Differences in COVID-19 vaccination coverage by occupation in England: a national linked data study

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Abstract

Background: Monitoring differences in COVID-19 vaccination uptake in different groups is crucial to help inform the policy response to the pandemic. A key data gap is the absence of data on uptake by occupation. This study investigates differences in vaccination rates by occupation in England, using nationwide population-level data.

Methods: We calculated the proportion of people who had received three COVID-19 vaccinations (assessed on 28 February 2022) by detailed occupational categories in adults aged 18 to 64 and estimated adjusted odds ratios to examine whether these differences were driven by occupation or other factors, such as education. We also examined whether vaccination rates differed by ability to work from home.

Results: Our study population included 15,456,651 adults aged 18 to 64 years. Vaccination rates differed markedly by occupation, being higher in health professionals (84.7%) and teaching and other educational professionals (83.6%) and lowest in people working in elementary trades and related occupations (57.6%). We found substantial differences in vaccination rates looking at finer occupational groups. Adjusting for other factors likely to be linked to occupation and vaccination, such as education, did not substantially alter the results. Vaccination rates were associated with ability to work from home, with the rate being higher in occupations which can be done from home. Many occupations with low vaccination rates also involved contact with the public or with vulnerable people

Conclusions: Increasing vaccination coverage in occupations with low vaccination rates is crucial to help protecting the public and control infection. Policies such as 'work from home if you can' may only have limited future impact on hospitalisations and deaths, as vaccination rates are higher in the occupations that can be done from home and lower in those which cannot. Efforts should be made to increase vaccination rates in occupations that cannot be done from home and involve contacts with the public.

Research in context

Evidence before this study

We searched PubMed for articles on occupational differences in COVID-19 vaccination coverage and hesitancy. Whilst several studies highlight differences in vaccination coverage by ethnicity, religion, socio-demographic factors and certain underlying health conditions, there is very little evidence on how vaccination coverage varies by occupation, in the UK and elsewhere. The few studies looking at occupational differences in vaccine hesitancy focus on healthcare workers or only examined broad occupational groups. There is currently no large-scale study on occupational differences in COVID-19 vaccination coverage in the UK.

Added value of this study

This study investigated differences in vaccination rates amongst workers in England, using population-level linked data combining the 2011 Census, Census 2021, primary care records, mortality and vaccination data. We found that the vaccination rates of adults aged 18 to 64 years differed markedly by occupation. Vaccination rates were high in health professionals and teaching and other educational professionals and low in people working in elementary occupations. Adjusting for confounding factors likely to be linked to occupation and vaccination, such as education, did not substantially alter the results. Vaccination uptake was also associated with the ability to work from home, with the vaccination rate being higher in occupations where work can be done from home.

Implications of all the available evidence

Many occupations with low vaccination rates involved contact with the public or with vulnerable people. Therefore, increasing vaccination coverage in these occupations would be crucial to help protecting the public and control infection. As vaccination coverage is associated with the ability to work from home, with vaccination rates typically being higher in occupations which can be done from home, policies such as ‘work from home if you can’ may only have limited impact on infection, hospitalisations and deaths, because it may not be enough to prevent transmission for those who are less likely to be vaccinated and cannot easily work from home. Policies aiming to increase vaccination rates in occupations that cannot be done from home and involve contacts with the public should be prioritised. As people working in these occupations tend to be in some of the more deprived groups in society, increasing vaccination rates in these groups would help reduce inequalities in vaccination coverage.

Introduction

The UK began an ambitious vaccination programme to combat the COVID-19 pandemic on 8 December 2020; by 28 February, 66.5% of the UK adult population had received three vaccinations and 91.5% at least one vaccination [1].

Monitoring differences in uptake in different groups is crucial to inform the policy response. Evidence suggests that rates of COVID-19 vaccination in England differ by ethnicity, religion, socio-demographic factors and certain underlying health conditions [2, 3, 4]. However, a key data gap is the absence of data on uptake by occupation. Producing vaccination rates by detailed occupational categories is challenging as routinely collected data used for the analysis of vaccination uptake do not contain information on occupation. The use of surveys is limited as a large sample size is needed to precisely estimate vaccination rates in small groups.

As there is evidence that people working in occupations involving contact with patients or the public are at greater risk of COVID-19 infection and death [5, 6, 7], it is important to ensure that vaccination coverage is high in these occupations. Measuring vaccination uptake by occupation also has implications for the management of the pandemic, especially as countries such as the UK have lifted all restrictions, have ended the furlough scheme and are encouraging workers to go back to the office. If vaccination rates are high in people working in occupations in which working from home is an option, then having workers back to the office would be expected to have less impact on cases and hospitalisation than if the vaccination rates are low. Similarly, imposing working from home where possible would be less effective if vaccination coverage is high in people who can work from home but low in those who cannot.

This study investigates differences in vaccination rates by occupation in England, using nationwide population-level data. We calculated vaccination rates by detailed occupational categories in working-age adults and estimated adjusted odds ratios to examine whether these differences were driven by potential confounding factors. We also examined whether vaccination rates differed by the ability to work from home.

Methods

Data

We linked vaccination data from NHS England's National Immunisation Management System (NIMS) to the Office for National Statistics (ONS) Public Health Data Asset (PHDA) based on NHS number. The ONS PHDA is a linked dataset combining the 2011 Census, mortality records, the General Practice Extraction Service (GPES) data for pandemic planning and research, and the Hospital Episode Statistics (HES). To obtain NHS numbers for the 2011 Census, we linked the 2011 Census to the 2011-2013 NHS Patient Registers using deterministic and probabilistic matching, with an overall linkage rate of 94.6%. All subsequent linkages were performed based on NHS numbers.

We updated the information on occupation in the PHDA by using an extract from Census 2021. We retrieved NHS numbers for 82.1% of Census 2021 participants, using the Personal Demographics Service (PDS).

