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

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Abstract

Objective: It is unknown whether SARS-CoV-2 exposure risks vary by socioeconomic deprivation within and across occupation sectors. We explored the risk of testing positive for Delta or Omicron variants, the predominantly dominant SARS-CoV-2 variants during our study period, within certain occupation sectors and deprivation groups in the UK.

Methods and Analysis: We used the COVID-19 Infection Survey (CIS) to examine the risk of testing positive with SARS-CoV-2 across area-level deprivation and occupation sectors. We divided our cohort into Delta (02.07.2020–19.12.2021) and Omicron (20.12.2021–31.01.2022) cohorts as they were the predominantly dominant variants during our study period. Multivariable Poisson regression models were used to estimate adjusted incidence rate ratio (IRR) after adjusting for age, sex, ethnicity, comorbid conditions, urban/rural home address, household size, healthcare/client-facing job categories and calendar time.

Results: There were 329,356 participants in the Delta cohort and 246,061 in the Omicron cohort. The crude incidence rate for Delta and Omicron cases were higher in the most deprived decile (Delta: 4.33 per 1000 person months; 95% CI: 4.09, 4.58; Omicron: 76.67; 71.60, 82.11) than in the least deprived decile (3.18; 3.05, 3.31; and 54.52; 51.93, 57.24, respectively); the corresponding adjusted IRRs were 1.37 (95% CI: 1.29, 1.47) and 1.34 (1.24, 1.46) during the Delta and Omicron period, respectively. The adjusted IRR for testing positive in the most deprived compared with the least deprived decile in the Delta cohort were 1.59 (1.25, 2.02) and 1.50 (1.19, 1.87) in healthcare and manufacturing or construction occupation sectors, respectively. Corresponding values in the Omicron cohort were 1.50 (1.15, 1.95) and 1.43 (1.09, 1.86) in healthcare and teaching and education sectors. The associations for the other employment sectors were not statistically significant or not tested due to small numbers.

Conclusion: The risk of testing positive for SARS-CoV-2 in the Delta and Omicron cohorts was higher in the most deprived compared with the least deprived decile in healthcare, manufacturing or construction, and teaching and education sectors.

Key messages

What is already known on this topic

People's occupation may have played a role in increasing the exposure to SARS-CoV-2 and may be associated with increased infection in individuals who were unable to work from home. However, the intersectionality between occupation and deprivation for SARS-CoV-2 infection risk has not been examined.

What this study adds

Our analysis demonstrates that the risk of testing positive for SARS-CoV-2 Delta and Omicron was 43-59% higher in the most deprived compared with the least deprived decile in 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 COVID-19 across occupation sectors in future pandemics or outbreaks of infectious disease. Further, these findings will

help in the planning of risk assessments and resource planning for future variants of concern for SARS-CoV-2.

Introduction

The risk of exposure to SARS-CoV-2 and subsequent health outcomes has widened pre-existing disparities and has disproportionately impacted the health of certain subpopulations, such as ethnic minority groups or those who are more deprived (1-4). Preliminary findings from England suggest a disproportionate degree of COVID-19 mortality, severe COVID-19 and infection across certain occupation groups, such as the healthcare sector (5-7). For example, people working in conditions with exposure to clients (patients or the public) reported elevated risk of death involving COVID-19, even after accounting for other factors. Therefore, throughout the pandemic, the nature of people's occupation may have played a role in increasing the exposure to, and risk of, SARS-CoV-2 infection in individuals who were unable to work from home (5, 7-9).

While several studies have reported important occupation differences in risk of SARS-CoV-2 infection and subsequent COVID-19 outcomes, few have investigated the intersectionality between occupation and deprivation. Occupation, employment sector, deprivation and poor health are all linked. Individuals working in low paid and insecure jobs are more likely to experience poorer housing conditions and household overcrowding (10). They may also be more likely to have poorer health. It is therefore important to assess these socioeconomic inequalities in exposure risk as evidence reports 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 increased risk of SARS-CoV-2 infection is important for health policy regarding COVID-19 and beyond. If excess risk is due to workplace exposures, then preventative interventions and policies within the workplace may reduce inequalities seen in COVID-19. Whereas, if deprivation and non-workplace factors are driving increased risk, then additional societal interventions and policies may be required.

Few studies have examined socioeconomic inequalities within, and across, occupation sectors, largely due to a lack of contemporaneous and longitudinal individual data on occupation and employment (12). Further, understanding whether specific variants of concern (and subsequent waves and restrictions) unevenly impacted individuals working in different occupation sectors or across deprivation groups is currently unknown.

In this study, we explored the risk of testing positive for Delta or Omicron variants throughout the coronavirus pandemic within certain occupation sectors and deprivation groups and assessed the prevalence of Delta and Omicron within these groups.

Materials and Methods

Population and databases

We used the United Kingdom (UK) COVID-19 Infection Survey (CIS) to examine the potential differential effects of SARS-CoV-2 risk exposure across occupation sectors. The CIS offers a unique opportunity to examine the longitudinal association between occupation sectors and SARS-CoV-2 during COVID-19 pandemic.

The CIS, conducted by the Office for National Statistics (ONS) and the University of Oxford, was approved by the South-Central Berkshire B Research Ethics Committee (20/SC/0195). It is a nation-wide longitudinal survey to monitor SARS-CoV-2 infection in the community and is currently closed (13). Participants were recruited from randomly selected households to reflect the UK population (England, Scotland, Wales and Northern Ireland). The CIS sampling was stratified geographically to

ensure representativeness of people from all local areas of the UK. The CIS response rate was 13.3% and the sample size was adjusted to account for varying response rates. The CIS is an open cohort study where new participants were recruited over the study period and longitudinal data collected from consenting existing participants. Each new participant was surveyed for five weeks initially, and monthly thereafter (14). Data collected per visit included nose and throat swabs, a blood sample and questionnaire data. The data in this analysis were collected by the CIS from April 26, 2020 to January 31, 2022. Only working age adults (16 to 64 years old) were eligible for the analysis (15). More detail on the CIS design and methodology can be found on the ONS website (16).

Exposures

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

Outcome

Variants of concern were limited to Delta and Omicron variants as they were the dominant variants during the time period of this analysis (19). We divided the cohort into Delta (02 July 2020 to 19 December 2021) and Omicron (on or after 20 December 2021) cohorts, as implemented in previously published ONS reports (20). SARS-CoV-2 diagnoses compatible with the Delta variant were defined based on the following gene patterns: "OR+S" or "N+S" or "OR+N+S" with a CT <30 in the Delta cohort. Similarly, diagnoses compatible with the Omicron variant were based on the gene pattern of "OR+N" with a CT <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 Delta variant during the Delta period. Similarly, during the Omicron period, it was coded as a binary variable if the gene pattern was compatible with the Omicron variant. This meant that people who were infected with other variants would be coded as not having the outcome. A PCR test was used to gather the sample for testing.

Covariates

Our analysis included self-reported sociodemographic and clinical data collected from the CIS survey, including age, sex, ethnicity, comorbid conditions, urban/rural home address, household size, patient/client facing job and time (as quarters of the year). Age in years was calculated at the time of the participants' first visit. Sex was self-reported as either male or female. Ethnicity was self-reported based on the UK 18-category ethnic classifications and, for the purposes of this analysis, categorised as white/non-white due to low counts of ethnic minority individuals. Comorbid conditions were measured by a binary variable for reporting having any physical or mental conditions or illnesses lasting or expected to last 12 months or more. Household size was categorised into three groups: single person household; double person household; household of three or more persons. Participants were asked about their employment status and those who were employed (or self-employed) were

further asked to select their employment category, including: Teaching and Education; Health Care; Social Care; Transport (incl. Storage, Logistic); Retail (incl. wholesale); Hospitality (e.g. Hotel, Restaurant, Café); Food Production and Agriculture (incl. Farming); Personal Services (e.g. Hairdressers, tattooists); Information Technology and Communication; Financial Services (incl. Insurance); Manufacturing or Construction; Civil Service or Local Government; Armed Forces; Arts, Entertainment or Recreation; Other (**Figure S1**). We used the most recent valid employment sector as reported by the participants.

