BMJ Open

Characteristics associated with COVID-19 vaccine uptake among adults in England (08 December – 17 May 2021)

SCHOLARONE™
Manuscripts

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

BMJ

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Characteristics associated with COVID-19 vaccine uptake among adults in England (08 December – 17 May 2021)

Elise Tessier	Epidemiologist [1]	Elise.Tessier@phe.gov.uk
Yuma Rai	Vaccine Tracking Officer [1]	Yuma.SangpangRai@phe.gov.uk
Eleanor Clarke	Scientist, Epidemiology [1]	Eleanor.Clarke@phe.gov.uk.uk
Anissa Lakhani	Scientist, Epidemiology [1]	Anissa.Lakhani@phe.gov.uk
Camille Tsang	Data Manager [1]	Camille.Tsang@phe.gov.uk
Ashley Makwana	Data Analyst[2]	Ashley.Makwana@phe.gov.uk
Heather Heard	Head of Data and Information Systems[3]	Heather.Heard@phe.gov.uk
Tim Rickeard	Head of Technical Services [2]	Tim.Rickeard@phe.gov.uk
Shreya Lakhani	Vaccine Tracking Officer [1]	Shreya.Lakhani@phe.gov.uk
Partho Roy	Consultant Epidemiologist [1]	Partho.Roy@phe.gov.uk
Michael Edelstein	Associate Professor [4]	michael.edelstein@biu.ac.il
Mary Ramsay	Deputy Director [1]	Mary.Ramsay@phe.gov.uk
Jamie Lopez-Bernal	Consultant Epidemiologist [1]	Jamie.LopezBernal2@phe.gov.uk
Joanne White	Senior Epidemiologist [1]	joannemshivji@gmail.com
Nick Andrews	Senior Statistician [1]	Nick.Andrews@phe.gov.uk
Colin Campbell	Consultant Epidemiologist [1]	Colin.NJ.Campbell@phe.gov.uk
Julia Stowe	Senior Epidemiologist [1]	Julia.Stowe@phe.gov.uk

Affiliations:

1. Immunisation and Countermeasures Division, Public Health England, 61 Colindale Avenue, London, NW9 5EQ UK
2. Vaccines and Countermeasures Division, Public Health England, 133-155, Waterloo Road, Lambeth SE1 8UG UK
3. Health Intelligence Division, Health Improvement Directorate, Public Health England, Station Rise, York, YO1 6GA
4. Faculty of Medicine, Bar Ilan University, Safed, Israel

Corresponding author: Elise.Tessier@phe.gov.uk
Immunisation and Countermeasures Division, Public Health England, 61 Colindale Avenue, London, NW9 5EQ UK

1

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Abstract:

Objective: To determine characteristics associated with COVID-19 vaccine coverage among individuals aged 50 years and above in England since the beginning of the programme.

Design: Observational cross-sectional study assessed by logistic regression and mean prevalence margins.

Setting: COVID-19 vaccinations delivered in England from 08 December 2020 – 17 May 2021.

Participants: 30,624,257/ 61,967,781 (49.4%) and 17,360,045/ 61,967,781 (28.1%) individuals in England were recorded as vaccinated in the National Immunisation Management System with a first dose and a second dose of a COVID-19 vaccine, respectively.

Interventions: Vaccination status with COVID-19 vaccinations.

Main Outcome Measures: Proportion, adjusted odds ratios and mean prevalence margins for individuals not vaccinated with dose 1 among those aged 50- 69 years old and dose 1 and 2 among those aged 70 years old and above.

Results: Among individuals aged 50 years and above, Black/African/Caribbean ethnic group was the least likely of all ethnic groups to be vaccinated with dose 1 of the COVID-19 vaccine. However, among those aged 70 years and above, the odds of not having dose 2 was 5.53 (95% CI 5.42 to 5.63) and 5.36 (90% CI 5.29 to 5.43) greater among Pakistani and Black/African/Caribbean compared to White British ethnicity, respectively. The odds of not receiving dose 2 was 1.18 (95% CI 1.16 to 1.20) higher among individuals who lived in a care home compared to those who did not. This was the opposite to that observed for dose 1, where the odds of not being vaccinated was significantly higher among those not living in a care home (0.89 (95% CI 0.87 to 0.91)).

Conclusions: We found that there are characteristics associated with low COVID-19 vaccine coverage. Inequalities, such as ethnicity are a major contributor to suboptimal coverage and tailored interventions are required to improve coverage and protect the population from SARS-CoV-2.

2

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Article summary:

Strengths and Limitations of this study:

- This is the is the first study assessing characteristics associated with COVID-19 vaccine coverage for all individuals aged 50 years and above in England.
- This study uses data from the National Immunisation Management System (NIMS) which is based on all individuals in England with a registered NHS number.
- This centralised national system captures individual level data for both vaccination status and demographic characteristics and allows for linkage to other datasets such as health care worker and care home resident status.
- This study does not include those without an NHS number and, therefore, it is possible we have underestimated the number of vaccines delivered and odds of not being vaccinated for characteristics such as ethnic groups where we have seen the greatest impact.
- Residual errors in data entry on the point of care apps at the vaccination sites may have also occurred, though these errors are not likely to be widespread.

3

Background:

The United Kingdom (UK) was the first country in the world to approve a COVID-19 vaccine to be used in response to the pandemic, getting a head start on the roll-out of its COVID-19 vaccination programme [1]. On December 08 2021, the UK launched its COVID-19 vaccination programme with the aim of reducing COVID-19 mortality and hospitalisations among those at highest risk. There are currently three vaccinations that the Medicines and Healthcare products Regulatory Agency (MHRA) have authorised; the Pfizer/BioNTech vaccine (offered from 08 December 2021), the AstraZeneca (Oxford) vaccine (offered from 04 January 2021) and the Moderna Tx (offered from 13 April 2021) [2-4].

To ensure the reduction of mortality from SARS-CoV-2 infection and protect the healthcare system, the Joint Committee on Vaccination and Immunisation (JCVI), an independent expert advisory committee which advises the UK health departments on vaccination, initially recommended extending the interval between doses up to 12 week in order to vaccinate a greater number of people sooner with the first dose of the COVID-19 vaccine [5][6]. The JCVI also recommended that the vaccination programme be rolled out in phases beginning on 08 December 2021, for those aged 80 years old and above and for frontline healthcare workers [6] gradually opening vaccination eligibility. This was followed by phases two to nine in descending age groups along with those who were identified as clinically extremely vulnerable and those classified at risk.

NHS England with support from Public Health England (PHE), the national public health agency, publish COVID-19 vaccination counts and denominators by region, age, ethnicity and for care home residents using a tracker tool [7]. Previous research on characteristics for low vaccine coverage in England have shown that deprivation and ethnicity are associated with lower coverage [8-10]. There is little to no data collected on vaccine coverage for individuals living in care homes, though barriers exist in achieving high influenza uptake in care homes such as care home size, geographical location, working relationships with primary care and pharmacies [11]. These studies and guidance assess routine vaccines delivered in England which are primarily delivered through general practices, pharmacies and schools. With the ongoing COVID-19 pandemic, the rapid development of COVID-19 vaccines and the urgency to rapidly roll out the programme in various settings including mass immunisation sites, it is unknown whether the same characteristics associated with vaccine coverage for routine programmes are associated with low coverage for COVID-19 vaccines.

The aim of this study is twofold:

1. To describe the number of individuals eligible for a COVID-19 vaccine in the first phase of the roll-out that have been vaccinated with a single or two doses of COVID-19 vaccine by age, sex, geographical location, vaccine type, ethnicity, deprivation, urban or rural setting and programme week.
2. To determine whether there are any characteristics independently associated with low vaccine coverage for dose 1 and dose 2 of COVID-19 vaccines.

Methods:

Data source

A National Immunisations Management System (NIMS) capable of recording any vaccination regardless of point of delivery has been used for the response to the pandemic to collect information about COVID-19 vaccines delivered across England. Individuals who present to a vaccination site, such as general practice, pharmacy, or hospital, provider and receive a COVID-19 vaccine will have their vaccine event information recorded on a Point of Care application. PHE

4

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

receives data which is linked to demographic data obtained from the NHS (e.g., gender, date of birth), using the individual's unique NHS number [12]. PHE uses these data for monitoring vaccine safety, effectiveness and coverage. All variables used for vaccine coverage are described in Supplementary Table 1. Age was calculated for all individuals based on their age on 31 March 2021.

Patient and Public Involvement

No patients were involved in the design or execution of the study

Study population

NIMS data was extracted on 17 May 2021 to assess vaccination status of all individuals aged 50 to 69 years old for a first dose of COVID-19 vaccine and of all individuals aged 70 years old and above vaccinated with a first and a second dose of a COVID-19 vaccine. The programme is still being rolled out among younger cohorts therefore not all 50-59 years olds had not been offered a second dose of COVID-19 vaccine at the time of data extraction. Individuals recorded in the NIMS must have an NHS number in order to link the population denominator and vaccination event files. All individuals with a death recorded were excluded from the analyses for the purpose of calculating coverage in the living resident population aged 50 and above on 31 March 2021.

Vaccine coverage

Vaccine coverage was calculated by dividing the total number of individuals with a recorded NHS number in the dataset who were vaccinated with 1 dose and 2 doses of COVID-19 vaccine since the beginning of the vaccine roll-out on 08 December 2020 (numerator) by the total number of individuals with a recorded NHS number in the dataset (denominator).

