bmjmedicine

Check for updates

Socioeconomic inequalities in risk of infection with SARS-CoV-2 delta and omicron variants in the UK, 2020-22: analysis of the longitudinal COVID-19 Infection Survey

Cameron Razieh [1,2] Sharmin Shabnam,[1,2] Hajira Dambha-Miller,[3] Eva J A Morris,[4] Tom Yates [1,5] Yogini Chudasama,[1,2] Francesco Zaccardi,[1,2] Clare Gillies,[1,2] Amitava Banerjee,[6] Manish Pareek,[7,8] Ben Lacey [4] Martin White,[9] Kamlesh Khunti,[1,2] Nazrul Islam [3,4]

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjmed-2023-000624).

For numbered affiliations see end of article.
Correspondence to: Dr Nazrul Islam, Primary Care Research Centre, Faculty of Medicine, University of Southampton, Southampton, SO16 5ST, UK; nazrul.islam@soton.ac.uk

Cite this as: *BMJMED* 2024;3:e000624. doi:10.1136/bmjmed-2023-000624

Received: 14 May 2023
Accepted: 17 January 2024

ABSTRACT

OBJECTIVE To explore the risk of a positive test result for the delta or omicron variant of the SARS-CoV-2 virus in different occupations and deprivation groups in the UK.

DESIGN Analysis of the longitudinal COVID-19 Infection Survey.

SETTING COVID-19 Infection Survey, conducted by the Office for National Statistics and the University of Oxford, UK, a nationwide longitudinal survey to monitor SARS-CoV-2 infection in the community, 26 April 2020 to 31 January 2022.

PARTICIPANTS Survey participants recruited from randomly selected households to reflect the UK population (England, Scotland, Wales, and Northern Ireland) were divided into the delta cohort (2 July 2020 to 19 December 2021) and the omicron variant (on or after 20 December 2021), the dominant variants during our study period.

MAIN OUTCOME MEASURES Incidence rate and incidence rate ratio for the presence of the delta and omicron variants by area level deprivation and occupation sector. Multivariable Poisson regression models were fitted to estimate the adjusted incidence rate ratio after adjusting for age, sex, ethnic group, comorbid conditions, urban or rural residence, household size, patient or client facing job, and time (as quarters of the year).

RESULTS 329 356 participants were included in the delta cohort and 246 061 in the omicron cohort. The crude incidence rate for the presence of the delta and omicron variants of the SARS-CoV-2 virus were higher in the most deprived group (based on the index of multiple deprivation divided by deciles; delta cohort 4.33 per 1000 person months, 95% confidence interval 4.09 to 4.58; omicron cohort 76.67 per 1000 person months, 71.60 to 82.11) than in the least deprived group (3.18, 3.05 to 3.31 and 54.52, 51.93 to 57.24, respectively); the corresponding adjusted incidence rate ratios were 1.37 (95% confidence interval 1.29 to 1.47) and 1.34 (1.24 to 1.46) during the delta and omicron variant dominant periods, respectively. The adjusted incidence rate ratios for a positive test result in the most deprived group compared with the least deprived group in the delta cohort were 1.59 (95% confidence interval 1.25 to 2.02) and 1.50 (1.19 to 1.87) in the healthcare and manufacturing or construction sectors, respectively. Corresponding values in the omicron cohort were 1.50 (1.15 to 1.95) and 1.43 (1.09 to 1.86) in the healthcare and teaching and education sectors, respectively. Associations between SARS-CoV-2 infection and other employment sectors were not significant or were not tested because of small numbers.

CONCLUSION In this study, the risk of a positive test result for the SARS-CoV-2 virus in the delta and omicron cohorts was higher in the most deprived than in the least deprived group in the healthcare, manufacturing or construction, and teaching and education sectors.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ An individual's occupation might have had a role in increasing the risk of infection with the SARS-CoV-2 virus during the covid-19 pandemic, and might have been associated with an increased infection rate in individuals who could not work from home

⇒ The intersectionality between occupation and deprivation for the risk of SARS-CoV-2 infection has not been examined

WHAT THIS STUDY ADDS

⇒ Risk of a positive test result for the SARS-CoV-2 virus during the delta and omicron variant dominant periods was 43-59% higher in the most deprived group than in the least deprived group (based on the index of multiple deprivation divided by deciles) in the healthcare, manufacturing or construction, and teaching and education sectors

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE, OR POLICY

⇒ These findings will help inform employers and health policy in conducting evidence based risk assessments and in allocating potentially limited resources to those at greatest risk of infection in different occupations in future pandemics or outbreaks of infectious diseases

⇒ These findings will also help in risk assessments and resource planning for future variants of concern of the SARS-CoV-2 virus

Introduction

The risk of infection with the SARS-CoV-2 virus and subsequent health outcomes has widened pre-existing inequalities and has disproportionately impacted the health of some populations, such as ethnic minority groups or those from more deprived areas.[1–4] Preliminary findings from England suggested a disproportionate degree of deaths from covid-19, severe covid-19, and infection in some occupations, such as the healthcare sector.[5–7] People working with clients (patients or the public), for example, reported an increased risk of death related to covid-19, even after accounting for other factors. Hence throughout the pandemic, the nature of people's occupation could have had a role in increasing exposure to, and risk of, SARS-CoV-2 infection in individuals who could not work from home.[5 7–9]

Although several studies have reported important differences in the risk of SARS-CoV-2 infection and subsequent covid-19 outcomes in different occupations, few have investigated the intersectionality between occupation and deprivation. Occupation, employment sector, deprivation, and poor health are linked. Individuals working in low paid and insecure jobs are more likely to have poorer housing conditions and household overcrowding,[10] and might also be more likely to have poorer health. Assessing these socioeconomic inequalities is therefore important because the evidence indicates that both occupation and deprivation are independent risk factors for SARS-CoV-2 infection and subsequent adverse outcomes.[2 5 6 11] Understanding whether one of these risk factors is more strongly associated with an increased risk of SARS-CoV-2 infection is important for health policy relating to covid-19 and beyond. If the increased risk is because of the workplace environment, then preventive interventions and policies in the workplace might reduce the inequalities seen in covid-19. If deprivation and non-workplace factors are causing the increased risk, however, then more societal interventions and policies might be required.