The CIS also collected information on whether individuals' current job regularly involved direct (in-person) contact with patients or clients. To adjust for this in the regression models, we further categorised participants into two groups: (1) patient/client facing workers; (2) non-patient/client facing workers. Calendar time was split into quarters of the year to account for any effects seen in infection due to seasonal fluctuations. These covariates were selected *a priori* based on expert opinion and an extensive literature review.

Statistical analysis

We compared the baseline characteristics for the Delta and Omicron cohorts, with data presented as median (IQR) or count (%) unless otherwise stated. We further presented baseline characteristics for both the Delta and Omicron time cohorts by the most (IMD decile 1) and least (IMD decile 10) deprived deciles.

We calculated the crude incidence rate assuming a Poisson distribution to examine the association between IMD and testing positive for either Delta or Omicron after adjusting for covariates. Multivariable Poisson regression models were fitted to estimate the adjusted incidence rate ratio (IRR) after adjusting for age, sex, ethnicity, comorbid conditions, urban/rural home address, household size, patient/client facing job and time (as quarters of the year). For the delta cohort, person-months were calculated by calculating the time between an individual's first registered study visit (index date) on or after 02.07.2020 and the earlier of the event data (i.e., the study visit date where they first reported a positive swab result compatible with Delta variant) and the earlier of their final study visit or study end date (19.12.2021). The corresponding dates to calculate the follow-up time in the Omicron cohort were 20.12.2021 (study start date) and the earlier of the outcome (event date) and the study end date (31.01.2022). We used the log of the follow-up time as the offset term, and robust variance for the estimation of confidence intervals (CI). We further included two separate interaction terms for IMD by occupation and IMD by sex in our models.

For Delta cohort analysis, we included samples from 02.07.2020 to 19.12.2021 and further removed those without information on health condition or ethnicity. For the Omicron cohort analysis, we included samples on or after 20.12.2021 to 31.01.2022. **Figure 1** shows the details of the flowchart of participants.

Due to a small amount of missing covariate data, we did not apply any imputation for covariate missingness (**Figure 1**). Since we adjusted for a range of covariates in the model, we restricted our subgroup analyses (i.e., by occupation sectors) when the outcome events were 50 or more in each of the 10 IMD deciles to ensure statistical stability of our estimates. This meant that we were only able to stratify our occupation sector analysis by the following work sectors: healthcare; manufacturing or construction; retail; teaching and education.

In a sensitivity analysis, we additionally used multilevel Poisson regression model allowing for random-effects at country level (to account for possible clustering at country-level), and second-order polynomial for age and time variables (to allow 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 ONS COVID Infection Survey. The public can ask questions provide feedback via the COVID Infection Survey inbox. We thank the participants in the COVID Infection Survey for taking part in the survey. Findings from this analysis and further analysis utilising the survey have been shared with the public through ONS publications.

Results

329,356 participants were included in the Delta cohort and 246,061 in the Omicron cohort. Baseline characteristics of the Delta and Omicron cohorts are presented in **Table 1**. Individuals in the Omicron cohort were marginally older (47 years [IQR 36, 46] vs 45 years [33, 55]) and had fewer people with comorbid conditions (15.8% vs 19.7%) than the Delta cohort. While the Omicron cohort had a smaller number of participants, similar distributions/proportions of characteristics were reported between the two cohorts for all other factors. The most deprived deciles for both Delta and Omicron cohorts had a higher proportion of people from minority ethnic backgrounds, single households and urban areas, while also having more people living with comorbid conditions and being marginally younger, compared to the least deprived decile. The total number and crude percentages of participants with Delta or Omicron in each occupation sector by IMD is shown in **Table S1.**

Incidence rate

The crude incidence rate for Delta and Omicron cases were higher in the most deprived decile (Delta: 4.33 per 1000 person months; 95% CI: 4.09, 4.58; Omicron: 76.67 per 1000 person months; 95% CI: 71.60, 82.11) than in the least deprived decile (3.18; 3.05, 3.31; and 54.52; 51.93, 57.24, respectively). There was no appreciable difference in incidence in males or females when stratifying by sex (**Table S2** and **Table S3**).

There were differences in incidence between the most and the least deprived deciles across occupation sectors. In the least deprived decile, the highest incidence rate in the Delta cohort was in the teaching sector (4.07; 3.65, 4.53); in the most deprived decile it was highest in the manufacturing or construction sector (5.41; 4.40, 6.65) (**Table 2**). In the least deprived decile for the Omicron cohort, the highest incidence of Omicron was in the manufacturing or construction sector (71.89; 61.36, 84.23); in the most deprived decile it was highest in the healthcare sector (97.47; 78.29, 121.35) (**Table 2**).

Adjusted incidence rate ratio (IRR)

The adjusted IRR for testing positive for Delta and Omicron gradually increased with increasing levels of deprivation, with the highest IRR found in the most compared with the least deprived deciles (Delta: aIRR 1.37, 95% CI: 1.29, 1.47; Omicron: aIRR 1.34, 95% CI: 1.24, 1.46) (**Figures S2** and **S3)**. Similar patterns were found when stratifying by males and females (**Figure 2**).

When comparing the most deprived with the least deprived decile across occupation sectors, the adjusted IRRs for testing positive with the Delta variant were higher in healthcare and manufacturing or construction sectors, with adjusted IRRs ≥1.50 (**Figure 3**).

The adjusted IRRs for testing positive with the Omicron variant when comparing the most deprived with the least deprived decile were higher in healthcare and teaching and education sectors, with adjusted IRRs ≥1.43 (**Figure 3**).

Results from the sensitivity analyses did not differ from those from the main results **(Table S4 and Table S5).**

Discussion

Main findings

Based on a large, nationally representative UK community-based survey, we found that testing positive for Delta and Omicron was associated with area-level deprivation, with higher incidence and IRR for testing positive in the most deprived decile compared with the least deprived deciles, with results consistent between males and females. Similar patterns were seen for certain occupation sectors, where testing positive for SARS-CoV-2 Delta and Omicron was higher in the most deprived compared with the least deprived decile in healthcare, manufacturing or construction and teaching and education sectors.

Comparison to previous literature

The findings from this study are consistent with previous evidence which reports that individuals who are more deprived had a higher risk of SARS-CoV-2 infection and Long COVID (4, 12, 22). However, we add to the literature with our investigation into whether specific variants have different prevalence across occupation sectors. While previous evidence has reported that occupational exposure may account for some infection, especially in healthcare and people facing occupations (4, 9, 23-25), we provide further detail stratifying by Delta and Omicron cohorts and demonstrate that the manufacturing or construction sector had the highest incidence of Delta variant while the healthcare occupation sector had the highest prevalence for Omicron variant.