Proportion of unvaccinated individuals

The proportion of individuals not vaccinated for dose 1 and/or not vaccinated with dose 2 was calculated by dividing the total number of individuals unvaccinated or with a single dose of the COVID-19 vaccine since the beginning of the vaccine roll-out on 08 December 2020 (numerator) by the total number of individuals with a recorded NHS number in the dataset (denominator).

Descriptive analyses:

The proportion of individuals vaccinated and unvaccinated was described by programme week, starting at week 1 (beginning on 07 December 2020). Cumulative vaccine uptake has been calculated by programme week. Furthermore, the number of and proportion of individuals unvaccinated were aggregated by age groups, region, rural/urban classification, ethnicity, for individuals clinically extremely vulnerable, for individuals over 65 years old living in a care home, for individuals less than 65 years old and a healthcare worker.

Statistical analyses:

Statistical analyses were conducted for individuals eligible for a COVID-19 vaccine in England in Phase 1, at the beginning of the roll out. The analyses were conducted for those vaccinated with dose 1 and dose 2 for individuals aged 70 years old and above, and for dose 1 among individuals aged 50 to 69 years old.

To assess the odds of not being vaccinated or not being vaccinated with dose 2, univariable logistic regression models for each characteristic were fitted with the binary outcome of vaccination status (not vaccinated/ vaccinated with a single dose and vaccinated with dose 1/ vaccinated with two

5

doses). A multivariable logistic regression model was conducted adjusting for all other characteristics.

The adjusted mean prevalence margins and 95% confidence intervals of being unvaccinated for each characteristic within the multivariable model fit were calculated using the adjusted ratios.

All statistical analyses were conducted using Stata 15.1.

Results

Descriptive results

As of 17 May 2021, a total of 30,624,257/ 61,967,781 (49.4%) and 17,360,045/ 61,967,781 (28.1%) individuals were vaccinated with a first dose and a second dose of a COVID-19 vaccine, respectively. The number of individuals vaccinated varied by programme week, plateauing at weeks 11 and 24 for dose 1 and 2 among those aged 70 years old and above, and week 23 for dose 1 among those aged 50 to 69 years old (Figures 1 and 2). Those aged 50 to 69 were still eligible for their second dose and had not yet plateaued at the time the data was extracted.

The proportion of individuals unvaccinated varied by age, dose and region; London consistently had the highest proportion of individuals being unvaccinated (Figure 3). Among the total population aged 50 and older, the North East of England had the lowest proportion of unvaccinated individuals (Figure 3).

70-year olds and above unvaccinated

Among individuals aged 70 years old and above, all the characteristics were significantly associated with not being vaccinated in both the univariable and multivariable logistic regression analyses.

The odds of not being vaccinated was higher among males and those aged 75-79 and 80 years old and above than the baseline of 70-74 years old (Table 1). The odds of not being vaccinated with 1 or 2 doses was higher in urban areas; particularly in London with an increased odds of 2.30 (2.27 to 2.33) and 1.96 (1.94 to 1.98) odds for not being vaccinated for both dose 1 and dose 2, respectively (Table 1).

Among those clinically extremely vulnerable, the odds of not being vaccinated was reduced (OR 0.61 (95% CI 0.61 to 0.62)) and (OR 0. 88 (95% CI 0.87 to 0.89)) for dose 1 and dose 2, respectively compared to those with no significant underlying health conditions.

The odds of not being vaccinated among those living in a care home was also reduced for dose 1 (OR 0.89 (95% CI 0.87 to 0.91)) compared to those not living in a care home. However, the odds of not being vaccinated for doses 2 of the COVID-19 vaccine was 1.18 (95% CI 1.16 to 1.20) greater. The greatest odds of not being vaccinated among 70 years olds was highest among those living in the most deprived areas and among Black/African/Caribbean ethnicities. Among the Black/African/Caribbean ethnicity, the odds of not having a first dose was 6.69 (95% CI 6.58 to 6.79) greater than White British ethnicity. The odds of not being vaccinated with a second dose was 5.53 (95% CI 5.42 to 5.63) greater among the Pakistani ethnicity, followed by the Black/African/Caribbean ethnicity with an odds of 5.36 (95% CI 5.29 to 5.43).

The mean prevalence of being unvaccinated for each characteristic within the adjusted multivariable model showed increased prevalence among the characteristics with the highest odds of being unvaccinated. The highest prevalence was among the Black/African/Caribbean ethnic group for dose 1 with a mean prevalence of 17.6% unvaccinated. The prevalence among those not being

6

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

vaccinated with dose 1 was 26.6% and 26.1% among the Pakistani and Black/African/ Caribbean ethnicities, though the 95% confidence intervals do overlap between the two ethnicities (Table 1).

50-69-year olds unvaccinated

Of those aged 50-69 years old, all the characteristics were significantly associated with not being vaccinated in both the univariable and multivariable logistic regression analyses.

Similarly to those aged 70 and above, the odds of not being vaccinated was higher among males and increased in the younger populations (Table 1). The odds of not being vaccinated was higher in urban areas and particularly in London where there was an increased odds of 1.85 (95% CI 1.84 to 1.86) (Table 2).

The greatest odds of not being vaccinated with dose 1 among 50-69 year olds was highest among those with an unknown or not stated ethnicity and Black/African/Caribbean ethnicity which had a 3.40 (95% CI 3.38 to 3.41) and 3.32 (95% CI 3.29 to 3.34) increased odds of being unvaccinated compared those of White British ethnicity (Table 2).

Both the clinically extremely vulnerable/ at risk and healthcare workers had decreased odds of not being vaccinated than those that were not in these groups (OR 0.59 (95% CI 0.59 to 0.59) and 0.34 (95% CI 0.34 to 0.35), respectively) (Table 2), showing a protective effect among those at highest risk of SARS-CoV-2 disease.

The highest predictive margin for not being vaccinated after adjusting for all variables in the multivariable logistic regression model was among the Unknown/Not Stated and Black/African/Caribbean ethnic groups with a prevalence of 24.7% and 23.9% unvaccinated, respectively (Table 2).

7

Table 1. Number and proportion of individuals aged 70 years old and above not vaccinated for dose 1 and dose 2 of the COVID-19 vaccine between 8 December 2020 – 17 May 2021 in England and the odds of not being vaccinated from a multivariable logistic regression and mean adjusted prevalence from the model fit

Characteristics		Dose 1 Not Vaccinated n/N (%)	Dose 1 Multivariable Regression Odds Ratio and 95% CI	Dose 1 Predictive margins	Dose 2 Not Vaccinated n/N (%)	Dose 2 Multivariable Regression Ration and 95% CI	Dose 2 Predictive margins (%) and 95% CI*
Age	70 to 74 years	169173 / 2877391 (5.9%)	Baseline	5.42% (5.39 to 5.44)	271998/2877391 (9.5%)	Baseline	9.14% (9.11 to 9.17)
	75 to 79 years	100478 / 2086215 (4.8%)	0.86 (0.85 to 0.87)	4.74% (4.72 to 4.77)	161503/2086215 (7.7%)	0.82 (0.82 to 0.83)	7.76% (7.72 to 7.79)
	Over 80 years	140785 / 2830943 (5.0%)	1.00 (1.00 to 1.01)	5.44$ (5.41 to 5.46)	247875/2830943 (8.8%)	0.98 (0.97 to 0.98)	8.95% (8.92 to 8.98)
Urban/ Rural status	Urban areas	348992 / 5906988 (5.9%)	Baseline	5.46% (5.44 to 5.47)	571598/5906988 (9.7%)	Baseline	9.00% (8.98 to 9.02)
	Rural areas	60218 / 1880742 (3.2%)	0.77 (0.76 to 0.77)	4.31% (4.28 to 4.35)	108020/1880742 (5.7%)	0.81 (0.80 to 0.81)	7.50% (7.45 to 7.54)
	Other/ Unknown	1226 / 6819 (18.0%)	-	-	1758/6819 (25.8%)	-	-
Clinically extremely vulnerable	Not clinically extremely vulnerable	333971 / 6158381 (5.4%)	Baseline	5.75% (5.73 to 5.77)	523938/6158381 (8.5%)	Baseline	8.93% (8.91 to 8.95)
	Clinically extremely vulnerable	76464 / 1636167 (4.7%)	0.61 (0.61 to 0.62)	3.72% (3.70 to 3.75)	157437/1636167 (9.6%)	0.88 (0.87 to 0.89)	8.01% (7.97 to 8.05)
Care home status	Not in a Care Home	404206 / 7578254 (5.3%)	Baseline	5.25% (5.24 to 5.27)	663275/7578254 (8.8%)	Baseline	8.67% (8.65 to 8.69)
	In a Care Home	6230 / 216295 (2.9%)	0.89 (0.87 to 0.91)	4.74% (4.63 to 4.85)	18101/216295 (8.%)	1.18 (1.16 to 1.20)	10.00% (9.86 to 10.13)
IMD Deprivation Decile	Most Deprived	44759 / 515973 (8.7%)	Baseline	9.47% (9.39 to 9.56)	76750/515973 (14.9%)	Baseline	15.13% (15.03 to 15.23)
		47804 / 567221 (8.4%)	0.75 (0.74 to 0.76)	7.44% (7.38 to 7.50)	77905/567221 (13.7%)	0.76 (0.76 to 0.77)	12.19% (12.11 to 12.27)
		47565 / 627241 (7.6%)	0.64 (0.64 to 0.65)	6.54% (6.49 to 6.60)	77343/627241 (12.3%)	0.66 (0.66 to 0.67)	10.85% (10.78 to 10.93)
		45373 / 722661 (6.3%)	0.57 (0.57 to 0.58)	5.93% (5.87 to 5.98)	73905/722661 (10.2%)	0.59 (0.58 to 0.59)	9.75% (9.69 to 9.82)
		42635 / 796652 (5.4%)	0.51 (0.5 to 0.52)	5.34% (5.29 to 5.39)	70283/796652 (8.8%)	0.52 (0.52 to 0.53)	8.84% (8.78 to 8.9)
		40935 / 858303 (4.8%)	0.46 (0.45 to 0.46)	4.84% (4.79 to 4.88)	67766/858303 (7.9%)	0.47 (0.46 to 0.47)	8.06% (8.00 to 8.12)
		38086 / 894485 (4.3%)	0.42 (0.41 to 0.43)	4.48% (4.44 to 4.52)	63503/894485 (7.1%)	0.43 (0.43 to 0.44)	7.48% (7.42 to 7.53)
		36684 / 918054 (4.0%)	0.39 (0.39 to 0.4)	4.21% (4.16 to 4.25)	61723/918054 (6.7%)	0.41 (0.4 to 0.41)	7.09% (7.04 to 7.14)
		33833 / 934779 (3.6%)	0.35 (0.34 to 0.35)	3.77% (3.73 to 3.81)	56910/934779 (6.1%)	0.36 (0.36 to 0.37)	6.40% (6.35 to 6.44)
	Least Deprived	30264 / 947216 (3.2%)	0.31 (0.30 to 0.31)	3.40% (3.36 to 3.43)	51417/947216 (5.4%)	0.32 (0.32 to 0.33)	5.79% (5.75 to 5.84)