The study population consisted of adults aged 18 to 64 years and alive on 28 February 2022, who were resident in England, registered with a general practitioner, enumerated and having reported an occupation at the 2011 Census and Census 2021. Of 22,289,910 adults aged 18 to 64 years who received three COVID-19 vaccinations in NIMS, 17,844,686 (80.0%) were linked to the ONS PHDA. Of the 33,073,531 people enumerated at the 2011 Census in England and Wales, who would be aged 18 to 64 years on 28 February 2022, we excluded 2,167,841 people (6.6%) who could not be linked deterministically or probabilistically to the NHS Patient register, and 461,951 individuals (1.4%) who had died between the Census and 28 February 2022. An additional 3,906,332 people (11.8%) were not linked to the English primary care records, either because they did not live in England in 2019 (the Census included people living in England and Wales), or because they were not registered with the NHS. A further 5,762,544 individuals (17.4%) could not be linked to Census 2021 or were not living in England in 2021 and 5,223,434 people (15.8%) were not employed or did not have occupation information at the time of Census 2021, and were therefore excluded from the analysis. After excluding 4,778 individuals who had received their vaccine before the beginning of the vaccination campaign (8 December 2020 for first and second vaccinations; 16 September 2021 for third vaccinations), our sample consisted of 15,546,651 individuals (see sample flow diagram in Supplementary Table S1). This amounts to 60.1% of people in England aged 18 to 64 years who are employed, based on estimates from the Annual Population Survey.

Outcome

The primary outcome was being fully vaccinated against COVID-19, that is having received three COVID-19 vaccinations as recorded in the NIMS data by 28 February 2022. Third vaccinations had been offered to all eligible adults in England aged 18 years and over by 31 December 2021. Therefore, by the end of February 2022, we would expect most people who wanted to be vaccinated to have received their third vaccination. Third vaccination may refer to a booster vaccination or a third dose vaccination received as part of the primary course. Third vaccinations that were received prior to 16 September 2021, and therefore prior to the official booster campaign, were excluded from this analysis.

To account for the delay in receiving the second vaccination, and therefore not having had time to receive the third vaccination by then end of the study period, we also examined having received no COVID-19 vaccine as a secondary outcome.

Exposure

The main exposure was occupation at the time of Census 2021. Occupations are coded using a hierarchical classification, the Standard Occupation Classification (SOC) 2020 [8]. The most detailed classification (Unit group, with 4-digit codes) includes 412 categories, whilst a more aggregated (Sub-major group, with 2-digit codes) has 26 groups. We used both SOC sub-major groups and unit groups in this paper.

Covariates

In addition to crude vaccination rates, we estimated vaccination rates adjusted for a range of factors known to be associated with vaccination uptake and occupation [9], and therefore likely to confound the relationship between occupation and vaccination. We adjusted for sex (Male, Female), age (10-year age bands), region, ethnicity (White British, Bangladeshi, Black African, Black Caribbean, Chinese, Indian, Mixed, Other, Pakistani, White other), disability status (non-disabled, disabled and limited a little, disabled and limited a lot), highest level of qualification (Level 4+ , Level 3, Apprenticeship, Level 2, Level 1, other, no qualification) and pre-existing health conditions (1+) based on the QCovid risk model (See Table S2 for more detail).

Occupation characteristics

We also used occupation-level (Unit group) data on ability to work from home. These data were derived by Office for National Statistics based on data from the Occupational Information Network (O*NET), which contains information about the features and the nature of the work of the US [10]. Occupations

were assigned a score of between one and five to reflect the frequency and importance of different tasks and characteristics to various jobs. Factors considered included whether the job has to be carried out in a specific location; the amount of face-to-face interaction with others; exposure to infections and other hazards; whether the job requires physical activity; and use of tools or protective equipment. An overall score was derived by summing the category scores, which were first rescaled to between 0 and 1. The final score was also rescaled to between 0 and 1, with one indicating a high ability to work from home.

Statistical analyses

First, we estimated the rate of people aged 18 to 64 who had received three COVID-19 vaccinations by occupation. Second, we estimated age standardised vaccination rates for the different unit groups, whereby the age distribution within each group was standardized to the 2013 European Standardised Population.

Third, we examined whether differences were driven by other socio-demographic and clinical factors likely to be associated with vaccination uptake and occupation. We selected factors known to be associated with vaccination uptake in England [9] and to be linked to occupation. We used logistic regression to estimate the odds of being fully vaccinated (receiving three vaccinations) by occupation, adjusting for sex, age, geographical and sociodemographic characteristics, disability status and pre-existing conditions. The occupations used as the reference category were elementary administration and service occupations (SOC sub-major group) and sales and retail assistants (SOC unit group) – these are large groups with relatively low vaccination coverage. For SOC sub-major group, we also estimated separate models for each occupation so that the odds ratios could be interpreted as the difference in the odds of not being vaccinated for people working in this occupation compared to all other occupations (see Supplementary Table S5). We estimated unadjusted odds ratios, odds ratios adjusted for age and sex, and fully adjusted odds ratios.

Finally, we investigated the association between vaccination rate and the ability to work from home. We visualised the relationship using a scatter plot and estimated the strength of the association using univariate linear regression models. We also used logistic regression models to estimate the association between working from home and the odds of being fully vaccinated, after adjusting for other characteristics. We used the same approach as for occupation and estimated standard error clustered at occupation level. Because the working from home score was standardised with a mean of 0 and a

standard deviation of 1, the odds ratio for the score can interpreted as the effect of an increase by one standard deviation. Analyses were conducted using R 3.5.

Results

Characteristics of study population

Our study population included 15,546,651 adults aged 18 to 64 years who lived in England at the beginning of the pandemic and reported being employed in Census 2021. 74.5% of people had received three vaccinations against COVID-19 by 28 February 2022, whilst 7.2% had not received any COVID-19 vaccination. The average age was 44.1 years and 51.5% were female; 83.0% identified themselves as White British. 17.3% of people had at least one of the health conditions included in the QCovid risk model. Table 1 provides detailed characteristics of the sample.

[Table 1]

Vaccination rates by occupation

As of 28 February 2022, vaccination coverage in workers aged 18 to 64 was high but differed by SOC sub-major Group. The proportion of people having received three vaccinations was highest in health professionals (84.7%) and teaching and other educational professionals (83.6%). Those working in elementary trades and related occupations had the lowest vaccination rate with 57.6% of people having received three vaccinations (Figure 1).