While previous research has reported that occupation and deprivation level are independently associated with risk of SARS-CoV-2 infection (22, 23), we extend this observation by quantifying the individual and combined associations and demonstrate that the pattern of increased incidence of infection in more deprived individuals is generally consistent across all occupation sectors. However, we did find the socioeconomic inequality did differ by occupation sectors. The risk of infection for the Delta variant in the most compared with the least deprived decile was highest in healthcare and manufacturing or construction sectors, whereas the risk of infection for the Omicron variant between these deciles was highest in healthcare and teaching sectors. Possible explanations for the almost dose-response fashion in which the IRR for testing positive increased with increasing levels of deprivation in both men and women may be that within workplaces, hierarchies are formed which place individuals in lower status roles in environments with increased risk (e.g. patient/public facing or not being given the opportunity to work remotely) (26). Examining intersectionality between sociodemographic factors is important as it allows for assessment whether risk attenuates, remains or increases across more granular social categories (e.g. deprivation and occupation), rather than within independent categories leaning toward a single-axis framework (e.g. deprivation or occupation) (27). Further, recent reports from the UK stated that certain sections of the healthcare workforce may have faced shortages of or received ill-fitting personal protective equipment (PPE), with it suggested people from minority ethnic or more deprived backgrounds being most affected (25, 28, 29). It has been shown that healthcare workers with less access to PPE are more likely to test positive for SARS-CoV-2 (25). However, the increased risk seen in manufacturing or construction and teaching and education sectors may be related to other factors, such as whether they were more likely to be infected and/or tested depending on occupation-specific policies, wider COVID-19 government policies and the timing of COVID-19 restrictions being introduced or eased.

Strengths and limitations

Our study has several strengths. We have used a nationally representative community-based survey and adjusted for a range of covariates in our models to estimate the independent effects of the IMD on our outcomes. We further examined the intersectional inequality by examining the inequality by sex, social deprivation, and occupation sectors. We have used the CIS which provides a uniquely rich, contemporaneous and longitudinal data on occupation and employment, job status, COVID-19 exposure and deprivation level. However, our study has some limitations. First, comorbid conditions were self-reported, and were not validated against an objective diagnosis. However, we assume that the potential measurement errors would be non-differential regarding IMD deciles. Second, IMD is an ecological area-level measure of deprivation and, therefore, the findings may not be applicable at an individual level. Third, the number of infections within each decile in some occupation sectors were low; therefore, these occupation sectors were excluded to ensure statistical stability of our estimates. Fourth, vaccination status data was unavailable in this study, which would be relevant in SARS-CoV-2 susceptibility for any date after 8 December 2020 (first date of vaccination in the UK). This is an important limitation given that vaccination has been shown to reduce transmission (30). Further, certain occupation sectors were prioritised (e.g., healthcare staff) for vaccination at the beginning of the vaccination rollout so this may bias our results, while further certain demographic groups have been shown to have lower vaccination uptake (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 account for potential changes in vaccination uptake. Fifth, because our outcome is variant of concern (VOC) specific, the rates of other infections in our study may have impacted on the IRR estimates for our VOC within our analyses. Further, because of this, our findings may have been even higher if we included all infections within our outcome as our current reference group in the outcome includes other infections. This may therefore suggest our findings are an underestimation of results. However, our results cannot demonstrate the associations of other less prevalent variants which were circulating at the time periods in our analysis. Sixth, this is an observational analysis and cannot establish any causality. Another limitation of our study is a lack of precise data on lockdowns or whether individuals were working from home. These might have varied by occupation sectors and individual situations. Nevertheless, some degree of residual confounding may still exist.

Potential non-response bias may cause uncertainty in the data, which may not be fully mitigated by the methods used to adjust for this in the original survey design. However, the sampling method implemented ensured representativeness of the UK population and invited a higher number of households to account for attrition and non-response bias. Even though the CIS sample was nationally representative, the response rate of the survey was relatively low. However, once recruited, the attrition rate was generally low; using a definition of either formally withdrawing from the study or having not attended the three most recently scheduled follow-up visits, the attrition rate among enrolled survey participants was less than 1% in 2021 (33). Nevertheless, it is possible that participants in the most deprived deciles were less likely to take COVID-19 tests. If this was true, our results are conservative estimates of the true incidence and rate ratios. Lastly, it was not possible to identify whether the source of infection was at a person's workplace (e.g., people may have been working from home). Therefore, the risk estimates reported in this study are a weighted average for the entire occupation sector (i.e., those worked from home and those who worked onsite).

Conclusion

Our analysis has demonstrated that there were differences between occupation sectors when comparing the risk of testing positive for SARS-CoV-2 between the most and the least deprived deciles. Further, in findings not stratified by occupation sectors, we found a pattern of increasing incidence

and rate ratios for SARS-CoV-2 seen from low to high deprivation deciles, with findings consistent between males and females. 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 COVID-19 across occupation sectors.

Declarations

Contributors: NI and KK conceived and designed the study, obtained the funding, developed the statistical methodology and managed and coordinated 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.

Competing Interests: 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 Research (NIHR) Applied Research Collaboration East Midlands (ARC-EM) and the NIHR Leicester Biomedical Research Centre (BRC). MW is supported by Medical Research Council funding for the MRC Epidemiology Unit, University of Cambridge [grant number MC/UU/00006/7]. Other authors declare no relevant conflicts of interest.

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Ethics Approval: The ONS COVID-19 Infection Survey (CIS) was approved by the South-Central Berkshire B Research Ethics Committee (Ethics Ref: 20/SC/0195). The study was assessed using the National Statistician's Data Ethics Advisory Committee (NSDEC) ethics self-assessment tool, and the committee confirmed that no further ethical consideration was required. Participants provided informed consent to take part in this study.

Data availability statement: The data from the Office of National Statistics COVID-19 Infection Survey (CIS) can be accessed only by ONS accredited researchers (AR) through the Secure Research Service (SRS). Researchers can apply for accreditation through the Research Accreditation Service and will need approval to access CIS data. For further details see: https://www.ons.gov.uk/aboutus/whatwedo/statistics/requestingstatistics/secureresearchservice.

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Tables and Figures

Table 1. Baseline characteristics of participants in Delta and Omicron cohorts, by IMD decile.

Characteristics	IMD decile 1 (most deprived) N=16125	IMD decile 10 (least deprived) N=43199	Total N=329356	IMD decile 1 (most deprived) N=11833	IMD decile 10 (least deprived) N=33452	Total N=246061
	Delta cohort (02.07.2020–19.12.2021)			Omicron cohort (on or after 20.12.2021)		
Age, (median (IQR))	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, n (%)						
Female	8875 (55.0%)	23224 (53.8%)	179705 (54.6%)	6623 (56.0%)	18308 (54.7%)	136888 (55.6%)
Ethnicity, n (%)						
White	14245 (88.3%)	40683 (94.2%)	300139 (91.1%)	10575 (89.4%)	31581 (94.4%)	225697 (91.7%)
Non-White	1880 (11.7%)	2516 (5.8%)	29217 (8.9%)	1258 (10.6%)	1871 (5.6%)	20364 (8.3%)
Rural/urban, n (%)						
Urban	15684 (97.3%)	35948 (83.2%)	263736 (80.1%)	11502 (97.2%)	27850 (83.3%)	195092 (79.3%)
Household size in persons, n (%)						
1	3649 (22.6%)	3544 (8.2%)	43674 (13.3%)	2703 (22.8%)	2826 (8.4%)	32970 (13.4%)
2	5520 (34.2%)	14082 (32.6%)	120635 (36.6%)	4122 (34.8%)	11333 (33.9%)	90860 (36.9%)
>=3	6956 (43.1%)	25573 (59.2%)	165047 (50.1%)	5008 (42.3%)	19293 (57.7%)	122231 (49.7%)
Any comorbid conditions, n (%)						
Yes	5154 (32.0%)	6934 (16.1%)	64911 (19.7%)	3274 (27.7%)	4118 (12.3%)	38757 (15.8%)
Patient/client contact, n (%)						
Yes	3518 (21.8%)	8987 (20.8%)	71947 (21.8%)	3902 (33.0%)	10272 (30.7%)	79670 (32.4%)
Country, n (%)						
England	13493 (83.7%)	35574 (82.3%)	277985 (84.4%)	9848 (83.2%)	27444 (82.0%)	205652 (83.6%)
Scotland	1390 (8.6%)	3886 (9.0%)	26209 (8.0%)	1044 (8.8%)	2971 (8.9%)	20255 (8.2%)
Wales	843 (5.2%)	2219 (5.1%)	15936 (4.8%)	648 (5.5%)	1776 (5.3%)	12700 (5.2%)
Northern Ireland	399 (2.5%)	1520 (3.5%)	9226 (2.8%)	293 (2.5%)	1261 (3.8%)	7454 (3.0%)

Data shown are median (interquartile range) or count (column wise percentage).