8

Category	Subcategory	n/N (%)	Adjusted OR	Predictive margin*	n/N (%)	Adjusted OR	Predictive margin*
	Unknown	2498 / 11964 (20.9%)	-	-	3871/11964 (32.4%)	-	-
Ethnicity	White	204842 / 6555567 (3.1%)	Baseline	3.23% (3.21 to 3.24)	409220/6555567 (6.2%)	Baseline	6.43% (6.41 to 6.45)
	Mixed/Multiple Ethnic	5446 / 34247 (15.9%)	4.38 (4.25 to 4.52)	12.44% (12.12 to 12.75)	7612/34247 (22.2%)	3.25 (3.17 to 3.34)	17.87% (17.50 to 18.25)
	Indian	11881 / 121720 (9.8%)	2.19 (2.14 to 2.23)	6.73% (6.61 to 6.85)	18257/121720 (15.0%)	1.82 (1.79 to 1.85)	11.02% (10.87 to 11.18)
	Pakistani	10528 / 52518 (20.0%)	5.26 (5.14 to 5.38)	14.47% (14.21 to 14.74)	18530/52518 (35.3%)	5.53 (5.42 to 5.63)	26.63% (26.28 to 26.97)
	Other Asian or Asian	13706 / 82251 (16.7%)	3.72 (3.65 to 3.79)	10.80% (10.62 to 10.98)	19797/82251 (24.1%)	3.04 (2.99 to 3.09)	16.93% (16.70 to 17.16)
	Black/African/Caribbean	29981 / 103294 (29.0%)	6.69 (6.58 to 6.79)	17.58% (17.37 to 17.79)	41162/103294 (39.8%)	5.36 (5.29 to 5.43)	26.06% (25.81 to 26.31)
	Other Ethnic Group	10227 / 58524 (17.5%)	4.16 (4.07 to 4.25)	11.89% (11.66 to 12.12)	13907/58524 (23.8%)	3.14 (3.07 to 3.2)	17.36% (17.09 to 17.64)
	Not stated/Unknown	123825 / 786428 (15.7%)	6.00 (5.95 to 6.04)	16.12% (16.03 to 16.2)	152891/786428 (19.4%)	3.69 (3.66 to 3.71)	19.73% (19.64 to 19.82)
Region	East of England	42261 / 971824 (4.3%)	Baseline	4.73% (4.69 to 4.78)	72699/971824 (7.5%)	Baseline	8.20% (8.15 to 8.26)
	London	108877 / 792575 (13.7%)	2.30 (2.27 to 2.33)	9.77% (9.70 to 9.83)	153166/792575 (19.3%)	1.96 (1.94 to 1.98)	14.39% (14.31 to 14.46)
	Midlands	69371 / 1515414 (4.6%)	0.97 (0.96 to 0.98)	4.60% (4.57 to 4.63)	120989/1515414 (8.0%)	0.97 (0.96 to 0.98)	7.98% (7.94 to 8.02)
	North East and Yorkshire	45147 / 1232540 (3.7%)	0.77 (0.76 to 0.78)	3.74% (3.71 to 3.78)	83505/1232540 (6.8%)	0.80 (0.79 to 0.81)	6.75% (6.71 to 6.8)
	North West	45973 / 973704 (4.7%)	0.95 (0.93 to 0.96)	4.51% (4.47 to 4.55)	82655/973704 (8.5%)	0.97 (0.96 to 0.98)	7.99% (7.94 to 8.04)
	South East	59447 / 1334389 (4.5%)	1.11 (1.09 to 1.12)	5.18% (5.14 to 5.22)	102275/1334389 (7.7%)	1.10 (1.09 to 1.11)	8.90% (8.85 to 8.96)
	South West	36862 / 962139 (3.8%)	0.90 (0.89 to 0.91)	4.30% (4.26 to 4.35)	62216/962139 (6.5%)	0.88 (0.87 to 0.89)	7.30% (7.25 to 7.36)
	Unknown	2498 / 11964 (20.9%)	-	-	3871/11964 (32.4%)	-	-
Sex	Female	217583 / 4279458 (5.1%)	Baseline	4.95% (4.93 to 4.97)	372475/4279458 (8.7%)	Baseline	8.60% (8.57 to 8.62)
	Male	192285 / 3510687 (5.5%)	1.16 (1.15 to 1.16)	5.62% (5.59 to 5.64)	305672/3510687 (8.7%)	1.03 (1.02 to 1.03)	8.78% (8.75 to 8.81)
	Unknown	568 / 4404 (12.9%)	0.94 (0.84 to 1.04)	4.67 (4.24 to 5.09)	3229/4404 (73.3%)	21.72 (19.92 to 23.69)	60.79% (58.88 to 62.7)

*The percent vaccinated may fall outside the range of the predictive margins, as they are based on the effect of the adjusted multivariable model.

9

Table 2. Number and proportion of individuals aged 50-69 years old not vaccinated for dose 1 of the COVID-19 vaccine between 8 December 2020 – 17 May 2021 in England and the odds of not being vaccinated from a multivariable logistic regression and mean adjusted prevalence from the model fit

	Characteristics	Dose 1 Not Vaccinated n/N (%)	Dose 1 Multivariable Regression Odds Ration and 95% CI	Dose 1 Predictive margins (%) and 95% CI*
Age	**50 to 54 years**	3018263 / 4214965 (71.6%)	Baseline	15.07% (15.04 to 15.10)
	55 to 64 years	4485055 / 7518324 (59.7%)	0.81 (0.81 to 0.82)	12.82% (12.8 to 12.85)
	65 to 69 years	561755 / 2891288 (19.4%)	0.51 (0.51 to 0.51)	8.72% (8.68 to 8.75)
Urban/ Rural status	**Urban areas**	6418686 / 11552097 (55.6%)	Baseline	13.17% (13.15 to 13.19)
	Rural areas	1632703 / 3052642 (53.5%)	0.75 (0.74 to 0.75)	10.39% (10.35 to 10.43)
	Other/ Unknown	13684 / 19838 (69.0%)	-	-
Clinically extremely vulnerable/ at risk (cohort 6)	**Not at risk**	6501682 / 10368328 (62.7%)	Baseline	14.18% (14.16 to 14.20)
	At Risk	1563391 / 4256249 (36.7%)	0.59 (0.59 to 0.59)	9.25% (9.22 to 9.28)
Health care worker	**Not Health Care Worker**	8003303 / 14162182 (56.5%)	Baseline	12.94% (12.93 to 12.96)
	Health Care Worker	61770 / 462395 (13.4%)	0.34 (0.34 to 0.35)	5.22% (5.16 to 5.28)
IMD Deprivation Decile	**Most Deprived**	760885 / 1290391 (59.0%)	Baseline	20.57% (20.50 to 20.65)
		782255 / 1339803 (58.4%)	0.74 (0.74 to 0.75)	16.52% (16.46 to 16.58)
		795155 / 1383303 (57.5%)	0.66 (0.65 to 0.66)	15.00% (14.95 to 15.06)
		803307 / 1437917 (55.9%)	0.59 (0.59 to 0.60)	13.88% (13.82 to 13.93)
		806095 / 1479989 (54.5%)	0.53 (0.53 to 0.53)	12.69% (12.64 to 12.74)
		816104 / 1522404 (53.6%)	0.47 (0.47 to 0.48)	11.60% (11.55 to 11.65)
		815712 / 1528345 (53.4%)	0.43 (0.43 to 0.43)	10.72% (10.67 to 10.77)
		816165 / 1543302 (52.9%)	0.40 (0.39 to 0.40)	9.97% (9.93 to 10.02)
		814550 / 1530600 (53.2%)	0.36 (0.35 to 0.36)	9.14% (9.10 to 9.19)
	Least Deprived	830441 / 1534627 (54.1%)	0.32 (0.31 to 0.32)	8.23% (8.19 to 8.28)
	Unknown	24404 / 33896 (72.0%)	-	-
Ethnicity	**White**	5532177 / 10821112 (51.1%)	Baseline	9.07% (9.05 to 9.08)
	Mixed/Multiple Ethnic	84371 / 135124 (62.4%)	2.60 (2.57 to 2.64)	19.97% (19.77 to 20.16)