[Figure 1]

Vaccination coverage also differed markedly by occupation unit groups (Table 2 for selected occupations, Supplementary Table S3 for all occupations). Third vaccination rates were highest in specialist medical practitioners (93.3% [93.1 – 93.6]), senior police officers (92.8% [92.1 – 93.6]), public relations and communications directors (92.0% [91.5 – 92.5]), and speech and language therapists (92.0% [91.5 – 92.6]). The third vaccination rate was over 85% in 64 out of 412 occupation unit groups, accounting 1,809,550 (11.6%) workers.

[Table 2]

The proportion of people having received three vaccinations was lower than 50% in three occupations, accounting for 97,205 (0.6%) people in our dataset. These included scaffolders, stagers and riggers (46.3% [45.5 – 47.0]), elementary construction occupations not elsewhere classified (48.2% [47.8 – 48.6]), and roofers, roof tilers and slaters (49.8% [49.1 – 50.4]).

The vaccination rates were lower than 65% in 63 out of 412 occupations; 3,122,825 (20.1%) people worked in these occupations. The larger occupations, those with more than 100,000 workers, with low vaccination rates included electricians and electrical fitters (58.7% [58.4 – 59.0]), warehouse operatives (59.9% [59.7 – 60.1]), kitchen and catering assistants (61.2% [60.9 – 61.4]) and carpenters and joiners (62.0% [61.8 – 62.3]). Low rates of vaccination were also found in sales and retail assistants (62.7% [62.6 – 62.9]) and care workers and home carers (68.2% [68.0 – 68.3]), two large occupational groups – over 1 million workers in our sample – which involve working with the public.

Amongst health professionals and health and social care associate professionals, there was some variation in vaccination rates. Most unit groups amongst health care workers had vaccination rates above average, with 93.3% [93.1 – 93.6] of specialist medical practitioners having received three vaccinations and 92.0% [91.5 – 92.6] of speech and language therapists. Vaccine coverage was low in early education and childcare practitioners (63.0% [62.6 – 63.4]); complementary health associate professionals (64.4% [63.5 – 65.3]), which includes homeopaths, hypnotherapists and others; and therapy professionals not elsewhere classified (71.9% [71.2 – 72.6]), which includes acupuncturists, nutritionists, chiropractors, art therapists and others. Vaccination rates were also low in care workers and home carers (68.2% [68.0 – 68.3]).

Standardising for age or adjusting further for other factors likely to be linked to occupation and vaccination did not substantially alter the results (See Supplementary Table S3). Adjusted OR for being fully vaccinated (three vaccinations) were lowest in scaffolders, stagers and riggers (0.41 [0.39 – 0.42]), complementary health associate professionals (0.41 [0.40 – 0.43]), roofers, roof tilers and slaters (0.42 [0.41 – 0.44]) and plasterers (0.45 [0.44 – 0.46]). The highest odds ratios for being fully vaccinated were found in healthcare occupations: generalist medical practitioners (5.97 [5.82 – 6.13]), speech and language therapists (4.99 [4.62 – 5.39]), specialist medical practitioners (4.75 [4.56 – 4.95]) and clinical psychologists (4.64 [4.28 – 5.02]).

Results were similar when looking at people who had not received any vaccine (See Supplementary Table S4), suggesting that the results are not driven by people working in some occupation being less likely to have been eligible to receive their second or third vaccination.

Vaccination rates and job characteristics

Vaccination rates were associated with the ability to work from home, as assessed based on O*NET data. Figure 2 shows that vaccination rates tend to be higher in occupations in which working from

home is more easily possible. The association was strong, with a R-squared of 0.313 and a F-statistic of 185.4. Results from a logistic regression model suggests that one standard deviation increase in the working from home score is associated with 0.46 [0.37 – 0.58] times lower odds of not being fully vaccinated. Adjusting for geographical factors, socio-demographic characteristics and health reduced the ORs did not substantially affect the results (adjusted ORs 0.59 [0.48 – 0.69]), indicating that working from home is independently associated with a reduction in the odds of not being vaccinated.

[Figure 2]

Discussion

Main findings of this study

Using whole population level linked data in England, our analysis shows that the vaccination rates of adults aged 18 to 64 years differed markedly by occupation. Vaccination rates were high in health professionals and teaching and other educational professionals and low in people working in elementary occupations. Vaccination rates were also associated with the ability to work from home, with vaccine coverage being higher in occupations which can be performed from home – this relationship remained when socio-demographic characteristics were adjusted for.

Comparison with other studies

Few studies have investigated how COVID-19 vaccination coverage varies by occupation. Several studies investigated vaccine hesitancy and vaccine coverage in health care workers, highlighting some differences between different job roles, with doctors having slightly higher vaccination coverage and lower hesitancy than midwives and nurses [11, 12]. Similarly, we found, once controlling for socio-demographic, geographic and health factors, Generalist Medical Practitioners – including doctors, general practitioners, house officers and others – were most likely to have received three vaccinations among Health Professionals (See Supplementary Table S3). Nurse Practitioners, Community Nurses, Other Nursing Professionals, Midwifery Nurses and Mental Health Nurses comprised five of the eight least likely occupations to have received three vaccinations among Health Professionals – there are 25 occupations in this SOC sub-major group.

Our findings that vaccination rates are higher among managers, directors and senior officials and in people working in professional occupations, compared with those working in elementary occupations, are in line with studies showing that vaccination rates in the UK and the US are higher in more wealthy

areas and amongst people from higher socio-economic status [14, 3, 15, 4]. Our results are also consistent with a study from the US showing that vaccine hesitancy varied widely by occupation category, with hesitancy being low in people working in professional occupations, especially in the life, physical and social sciences and particularly high in people working in construction and extraction [16].