Few studies have examined socioeconomic inequalities in specific occupation sectors, or across different occupations, largely because of a lack of contemporaneous and longitudinal individual data on occupation and employment.[12] Also, understanding whether specific variants of concern of the SARS-CoV-2 virus (and subsequent periods of infection and restrictions) disproportionately affected individuals working in different occupation sectors or belonging to specific deprivation groups is not known. In this study, we explored the risk of having a positive test result for the delta or omicron variant of the SARS-CoV-2 virus throughout the covid-19 pandemic in specific occupation sectors and deprivation groups, and assessed the incidence of the delta and omicron variants in these groups.

Materials and methods

Population and databases

We used the UK COVID-19 Infection Survey to examine the potential differential effects of the risk of infection with the SARS-CoV-2 virus in different occupations. The COVID-19 Infection Survey offered a unique opportunity to examine the longitudinal association between occupation sectors and the SARS-CoV-2 virus during the covid-19 pandemic. The COVID-19 Infection Survey, conducted by the Office for National Statistics and the University of Oxford, was a nationwide longitudinal survey to monitor SARS-CoV-2 infection in the community and is currently closed.[13]

Participants in the survey were recruited from randomly selected households to reflect the UK population (England, Scotland, Wales, and Northern Ireland). Sampling was grouped geographically to ensure that people from all local areas of the UK were represented; the response rate was 13.3% and the sample size was adjusted to account for varying response rates. The COVID-19 Infection Survey was an open cohort study where new participants were recruited over the study period and longitudinal data were collected from consenting existing participants. Each new participant was surveyed for five weeks initially, and then monthly.[14] Data collected at each visit included nose and throat swabs, a blood sample, and questionnaire data. The data in this analysis were collected by the COVID-19 Infection Survey from 26 April 2020 to 31 January 2022. Only working aged adults (16-64 years) were eligible for the analysis.[15] The website of the Office for National Statistics has more details on the design and methodology of the COVID-19 Infection Survey.[16]

Exposure

The main exposure of interest in this study was deprivation, measured by the index of multiple deprivation.[17 18] The index of multiple deprivation is the official measure of relative deprivation in the UK and is calculated from 39 separate indicators, organised across seven distinct domains (income, employment, health deprivation and disability, education and skills training, crime, barriers to housing and services, and living environment). The index of multiple deprivation is an area level marker of deprivation based on the geographical location of residence and calculated for every Lower layer Super Output Area (LSOA), with each area's deprivation level ranked based on their relative scores. LSOAs comprise 400-1200 households, each with a resident population of 1000-3000 people. The index of multiple deprivation does not provide individual level estimates of deprivation for a person. The index of multiple deprivation was based on the residential address of participants in the study. For the purposes of this study, we used the index of multiple deprivation deciles as our marker of deprivation, which ranged from the most deprived 10% to the least deprived 10%.

Outcome

Variants of the SARS-CoV-2 virus of concern were limited to the delta and omicron variants because these were the dominant variants during the period of this analysis.[19] We divided the cohort into a delta cohort (2 July 2020 to 19 December 2021) and an omicron cohort (on or after 20 December 2021), as implemented in previously published reports from the Office for National Statistics.[20] SARS-CoV-2 diagnoses compatible with the delta variant were defined based on the gene patterns OR+S or N+S or OR+N+S, with a cycle threshold <30 in the delta cohort. Similarly, diagnoses compatible with the omicron variant were based on the gene pattern of OR+N with a cycle threshold <30 in the omicron cohort, as used in previous reports.[21] The outcome variable was coded as a binary variable, denoting whether the gene pattern was compatible with the delta variant during the delta period. Similarly, during the omicron period, the outcome variable was coded as a binary variable if the gene pattern was compatible with the omicron variant. This approach meant that people infected with other variants were coded as not having the outcome. A polymerase chain reaction test result was used to collect the sample for testing.

Covariates

Our analysis included self-reported sociodemographic and clinical data collected from the COVID-19 Infection Survey, including age, sex, ethnic group, comorbid conditions, urban or rural home address, household size, patient or client facing job, and time of year (as quarters of the year). Age in years was calculated at the time of the participant's first visit. Sex was self-reported as either male or female sex. Ethnic group was self-reported based on the 18 UK category ethnic classifications and, for the purposes of this analysis, categorised as white or non-white participants because of the low numbers of individuals from ethnic minority groups. Comorbid conditions were measured by a binary variable for reporting of having any physical or mental conditions or illnesses lasting or expected to last ≥12 months. Household size was categorised into three groups: one person household, double person household, and household of three or more persons.

Participants were asked about their employment status, and those who were employed or self-employed were asked to select their employment category from this list: teaching and education; healthcare; social care; transport (including storage and logistics); retail (including wholesale); hospitality (eg, hotel, restaurant, or cafe); food production and agriculture (including farming); personal services (eg, hairdressers and tattooists); information technology and communication; financial services (including insurance); manufacturing or construction; civil service or local government; armed forces; arts, entertainment, or recreation; and other (online supplemental figure S1). We used the most recent valid employment sector as reported by participants.

The COVID-19 Infection Survey also collected information on whether the individual's current job regularly involved direct (in-person) contact with patients or clients. To adjust for this information in the regression models, we further categorised participants into patient or client facing workers and non-patient or client facing workers. Calendar time was divided into quarters of the year to account for any seasonal fluctuations in the incidence of infections. These covariates were selected a priori based on expert opinion and an extensive literature review.

Statistical analysis

We compared baseline characteristics for the delta and omicron cohorts, with data presented as median (interquartile range) or number (percentage), unless otherwise stated. We also presented baseline characteristics for the delta and omicron cohorts by the most deprived group (group 1; using the index of multiple deprivation divided by deciles) and least deprived group (group 10).