Table 2. Crude incidence rates (per 1000 person-months) for participants testing positive in the Delta and Omicron cohorts, by IMD deciles and occupation sectors.

Delta cohort (02.07.2020–19.12.2021)				
IMD	**Manufacturing and construction**	**Healthcare**	**Retail**	**Teaching and education**
1 (most deprived)	5.41 (4.40, 6.65)	4.51 (3.69, 5.51)	4.38 (3.53, 5.43)	4.90 (4.00, 6.00)
2	4.04 (3.35, 4.87)	3.24 (2.67, 3.93)	4.16 (3.43, 5.05)	4.33 (3.67, 5.11)
3	4.69 (3.98, 5.52)	2.83 (2.35, 3.41)	2.81 (2.24, 3.53)	4.67 (4.06, 5.37)
4	3.82 (3.24, 4.51)	3.06 (2.58, 3.63)	3.14 (2.56, 3.85)	4.39 (3.84, 5.02)
5	3.98 (3.42, 4.63)	3.02 (2.57, 3.56)	3.18 (2.60, 3.89)	4.51 (3.98, 5.11)
6	3.51 (3.01, 4.09)	2.65 (2.23, 3.14)	3.40 (2.82, 4.11)	4.52 (4.02, 5.09)
7	3.34 (2.86, 3.91)	2.79 (2.38, 3.26)	3.47 (2.89, 4.18)	4.12 (3.64, 4.65)
8	3.58 (3.10, 4.12)	2.88 (2.47, 3.35)	3.65 (3.05, 4.37)	4.34 (3.88, 4.85)
9	4.14 (3.64, 4.72)	2.36 (2.01, 2.78)	3.37 (2.81, 4.05)	4.61 (4.15, 5.12)
10 (least deprived)	3.54 (3.06, 4.09)	2.86 (2.47, 3.31)	3.50 (2.90, 4.22)	4.07 (3.65, 4.53)
Omicron cohort (on or after 20.12.2021)				
IMD	**Manufacturing and construction**	**Healthcare**	**Retail**	**Teaching and education**
1 (most deprived)	86.34 (67.04, 111.20)	97.47 (78.29, 121.35)	80.46 (62.60, 103.41)	87.69 (69.14, 111.22)
2	85.94 (70.13, 105.30)	78.53 (64.22, 96.02)	87.44 (69.83, 109.48)	86.26 (71.62, 103.9)
3	65.82 (52.65, 82.30)	64.79 (52.93, 79.30)	68.39 (54.10, 86.44)	81.73 (69.21, 96.51)
4	70.17 (57.74, 85.28)	83.84 (71.00, 99.00)	53.94 (42.05, 69.18)	65.29 (54.91, 77.64)
5	65.63 (54.35, 79.25)	65.46 (54.85, 78.11)	71.24 (57.37, 88.45)	70.90 (60.75, 82.74)
6	71.16 (59.76, 84.74)	69.19 (58.52, 81.80)	61.45 (49.00, 77.05)	73.46 (63.75, 84.65)
7	53.52 (44.04, 65.04)	58.84 (49.54, 69.87)	50.41 (39.53, 64.28)	62.82 (54.01, 73.08)
8	63.30 (53.48, 74.93)	56.10 (47.18, 66.71)	61.22 (49.17, 76.22)	67.36 (58.72, 77.26)
9	68.11 (58.04, 79.93)	67.64 (58.12, 78.72)	58.54 (46.82, 73.19)	64.15 (56.01, 73.46)
10 (least deprived)	71.89 (61.36, 84.23)	59.27 (50.50, 69.55)	60.78 (48.54, 76.10)	55.59 (48.24, 64.06)

We restricted our subgroup analyses (i.e., by occupation sectors) when the outcome events were 50 or more in each of the 10 IMD deciles to ensure statistical stability of our estimates.

Figure 1. Flow chart for the analysis of variants of concern.