Strengths and limitations

A major strength of this study is the use of nationwide linked population-level data from clinical records and the Census. This study is the first to examine how vaccination rates vary by occupation using population-level data. Because information on occupation is not collected in electronic health records, we used data from the Census to assess people's occupation. Some surveys collect data on both occupations and vaccination but face the issue that non-response is likely correlated with the propensity to be vaccinated. Having population-level data based on electronic health records and the Census, which is mandatory and has a high response rate, we were able to precisely estimate vaccination rates for detailed occupational groups. A further strength is the use of occupation information from Census 2021, providing recent occupation information at a population level.

The main limitation of our study is that, because the Public Health Data Asset was based on the 2011 Census, it excluded people who were living in England in 2011 but who did not take part in the Census, as well as respondents who could not be linked to the 2011-2013 NHS patient register and recent migrants. Those that did not take part in Census 2021, as well as those who could not be linked to an NHS number, were also excluded. Still, our dataset contains 15,546,651 people, which amounts to 60.1% of people aged 18 to 64 years who are employed, based on estimates from the Annual Population Survey.

Mechanisms

Differences in vaccination rates between occupations are only partially explained by other factors, including education, suggesting that some occupations are independently associated with vaccination status. People working in elementary occupations may have little job control and therefore may find it more difficult to attend vaccination or may be put off by the potential side effects, which could prevent them from working. Existing evidence suggests that occupational characteristics, such as job strain, can affect health behaviours, such as compliance with treatment [17]. Vaccine hesitancy may also be driving differences in uptake. The drivers of vaccine hesitancy are complex, and occupation may play a part. Indeed, we find that vaccine coverage is low in complementary health associate professionals, such as

homeopaths and hypnotherapists, and therapy professionals not elsewhere classified, such as acupuncturists, nutritionists and chiropractors. They may be more likely to reject mainstream medicine than other groups. The rates were also low in sports players, who may be more likely to believe they are very healthy and therefore may not need the vaccine.

Conclusions

Vaccination is just one of the strategies that can be used to prevent or control infections from SARS-CoV-2, albeit one of the most important ones as it also reduces the risk of developing symptoms and severe disease. Other important strategies involve particularly the use of face masks and ventilation, and for that reason, a "vaccine plus" strategy has been advocated by some commentators. Recent studies show that vaccines continue to have extremely good effectiveness even against new variants, such as Omicron. Although the effectiveness against symptomatic infection wanes relatively rapidly, high effectiveness is maintained against severe disease (hospitalisation and death).

In our study population of working-age adults in England, 74.5% had received three vaccinations against COVID-19 by 28 February 2022 – a result which is good by the standards of most Western countries. However, many occupations with lower vaccination rates involve contact with the public (bar staff, sales and retail assistants, waiters and waitresses) or with vulnerable people (care workers and home carers). Therefore, increasing vaccination coverage in these occupations would be important, not only to protect workers in these occupations, but also to help protect the public and to control infection. Our findings also show that vaccination rates were typically higher in occupations which can be done from home. Therefore, policies such as 'work from home if you can' may only have a limited impact on hospitalisations and deaths, as the vaccination rates are already higher in the occupations that can be done from home and lower in those which cannot. Efforts should therefore be made to increase vaccination rates in occupations that cannot be done from home. This includes many elementary occupations where it may be difficult to get time off work to be vaccinated, or where workers may not have the spare time or resources to access vaccination or are worried about missing work because of the side effects of the vaccines. As these are some of the more deprived groups in society, increasing vaccination rates in these groups would help reduce inequalities in vaccination coverage. Our results could also help inform future vaccination strategy and future models of COVID-19 transmission.

References

[1] UK Coronavirus Dashboard, "Coronavirus (COVID-19) in the UK - Vaccinations," [Online]. Available: https://coronavirus.data.gov.uk/details/vaccinations. [Accessed 27 04 2021].

[2] V. Nafilyan, T. Dolby, C. Razieh, C. H. Gaughan, J. Morgan, D. Ayoubkhani, S. Walker, K. Khunti, M. Glickman and T. Yates, "Sociodemographic inequality in COVID-19 vaccination coverage among elderly adults in England: a national linked data study," *BMJ Open,* vol. 11, no. 7, p. e053402, 2021.

[3] The OpenSAFELY Collaborative, H. J. Curtis, P. Inglesby, C. E. Morton, B. MacKenna, A. J. Walker, J. Morley, A. Mehrkar, S. Bacon, G. Hickman, C. Bates, R. Croker, D. Evans, T. Ward, J. Cockburn, S. Davy, K. Bhaskaran, A. Schultze, C. T. Rentsch, E. Williamson and et al., "Trends and clinical characteristics of COVID-19 vaccine recipients: a federated analysis of 57.9 million patients' primary care records in situ using OpenSAFELY," medRxiv, 2021.

[4] ONS, "Coronavirus and vaccination rates in people aged 18 years and over by socio-demographic characteristic and occupation, England: 8 December 2020 to 31 December 2021," 2022. [Online]. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthinequalities/bulletins/coronavirusandvaccinationratesinpeopleaged18yearsandoverbysociodemographiccharacteristicandoccupationengland/8december2020to31december2021.

[5] M. Mutambudzi, C. Niedwiedz, E. B. Macdonald, A. Leyland, F. Mair, J. Anderson, C. Celis-Morales, J. Cleland, J. Forbes, J. Gill, C. Hastie, F. Ho, B. Jani, D. F. Mackay, B. Nicholl, C. O'Donnell, N. Sattar, P. Welsh, J. P. Pell, S. V. Katikireddi and E. Demou, "Occupation and risk of severe COVID-19: prospective cohort study of 120 075 UK Biobank participants," *Occup Environ Med,* 2020.

[6] ONS, "Coronavirus (COVID-19) related deaths by occupation, England and Wales: deaths registered between 9 March and 28 December 2020," 2021. [Online]. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/causesofdeath/bulletins/coronaviruscovid19relateddeathsbyoccupationenglandandwales/deathsregisteredbetween9marchand28december2020.

[17] V. Nafilyan, P. Pawelek, D. Ayoubkhani, S. Rhodes, L. Pembrey, M. Matz, M. P. Coleman, C. Allemani, B. Windsor-Shellard, M. van Tongeren and N. Pearce, "Occupation and COVID-19 mortality in England: a national linked data study of 14.3 million adults," *medRxiv,* p. 2021.05.12.21257123, 1 2021.