We calculated the crude incidence rate, assuming a Poisson distribution, to examine the association between index of multiple deprivation and having a positive test result for the delta or omicron variant of the virus after adjusting for covariates. Multivariable Poisson regression models were fitted to estimate the adjusted incidence rate ratio after adjusting for age, sex, ethnic group, comorbid conditions, urban or rural residence, household size, patient or client facing job, and time (as quarters of the year). For the delta cohort, person months were calculated as the time between an individual's first registered study visit (index date) on or after 2 July 2020 and the earlier of the event date (ie, the study visit date where they first reported a positive swab test result compatible with the delta variant) and their final study visit or study end date (19 December 2021). The corresponding dates in the omicron cohort were 20 December 2021 (study start date) and the earlier of the outcome (event date) and the study end date (31 January 2022). We used the log of the follow-up time as the offset term, and robust variance for estimation of confidence intervals. We also included two separate interaction terms for index of multiple deprivation by occupation and index of multiple deprivation by sex in our models.

For analysis of the delta cohort, we included samples from 2 July 2020 to 19 December 2021, and removed participants with no information on health condition or ethnic group. For analysis of the omicron cohort, we included samples on or after 20 December 2021 to 31 January 2022. Figure 1 shows the details of the selection of participants.

We did not apply any imputation for covariate missingness because of the small amount of missing covariate data (figure 1). Because we adjusted for a range of covariates in the model, we restricted our subgroup analyses (ie, by occupation sectors) when the outcome events were ≥50 in each of the 10 equal groups of index of multiple deprivation to ensure the statistical stability of our estimates. This approach

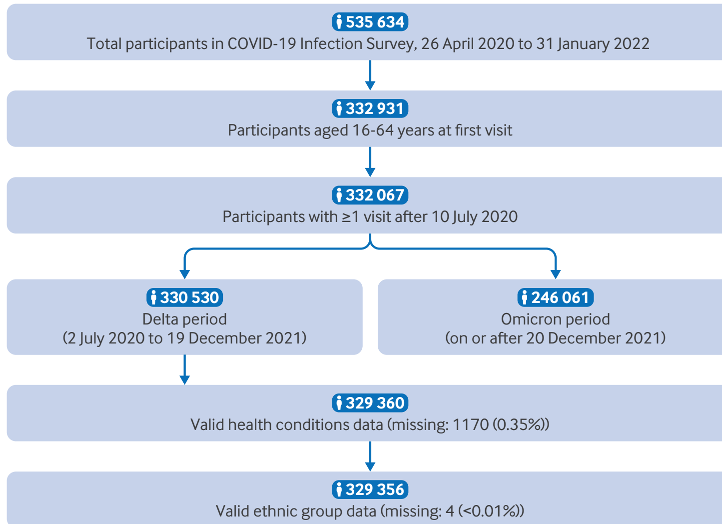

Figure 1 | Flowchart of selection of study population for analysis of SARS-CoV-2 variants of concern (delta and omicron)

meant that we were only able to use the work sectors, healthcare, manufacturing or construction, retail, and teaching and education. In a sensitivity analysis, we also used a multilevel Poisson regression model allowing for random effects at the country level (to account for possible clustering at the country level), and a second order polynomial for age and time variables (to allow for any potential non-linear associations).

Patient and public involvement
Patients were involved in the design stage of this research, with feedback implemented in the design and setup of the Office for National Statistics COVID-19 Infection Survey. The public can ask questions and provide feedback to the COVID-19 Infection Survey inbox. We thank the participants in the COVID-19 Infection Survey for taking part in the survey. Findings from this analysis and further analysis based on the survey have been shared with the public through publications from the Office for National Statistics.

Results
We included 329 356 participants in the delta cohort and 246 061 in the omicron cohort. Table 1 shows the baseline characteristics of the delta and omicron cohorts. Individuals in the omicron cohort were slightly older (47 years, interquartile range 36-46 *v* 45 years, 33-55) than those in the delta cohort, and fewer people had comorbid conditions (15.8% *v* 19.7%). Although the omicron cohort had a smaller number of participants, the distributions and proportions of characteristics were similar between the two cohorts for all other factors. In the most deprived group compared with the least deprived group, we found a higher proportion of people from ethnic minority backgrounds, one person households, and urban areas, as well as more people living with comorbid conditions and being marginally younger, in both the delta and omicron cohorts. Online supplemental table S1 shows the total number and crude percentages of participants in each occupation sector by index of multiple deprivation group for the delta and omicron cohorts.

Incidence rate
The crude incidence rate for the presence of the delta and omicron variants of the SARS-CoV-2 virus were higher in the most deprived group (delta cohort 4.33 per 1000 person months, 95% confidence interval 4.09 to 4.58; omicron cohort 76.67 per 1000 person months, 71.60 to 82.11) than in the least deprived group (3.18, 3.05 to 3.31 and 54.52, 51.93 to 57.24, respectively). We found no appreciable difference in incidence between men and women (online supplemental table S2 and table S3).

Across occupations, we found differences in incidence between the most and least deprived groups. In the least deprived group, the highest incidence rate in the delta cohort was in the teaching sector (4.07, 95% confidence interval 3.65 to 4.53); in the most deprived group, the highest incidence was in the manufacturing or construction sector (5.41, 4.40 to 6.65) (table 2). In the least deprived group, the highest incidence of the omicron variant was in the manufacturing or construction sector (71.89, 61.36 to 84.23); in the most deprived group, the highest incidence was in the healthcare sector (97.47, 78.29 to 121.35) (table 2).