10

	Indian	152271 / 325697 (46.8%)	1.19 (1.18 to 1.20)	10.55% (10.45 to 10.64)
	Pakistani	130526 / 197437 (66.1%)	2.48 (2.46 to 2.51)	19.26% (19.10 to 19.42)
	Other Asian or Asian	177291 / 305023 (58.1%)	1.56 (1.54 to 1.57)	13.24% (13.13 to 13.35)
	Black/African/Caribbean	306972 / 450853 (68.1%)	3.32 (3.29 to 3.34)	23.87% (23.75 to 23.98)
	Other Ethnic Group	139813 / 217886 (64.2%)	2.61 (2.59 to 2.64)	20.01% (19.86 to 20.16)
	Not stated/Unknown	1541652 / 2171445 (71.0%)	3.40 (3.38 to 3.41)	24.27% (24.21 to 24.32)
Region	East of England	966550 / 1721713 (56.1%)	Baseline	11.86% (11.81 to 11.91)
	London	1197210 / 2056938 (58.2%)	1.85 (1.84 to 1.86)	19.14% (19.09 to 19.19)
	Midlands	1508576 / 2758546 (54.7%)	0.98 (0.98 to 0.99)	11.69% (11.66 to 11.73)
	North East and Yorkshire	1245671 / 2284027 (54.5%)	0.80 (0.79 to 0.81)	9.85% (9.81 to 9.89)
	North West	967344 / 1865618 (51.9%)	0.99 (0.98 to 1.00)	11.77% (11.73 to 11.81)
	South East	1321417 / 2353321 (56.2%)	1.05 (1.05 to 1.06)	12.37% (12.32 to 12.41)
	South West	833901 / 1550518 (53.8%)	0.88 (0.88 to 0.89)	10.70% (10.65 to 10.76)
	Unknown	24404 / 33896 (72.0%)	-	-
Sex	Female	3659928 / 7229063 (50.6%)	Baseline	11.45% (11.42 to 11.47)
	Male	4388976 / 7376483 (59.5%)	1.27 (1.27 to 1.28)	13.87% (13.84 to 13.89)
	Unknown	16169 / 19031 (85.0%)	0.78 (0.75 to 0.81)	9.33% (9.01 to 9.65)

*The percent vaccinated may fall outside the range of the predictive margins, as they are based on the effect of the adjusted multivariable model.

11

Discussion:

As of 17 May 2021, 49.4% of the population aged 50 and above in England had received a first dose of the COVID-19 vaccine and 28.1% had their second dose. Vaccine coverage for dose 1 among those aged 50 years old and for dose 2 for those aged 70 years old and above have plateaued. A significant increase in the number of individuals aged 50-69 years old occurred in week 15 of the programme (the week commencing the 15 March 2021), when those aged 50 – 69 became eligible for the vaccine [13][14]. Individuals aged 50 to 69 vaccinated in earlier weeks were most likely to have been healthcare workers, individuals clinically extremely vulnerable/Cohort 6 at risk for severe coronavirus disease [15].

The overall proportion of individuals eligible for the vaccine but not vaccinated was highest in London, followed by areas in the Midlands and East of England. These results coincide with findings from studies assessing influenza and shingles vaccination programmes [8][9], which offered vaccines to individuals in similar populations such as elderly individuals and those at risk, where lower coverage in London and in urban areas is observed.

Results from the multivariable logistic regression model and the predictive margins for two doses among those aged 70 years old and above and for one dose among those aged 50-69 indicate an increased odds and predicted margins of being unvaccinated with lower age groups. Should lower coverage among younger adults continue to be observed as the programme continues to roll-out, efforts will need to be made to address this. Moreover, after adjusting for all variables in the multivariable models the odds of being unvaccinated was higher among males compared to females, in urban areas compared to rural areas, and highest in London compared to all other regions in England among all individuals aged 50 years old and above. An overall reduced odds of not being vaccinated was observed among those clinically extremely vulnerable/ at risk aged 50 years and above and among healthcare workers aged 50 to 69 years old. These individuals were all eligible for the vaccine early within the programme.

Individuals aged 70 years old and above living in a care home had a reduced odds of not being vaccinated for dose 1 compared to those not living in a care home. In contrary, care home residents had an increased odds of not being vaccinated for the second dose compared to those living in a care home. The delivery of COVID-19 vaccines to care homes was primarily carried out by mobile teams which required a lot of logistics and coordination [16]. The delivery of second doses of COVID-19 vaccinations in care homes may be lower due to following up individuals who were not vaccinated or partially vaccinated and moved into a care home after or between mobile vaccination unit visits. It is important to further investigate the increased odds of not being vaccinated with dose 2 in care homes, as residents have been disproportionately affected by SARS-CoV-2 [17]. It is unlikely that the death rates are associated with low coverage as deaths are recorded in a timely manner in the NIMS [18], though it is possible that care home residents might have had COVID-19 or another illness at the time of offer, thus causing a lag in the number of second doses received.

Both the highest odds and the predictive margins for not being vaccinated for dose 1 among all individuals in the study and for dose 2 among those aged 70 years old and above were observed in the most deprived and among the Black/African/Caribbean ethnicity. This coincides with findings assessing COVID-19 vaccine coverage for those aged 70 years old and above using the 2011 ONS denominator population estimates [19] and using general practice records for population estimates based on registrations for two of the three GP IT System Suppliers in England [20]. Furthermore, among those aged 70 years old and above, the odds and prevalence of being unvaccinated among those of Pakistani ethnicity further increased for dose 2. Our findings highlight the structural and

12

complex interplay of ethnicity and deprivation which has also been observed with finding on SARS-CoV-2 infection, hospitalisations and mortality [21] [22].

Strengths and Limitations of this study

Our study has several strengths; this is the is the first study assessing characteristics associated with COVID-19 vaccine coverage for all individuals aged 50 years and above in England and one of the first studies globally assessing COVID-19 vaccine coverage. Our study also uses data from the NIMS which is based on all individuals in England with a registered NHS number which is likely to be more complete than other datasets used to estimate COVID-19 vaccine coverage. Furthermore, immunisation registers have been proven to be fundamental when assessing and protecting the population, can be used for linkage to health-outcome databases and can play a key role in the delivery of a national immunisation programme [23-25]. This is the first time England has developed a centralised national system capturing individual level data for both vaccination status and demographic characteristics. Previous studies assessing factors influencing vaccine coverage in England have been based on aggregate general practice-level data where estimates such as deprivation were based on the general practice post code. Having individual level data such as for frontline healthcare workers and care home residents allowed us to link individual NHS numbers to properly account for these individuals which is not available in similar studies or in general practice records.

We are unable to capture details on the total number of individuals without an NHS number and, of those who had not received a vaccine, therefore, it is possible we have underestimated the number of vaccines delivered and odds of not being vaccinated for characteristics such as ethnic groups where we have seen the greatest impact. The proportion of individuals aged 50 years and above with no NHS number is expected to be marginal. Furthermore, it is possible that there could be residual errors in data entry on the point of care apps at the vaccination sites, though these errors are not widespread. Though the NIMS was rapidly set up for monitoring COVID-19 vaccinations, it was piloted with influenza vaccinations delivered in the 2020/21 influenza season and the trends observed in our study align with other immunisation programmes.

Conclusions

This study provides evidence that in England, being male, being in a younger age group, belonging to certain minority groups, living in urban setting or being a care home resident were associated with low COVID-19 vaccine coverage. The largest odds of not being vaccinated was observed among those of Black/African/Caribbean ethnicity and those in the most deprived decile. It is of utmost importance to reduce inequalities in vaccine coverage, particularly among Black, Asian and Minority Ethnic groups and care home residents who have been most impacted by the SARS-CoV-2 infection. As vaccine coverage increases in England, tailored strategies taking into consideration barriers specific to these under-vaccinated groups should be designed and implemented in order to improve coverage.

Acknowledgements

13

Contributor and guarantor information:
Elise Tessier is the guarantor of the paper and confirms that the manuscript is honest, accurate and transparent. There are no important aspects of the paper omitted.

Competing interests declaration: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: funding from Public Health England for the submitted work; 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: Surveillance of covid-19 vaccination data is undertaken under Regulation 3 of The Health Service (Control of Patient Information) Regulations 2002 to collect confidential patient information (www.legislation.gov.uk/uksi/2002/1438/regulation/3/made) under Sections 3(i) (a) to (c), 3(i)(d) (i) and (ii) and 3(3).

Role and Funding source: There was no external funding for this study.

Data Sharing Statement: No additional data available.