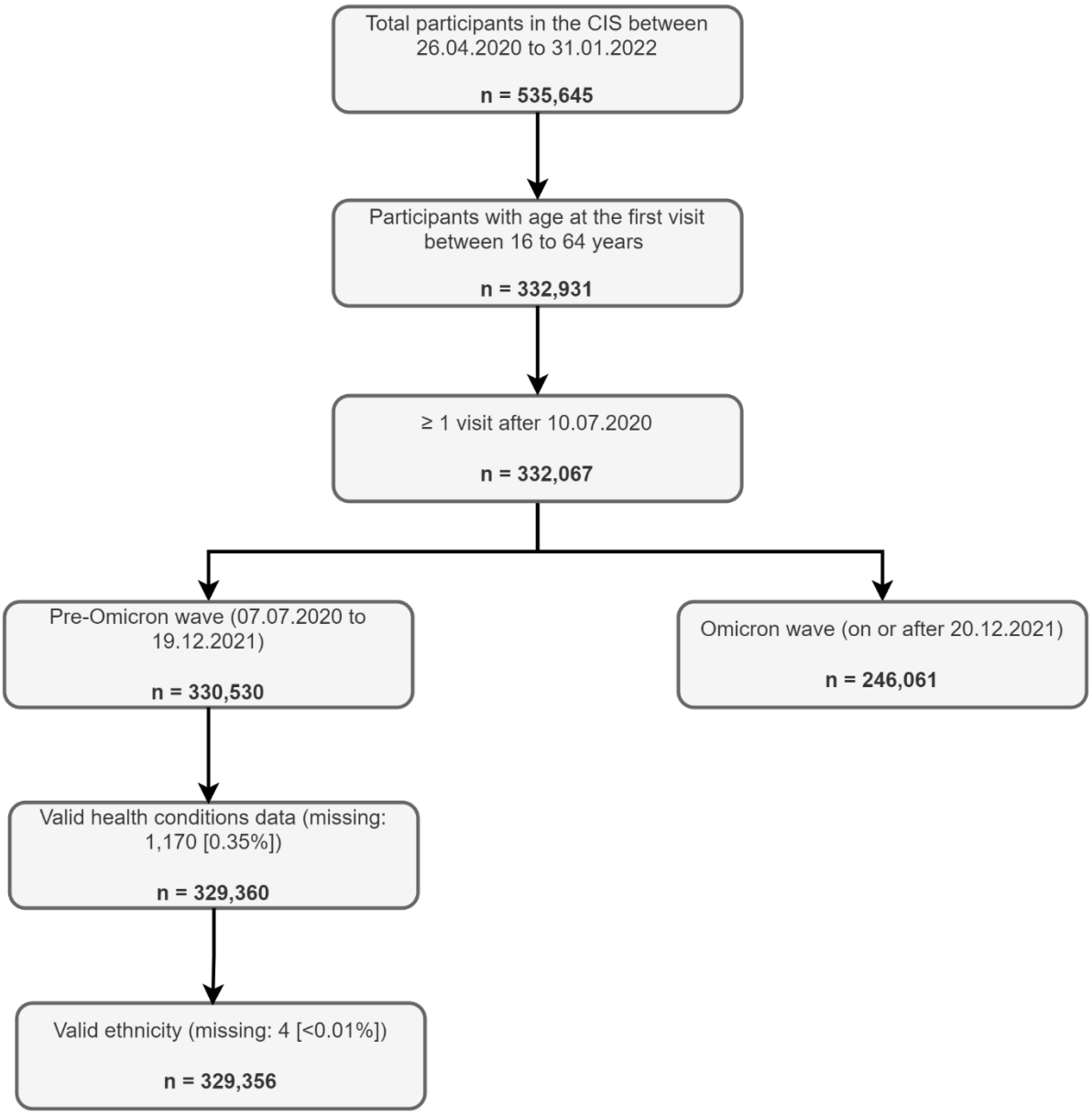
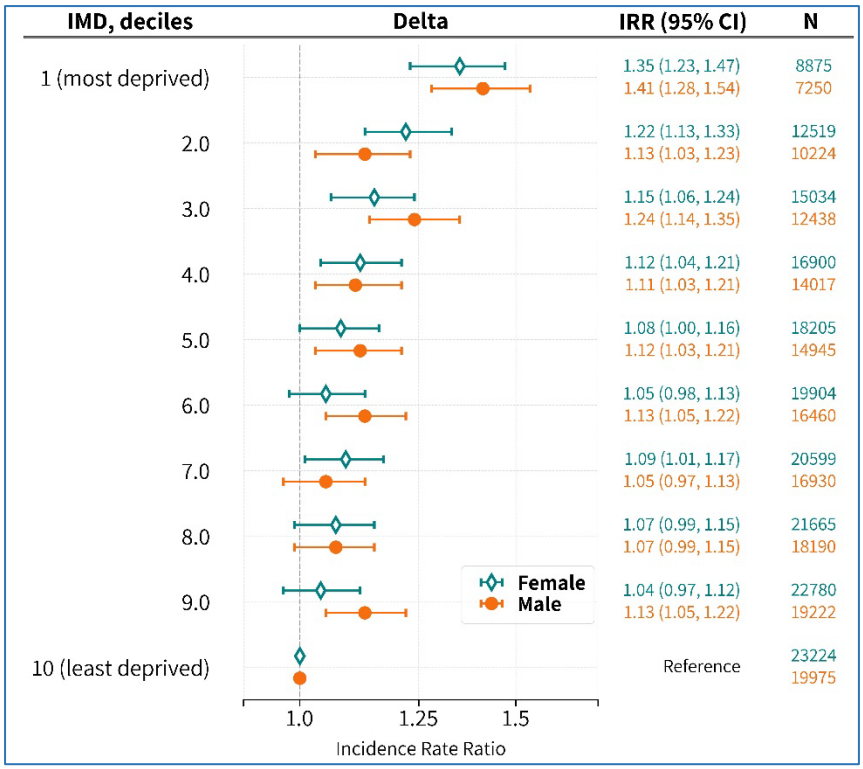
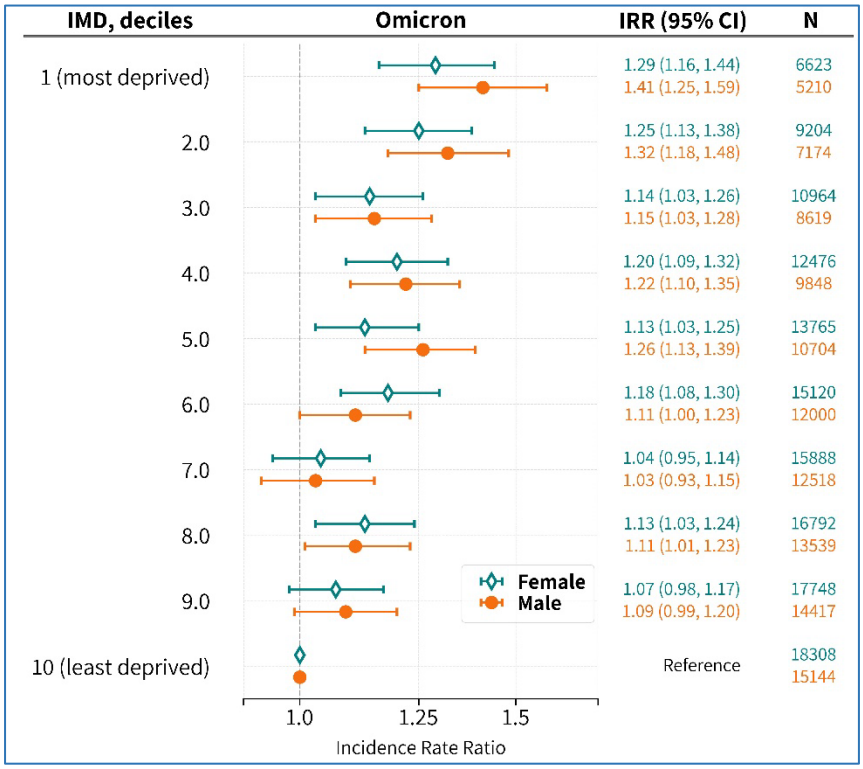


Figure 2. Association between deprivation and Delta (A) and Omicron (B) variants, stratified by sex.

2A



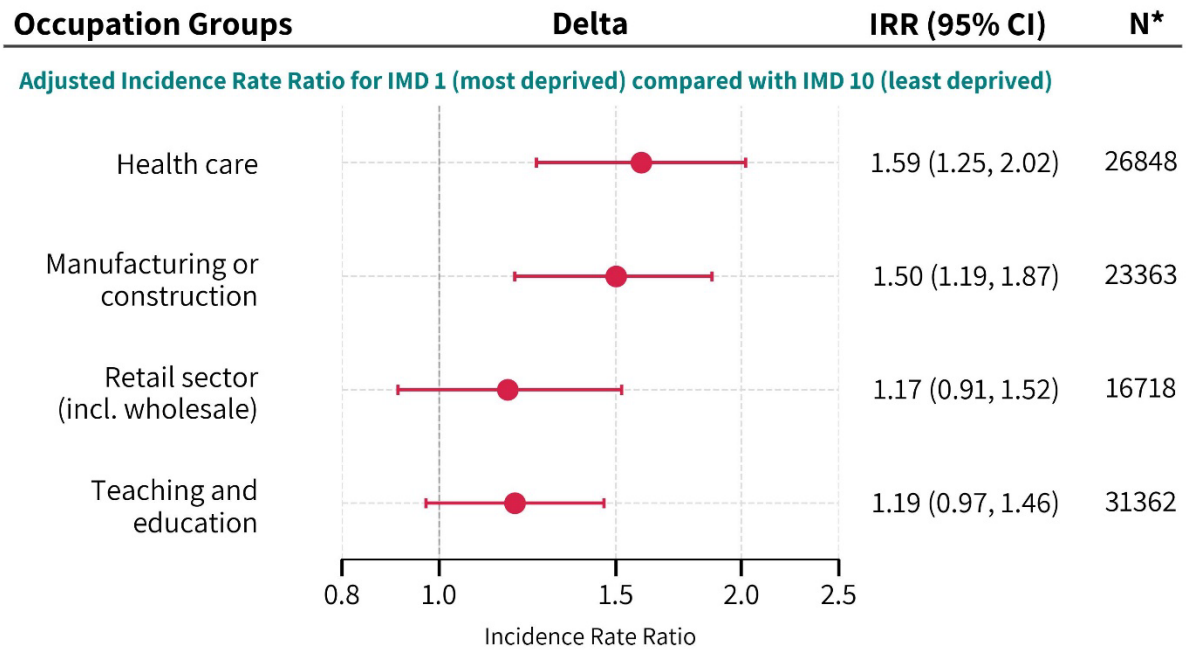
2B



Adjusted for age, ethnicity, urban/rural, comorbid conditions, household size, patient/client-facing nature of the job, country, and time (as quarters of the year). Reference group are the least deprived decile within each occupation sectors.