[18] ONS, "SOC 2020," [Online]. Available: https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc/soc2020. [Accessed 22 04 2022].

[19] T. Dolby, F. Finning, A. Baker, L. Dowd, K. Khunti, C. Razieh, T. Yates and V. Nafilyan, "Monitoring sociodemographic inequality in COVID-19 vaccination coverage in England: a national linked data study," *medRxiv,* 2021.

[20] ONS, "Which jobs can be done from home?," 2020. [Online]. Available: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/articles/whichjobscanbedonefromhome/2020-07-21.

[21] K. Woolf, I. C. McManus, C. A. Martin, L. B. Nellums, A. L. Guyatt, C. Melbourne, L. Bryant, M. Gogoi, F. Wobi, A. Al-Oraibi, O. Hassan, A. Gupta, C. John, M. D. Tobin, S. Carr, S. Simpson, B. Gregary, A. Aujayeb, S. Zingwe, R. Reza, L. J. Gray, K. Khunti and M. Pareek, "Ethnic differences in SARS-CoV-2 vaccine hesitancy in United Kingdom healthcare workers: Results from the UK-REACH prospective nationwide cohort study," *The Lancet Regional Health – Europe,* 9 2021.

[22] J. T. Lee, S. P. Althomsons, H. Wu, D. S. Budnitz, E. J. Kalayil, M. C. Lindley, C. Pingali, C. B. Bridges, A. I. Geller, A. P. Fiebelkorn, S. B. Graitcer, J. A. Singleton and S. A. Patel, "Disparities in COVID-19 Vaccination Coverage Among Health Care Personnel Working in Long-Term Care Facilities, by Job Category, National Healthcare Safety Network — United States, March 2021," *MMWR Recommendations and Reports,* vol. 70, p. 1036–1039, 2021.

[23] M. Dayan and B. Palmer, "Stopping the staff we need?," *Nuffield Trust Election briefing ,* vol. December 2019, 2019.

[24] V. Nafilyan, T. Dolby, C. Razieh, C. H. Gaughan, J. Morgan, D. Ayoubkhani, S. Walker, K. Khunti, M. Glickman and T. Yates, "Sociodemographic inequality in COVID-19 vaccination coverage among elderly adults in England: a national linked data study," *BMJ Open,* vol. 11, p. e053402, 7 2021.

[25] C. C. Brown, S. G. Young and G. C. Pro, "COVID-19 vaccination rates vary by community vulnerability: A county-level analysis," *Vaccine,* vol. 39, p. 4245–4249, 2021.

[15] W. C. King, M. Rubinstein, A. Reinhart and R. J. Mejia, "COVID-19 vaccine hesitancy January-March 2021 among 18-64 year old US adults by employment and occupation," *medRxiv,* p. 2021.04.20.21255821, 1 2021.

[17] S. M. Kearney, A. P. Aldridge, N. G. Castle, J. Peterson and J. L. Pringle, "The Association of Job Strain With Medication Adherence: Is Your Job Affecting Your Compliance With a Prescribed Medication Regimen?," *J Occup Environ Med,* vol. 58, no. 7, pp. 707-11, 2016.

[18] "Who Doesn't Want to be Vaccinated? Determinants of Vaccine Hesitancy During COVID-19," *IMF Working Papers,* vol. WP/21/130, 2021.

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Ethical approval was obtained from the National Statistician's Data Ethics Advisory Committee (NSDEC(20)12).

Authorship statement
Study conceptualisation was led by VN and TD. VN and TD contributed to the development of the research question, study design, with development of statistical aspects led by TD and VN. TD and VN were involved in data specification, curation and collection. TD, PP and VN conducted and checked the statistical analyses. VN, TD , KF, RE, MG, NP, MvT, contributed to the interpretation of the results. VN wrote the first draft of the paper. TD , MG, KF, RE, NP, MvT contributed to the critical revision of the manuscript for important intellectual content and approved the final version of the manuscript. VN had full access to all

data in the study and takes responsibility of the integrity of the data and the accuracy of the data analysis. VN 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 have been explained

Conflict of interest
None

Tables and Figures

Table 1 Characteristics of the study population

Characteristic	Group	Population (%)
Vaccination status	Received 3 vaccinations	11,576,503 (74.46)
	Received 0 vaccinations	1,113,973 (7.17)
SOC sub-major group	Administrative Occupations	1,244,507 (8.00)
	Business and Public Service Associate Professionals	976,115 (6.28)
	Business, Media and Public Service Professionals	1,021,549 (6.57)
	Caring Personal Service Occupations	1,193,290 (7.68)
	Community and Civil Enforcement Occupations	13,016 (0.08)
	Corporate Managers and Directors	1,387,815 (8.93)
	Culture, Media and Sports Occupations	283,576 (1.82)
	Customer Service Occupations	245,821 (1.58)
	Elementary Administration and Service Occupations	1,205,342 (7.75)
	Elementary Trades and Related Occupations	194,801 (1.25)
	Health and Social Care Associate Professionals	376,722 (2.42)
	Health Professionals	725,672 (4.67)
	Leisure, Travel and Related Personal Service Occupations	312,517 (2.01)
	Other Managers and Proprietors	645,289 (4.15)
	Process, Plant and Machine Operatives	395,644 (2.54)
	Protective Service Occupations	184,645 (1.19)
	Sales Occupations	943,992 (6.07)
	Science, Engineering and Technology Associate Professionals	291,130 (1.87)
	Science, Research, Engineering and Technology Professionals	762,528 (4.90)
	Secretarial and Related Occupations	353,422 (2.27)
	Skilled Agricultural and Related Trades	147,699 (0.95)
	Skilled Construction and Building Trades	538,663 (3.46)
	Skilled Metal, Electrical and Electronic Trades	538,295 (3.46)
	Teaching and Other Educational Professionals	732,189 (4.71)
	Textiles, Printing and Other Skilled Trades	260,541 (1.68)
	Transport and Mobile Machine Drivers and Operatives	571,871 (3.68)