14

References:

1. Baraniuk C. Covid-19: How the UK vaccine rollout delivered success, so far. *BMJ* 2021;372:n421. doi: 10.1136/bmj.n421
2. Department of Health and Social Care. Statement from the UK Chief Medical Officers on the prioritisation of first doses of COVID-19 vaccines 2020 [Available from: https://www.gov.uk/government/news/statement-from-the-uk-chief-medical-officers-on-the-prioritisation-of-first-doses-of-covid-19-vaccines accessed 02 February 2021 2021.
3. Public Health England. COVID-19 - SARS-CoV-2 Chapter 14a 2021 [Available from: https://www.gov.uk/government/publications/covid-19-the-green-book-chapter-14a.
4. Public Health England. National protocol for COVID-19 Vaccine Moderna 2021 [Available from: https://www.gov.uk/government/publications/national-protocol-for-covid-19-vaccine-moderna accessed 25/05/2021.
5. Department of Health and Social Care. Optimising the COVID-19 vaccination programme for maximum short-term impact 2021 [Available from: https://www.gov.uk/government/publications/prioritising-the-first-covid-19-vaccine-dose-jcvi-statement/optimising-the-covid-19-vaccination-programme-for-maximum-short-term-impact accessed 03 February 2021 2021.
6. Care. DoHS. Joint Committee on Vaccination and Immunisation: advice on priority groups for COVID-19 vaccination, 30 December 2020 2020 [Available from: https://www.gov.uk/government/publications/priority-groups-for-coronavirus-covid-19-vaccination-advice-from-the-jcvi-30-december-2020/joint-committee-on-vaccination-and-immunisation-advice-on-priority-groups-for-covid-19-vaccination-30-december-2020 accessed 20/05/2021.
7. NHS Digital. COVID-19 Vaccinations 2021 [Available from: https://www.england.nhs.uk/statistics/statistical-work-areas/covid-19-vaccinations/ accessed 18/06/2021.
8. Ward C, Byrne L, White JM, et al. Sociodemographic predictors of variation in coverage of the national shingles vaccination programme in England, 2014/15. *Vaccine* 2017;35(18):2372-78. doi: 10.1016/j.vaccine.2017.03.042 [published Online First: 2017/04/02]
9. Tessier E, Warburton F, Tsang C, et al. Population-level factors predicting variation in influenza vaccine uptake among adults and young children in England, 2015/16 and 2016/17. *Vaccine* 2018;36(23):3231-38. doi: 10.1016/j.vaccine.2018.04.074 [published Online First: 2018/05/03]
10. Green HK, Andrews N, Letley L, et al. Phased introduction of a universal childhood influenza vaccination programme in England: population-level factors predicting variation in national uptake during the first year, 2013/14. *Vaccine* 2015;33(22):2620-8. doi: 10.1016/j.vaccine.2015.03.049 [published Online First: 2015/04/04]
11. Public Health England. Flu and flu vaccination 2019/20: A toolkit for care homes (South West), 2020.
12. NHS Digital. Spine 2021 [Available from: https://digital.nhs.uk/services/spine accessed 27/05/2021.
13. NHS England. NHS England invites everyone aged 50 and over to be jabbed as NHS vaccination programme marks 100th day 2021 [Available from: https://www.england.nhs.uk/2021/03/nhs-england-invites-everyone-aged-50-and-over-to-be-jabbed-as-nhs-vaccination-programme-marks-100th-day/ accessed 05/06/2021.
14. NHS England. NHS invites people aged 56 to 59 for their COVID jab 2021 [05/06/2021]. Available from: https://www.england.nhs.uk/2021/03/56-59/.
15. NHS Digital. Vaccination of JCVI cohorts 5-6 and additional funding for vaccination in residential settings 2021 [Available from: https://www.england.nhs.uk/coronavirus/publication/vaccination-of-jcvi-cohorts-5-6-and-additional-funding-for-vaccination-in-residential-settings/ accessed 07/06/2021.

15

16. Mills MC, Salisbury D. The challenges of distributing COVID-19 vaccinations. *EClinicalMedicine* 2021;31 doi: 10.1016/j.eclinm.2020.100674

17. Gordon AL, Goodman C, Achterberg W, et al. Commentary: COVID in care homes—challenges and dilemmas in healthcare delivery. *Age and Ageing* 2020;49(5):701-05. doi: 10.1093/ageing/afaa113 %J Age and Ageing

18. NHS Digital. Mortality data review 2020 [Available from: https://digital.nhs.uk/coronavirus/coronavirus-data-services-updates/mortality-data-review accessed 22/06/2021.

19. Statistics. OfN. Coronavirus and vaccination rates in people aged 70 years and over by sociodemographic characteristic, England: 8 December 2020 to 9 May 2021, 2021.

20. Curtis HJ, Inglesby P, Morton CE, 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* 2021:2021.01.25.21250356. doi: 10.1101/2021.01.25.21250356

21. Mathur R, Rentsch CT, Morton CE, et al. Ethnic differences in SARS-CoV-2 infection and COVID-19-related hospitalisation, intensive care unit admission, and death in 17 million adults in England: an observational cohort study using the OpenSAFELY platform. *Lancet (London, England)* 2021;397(10286):1711-24. doi: 10.1016/S0140-6736(21)00634-6 [published Online First: 2021/04/30]

22. Robert W. Aldridge DL, Srinivasa Vittal Katikireddi, Rohini Mathur, Neha Pathak, Rachel Burns, Ellen B. Fragaszy, Anne M. Johnson, Delan Devakumar, Ibrahim Abubakar, Andrew Hayward Black, Asian and Minority Ethnic groups in England are at increased risk of death from COVID-19: indirect standardisation of NHS mortality data. *Wellcome Open Research* 2020;5(88)

23. Crowcroft NS, Levy-Bruhl D. Registries: An essential tool for maximising the health benefits of immunisation in the 21st century. 2017;22(17):30523. doi: doi:https://doi.org/10.2807/1560-7917.ES.2017.22.17.30523

24. Johansen K, Lopalco PL, Giesecke J. Immunisation registers – important for vaccinated individuals, vaccinators and public health. 2012;17(16):20151. doi: doi:https://doi.org/10.2807/ese.17.16.20151-en

25. Pebody R. Vaccine registers – experiences from Europe and elsewhere. 2012;17(17):20159. doi: doi:https://doi.org/10.2807/ese.17.17.20159-en
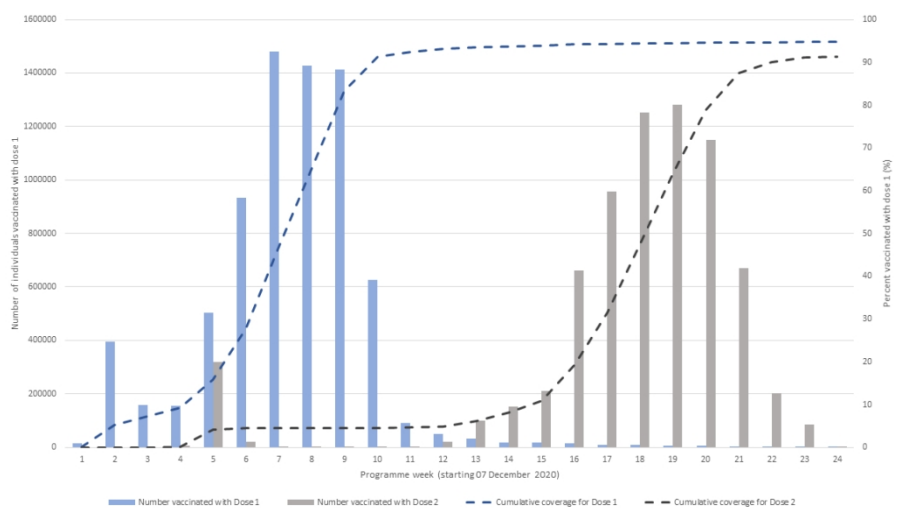
16

Figure 1. Number of individuals aged 70 years old and above vaccinated with dose 1 and dose 2 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.
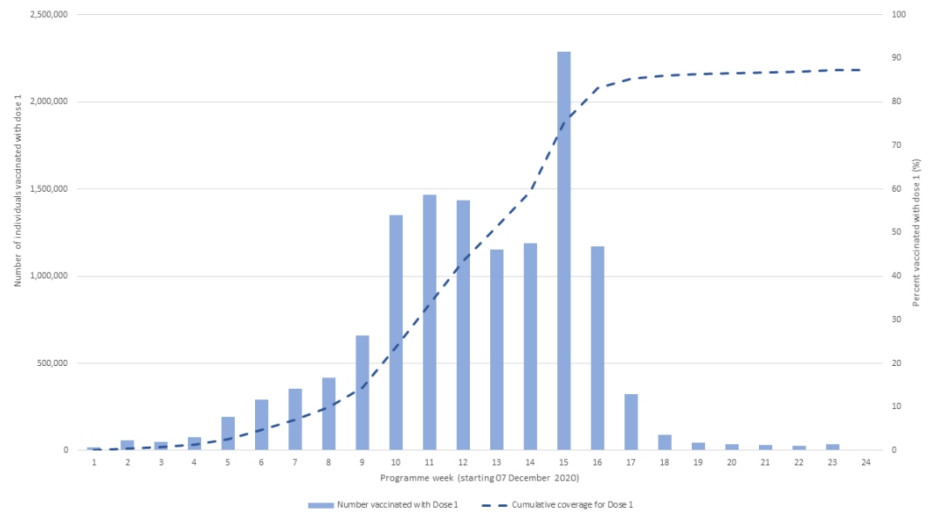
338x190mm (96 x 96 DPI)