Adjusted incidence rate ratio
The adjusted incidence rate ratio for a positive test result for the delta and omicron variants gradually increased with increasing levels of deprivation. We found the highest incidence rate ratio in the most deprived group compared with the least deprived group (delta cohort

Table 1 | Baseline characteristics of participants in delta and omicron cohorts, by index of multiple deprivation (divided by deciles)

Characteristics	Delta cohort: IMD group 1 (most deprived, n=16 125)	Delta cohort: IMD group 10 (least deprived, n=43 199)	Delta cohort: Total (n=329 356)	Omicron cohort: IMD group 1 (most deprived, n=11 833)	Omicron cohort: IMD group 10 (least deprived, n=33 452)	Omicron cohort: Total (n=246 061)
Median (IQR) age (years)	43.0 (32.0-55.0)	47.0 (36.0-56.0)	45.0 (33.0-55.0)	46.0 (34.0-56.0)	49.0 (39.0-57.0)	47.0 (36.0-56.0)
Sex						
Women	8875 (55.0)	23 224 (53.8)	179 705 (54.6)	6623 (56.0)	18 308 (54.7)	136 888 (55.6)
Ethnic group						
White	14 245 (88.3)	40 683 (94.2)	300 139 (91.1)	10 575 (89.4)	31 581 (94.4)	225 697 (91.7)
Non-white	1880 (11.7)	2516 (5.8)	29 217 (8.9)	1258 (10.6)	1871 (5.6)	20 364 (8.3)
Rural or urban residence						
Urban	15 684 (97.3)	35 948 (83.2)	263 736 (80.1)	11 502 (97.2)	27 850 (83.3)	195 092 (79.3)
Household size (No of people per household)						
1	3649 (22.6)	3544 (8.2)	43 674 (13.3)	2703 (22.8)	2826 (8.4)	32 970 (13.4)
2	5520 (34.2)	14 082 (32.6)	120 635 (36.6)	4122 (34.8)	11 333 (33.9)	90 860 (36.9)
≥3	6956 (43.1)	25 573 (59.2)	165 047 (50.1)	5008 (42.3)	19 293 (57.7)	122 231 (49.7)
Any comorbid conditions						
Yes	5154 (32.0)	6934 (16.1)	64 911 (19.7)	3274 (27.7)	4118 (12.3)	38 757 (15.8)
Patient or client contact						
Yes	3518 (21.8)	8987 (20.8)	71 947 (21.8)	3902 (33.0)	10 272 (30.7)	79 670 (32.4)
Country						
England	13 493 (83.7)	35 574 (82.3)	277 985 (84.4)	9848 (83.2)	27 444 (82.0)	205 652 (83.6)
Scotland	1390 (8.6)	3886 (9.0)	26 209 (8.0)	1044 (8.8)	2971 (8.9)	20 255 (8.2)
Wales	843 (5.2)	2219 (5.1)	15 936 (4.8)	648 (5.5)	1776 (5.3)	12 700 (5.2)
Northern Ireland	399 (2.5)	1520 (3.5)	9226 (2.8)	293 (2.5)	1261 (3.8)	7454 (3.0)

Data are median (interquartile range) or number (column wise %).
IMD, index of multiple deprivation.

adjusted incidence rate ratio 1.37, 95% confidence interval 1.29 to 1.47; omicron cohort adjusted incidence rate ratio 1.34, 1.24 to 1.46) (online supplemental figure S2 and figure S3). Similar patterns were found when the cohorts were examined by sex (figure 2).

The adjusted incidence rate ratios for a positive test result for the delta variant were higher (≥1.50) in the healthcare and manufacturing or construction sectors, when comparing the most deprived group with the least deprived group (figure 3); for the omicron variant, the adjusted incidence rate ratios were higher (≥1.43) in the healthcare and teaching and education sectors (figure 3) when comparing the most deprived group with the least deprived group. Results from the sensitivity analyses did not differ from the main results (online supplemental table S4 and table S5).

Discussion

Main findings

Based on this large, nationally representative UK community based survey, we found that a positive test result for the delta and omicron variants of the SARS-CoV-2 virus was associated with area level deprivation, with a higher incidence and higher incidence rate ratio in the most deprived group compared with the least deprived group. Results did not differ between men and women. Similar patterns were seen for some occupations, where a positive test result for the SARS-CoV-2 delta and omicron variants was higher in the most deprived group than in the least deprived group for the healthcare, manufacturing or construction, and teaching and education sectors.

Comparison with previous literature

Our findings are in agreement with previous evidence indicating that individuals from more deprived areas had a higher risk of SARS-CoV-2 infection and long covid.[4 12 22] Our investigation, however, also assessed whether specific variants of the virus had different incidence rates across occupations. Previous evidence indicated that occupational exposure to the virus might account for some incidences of SARS-CoV-2 infection, especially in healthcare and in people facing occupations.[4 9 23–25] In our analysis, we have provided more detail, however, by showing that the manufacturing or construction sector had the highest incidence of the delta variant whereas the healthcare sector had the highest incidence of the omicron variant.

Although previous research has reported that occupation and deprivation level are independently associated with the risk of SARS-CoV-2 infection,[22 23] we have extended this observation by quantifying individual and combined associations, and showed that the pattern of increased incidence of infection

Table 2 | Crude incidence rates (per 1000 person months) for participants with a positive test result in delta and omicron cohorts, by index of multiple deprivation (divided by deciles) and occupation sectors