Sex	Female	8,009,818 (51.52)
	Male	7,536,833 (48.48)
Age	Mean (SD)	44.1 (12.47)
Age group	18-24	1,294,652 (8.33)
	25-34	2,910,996 (18.72)
	35-44	3,445,155 (22.16)
	45-54	4,155,959 (26.73)
	55-64	3,739,889 (24.06)
Level of highest qualification	No qualification	983,902 (6.33)
	Level 1	2,150,553 (13.83)
	Level 2	2,640,381 (16.98)
	Apprenticeship	367,823 (2.37)
	Level 3	2,318,829 (14.92)
	Level 4+	4,701,177 (30.24)
	Other	520,858 (3.35)
	Not classified	1,863,128 (11.98)
Ethnic group	Bangladeshi	104,000 (0.67)
	Black African	231,434 (1.49)
	Black Caribbean	148,454 (0.95)
	Chinese	69,477 (0.45)
	Indian	457,191 (2.94)
	Mixed	260,099 (1.67)
	Other	348,107 (2.24)
	Pakistani	276,800 (1.78)
	White British	12,907,641 (83.03)
	White other	743,448 (4.78)
Disability status	Not Limited	14,814,803 (95.29)
	Limited a little	573,137 (3.69)
	Limited a lot	158,711 (1.02)
Region	East Midlands	1,432,338 (9.21)
	East of England	1,869,432 (12.02)
	London	1,877,568 (12.08)
	North East	761,281 (4.90)
	North West	2,071,728 (13.33)
	South East	2,694,185 (17.33)
	South West	1,636,578 (10.53)
	West Midlands	1,609,477 (10.35)
	Yorkshire and The Humber	1,594,064 (10.25)
Pre-existing condition	One or more (1+)	2,694,722 (17.33)

Table 2 Third vaccination coverage and odds ratios for having received three vaccinations for SOC unit groups, top and bottom 20

Occupation	Population	Number of people who had received three vaccinations	Proportion of people who had received three vaccinations	Age-standardised proportion of people who had received three vaccinations	Unadjusted OR for having received three vaccinations	Fully adjusted OR for having received three vaccinations
Scaffolders, Stagers and Riggers	16,205	7,500	46.3 (45.5 - 47.0)	50.4 (49.3 - 51.6)	0.51 (0.50 - 0.53)	0.41 (0.39 - 0.42)
Elementary Construction Occupations n.e.c.	57,595	27,780	48.2 (47.8 - 48.6)	53.4 (52.7 - 54.1)	0.55 (0.54 - 0.56)	0.50 (0.49 - 0.51)
Roofers, Roof Tilers and Slaters	23,405	11,650	49.8 (49.1 - 50.4)	50.3 (49.4 - 51.2)	0.59 (0.57 - 0.60)	0.42 (0.41 - 0.44)
Bar Staff	47,345	23,705	50.1 (49.6 - 50.5)	60.7 (59.7 - 61.7)	0.60 (0.58 - 0.61)	0.77 (0.75 - 0.78)
Sports Players	6,550	3,330	50.8 (49.6 - 52.1)	68.9 (65.9 - 71.9)	0.61 (0.58 - 0.64)	0.84 (0.79 - 0.88)
Beauticians and Related Occupations	52,240	26,935	51.6 (51.1 - 52.0)	59.1 (58.3 - 59.9)	0.63 (0.62 - 0.64)	0.60 (0.58 - 0.61)
Tyre, Exhaust and Windscreen Fitters	7,125	3,705	52.0 (50.8 - 53.2)	56.1 (54.2 - 57.9)	0.64 (0.61 - 0.67)	0.59 (0.56 - 0.62)
Plasterers	30,685	16,065	52.4 (51.8 - 52.9)	50.2 (49.4 - 51.0)	0.65 (0.64 - 0.67)	0.45 (0.44 - 0.46)
Groundworkers	20,440	10,795	52.8 (52.1 - 53.5)	53.5 (52.5 - 54.5)	0.67 (0.65 - 0.68)	0.51 (0.49 - 0.53)
Waiters and Waitresses	68,340	36,495	53.4 (53.0 - 53.8)	62.3 (61.4 - 63.1)	0.68 (0.67 - 0.69)	0.99 (0.98 - 1.01)
Coffee Shop Workers	18,065	9,925	54.9 (54.2 - 55.7)	65.8 (64.0 - 67.5)	0.72 (0.70 - 0.74)	1.04 (1.01 - 1.07)
Air-conditioning and Refrigeration Installers and Repairers	7,570	4,260	56.3 (55.2 - 57.4)	57.6 (55.8 - 59.3)	0.77 (0.73 - 0.80)	0.57 (0.54 - 0.60)
Floorers and Wall Tilers	23,570	13,520	57.4 (56.7 - 58.0)	53.2 (52.3 - 54.1)	0.80 (0.78 - 0.82)	0.53 (0.51 - 0.54)
Bricklayers	32,555	18,690	57.4 (56.9 - 57.9)	55.6 (54.8 - 56.5)	0.80 (0.78 - 0.82)	0.52 (0.51 - 0.54)
Vehicle Valeters and Cleaners	8,985	5,185	57.7 (56.7 - 58.7)	55.6 (54.1 - 57.1)	0.81 (0.78 - 0.85)	0.67 (0.64 - 0.71)
Road Construction Operatives	11,280	6,520	57.8 (56.9 - 58.7)	55.8 (54.4 - 57.2)	0.81 (0.78 - 0.84)	0.59 (0.56 - 0.61)
Delivery Operatives	13,145	7,605	57.9 (57.0 - 58.7)	58.1 (56.8 - 59.5)	0.82 (0.79 - 0.85)	0.73 (0.70 - 0.76)
Packers, Bottlers, Canners and Fillers	39,610	22,915	57.9 (57.4 - 58.3)	55.2 (54.5 - 55.9)	0.81 (0.80 - 0.83)	0.76 (0.74 - 0.77)
Steel Erectors	3,310	1,940	58.6 (56.9 - 60.3)	55.7 (53.1 - 58.2)	0.84 (0.79 - 0.90)	0.57 (0.53 - 0.62)
Electricians and Electrical Fitters	108,865	63,925	58.7 (58.4 - 59.0)	60.8 (60.3 - 61.2)	0.84 (0.83 - 0.86)	0.64 (0.63 - 0.64)
.....	.....	.....	.....	.....	.....	.....
Chief Executives and Senior Officials	61,700	54,610	88.5 (88.3 - 88.8)	78.6 (77.5 - 79.7)	4.57 (4.46 - 4.69)	2.04 (1.99 - 2.10)

