68.92%)	373 (22.76%)
Any Other	46 (1.93%)	12 (26.09%)
Arab	25 (1.05%)	7 (28%)
South Asian	333 (14%)	88 (26.43%)
Black	218 (9.17%)	83 (38.07%)
Chinese	41 (1.72%)	9 (21.95%)
Mixed	76 (3.2%)	21 (27.63%)
Occupational		

DOI: 10.1093/cid/ciad522

Occupation		
AHPs	548 (23.04%)	136 (24.82%)
Cleaning/Catering/Porters	121 (5.09%)	51 (42.15%)
Doctor	342 (14.38%)	79 (23.1%)
ICT	28 (1.18%)	10 (35.71%)
Manager	138 (5.8%)	35 (25.36%)
Nurse	859 (36.12%)	205 (23.86%)
Other	154 (6.48%)	43 (27.92%)
Scientist	188 (7.91%)	34 (18.09%)
Symptoms and severity		
Asymptomatic	1316 (55.34%)	266 (20.21%)
Abnormal smell sensation	425 (17.87%)	257 (60.47%)
Abnormal taste sensation	477 (20.06%)	276 (57.86%)
Altered conscious state	11 (0.46%)	5 (45.45%)
Attended hospital	48 (2.02%)	16 (33.33%)
Chills	162 (6.81%)	56 (34.57%)
Conjunctivitis	21 (0.88%)	8 (38.1%)
Cough	1003 (42.18%)	313 (31.21%)
Diarrhoea	301 (12.66%)	113 (37.54%)
Extreme fatigue	700 (29.44%)	267 (38.14%)
Fever (> 38 °C)	649 (27.29%)	244 (37.6%)
Headache	254 (10.68%)	91 (35.83%)
Loss of appetite	148 (6.22%)	58 (39.19%)
Muscle pain	796 (33.47%)	300 (37.69%)
Nose bleed	19 (0.8%)	8 (42.11%)
Runny nose	597 (25.11%)	176 (29.48%)

DOI: 10.1093/cid/ciad522

Shortness of breath	555 (23.34%)	174 (31.35%)
Vomiting	80 (3.36%)	27 (33.75%)
Wheeze	318 (13.37%)	96 (30.19%)

Table 2: Association of risk factors with Covid-19 seropositivity

			Univariate		Multivariate	
	Total number	Seropositive	OR (95% CI)	p-value	OR (95% CI)	p-value
Demographic						
Age						
[17,30)	719	142	1.0 (reference)	---	1.0 (reference)	---
[30,40)	752	174	1.2 (1.0, 1.6)	0.114	1.2 (0.9, 1.6)	0.146
[40,50)	469	142	1.8 (1.4, 2.3)	<0.001***	1.7 (1.3, 2.3)	<0.001***
[50,60)	331	104	1.9 (1.4, 2.5)	<0.001***	1.8 (1.3, 2.4)	<0.001***
[60,80)	107	31	1.7 (1.0, 2.6)	0.03*	1.7 (1.0, 2.7)	0.043*
Sex						
Male	496	138	1.0 (reference)	---	1.0 (reference)	---
Female	1865	455	0.8 (0.7, 1.1)	0.118	0.9 (0.7, 1.2)	0.6
Undetermined	17	0	---	---	---	---
Ethnicity						
White	1639	373	1.0 (reference)	---	1.0 (reference)	---
Any Other	46	12	1.2 (0.6,2.3)	0.596	1.0 (0.5, 2.0)	0.987
Arab	25	7	1.3 (0.5,3.1)	0.537	1.3 (0.5, 3.1)	0.556
South Asian	333	88	1.4 (1.0, 1.8)	0.015*	1.2 (0.9, 1.6)	0.23
Black	218	83	2.1 (1.6,2.8)	<0.001***	1.7 (1.2, 2.3)	0.003**
Chinese	41	9	1.0 (0.4,1.9)	0.903	1.2 (0.5, 2.5)	0.667
Mixed	76	21	1.3 (0.8,2.1)	0.325	1.2 (0.7, 2.1)	0.427
Occupational						
Occupation						

AHPs	548	136	1.0 (reference)	---	1.0 (reference)	---
Cleaning/Catering/ Porters	121	51	2.2 (1.5, 3.3)	<0.001***	1.4 (0.8, 2.2)	0.196
Doctor	342	79	0.9 (0.7, 1.2)	0.56	0.8 (0.6, 1.1)	0.232
ICT	28	10	1.7 (0.7, 3.7)	0.2	1.3 (0.6, 3.0)	0.512
Manager	138	35	1.0 (0.7, 1.6)	0.895	1.0 (0.6, 1.6)	0.979
Nurse	859	205	1.0 (0.7, 1.2)	0.684	1.1 (0.8, 1.4)	0.592
Other	154	43	1.2 (0.8, 1.7)	0.435	1.0 (0.7, 1.6)	0.832
Scientist	188	34	0.7 (0.4, 1.0)	0.06	0.7 (0.4, 1.0)	0.064
Working from home						
No	1748	440	1.0 (reference)	---	1.0 (reference)	---
Yes	630	153	1.0 (0.8, 1.2)	0.659	0.9 (0.7, 1.2)	0.486
Regular income						
Yes	835	155	1.0 (reference)	---	---	---
No	100	33	2.2 (1.4, 3.4)	0.001**	---	---
Difficulty accessing sick leave (1)						
No	2134	497	1.0 (reference)	---	---	---
Yes	244	96	2.1 (1.6, 2.8)	<0.001***	1.8 (1.3, 2.4)	<0.001***
Environmental						
Public transport						
No	473	123	1.0 (reference)	---	---	---
Yes	637	128	0.7 (0.5, 1.0)	0.02*	---	---
Known contact with covid-19						
No	1496	328	1.0 (reference)	---	1.0 (reference)	---
Yes: Household	263	75	1.4 (1.1, 1.9)	0.019*	1.6 (1.2, 2.2)	0.002**
Yes: Other	60	22	2.1 (1.2, 3.5)	0.009**	1.9 (1.1, 3.3)	0.029*
Yes: Patient	65	14	1.0 (0.5, 1.7)	0.941	1.2 (0.6, 2.1)	0.651
Yes: Staff	402	125	1.6 (1.3, 2.0)	<0.001***	1.8 (1.4, 2.4)	<0.001***