Index of multiple deprivation group	Incidence rate by occupation (95% CI)			
	Manufacturing or construction	Healthcare	Retail	Teaching and education
Delta cohort (2 July 2020-19 December 2021)				
1 (most deprived)	5.41 (4.40 to 6.65)	4.51 (3.69 to 5.51)	4.38 (3.53 to 5.43)	4.90 (4.00 to 6.00)
2	4.04 (3.35 to 4.87)	3.24 (2.67 to 3.93)	4.16 (3.43 to 5.05)	4.33 (3.67 to 5.11)
3	4.69 (3.98 to 5.52)	2.83 (2.35 to 3.41)	2.81 (2.24 to 3.53)	4.67 (4.06 to 5.37)
4	3.82 (3.24 to 4.51)	3.06 (2.58 to 3.63)	3.14 (2.56 to 3.85)	4.39 (3.84 to 5.02)
5	3.98 (3.42 to 4.63)	3.02 (2.57 to 3.56)	3.18 (2.60 to 3.89)	4.51 (3.98 to 5.11)
6	3.51 (3.01 to 4.09)	2.65 (2.23 to 3.14)	3.40 (2.82 to 4.11)	4.52 (4.02 to 5.09)
7	3.34 (2.86 to 3.91)	2.79 (2.38 to 3.26)	3.47 (2.89 to 4.18)	4.12 (3.64 to 4.65)
8	3.58 (3.10 to 4.12)	2.88 (2.47 to 3.35)	3.65 (3.05 to 4.37)	4.34 (3.88 to 4.85)
9	4.14 (3.64 to 4.72)	2.36 (2.01 to 2.78)	3.37 (2.81 to 4.05)	4.61 (4.15 to 5.12)
10 (least deprived)	3.54 (3.06 to 4.09)	2.86 (2.47 to 3.31)	3.50 (2.90 to 4.22)	4.07 (3.65 to 4.53)
Omicron cohort (on or after 20 December 2021)				
1 (most deprived)	86.34 (67.04 to 111.20)	97.47 (78.29 to 121.35)	80.46 (62.60 to 103.41)	87.69 (69.14 to 111.22)
2	85.94 (70.13 to 105.30)	78.53 (64.22 to 96.02)	87.44 (69.83 to 109.48)	86.26 (71.62 to 103.9)
3	65.82 (52.65 to 82.30)	64.79 (52.93 to 79.30)	68.39 (54.10 to 86.44)	81.73 (69.21 to 96.51)
4	70.17 (57.74 to 85.28)	83.84 (71.00 to 99.00)	53.94 (42.05 to 69.18)	65.29 (54.91 to 77.64)
5	65.63 (54.35 to 79.25)	65.46 (54.85 to 78.11)	71.24 (57.37 to 88.45)	70.90 (60.75 to 82.74)
6	71.16 (59.76 to 84.74)	69.19 (58.52 to 81.80)	61.45 (49.00 to 77.05)	73.46 (63.75 to 84.65)
7	53.52 (44.04 to 65.04)	58.84 (49.54 to 69.87)	50.41 (39.53 to 64.28)	62.82 (54.01 to 73.08)
8	63.30 (53.48 to 74.93)	56.10 (47.18 to 66.71)	61.22 (49.17 to 76.22)	67.36 (58.72 to 77.26)
9	68.11 (58.04 to 79.93)	67.64 (58.12 to 78.72)	58.54 (46.82 to 73.19)	64.15 (56.01 to 73.46)
10 (least deprived)	71.89 (61.36 to 84.23)	59.27 (50.50 to 69.55)	60.78 (48.54 to 76.10)	55.59 (48.24 to 64.06)

Subgroup analyses were restricted (ie, by occupation sectors) when the outcome events were ≥50 in each of the 10 index of multiple deprivation groups to ensure statistical stability of the estimates.
CI, confidence interval.

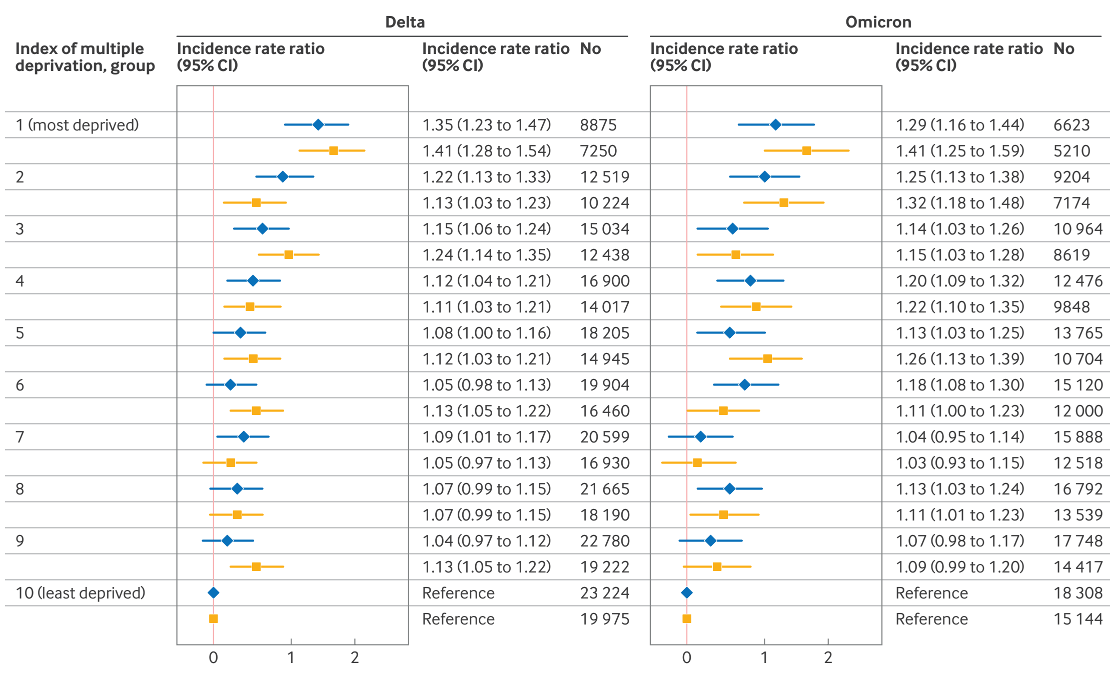

Figure 2 | Association between deprivation and a positive test result for delta and omicron variants of the SARS-CoV-2 virus, by sex. Adjusted for age, ethnic group, urban or rural residence, comorbid conditions, household size, patient or client facing occupation, country, and time (as quarters of the year). Groups are measured by index of multiple deprivation divided by deciles. Reference group is least deprived group. CI=confidence interval