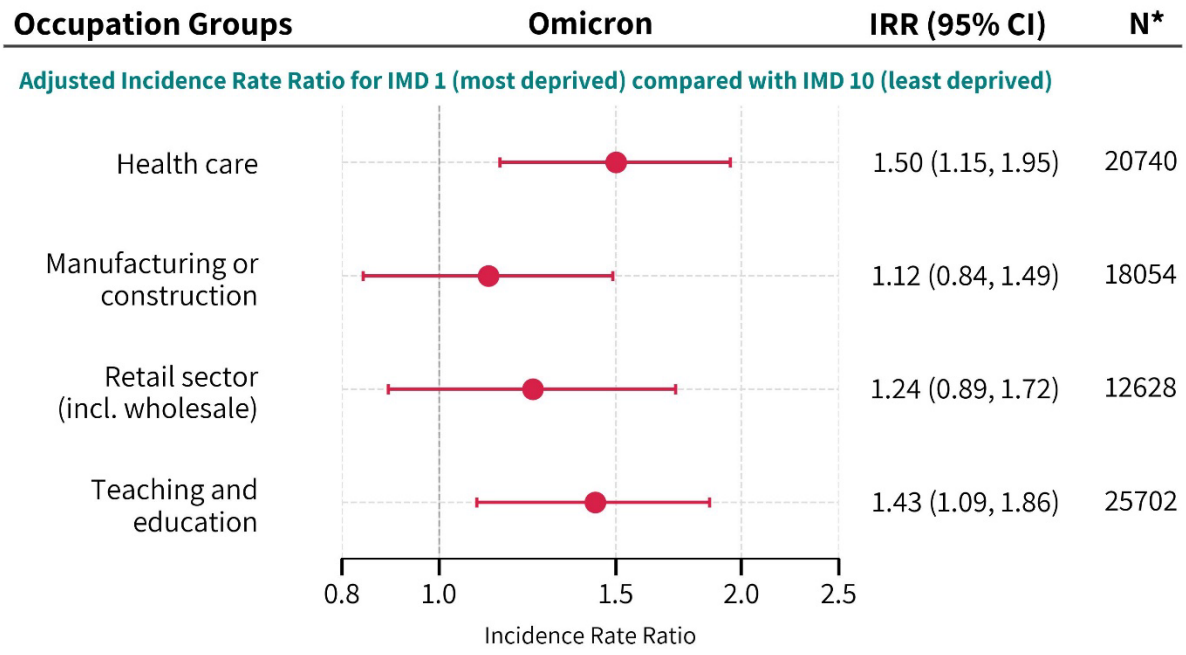
Figure 3. Association between deprivation and testing positive with SARS-CoV-2 in the Delta (A) and Omicron (B) cohorts, by occupation sectors.

3A



* Overall sample size in the occupation group

3B



* Overall sample size in the occupation group

*Adjusted for age, sex, ethnicity, urban/rural, comorbid conditions, household size, patient/client-facing nature of the job, country, and time (as quarters of the year).

Reference group are the least deprived decile within each occupation sectors.

Supplementary material

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

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Supplementary Table 1. Count and crude percentage of participants testing compatible with the Delta and Omicron variant, by IMD deciles and occupation sector.

IMD	Delta cohort (02.07.2020–19.12.2021)							
	Manufacturing and construction		Healthcare		Retail		Teaching and education	
	Total N	Positive n (%)	Total N	Positive n (%)	Total N	Positive n (%)	Total N	Positive n (%)
1 (most deprived)	966	90 (9.3)	1225	95 (7.8)	1097	83 (7.6)	1098	93 (8.5)
2	1579	111 (7.0)	1846	104 (5.6)	1422	103 (7.2)	1861	140 (7.5)
3	1769	144 (8.1)	2223	110 (4.9)	1519	75 (4.9)	2433	197 (8.1)
4	2127	142 (6.7)	2452	131 (5.3)	1675	92 (5.5)	2793	214 (7.7)
5	2424	168 (6.9)	2750	145 (5.3)	1708	95 (5.6)	3112	245 (7.9)
6	2656	163 (6.1)	2844	132 (4.6)	1828	109 (6.0)	3535	279 (7.9)
7	2660	156 (5.9)	3167	154 (4.9)	1842	112 (6.1)	3586	258 (7.2)
8	3052	191 (6.3)	3292	166 (5.0)	1878	120 (6.4)	4060	307 (7.6)
9	3149	228 (7.2)	3497	145 (4.1)	1955	115 (5.9)	4334	348 (8.0)
10 (least deprived)	2981	185 (6.2)	3552	178 (5.0)	1794	110 (6.1)	4550	324 (7.1)
IMD	**Omicron cohort (on or after 20.12.2021)**							
	Manufacturing and construction		Healthcare		Retail		Teaching and education	
	Total N	Positive n (%)	Total N	Positive n (%)	Total N	Positive n (%)	Total N	Positive n (%)
1 (most deprived)	759	60 (7.9)	920	80 (8.7)	841	61 (7.3)	867	68 (7.8)
2	1189	93 (7.8)	1360	95 (7.0)	987	76 (7.7)	1465	111 (7.6)
3	1322	77 (5.8)	1621	94 (5.8)	1135	70 (6.2)	1914	139 (7.3)
4	1590	101 (6.4)	1873	139 (7.4)	1264	62 (4.9)	2192	128 (5.8)
5	1844	108 (5.9)	2097	123 (5.9)	1293	82 (6.3)	2553	161 (6.3)
6	2010	126 (6.3)	2221	137 (6.2)	1368	75 (5.5)	2910	191 (6.6)
7	2114	101 (4.8)	2449	130 (5.3)	1424	65 (4.6)	2956	168 (5.7)
8	2400	135 (5.6)	2585	128 (5.0)	1458	80 (5.5)	3377	204 (6.0)
9	2447	150 (6.1)	2778	167 (6.0)	1464	77 (5.3)	3639	209 (5.7)
10 (least deprived)	2379	153 (6.4)	2836	150 (5.3)	1394	76 (5.5)	3829	191 (5.0)

Supplementary Table 2. Crude incidence rate of testing compatible with the Delta variant by IMD, and by IMD decile and sex.

	Incidence Rate per 1000 person months (95% CI)		
IMD, deciles	**Overall**	**Male**	**Female**
1 (most deprived)	4.33 (4.09, 4.58)	4.46 (4.10, 4.84)	4.22 (3.91, 4.56)
2	3.57 (3.39, 3.76)	3.49 (3.23, 3.78)	3.63 (3.39, 3.89)
3	3.52 (3.36, 3.69)	3.81 (3.55, 4.07)	3.28 (3.07, 3.51)
4	3.41 (3.26, 3.57)	3.47 (3.24, 3.71)	3.35 (3.15, 3.57)
5	3.31 (3.17, 3.46)	3.50 (3.28, 3.73)	3.16 (2.97, 3.36)
6	3.32 (3.18, 3.47)	3.58 (3.36, 3.80)	3.11 (2.93, 3.30)
7	3.22 (3.08, 3.36)	3.24 (3.05, 3.46)	3.20 (3.02, 3.39)
8	3.24 (3.11, 3.38)	3.37 (3.17, 3.57)	3.14 (2.97, 3.32)
9	3.34 (3.21, 3.47)	3.60 (3.40, 3.81)	3.12 (2.95, 3.30)
10 (least deprived)	3.18 (3.05, 3.31)	3.27 (3.09, 3.47)	3.09 (2.93, 3.27)

Supplementary Table 3. Crude incidence rate of testing compatible with the Omicron variant by IMD decile, and by IMD decile and sex.