Figure 2. Number of individuals aged 50 to 69 years old vaccinated with dose 1 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.
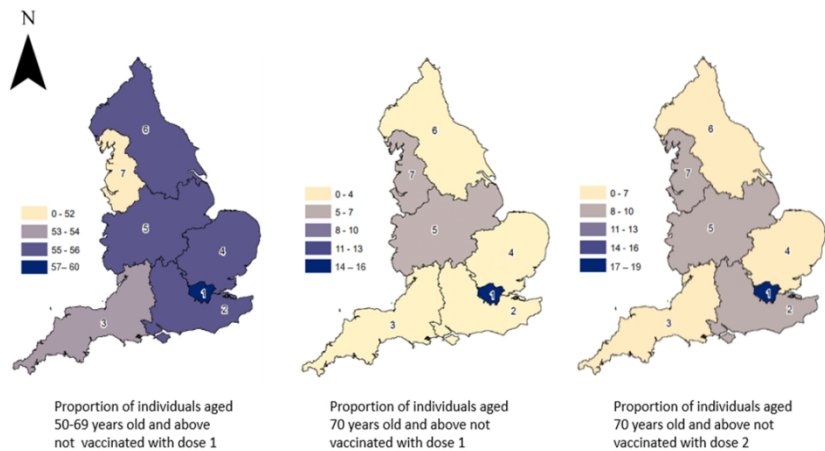
338x190mm (96 x 96 DPI)

Figure 3. Proportion of individuals aged (a) 50-69 not vaccinated with dose 1 (b) 70 years old and above not vaccinated with dose 1 and (c) 70 years old and above not vaccinated with dose 2 of COVID-19 vaccine (1: London; 2: South East; 3: South West; 4: East of England; 5: Midlands; 6: North East and Yorkshire; 7: North West)

338x190mm (96 x 96 DPI)

Supplementary Table 1. Data fields provided by NIMS and other data sources used for vaccine coverage PHE for Vaccine Coverage

Data source	Data Field	Field explanations
Population denominator data file	First name	Limited to 50 characters
	Surname	Limited to 50 characters
	Date of birth	DD/MM/YYYY
	NHS number	10 Digit number without space
	Sex	Male; Female; Unknown
	Ethnicity	Based on the 2001 ethnic category codes: ETHNIC CATEGORY CODE 2001 (datadictionary.nhs.uk)
	Postcode	Post code with no spaces
	General practice code	Code of the individuals GP practice
	Flag for individuals clinically extremely vulnerable	
	Flag for frontline healthcare and social care workers	Based on the English Shielded Patient List Provided by NHS Business Services Authority for all staff who are directly employed by the NHS organisations using the Electronic Staff Record (ESR).
	Clinically Extremely Vulnerable	Provided by NHS Digital and is a record of vulnerable patients thought to be at high risk of complications from COVID-19. The data heavily relies on data linkage using the NHS number to extract data from the GP electronic health record (EHR), Hospital Episode Statistics (HES), and the QCOVID risk stratification assessment. Specific rule logic can be found here: https://digital.nhs.uk/coronavirus/shielded-patient-list/methodology/rule-logic
	Flag for individuals 16-65 at risk (Cohort 6)	Provided by NHS Digital and is based on a list of NHS numbers extracted from the EHR based on the national PHE PRIMIS SNOMED specification. This includes all those who are in a clinical risk group and coded as a carer within the EHR. For more information on the national specification can be found here: https://www.nottingham.ac.uk/primis/covid-19/covid-19.aspx
Vaccination events data file	NHS Number	10 Digit number without space
	Date of vaccination administration	DD/MM/YYYY
	Location Code	The unique code for the location where the vaccination event occurred
	Location Name	The name of the location where the vaccination event occurred
	Vaccine code	SNOMED CT concept code for the Vaccine Code

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

	Vaccine Procedure Code	SNOMED CT concept code for the Vaccination Procedure
	Route of vaccination	SNONED CT concept code for the route the vaccine was administered.
	Body Site	SNOMED CT concept code for the for the body site where the vaccination was administered
	Batch number	Vaccination's batch number (from the physical product)
	Manufacturer	Vaccination manufacturer name
Externally provided data sources	Index of Multiple Deprivation	From 2011 Census - linked by individuals post code.
	Care home status	Unique Property Reference Numbers and NHS-Addresses are used to link to the care home Care Quality Commission addresses. These are the used to linked to the Master Patient Index provided by NHS England and Improvement. The list of individuals in a care home is updated monthly.
Derived variables for coverage	Age as of 31 March 2021	Calculated based on DOB
	Manufacturer	Manufacturer is allocated using the first few characters of the Batch Number fields once any leading spaces and prefixes of Batch or BN are removed from the text string. Where it is not possible to identify the manufacturer using the first few characters of the trimmed Batch Number string, records where the batch number includes the string 'Pfizer' are allocated a Pfizer manufacturer code Pfizer, records including the strings 'AstraZeneca' (or 'Astra' and 'Zeneca') are allocated an AstraZeneca Code and records including the strings 'Moderna' are allocated a Moderna code. Finally, where manufacturer cannot be allocated using the above rules the manufacturer specific SNOMED codes are used to allocate manufacturer
	Dose number	Dose 1 should be on or after 08 December 2021. A completed course considered valid if dose 2 is a minimum of 20 days after dose 1
	Clinically Extremely Vulnerable/Cohort 6	This is a merged flag for those ages 16-65 that have been coded as at risk, anyone ages 16-69 clinically extremely vulnerable, or categorised as both.

Characteristics associated with COVID-19 vaccine uptake among adults in England (08 December – 17 May 2021)

	Item No	Recommendation	Section in manuscript	Page and Paragraph
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title	page 2 paragraph 6
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract	page 2
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction	Page 3
Objectives	3	State specific objectives, including any prespecified hypotheses	Introduction	Page 3 paragraph 4
Methods				
Study design	4	Present key elements of study design early in the paper	Methods	Page 5 paragraph 7 (subheading statistical analyses)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods	Page 5 paragraph 3 (subheading study population)
		Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	Methods	Page 5 paragraph 3 and 4 (subheading study population and vaccine coverage)
		For matched studies, give matching criteria and the number of controls per case	Methods	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Methods	Page 4 paragraph 5 (subheading data source) onto page 5.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Methods	Page 4 paragraph 5 (subheading data source) onto page 5. Also, in supplementary Table 1

Bias	9	Describe any efforts to address potential sources of bias	Methods	Page 5 paragraph 1 and 2 (statistical methods adjusting and mean prevalence margins)
Study size	10	Explain how the study size was arrived at	Methods	Page 5 paragraph 4 (under Vaccine coverage subheading). The total number of individuals vaccinated
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Methods	Page 4 paragraph 2 (subheading study population) Age groups based on the roll-out of the vaccination programme
		(*a*) Describe all statistical methods, including those used to control for confounding	Methods	Page 5 paragraph 7 (subheading statistical analyses)
		(*b*) Describe any methods used to examine subgroups and interactions	Methods	Page 5 paragraph 7 (statistical methods adjusting and mean prevalence margins)
	12	(*c*) Explain how missing data were addressed	methods/discussion	Page 5 paragraph 2 and page 13 paragraph 3. (age Individuals with no NHS number and DOB were excluded - this is addressed in the discussion)
		If applicable, explain how matching of cases and controls was addressed	N/A	N/A
Statistical methods		(*e*) Describe any sensitivity analyses	N/A	N/A
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—egg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Results	Page 6 paragraph 3 (under descriptive results subheading)
		(b) Give reasons for non-participation at each stage	Results	N/A

		(c) Consider use of a flow diagram	Results	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results	Pages 8 to 10 (Table 1 and Table 2)
		(b) Indicate number of participants with missing data for each variable of interest		N/A
		Report numbers in each exposure category, or summary measures of exposure	Results	Pages 8 to 10 (Table 1 and Table 2)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Results	Pages 8 to 10 (Table 1 and Table 2)
		(*b*) Report category boundaries when continuous variables were categorized	Results	Pages 8 -10 (Age groups shown in tables)
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		Pages 8 to 10 (Table 1 and Table 2) Predictive margins
Other analyses	17	Report other analyses done—egg analyses of subgroups and interactions, and sensitivity analyses	Results	N/A
Discussion				
Key results	18	Summarise key results with reference to study objectives	Discussion	Page 12 paragraph 1
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion	Page 13 paragraph 3
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion	Page 13 paragraph 4
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion	Page 13 paragraph 4
Other information				

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based		Page 14

BMJ Open

Characteristics associated with COVID-19 vaccine uptake among adults aged 50 years and above in England (08 December – 17 May 2021)

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-055278.R1
Article Type:	Original research
Date Submitted by the Author:	05-Jan-2022
Complete List of Authors:	Tessier, Elise; Public Health England, immunisation Rai, Yuma; Public Health England, Immunisation and countermeasures division Clarke, Eleanor; Public Health England, Immunisation and countermeasures division Lakhani, Anissa; Public Health England, Immunisation and countermeasures division Tsang, Camille; Public Health England, Immunisation and countermeasures division Makwana, Ashley; Public Health England, Immunisation and countermeasures division Heard, Heather; Public Health England, Health Improvement Directorate, Health Intelligence Division Rickeard, Tim; Public Health England, Immunisation and countermeasures division Lakhani, Shreya; Public Health England, Immunisation and countermeasures division Roy, Partho; Public Health England, Immunisation and countermeasures division Edelstein, Michael; Bar-Ilan University Ramsay, Mary; Public Health England, immunisation; London School of Hygiene and Tropical Medicine, Epidemiology Lopez-Bernal, Jamie; Public Health England, Immunisation and countermeasures division White, Joanne; Public Health England, Immunisation and countermeasures division Andrews, Nick; Public Health England, Statistics Modelling and Economics Department Campbell, Colin; Public Health England Stowe, Julia; Public Health England Colindale, Immunisation & Countermeasures
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Epidemiology, Health policy, Public health
Keywords:	COVID-19, Public health < INFECTIOUS DISEASES, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