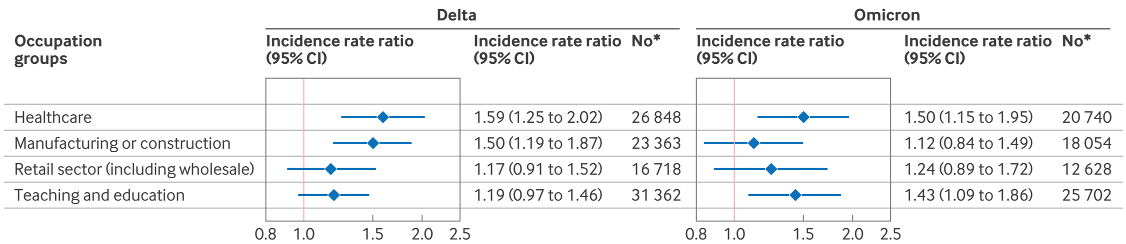

Figure 3 | Association between deprivation and a positive test result for SARS-CoV-2 virus in delta and omicron cohorts, by occupation. Adjusted incidence rate ratios apply to index of multiple deprivation group 1 (most deprived) compared with group 10 (least deprived), where index of multiple deprivation is divided by deciles. Results are adjusted for age, sex, ethnic group, urban or rural home address, comorbid conditions, household size, patient or client facing occupation, country, and time (as quarters of the year). Reference group is least deprived group in each occupation group. *Overall sample size in occupation group. CI=confidence interval

in individuals from more deprived areas was generally consistent across all occupations. We found, however, that socioeconomic inequality differed by occupation. The risk of infection with the delta variant in the most deprived group compared with the least deprived group was highest in the healthcare and manufacturing or construction sectors, whereas the risk of infection with the omicron variant between these two deprivation groups was highest in the healthcare and teaching sectors. Possible explanations for the almost dose-response way in which the incidence rate ratio for a positive test result increased with increasing levels of deprivation in both men and women might be that hierarchies are formed in the workplace, with individuals in lower status roles at increased risk (eg, in patient or public facing occupations or not having the opportunity to work remotely).[26]

Examining intersectionality between sociodemographic factors is important because it allows us to assess whether risk decreases, remains the same, or increases across more granular social categories (eg, deprivation and occupation), rather than within independent categories leaning towards a single axis framework (eg, deprivation or occupation).[27] Also, recent reports from the UK suggested that in some sections of the healthcare workforce, shortages or poor fitting personal protective equipment was a problem, with people from ethnic minority groups or from more deprived backgrounds being most affected.[25 28 29] Healthcare workers with less access to personal protective equipment were reported to be more likely to have a positive test result for SARS-CoV-2.[25] The increased risk in manufacturing or construction and teaching and education sectors in our analysis, however, could be related to other factors, such as whether participants were more likely to be infected or tested, or both, depending on policies specific to their occupation, wider government policies on covid-19, and the timing of covid-19 restrictions.

Strengths and limitations

Our study had several strengths. We used data from a nationally representative community based survey and adjusted for a range of covariates in our models to estimate the independent effects of the index of multiple deprivation on our outcomes. We also examined intersectional inequality by examining inequality by sex, social deprivation, and occupation. The COVID-19 Infection Survey provided uniquely rich, contemporaneous, and longitudinal data on occupation and employment, job status, covid-19 status, and deprivation level.

Our study had some limitations. Comorbid conditions were self-reported, and were not validated against an objective diagnosis. We assumed that the potential measurement errors, however, would be non-differential for the index of multiple deprivation group. The index of multiple deprivation is an ecological area level measure of deprivation and, therefore, the findings might not be applicable at the individual level. Also, the number of infections in each deprivation group for some occupations were low and hence these occupations were excluded to ensure the statistical stability of our estimates.

Data on vaccination status were not available in this study, which is relevant to susceptibility to the SARS-CoV-2 virus after 8 December 2020 (date of first vaccination in the UK). This limitation is important because vaccination has been shown to reduce transmission.[30] Also, some sectors were prioritised (eg, healthcare staff) for vaccination at the beginning of the vaccine rollout, which could have biased our results, while some sociodemographic groups also reported a lower uptake of the vaccine.[31 32] However, the effect of vaccination should be non-differential for all individuals who received a vaccine during our study, while accounting for time will take into consideration potential changes in vaccination uptake.

Because our outcome was specific for the variants of concern (delta and omicron), infection rates of other variants might have affected the estimates of the incidence rate ratio in our analyses. Hence our incidence rate ratios might have been even higher if we had included all infections in our outcome, suggesting possible underestimation of our results. Our analysis, however, could not determine associations between deprivation or occupation and less prevalent variants of the SARS-CoV-2 virus circulating at the time of our study.

An observational analysis cannot establish causality and our study also lacked precise data on lockdowns or whether individuals were working from home. These factors might have varied by occupation and individual situations. Nevertheless, some degree of residual confounding might still exist.

Potential non-response bias could cause uncertainty in the data, which might not be fully mitigated by the methods used to adjust for this bias in the original survey design. The sampling method ensured that the UK population was well represented, however, and a higher number of households were invited to take part in the survey to account for attrition and non-response bias. Although the COVID-19 Infection Survey sample was nationally representative, the response rate was relatively low. Once recruited, however, the attrition rate was generally low; based on a definition of formally withdrawing from the study or not attending the three most recently scheduled follow-up visits, the attrition rate among enrolled survey participants was <1% in 2021.[33] Nevertheless, participants in the most deprived groups might have been less likely to take covid-19 tests. If this is true, our results are conservative estimates of the true incidence and rate ratios.

Lastly, we could not determine if the source of infection was at a person's workplace (eg, people could have been working from home). Therefore, the risk estimates reported in this study are a weighted average for the whole occupational sector (ie, those who worked from home and those who worked on site).