DOI: 10.1093/cid/ciad522

Yes: Travel	92	29	1.6 (1.0, 2.6)	0.034*	1.9 (1.2, 3.0)	0.008**
Crowding						
Multi-generational household						
No	2233	557	1.0 (reference)	---	1.0 (reference)	---
Yes	145	36	1.0 (0.7, 1.4)	0.975	0.9 (0.6, 1.4)	0.689
Household rooms						
Number of rooms	2378	---	1.0 (1.0, 1.1)	0.98	---	---
Household members						
Number of members	2378	---	1.1 (1.1, 1.2)	<0.001***	---	---
Children						
Number of children under 5 yo	864	---	1.0 (0.7, 1.2)	0.774	---	---
Household index						
Household members / rooms	2378	---	1.5 (1.2, 2.0)	<0.001***	1.4 (1.1, 1.9)	0.006**
Socioeconomic deprivation						
Deprivation index quantile[2]						
4 (least deprived)	501	120	1.0 (reference)	---	1.0 (reference)	---
3	635	149	1.0 (0.7, 1.3)	0.848	1.0 (0.8, 1.3)	0.978
2	768	195	1.1 (0.8, 1.4)	0.562	1.0 (0.8, 1.4)	0.767
1 (most deprived)	474	129	1.2 (0.9, 1.6)	0.243	1.1 (0.8, 1.4)	0.76

Statistical significance of the logistic regression presented next to the p-value (*,p<0.05; **,p<0.01; ***, p<0.001).

1 Do any working people in your household have difficulty accessing sick leave pay?

2 Index of multiple deprivation as reported by the UK Ministry of Housing, Communities & Local Government (www.gov.uk/government/statistics/english-indices-of-deprivation-2019).

Table 3: Association between variables and missing "regular income" data

	OR (95% CI)	p-value
Seropositivity	1.8(1.5, 2.2)	<0.001***
Age		
[17,30)	1.0 (reference)	---
[30,40)	1.2(0.9, 1.5)	0.14
[40,50)	1.3(1, 1.7)	0.057
[50,60)	1.6(1.2, 2.1)	0.004**
[60,80)	1(0.6, 1.6)	0.94
Sex		
Male	1.0 (reference)	---
Female	1(0.8, 1.2)	0.9
Undetermined	1.5(0.5, 4.9)	0.45
Ethnicity		
White	1.0 (reference)	---
Any Other	0.5(0.3, 0.9)	0.031
Arab	0.5(0.2, 1.2)	0.12
South Asian	0.7(0.5, 0.9)	0.003**
Black	0.6(0.4, 0.8)	<0.001***
Chinese	1.2(0.6, 2.5)	0.55
Mixed	1(0.6, 1.7)	0.86
Occupation		
AHPs	1.0 (reference)	---
Cleaning/Catering/Porters	0.3(0.2, 0.5)	<0.001***

DOI: 10.1093/cid/ciad522

Doctor	1.1(0.8, 1.5)	0.65
ICT	1(0.4, 2.4)	0.99
Manager	1.1(0.7, 1.7)	0.62
Nurse	1.2(0.9, 1.5)	0.13
Other	0.7(0.5, 1)	0.03*
Scientist	1.7(1.2, 2.5)	0.004**
Working from home		
No	1.0 (reference)	---
Yes	1.1(0.9, 1.4)	0.25
Difficulty accessing sick leave		
No	---	---
Yes	0.6(0.5, 0.8)	0.0013**
Known contact with covid-19		
No	1.0 (reference)	---
Yes: Household	1.5(1.2, 2.1)	0.003**
Yes: Other	1.1(0.6, 2)	0.7
Yes: Patient	2(1.1, 3.6)	0.021*
Yes: Staff	1.5(1.2, 1.9)	0.0012**
Yes: Travel	1.3(0.8, 2)	0.29
Multi-generational household		
No	1.0 (reference)	---
Yes	0.8(0.5, 1.1)	0.17
Household index		
Household members / rooms	0.9(0.7, 1.2)	0.52

DOI: 10.1093/cid/ciad522

Deprivation index quartile		
4 (least deprived)	1.0 (reference)	---
3	1(0.8, 1.3)	0.82
2	1.1(0.9, 1.4)	0.45
1 (most deprived)	1.2(0.9, 1.6)	0.26

Statistical significance of the logistic regression presented next to the p-value (*, p<0.05; **,p<0.01; ***, p<0.001

DOI: 10.1093/cid/ciad522