SCHOLARONE™
Manuscripts

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

BMJ

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Characteristics associated with COVID-19 vaccine uptake among adults aged 50 years and above in England (08 December – 17 May 2021)

Elise Tessier	Epidemiologist [1]	Elise.Tessier@phe.gov.uk
Yuma Rai	Vaccine Tracking Officer [1]	Yuma.SangpangRai@phe.gov.uk
Eleanor Clarke	Scientist, Epidemiology [1]	Eleanor.Clarke@phe.gov.uk.uk
Anissa Lakhani	Scientist, Epidemiology [1]	Anissa.Lakhani@phe.gov.uk
Camille Tsang	Data Manager [1]	Camille.Tsang@phe.gov.uk
Ashley Makwana	Data Analyst[2]	Ashley.Makwana@phe.gov.uk
Heather Heard	Head of Data and Information Systems[3]	Heather.Heard@phe.gov.uk
Tim Rickeard	Head of Technical Services [2]	Tim.Rickeard@phe.gov.uk
Shreya Lakhani	Vaccine Tracking Officer [1]	Shreya.Lakhani@phe.gov.uk
Partho Roy	Consultant Epidemiologist [1]	Partho.Roy@phe.gov.uk
Michael Edelstein	Associate Professor [4]	michael.edelstein@biu.ac.il
Mary Ramsay	Deputy Director [1]	Mary.Ramsay@phe.gov.uk
Jamie Lopez-Bernal	Consultant Epidemiologist [1]	Jamie.LopezBernal2@phe.gov.uk
Joanne White	Senior Epidemiologist [1]	joannemshivji@gmail.com
Nick Andrews	Senior Statistician [1]	Nick.Andrews@phe.gov.uk
Colin Campbell	Consultant Epidemiologist [1]	Colin.NJ.Campbell@phe.gov.uk
Julia Stowe	Senior Epidemiologist [1]	Julia.Stowe@phe.gov.uk

Affiliations:

1. Immunisation and Countermeasures Division, Public Health England, 61 Colindale Avenue, London, NW9 5EQ UK
2. Vaccines and Countermeasures Division, Public Health England, 133-155, Waterloo Road, Lambeth SE1 8UG UK
3. Health Intelligence Division, Health Improvement Directorate, Public Health England, Station Rise, York, YO1 6GA
4. Faculty of Medicine, Bar Ilan University, Safed, Israel

Corresponding author: Elise.Tessier@phe.gov.uk
Immunisation and Countermeasures Division, Public Health England, 61 Colindale Avenue, London, NW9 5EQ UK

1

Abstract:

Objective: To determine characteristics associated with COVID-19 vaccine coverage among individuals aged 50 years and above in England since the beginning of the programme.

Design: Observational cross-sectional study assessed by logistic regression and mean prevalence margins.

Setting: COVID-19 vaccinations delivered in England from 08 December 2020 – 17 May 2021.

Participants: 30,624,257/ 61,967,781 (49.4%) and 17,360,045/ 61,967,781 (28.1%) individuals in England were recorded as vaccinated in the National Immunisation Management System with a first dose and a second dose of a COVID-19 vaccine, respectively.

Interventions: Vaccination status with COVID-19 vaccinations.

Main Outcome Measures: Proportion, adjusted odds ratios and mean prevalence margins for individuals not vaccinated with dose 1 among those aged 50- 69 years old and dose 1 and 2 among those aged 70 years old and above.

Results: Of individuals aged 50 years and above, Black/African/Caribbean ethnic group was the least likely of all ethnic groups to be vaccinated with dose 1 of the COVID-19 vaccine. However, of those aged 70 years and above, the odds of not having dose 2 was 5.53 (95% CI 5.42 to 5.63) and 5.36 (90% CI 5.29 to 5.43) greater among Pakistani and Black/African/Caribbean compared to White British ethnicity, respectively. The odds of not receiving dose 2 was 1.18 (95% CI 1.16 to 1.20) higher among individuals who lived in a care home compared to those who did not. This was the opposite to that observed for dose 1, where the odds of being unvaccinated was significantly higher among those not living in a care home (0.89 (95% CI 0.87 to 0.91)).

Conclusions: We found that there are characteristics associated with low COVID-19 vaccine coverage. Inequalities, such as ethnicity are a major contributor to suboptimal coverage and tailored interventions are required to improve coverage and protect the population from SARS-CoV-2.

2

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Article summary:

Strengths and Limitations of this study:

- This is the is the first study assessing characteristics associated with COVID-19 vaccine coverage for all individuals aged 50 years and above in England.
- This study uses data from the National Immunisation Management System (NIMS) which is based on all individuals in England with a registered NHS number.
- This centralised national system captures individual level data for both vaccination status and demographic characteristics and allows for linkage to other datasets such as health care worker and care home resident status.
- This study does not include those without an NHS number and, therefore, it is possible we have underestimated the number of vaccines delivered and odds of being unvaccinated for characteristics such as ethnic groups where we have seen the greatest impact.
- Residual errors in data entry on the point of care apps at the vaccination sites may have also occurred, though these errors are not likely to be widespread.

3

Background:

The United Kingdom (UK) was the world's first country to approve a COVID-19 vaccine for the pandemic, getting a head start on the roll-out of its COVID-19 vaccination programme [1]. On December 08 2021, the UK launched its COVID-19 vaccination programme with the aim of reducing COVID-19 mortality and hospitalisations among those at highest risk. There are currently three vaccines that the Medicines and Healthcare products Regulatory Agency (MHRA) have authorised; the Pfizer/BioNTech vaccine (offered from 08 December 2021), the AstraZeneca (Oxford) vaccine (offered from 04 January 2021) and the Moderna Tx (offered from 13 April 2021) [2-4].

To ensure the reduction of mortality from SARS-CoV-2 infection and protect the healthcare system, the Joint Committee on Vaccination and Immunisation (JCVI), an independent expert advisory committee that advises UK health departments on vaccination, initially recommended extending the interval between doses to as long as 12 weeks. Its goal was to vaccinate a greater number of people sooner with the first dose of the COVID-19 vaccine [5] [6]. The JCVI also recommended that the vaccination programme be rolled out in phases beginning on 08 December 2021, for those aged 80 years old and above and for frontline healthcare workers. [6] The UK then opened eligibility to others, first among individuals identified as clinically extremely vulnerable, meaning they had been classified as at risk and advise to shield at home, and then in descending age groups.[7] By 17 March 2021, all adults aged 50 years and above were eligible for their first dose of a coronavirus vaccine.

NHS England, with support from Public Health England (PHE), the national public health agency, publishes COVID-19 vaccination counts and denominators by region, age, ethnicity and for care home residents using a tracker tool [8]. Previous research on characteristics for low vaccine coverage in England have shown that deprivation and ethnicity are associated with lower coverage for a range of routine immunisations delivered in England [9-11]. There is little to no data collected on vaccine coverage for routine vaccines such as shingles and influenza for individuals living in care homes, though evidence shows that barriers exist in achieving high influenza uptake in care homes. These barriers include care home size, geographical location, and working relationships with primary care and pharmacies [12]. These studies and guidance assess routine vaccines delivered in England, which are primarily delivered through general practices, pharmacies, and schools. With the ongoing COVID-19 pandemic, the rapid development of COVID-19 vaccines and the urgency to rapidly roll out the programme in various settings including mass immunisation sites, it is unknown whether the same characteristics associated with vaccine coverage for routine programmes are associated with low coverage for COVID-19 vaccines.

The aim of this study is twofold:

1. To describe the number of individuals eligible for a COVID-19 vaccine in the first phase of the roll-out that have been vaccinated with a single or two doses of COVID-19 vaccine by age, sex, geographical location, vaccine type, ethnicity, deprivation, urban, or rural setting and programme week.
2. To determine whether there are any characteristics independently associated with low vaccine coverage for dose 1 and dose 2 of COVID-19 vaccines.

Methods:

Data source

A National Immunisations Management System (NIMS) capable of recording any vaccination, regardless of point of delivery, has been used for the pandemic response to collect information

4

about COVID-19 vaccines delivered across England. Individuals who present to a vaccination site, such as general practice, pharmacy, or hospital provider and receive a COVID-19 vaccine will have their vaccine event information recorded on a Point of Care application. PHE receives data that is linked to demographic data obtained from the NHS (e.g., gender, date of birth), using the individual's unique NHS number [13]. PHE uses these data for monitoring vaccine safety, effectiveness, and coverage. All variables for vaccine coverage are described in Supplementary Table 1. Age was calculated for all individuals based on their age on 31 March 2021.

Patient and Public Involvement

No patients were involved in the design or execution of the study

Study population

NIMS data was extracted on 17 May 2021 to assess vaccination status of all individuals aged 50 to 69 years old for a first dose of COVID-19 vaccine, and of all individuals aged 70 years old and above vaccinated with a first and a second dose of a COVID-19 vaccine. The programme is still being rolled out among younger cohorts, so not all 50-59 years olds had been offered a second dose of a COVID-19 vaccine at the time of data extraction. Individuals recorded in the NIMS must have an NHS number in order to link the population denominator and vaccination event files. All individuals with a death recorded were excluded from the analyses for the purpose of calculating coverage in the living resident population aged 50 and above on 31 March 2021.