Conclusions

Our analysis showed that differences existed between occupations when the risk of a positive test result for the SARS-CoV-2 virus was compared between the most and least deprived groups. Also, when the results were not grouped by occupation, we found a pattern of increasing incidence and rate ratios for SARS-CoV-2 from low to high deprivation groups, with findings similar in men and women. These results will help inform employers and health policy in conducting evidence based risk assessments and in allocating potentially limited resources to those at greatest risk of covid-19 in different occupation sectors.

AUTHOR AFFILIATIONS

[1]Diabetes Research Centre, University of Leicester, Leicester, UK
[2]Leicester Real World Evidence Unit, University of Leicester, Leicester, UK
[3]Primary Care Research Centre, Faculty of Medicine, University of Southampton, Southampton, UK
[4]Nuffield Department of Population Health, University of Oxford, Oxford, UK
[5]National Institute for Health and Care Research (NIHR) Leicester Biomedical Research Centre, Leicester, UK
[6]Institute of Health Informatics, University College London, London, UK
[7]Department of Respiratory Sciences, University of Leicester, Leicester, UK
[8]Department of Infection and HIV Medicine, University Hospitals Leicester NHS Trust, Leicester, UK
[9]MRC Epidemiology Unit, University of Cambridge, Cambridge, UK

Acknowledgements We are grateful to Vahé Nafilyan and Daniel Ayoubkhani, Office for National Statistics, for their contributions to the analysis and helpful feedback on earlier versions of the manuscript.

Contributors NI and KK conceived and designed the study, obtained the funding, developed the statistical methodology, and managed and coordinated the research activity. CR, SS, and NI carried out the data preparation, analyses, and data visualisation. CR drafted the first version of the article. All authors contributed to reviewing the article and interpreting the findings. All authors have approved the final published version. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. NI is the guarantor. Transparency: The lead author (the guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Funding The study was funded by the Office for National Statistics (ONS, project No 2002569, reference PU22-0205(a), https://www.ons.gov.uk/). The funder had no role in considering the study design or in the collection, analysis, interpretation of data, writing of the report, or decision to submit the article for publication. The opinions expressed in this report are solely the authors' and do not necessarily reflect the opinions of the organisations or entities the authors are employed by or affiliated with. This work contains statistical data from ONS which are crown copyright. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which might not exactly reproduce national statistics aggregates. This work was produced with statistical data in the secure research service, part of ONS.

Competing interests All authors have completed the ICMJE uniform disclosure form at www.icmje.org/disclosure-of-interest/ and declare: support from the Office for National Statistics for the submitted work; KK is chair of the ethnicity subgroup of the UK Scientific Advisory Group for Emergencies (SAGE) and is a member of SAGE; KK, SS, TY, FZ, CG, YC, and CR are supported by the National Institute for Health and Care Research (NIHR) Applied Research Collaboration East Midlands (ARC-EM) and the NIHR Leicester Biomedical Research Centre; MW is supported by Medical Research Council (MRC) funding for the MRC Epidemiology Unit, University of Cambridge (grant No MC/UU/00006/7); no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethics approval The Office for National Statistics COVID-19 Infection Survey was approved by the South-Central Berkshire B research ethics committee (20/SC/0195). The study was assessed with the National Statistician's Data Ethics Advisory Committee (NSDEC) ethics self-assessment tool, and the committee confirmed that no further ethical consideration was required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Data from the Office of National Statistics (ONS) COVID-19 Infection Survey can be accessed only by ONS accredited researchers through the secure research service. Researchers can apply for accreditation through the research accreditation service and will need approval to access the COVID-19 Infection Survey data. Further details can be found at https://www.ons.gov.uk/aboutus/whatwedo/statistics/requestingstatistics/secureresearchservice

ORCID iDs
Cameron Razieh http://orcid.org/0000-0003-3597-2945
Tom Yates http://orcid.org/0000-0002-5724-5178
Ben Lacey http://orcid.org/0000-0003-0139-2934
Nazrul Islam http://orcid.org/0000-0003-3982-4325