Physical Scientists	4,055	3,595	88.7 (87.7 - 89.6)	88.1 (84.9 - 91.3)	4.69 (4.26 - 5.17)	3.32 (3.00 - 3.67)
Conservation Professionals	6,070	5,395	88.9 (88.1 - 89.7)	87.3 (84.5 - 90.0)	4.68 (4.32 - 5.07)	2.78 (2.56 - 3.02)
Veterinarians	9,125	8,110	88.9 (88.2 - 89.5)	88.0 (85.4 - 90.6)	4.74 (4.44 - 5.07)	3.51 (3.28 - 3.75)
Business, Research and Administrative Professionals n.e.c.	22,305	19,835	88.9 (88.5 - 89.3)	88.3 (86.9 - 89.6)	4.75 (4.56 - 4.96)	4.11 (3.93 - 4.30)
Directors in Consultancy Services	37,130	33,240	89.5 (89.2 - 89.8)	79.9 (77.7 - 82.0)	5.08 (4.91 - 5.25)	1.99 (1.92 - 2.06)
Higher Education Teaching Professionals	74,220	66,430	89.5 (89.3 - 89.7)	84.5 (83.4 - 85.5)	5.06 (4.94 - 5.19)	2.53 (2.47 - 2.60)
Exam Invigilators	4,030	3,620	89.8 (88.9 - 90.8)	76.6 (72.3 - 80.9)	5.17 (4.67 - 5.73)	1.83 (1.64 - 2.04)
Physiotherapists	27,215	24,445	89.8 (89.5 - 90.2)	90.1 (88.8 - 91.4)	5.25 (5.04 - 5.46)	4.00 (3.84 - 4.17)
Newspaper and Periodical Editors	16,705	15,015	89.9 (89.4 - 90.3)	87.2 (85.6 - 88.9)	5.29 (5.03 - 5.56)	3.50 (3.31 - 3.69)
Specialist Nurses	29,005	26,180	90.3 (89.9 - 90.6)	86.1 (84.3 - 87.8)	5.51 (5.30 - 5.73)	2.84 (2.72 - 2.95)
Librarians	6,605	5,975	90.5 (89.8 - 91.2)	85.1 (82.1 - 88.2)	5.77 (5.31 - 6.28)	2.52 (2.31 - 2.76)
Generalist Medical Practitioners	76,175	69,215	90.9 (90.7 - 91.1)	88.6 (87.5 - 89.7)	5.91 (5.76 - 6.06)	5.97 (5.82 - 6.13)
Archivists and Curators	5,135	4,685	91.2 (90.5 - 92.0)	87.7 (84.3 - 91.1)	6.18 (5.61 - 6.81)	3.52 (3.18 - 3.89)
Clinical Psychologists	8,385	7,690	91.7 (91.1 - 92.3)	92.1 (88.2 - 96.0)	6.51 (6.03 - 7.04)	4.64 (4.28 - 5.02)
Head Teachers and Principals	37,510	34,430	91.8 (91.5 - 92.1)	83.8 (80.7 - 87.0)	6.65 (6.40 - 6.90)	2.68 (2.57 - 2.78)
Public Relations and Communications Directors	12,410	11,415	92.0 (91.5 - 92.5)	84.4 (79.9 - 89.0)	6.86 (6.42 - 7.32)	3.06 (2.86 - 3.27)
Speech and Language Therapists	9,525	8,765	92.0 (91.5 - 92.6)	92.0 (89.6 - 94.5)	6.79 (6.30 - 7.31)	4.99 (4.62 - 5.39)
Senior Police Officers	4,955	4,600	92.8 (92.1 - 93.6)	83.4 (75.6 - 91.2)	7.66 (6.87 - 8.53)	3.24 (2.90 - 3.61)
Specialist Medical Practitioners	39,955	37,280	93.3 (93.1 - 93.6)	87.7 (85.8 - 89.5)	8.27 (7.95 - 8.60)	4.75 (4.56 - 4.95)

Note: ONS Public Health Data Asset; Results for all SOC unit groups are presented in Supplementary Table S3. The reference category for the ORs is the Sales and Retail Assistants occupation. Fully adjusted models include sex, 10-year age bands, ethnic group, region, highest level of qualification, disability status and pre-existing health conditions.