	Incidence Rate per 1000 person months (95% CI)		
IMD, deciles	**Overall**	**Male**	**Female**
1 (most deprived)	76.67 (71.60, 82.11)	79.45 (71.78, 87.93)	74.50 (67.89, 81.74)
2	74.11 (69.82, 78.66)	76.56 (70.07, 83.65)	72.19 (66.60, 78.25)
3	65.41 (61.72, 69.33)	65.95 (60.44, 71.97)	64.99 (60.12, 70.25)
4	67.53 (64.02, 71.24)	68.15 (62.90, 73.84)	67.05 (62.40, 72.04)
5	64.53 (61.24, 67.99)	68.50 (63.43, 73.98)	61.47 (57.24, 66.01)
6	61.90 (58.84, 65.12)	59.99 (55.52, 64.82)	63.42 (59.30, 67.82)
7	55.23 (52.42, 58.20)	55.27 (51.07, 59.81)	55.21 (51.48, 59.20)
8	59.99 (57.14, 62.99)	59.67 (55.45, 64.20)	60.26 (56.45, 64.33)
9	58.03 (55.31, 60.89)	58.73 (54.68, 63.08)	57.47 (53.86, 61.33)
10 (least deprived)	54.52 (51.93, 57.24)	54.55 (50.74, 58.65)	54.49 (51.02, 58.20)

Supplementary Table 4. Association between deprivation and Delta and Omicron variant using multilevel Poisson regression model and random-effects at country level.

IMD, deciles	Delta cohort; N=329,356		Omicron cohort; N=246,061	
	IRR (95% CI)	P value	IRR (95% CI)	P value
1 (most deprived)	1.37 (1.33, 1.42)	<0.0001	1.34 (1.31, 1.37)	<0.0001
2	1.18 (1.13, 1.23)	<0.0001	1.28 (1.24, 1.32)	<0.0001
3	1.19 (1.12, 1.26)	<0.0001	1.14 (1.11, 1.18)	<0.0001
4	1.12 (1.07, 1.17)	<0.0001	1.21 (1.17, 1.25)	<0.0001
5	1.10 (1.03, 1.17)	0.003	1.19 (1.15, 1.22)	<0.0001
6	1.09 (1.05, 1.13)	<0.0001	1.15 (1.09, 1.22)	<0.0001
7	1.07 (1.06, 1.08)	<0.0001	1.04 (1.02, 1.06)	0.001
8	1.07 (1.05, 1.09)	<0.0001	1.12 (1.07, 1.18)	<0.0001
9	1.09 (1.07, 1.10)	<0.0001	1.08 (1.06, 1.1)	<0.0001
10 (least deprived)	Reference			

IRR = incident rate ratio

*Adjusted for age, sex, ethnicity, urban/rural, comorbid conditions, household size, patient/client-facing nature of the job, and time (as the quarter of the year) in the multilevel Poisson regression model using random-effects at country level.

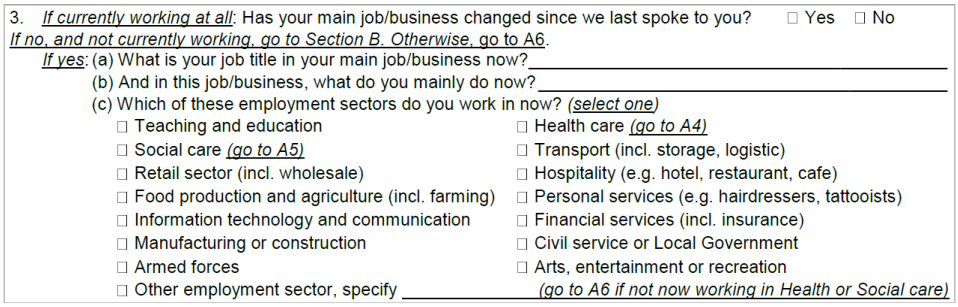
Supplementary Table 5. Association between deprivation and Delta and Omicron variant using multilevel Poisson regression model and second-order polynomial for age and time variables.

IMD, deciles	Delta cohort; N=329,356		Omicron cohort; N=246,061	
	IRR (95% CI)	P value	IRR (95% CI)	P value
1 (most deprived)	1.39 (1.30, 1.48)	<0.0001	1.34 (1.23, 1.45)	<0.0001
2	1.19 (1.12, 1.27)	<0.0001	1.27 (1.18, 1.37)	<0.0001
3	1.21 (1.14, 1.28)	<0.0001	1.14 (1.05, 1.22)	0.001
4	1.13 (1.07, 1.20)	<0.0001	1.20 (1.12, 1.29)	<0.0001
5	1.11 (1.05, 1.17)	<0.0001	1.18 (1.10, 1.27)	<0.0001
6	1.10 (1.04, 1.16)	<0.0001	1.15 (1.07, 1.23)	<0.0001
7	1.07 (1.02, 1.13)	0.007	1.03 (0.96, 1.11)	0.336
8	1.07 (1.02, 1.13)	0.008	1.12 (1.05, 1.20)	0.001
9	1.09 (1.04, 1.14)	0.001	1.07 (1.00, 1.15)	0.037
10 (least deprived)	Reference			

IRR = incident rate ratio

*Adjusted for age, sex, ethnicity, urban/rural, comorbid conditions, household size, patient/client-facing nature of the job, and time (as the quarter of the year) in the multilevel Poisson regression model using second-order polynomial for age and time variables.

Supplementary Figure 1. Occupational groups or employment sectors in the survey questionnaire.



3. *If currently working at all*: Has your main job/business changed since we last spoke to you? ☐ Yes ☐ No

If no, and not currently working, go to Section B. Otherwise, go to A6.