REFERENCES

1 Blundell R, Cribb J, McNally S, *et al*. Inequalities in education, skills, and incomes in the UK: the implications of the COVID-19 pandemic [Institute for Fiscal Studies]. 2021. Available: https://ifs.org.uk/inequality/inequalities-in-education-skills-and-incomes-in-the-uk-theimplications-of-the-covid-19-pandemic
2 Razieh C, Zaccardi F, Islam N, *et al*. Ethnic minorities and COVID-19: examining whether excess risk is mediated through deprivation. Eur J Public Health 2021;31:630–4. 10.1093/eurpub/ckab041
3 Nafilyan V, Islam N, Mathur R, *et al*. Ethnic differences in COVID-19 mortality during the first two waves of the coronavirus pandemic: a nationwide cohort study of 29 million adults in England. Eur J Epidemiol 2021;36:605–17. 10.1007/s10654-021-00765-1
4 Public Health England. Disparities in the risk and outcomes of COVID-19. 2020. Available: https://www.gov.uk/government/publications/covid-19-review-of-disparities-in-risks-and-outcomes
5 Nafilyan V, Pawelek P, Ayoubkhani D, *et al*. Occupation and COVID-19 mortality in England: a national linked data study of 14.3 million adults. Occup Environ Med 2022;79:433–41. 10.1136/oemed-2021-107818
6 Mutambudzi M, Niedzwiedz C, Macdonald EB, *et al*. Occupation and risk of severe COVID-19: prospective cohort study of 120 075 UK Biobank participants. Occup Environ Med 2021;78:307–14. 10.1136/oemed-2020-106731
7 Rhodes S, Wilkinson J, Pearce N, *et al*. Occupational differences in SARS-Cov-2 infection: analysis of the UK ONS COVID-19 infection survey. J Epidemiol Community Health 2022;76:841–6. 10.1136/jech-2022-219101
8 Blundell R, Costa Dias M, Joyce R, *et al*. COVID-19 and inequalities. Fisc Stud 2020;41:291–319. 10.1111/1475-5890.12232
9 Rowlands AV, Gillies C, Chudasama Y, *et al*. Association of working shifts, inside and outside of healthcare, with severe COVID-19: an observational study. BMC Public Health 2021;21::773. 10.1186/s12889-021-10839-0
10 Marmot M. Health equity in England: the Marmot review 10 years on. BMJ 2020;368:m693. 10.1136/bmj.m693
11 Caul S. Deaths involving COVID-19 by local area and socioeconomic deprivation: deaths occurring between 1 March and 31 July 2020. Statistical Bulletin, 2020. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/deathsinvolvingcovid19bylocalareasanddeprivation/deathsoccurringbetween1marchand31july2020
12 Shabnam S, Razieh C, Dambha-Miller H, *et al*. Socioeconomic inequalities of long COVID: a retrospective population-based cohort study in the United Kingdom. J R Soc Med 2023;116:263–73. 10.1177/01410768231168377
13 Pouwels KB, House T, Pritchard E, *et al*. Community prevalence of SARS-Cov-2 in England from April to November, 2020: results from the ONS coronavirus infection survey. Lancet Public Health 2021;6:e30–8. 10.1016/S2468-2667(20)30282-6
14 Nuffield Department of Medicine. Protocol and information sheets. 2022. Available: https://www.ndm.ox.ac.uk/covid-19/covid-19-infection-survey/protocol-and-information-sheets
15 Office for National Statistics. A05 SA: employment, unemployment and economic inactivity by age group (seasonally adjusted) [Internet]. Available: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/employmentunemploymentandeconomicinactivitybyagegroupseasonallyadjusteda05sa [Accessed 8 Aug 2022].
16 Office for National Statistics. Coronavirus (COVID-19) infection survey: methods and further information [Internet]. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/methodologies/covid19infectionsurveypilotmethodsandfurtherinformation [Accessed 22 Feb 2023].
17 McLennan D, Noble S, Noble M, *et al*. The English indices of deprivation 2019: technical report; 2019. Available: https://www.gov.uk/government/publications/english-indices-of-deprivation-2019-technical-report
18 Penney B. The English Indices of Deprivation 2019 (IoD2019). Ministry of Housing, Communities & Local Government, 2019. Available: https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019
19 GOV.UK. COVID-19 dashboard [Internet]. 2023. Available: https://coronavirus.data.gov.uk/details/cases?areaType=nation&areaName=England
20 Office for National Statistics. Coronavirus (COVID-19) infection survey, characteristics of people testing positive for COVID-19, UK: 2 February 2022 [Internet]. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/coronaviruscovid19infectionsurveycharacteristicsofpeopletestingpositiveforcovid19uk/2february2022 [Accessed 26 Jul 2023].
21 Coronavirus (COVID-19) Infection Survey, early analysis of characteristics associated with the omicron variant among COVID-19 infections, UK, Available: https://www.ons.gov.uk/news/statementsandletters/coronaviruscovid19infectionsurveyearlyanalysisofcharacteristicsassociatedwiththeomicronvariantamongcovid19infectionsuk20december2021 [Accessed 21 Dec 2021].
22 Vandentorren S, Smaïli S, Chatignoux E, *et al*. The effect of social deprivation on the dynamic of SARS-Cov-2 infection in France: a population-based analysis. Lancet Public Health 2022;7:S2468-2667(22)00007-X:e240–9.:. 10.1016/S2468-2667(22)00007-X
23 Koh D. Occupational risks for COVID-19 infection. Occup Med 2020;70:3–5. 10.1093/occmed/kqaa036
24 Which occupations have the highest potential exposure to the coronavirus (COVID-19), Available: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/articles/whichoccupationshavethehighestpotentialexposuretothecoronaviruscovid19/2020-05-11
25 Martin CA, Pan D, Melbourne C, *et al*. Risk factors associated with SARS-Cov-2 infection in a multiethnic cohort of United Kingdom healthcare workers (UK-REACH): a cross-sectional analysis. PLoS Med 2022;19:e1004015. 10.1371/journal.pmed.1004015
26 Crenshaw K. Demarginalizing the intersection of race and sex: a black feminist critique of Antidiscrimination doctrine, feminist theory and Antiracist politics. In: Feminist legal theories. Routledge, 2013: 23–51. Available: https://www.taylorfrancis.com/chapters/edit/10.4324/9781315051536-2/demarginalizing-intersection-race-sex-kimberle-crenshaw
27 Bauer GR, Churchill SM, Mahendran M, *et al*. Intersectionality in quantitative research: A systematic review of its emergence and applications of theory and methods. SSM Popul Health 2021;14:100798. 10.1016/j.ssmph.2021.100798
28 Network BL. The impact of COVID-19 on BME communities and health and care staff. *BME* 2020. Available: https://www.nhsconfed.org/publications/impact-covid-19-bme-communities-and-health-and-care-staff
29 Public Health England. Beyond the data: understanding the impact of COVID-19 on BAME groups; 2020. PheAvailable: https://www.gov.uk/government/publications/covid-19-understanding-the-impact-on-bame-communities
30 Harris RJ, Hall JA, Zaidi A, *et al*. Effect of vaccination on household transmission of SARS-Cov-2 in England. N Engl J Med 2021;385:NEJMc2107717:759–60.:. 10.1056/NEJMc2107717
31 Gaughan CH, Razieh C, Khunti K, *et al*. COVID-19 vaccination uptake amongst ethnic minority communities in England: a linked study exploring the drivers of differential vaccination rates. J Public Health (Bangkok) 2023;45:e65–74. 10.1093/pubmed/fdab400
32 Nafilyan V, Dolby T, Razieh C, *et al*. Sociodemographic inequality in COVID-19 vaccination coverage amongst elderly adults in England: a national linked data study. *Public and Global Health* [Preprint]. 10.1101/2021.05.13.21257146
33 Ayoubkhani D, Bermingham C, Pouwels KB, *et al*. Trajectory of long covid symptoms after COVID-19 vaccination: community based cohort study. BMJ 2022;377:e069676. 10.1136/bmj-2021-069676

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjmed-2023-000624).