Figure 1 Vaccination coverage by SOC sub-major group

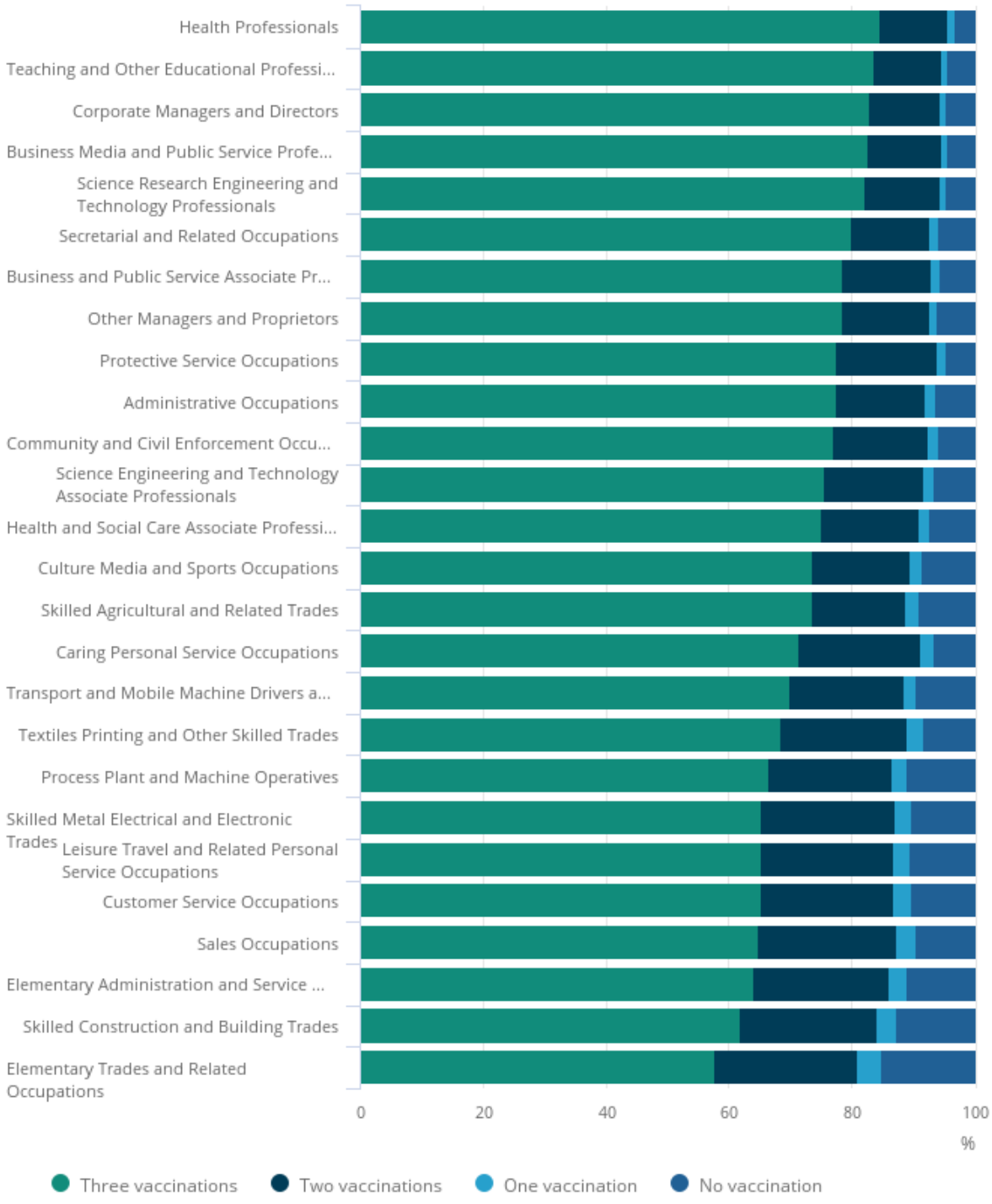
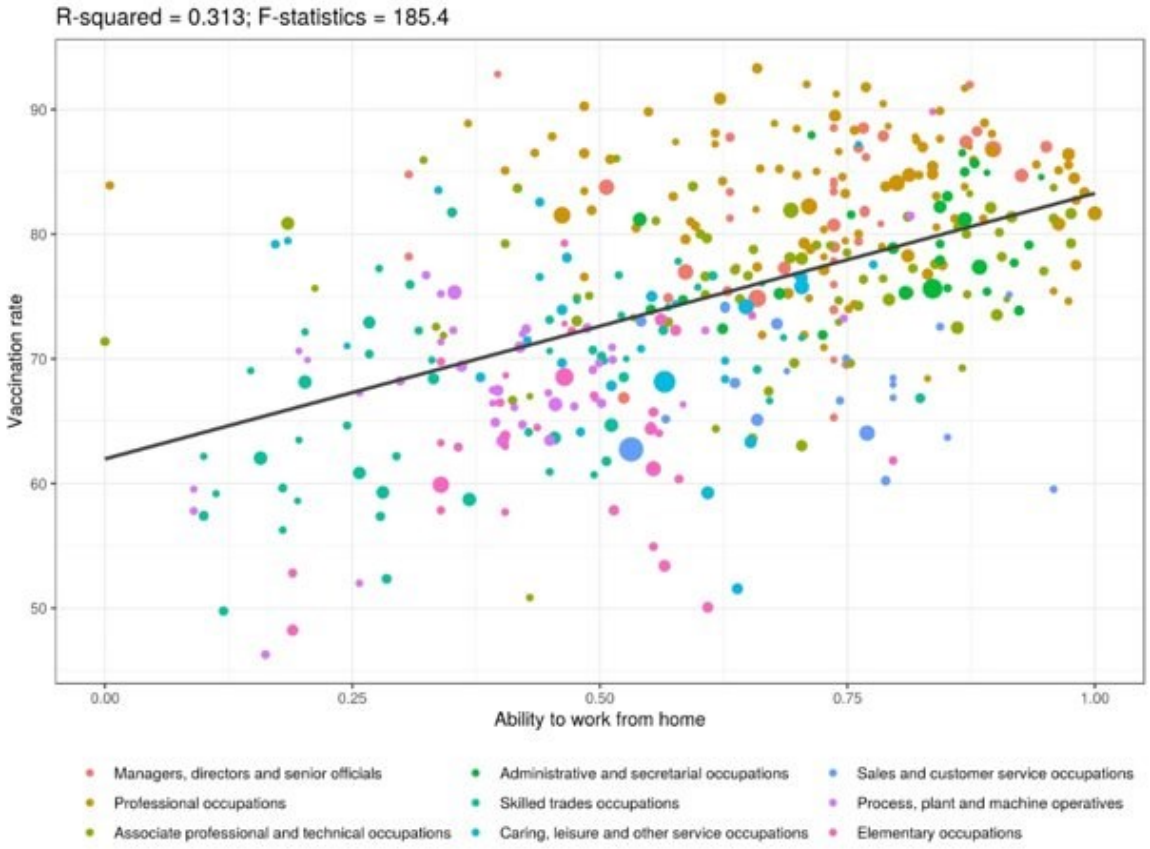


Figure 2 Association between vaccination rates and ability to work from home at unit group level



Note: The size of each point represents the number of people in the study population employed in the given SOC unit group.