If yes: (a) What is your job title in your main job/business now? _____

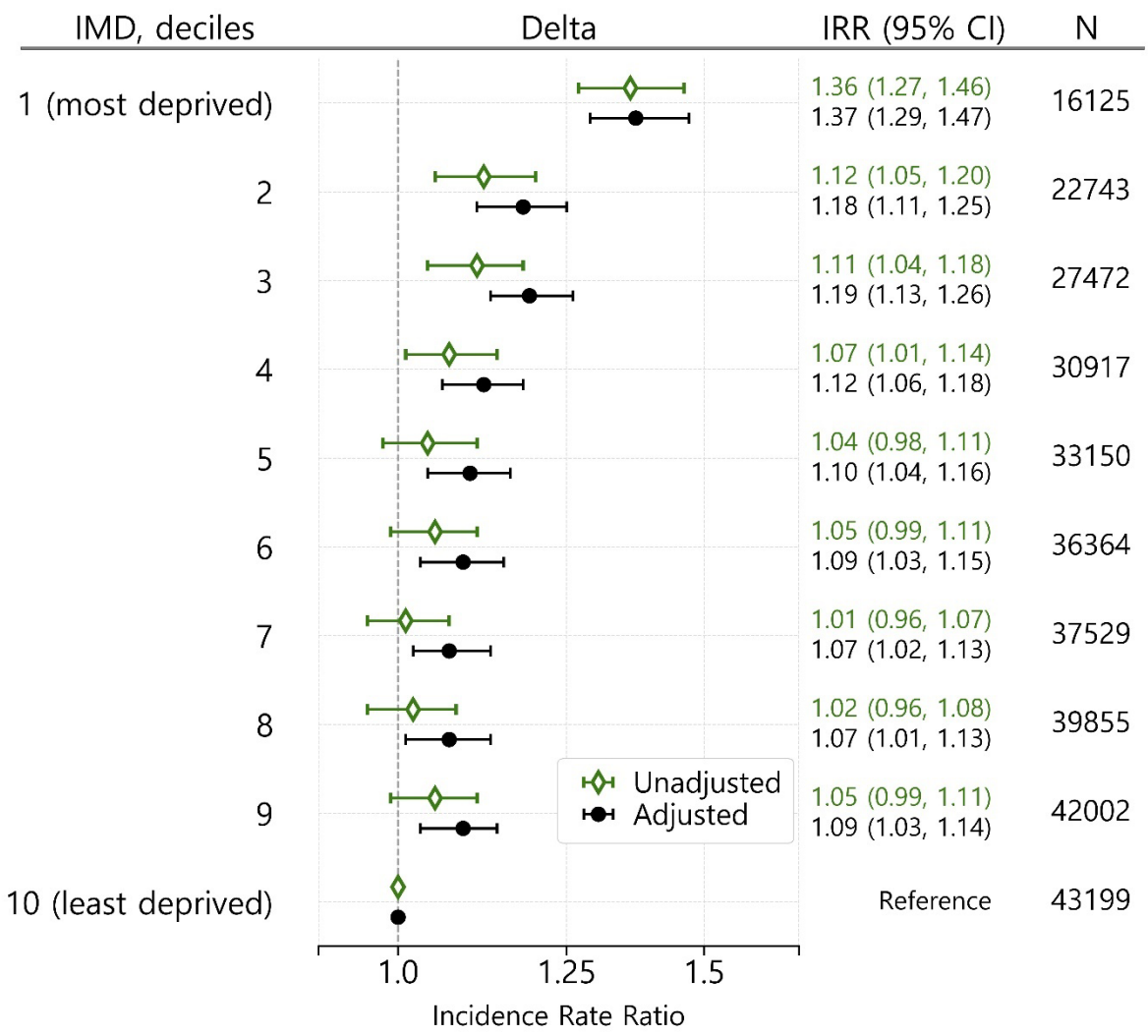
(b) And in this job/business, what do you mainly do now? _____

(c) Which of these employment sectors do you work in now? *(select one)*

- ☐ Teaching and education
- ☐ Social care *(go to A5)*
- ☐ Retail sector (incl. wholesale)
- ☐ Food production and agriculture (incl. farming)
- ☐ Information technology and communication
- ☐ Manufacturing or construction
- ☐ Armed forces
- ☐ Other employment sector, specify _____
- ☐ Health care *(go to A4)*
- ☐ Transport (incl. storage, logistic)
- ☐ Hospitality (e.g. hotel, restaurant, cafe)
- ☐ Personal services (e.g. hairdressers, tattooists)
- ☐ Financial services (incl. insurance)
- ☐ Civil service or Local Government
- ☐ Arts, entertainment or recreation

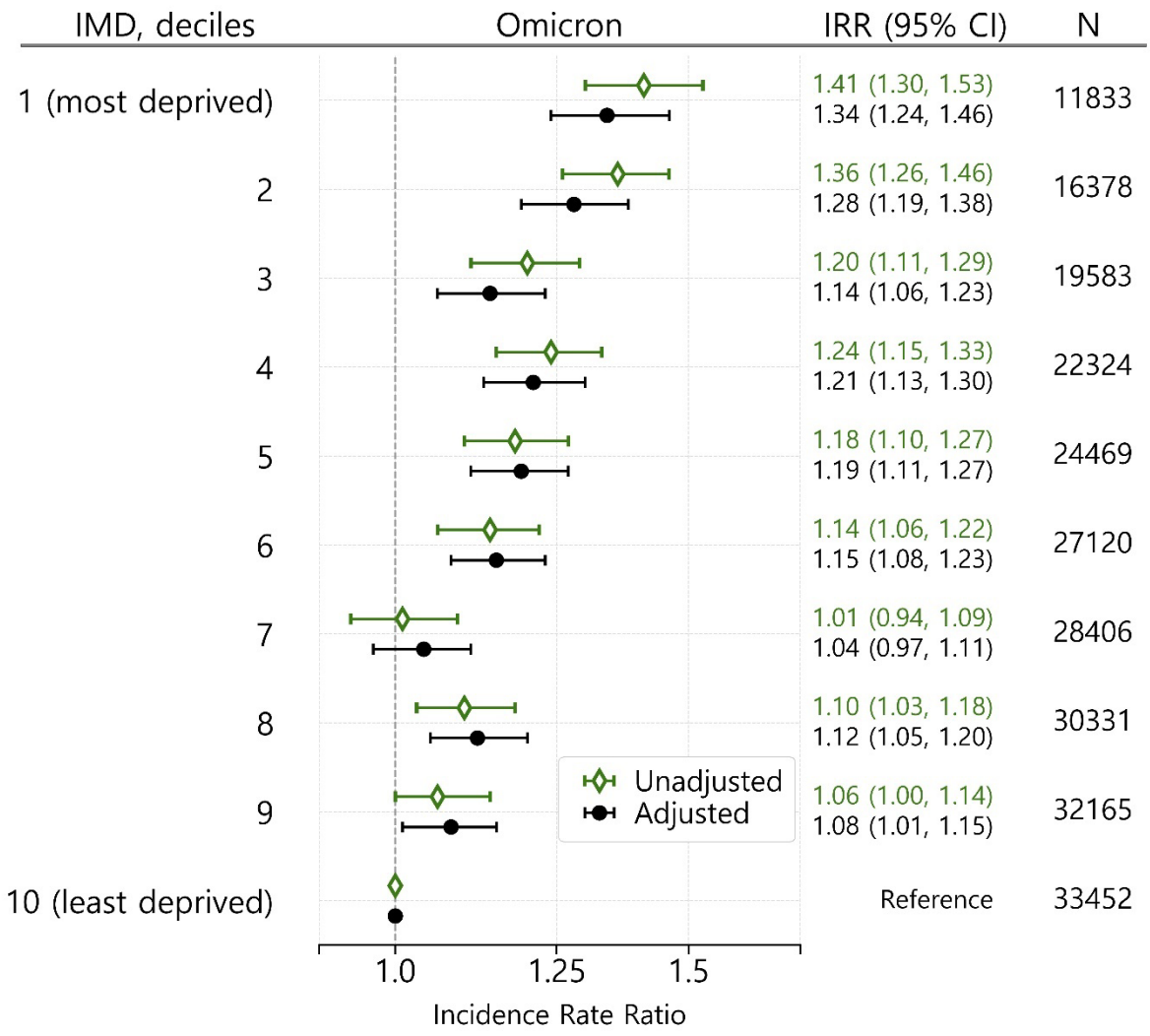
(go to A6 if not now working in Health or Social care)

Supplementary Figure 2. Association between deprivation and Delta variant.



*Adjusted for age, sex, ethnicity, urban/rural, comorbid conditions, household size, patient/client-facing nature of the job, country, and time (as quarters of the year).

Supplementary Figure 3. Association between deprivation and Omicron variant.



*Adjusted for age, sex, ethnicity, urban/rural, comorbid conditions, household size, patient/client-facing nature of the job, country, and time (as quarters of the year).