Vaccine coverage

Vaccine coverage was calculated by dividing the total number of individuals with a recorded NHS number in the dataset who were vaccinated with 1 dose and 2 doses of COVID-19 vaccine since the beginning of the vaccine roll-out on 08 December 2020 (numerator) by the total number of individuals with a recorded NHS number in the dataset (denominator).

Proportion of unvaccinated individuals

The proportion of individuals not vaccinated for dose 1 and/or not vaccinated with dose 2 was calculated by dividing the total number of individuals unvaccinated or with a single dose of the COVID-19 vaccine since the beginning of the vaccine roll-out on 08 December 2020 (numerator) by the total number of individuals with a recorded NHS number in the dataset (denominator).

Descriptive analyses:

The proportion of individuals vaccinated and unvaccinated was described by programme week, starting at week 1 (beginning on 07 December 2020). Cumulative vaccine uptake has been calculated by programme week. Furthermore, the number of and proportion of individuals unvaccinated were aggregated by age groups, region, rural/urban classification, ethnicity, for individuals clinically extremely vulnerable, for individuals over 65 years old living in a care home, for individuals less than 65 years old, and a healthcare worker.

Statistical analyses:

Statistical analyses were conducted for individuals eligible for a COVID-19 vaccine in England in Phase 1, at the beginning of the roll out. The analyses were conducted for those vaccinated with dose 1 and dose 2 for individuals aged 70 years old and above, and for dose 1 among individuals aged 50 to 69 years old.

5

To assess the odds of being unvaccinated or being unvaccinated with dose 2, univariable logistic regression models for each characteristic were fitted with the binary outcome of vaccination status (not vaccinated/ vaccinated with a single dose and vaccinated with dose 1/ vaccinated with two doses). A multivariable logistic regression model was conducted adjusting for all other characteristics.

The adjusted mean prevalence margins and 95% confidence intervals of being unvaccinated for each characteristic within the multivariable model fit were calculated using the adjusted ratios. All statistical analyses were conducted using Stata 15.1.

Ethics Statement: Surveillance of covid-19 vaccination data was undertaken under Regulation 3 of The Health Service (Control of Patient Information) Regulations 2002 to collect confidential patient information (www.legislation.gov.uk/uksi/2002/1438/regulation/3/made) under Sections 3(i) (a) to (c), 3(i)(d) (i) and (ii) and 3(3).

Results

Descriptive results

From 17 March 2021 all individual ages 50 and above were eligible for a COVID-19 vaccine. As of 17 May 2021, a total of 30,624,257/ 61,967,781 (49.4%) and 17,360,045/ 61,967,781 (28.1%) individuals were vaccinated with a first dose and a second dose of a COVID-19 vaccine, respectively. A total of 90.9% of individuals aged 65 years and older had received at least one dose of the COVID-19 vaccine. The number of individuals vaccinated varied by programme week, plateauing at weeks 11 and 24 for dose 1 and 2 among those aged 70 years old and above, and week 23 for dose 1 among those aged 50 to 69 years old (Figures 1 and 2). Those aged 50 to 69 were still eligible for their second dose and had not yet plateaued at the time the data was extracted.

The proportion of individuals unvaccinated varied by age, dose and region; London consistently had the highest proportion of individuals being unvaccinated (Figure 3). Among the total population aged 50 and older, the North East of England had the lowest proportion of unvaccinated individuals (Figure 3).

70-year olds and above unvaccinated

Of individuals aged 70 years old and above, all characteristics were significantly associated with being unvaccinated in both the univariable and multivariable logistic regression analyses.

The odds of being unvaccinated was higher among males and those aged 75-79 and 80 years old and above than the baseline of 70-74 years old (Table 1). The odds of being unvaccinated with 1 or 2 doses was higher in urban areas; particularly in London with an increased odds of 2.30 (2.27 to 2.33) and 1.96 (1.94 to 1.98) odds for being unvaccinated for both dose 1 and dose 2, respectively (Table 1).

Among those clinically extremely vulnerable, the odds of being unvaccinated was reduced (OR 0.61 (95% CI 0.61 to 0.62)) and (OR 0. 88 (95% CI 0.87 to 0.89)) for dose 1 and dose 2, respectively compared to those with no significant underlying health conditions.

The odds of being unvaccinated among those living in a care home was also reduced for dose 1 (OR 0.89 (95% CI 0.87 to 0.91)) compared to those not living in a care home. However, the odds of being unvaccinated for dose 2 was 1.18 (95% CI 1.16 to 1.20) greater.
The greatest odds of being unvaccinated among 70 years olds was among those living in the most deprived areas and among Black/African/Caribbean ethnicities. Among the Black/African/Caribbean

6

ethnicity, the odds of not having a first dose was 6.69 (95% CI 6.58 to 6.79) greater than White British ethnicity. The odds of being unvaccinated with a second dose was 5.53 (95% CI 5.42 to 5.63) greater among the Pakistani ethnicity, followed by the Black/African/Caribbean ethnicity with an odds of 5.36 (95% CI 5.29 to 5.43).

The mean prevalence of being unvaccinated for each characteristic within the adjusted multivariable model showed increased prevalence among the characteristics with the highest odds of being unvaccinated. The highest prevalence was among the Black/African/Caribbean ethnic group for dose 1 with a mean prevalence of 17.6% unvaccinated. The prevalence among those unvaccinated with dose 1 was 26.6% and 26.1% among the Pakistani and Black/African/ Caribbean ethnicities, though the 95% confidence intervals do overlap between the two ethnicities (Table 1).

50-69-year olds unvaccinated

Of those aged 50-69 years old, all the characteristics were significantly associated with being unvaccinated in both the univariable and multivariable logistic regression analyses.

Similarly to those aged 70 and above, the odds of being unvaccinated was higher among males and increased in the younger populations (Table 1). The odds of being unvaccinated was higher in urban areas and particularly in London where there was an increased odds of 1.85 (95% CI 1.84 to 1.86) (Table 2).

The greatest odds of being unvaccinated with dose 1 among 50-69 year olds was highest among those with an unknown or not stated ethnicity and Black/African/Caribbean ethnicity which had a 3.40 (95% CI 3.38 to 3.41) and 3.32 (95% CI 3.29 to 3.34) increased odds of being unvaccinated compared those of White British ethnicity (Table 2).

Both the clinically extremely vulnerable/ at risk and healthcare workers had decreased odds of being unvaccinated than those that were not in these groups (OR 0.59 (95% CI 0.59 to 0.59) and 0.34 (95% CI 0.34 to 0.35), respectively) (Table 2), showing a protective effect among those at highest risk of SARS-CoV-2 disease.

The highest predictive margin for being unvaccinated after adjusting for all variables in the multivariable logistic regression model was among the Unknown/Not Stated and Black/African/Caribbean ethnic groups with a prevalence of 24.7% and 23.9% unvaccinated, respectively (Table 2).

7

Table 1. Number and proportion of individuals aged 70 years old and above not vaccinated for dose 1 and dose 2 of the COVID-19 vaccine between 8 December 2020 – 17 May 2021 in England and the odds of being unvaccinated from a multivariable logistic regression and mean adjusted prevalence from the model fit

Characteristics		Dose 1 Not Vaccinated n/N (%)	Dose 1 Multivariable Regression Odds Ratio and 95% CI	Dose 1 Predictive margins	Dose 2 Not Vaccinated n/N (%)	Dose 2 Multivariable Regression Ration and 95% CI	Dose 2 Predictive margins (%) and 95% CI*
Age	70 to 74 years	169173 / 2877391 (5.9%)	Baseline	5.42% (5.39 to 5.44)	271998/2877391 (9.5%)	Baseline	9.14% (9.11 to 9.17)
	75 to 79 years	100478 / 2086215 (4.8%)	0.86 (0.85 to 0.87)	4.74% (4.72 to 4.77)	161503/2086215 (7.7%)	0.82 (0.82 to 0.83)	7.76% (7.72 to 7.79)
	Over 80 years	140785 / 2830943 (5.0%)	1.00 (1.00 to 1.01)	5.44$ (5.41 to 5.46)	247875/2830943 (8.8%)	0.98 (0.97 to 0.98)	8.95% (8.92 to 8.98)
Urban/ Rural status	Urban areas	348992 / 5906988 (5.9%)	Baseline	5.46% (5.44 to 5.47)	571598/5906988 (9.7%)	Baseline	9.00% (8.98 to 9.02)
	Rural areas	60218 / 1880742 (3.2%)	0.77 (0.76 to 0.77)	4.31% (4.28 to 4.35)	108020/1880742 (5.7%)	0.81 (0.80 to 0.81)	7.50% (7.45 to 7.54)
	Other/ Unknown	1226 / 6819 (18.0%)	-	-	1758/6819 (25.8%)	-	-
Clinically extremely vulnerable	Not clinically extremely vulnerable	333971 / 6158381 (5.4%)	Baseline	5.75% (5.73 to 5.77)	523938/6158381 (8.5%)	Baseline	8.93% (8.91 to 8.95)
	Clinically extremely vulnerable	76464 / 1636167 (4.7%)	0.61 (0.61 to 0.62)	3.72% (3.70 to 3.75)	157437/1636167 (9.6%)	0.88 (0.87 to 0.89)	8.01% (7.97 to 8.05)
Care home status	Not in a Care Home	404206 / 7578254 (5.3%)	Baseline	5.25% (5.24 to 5.27)	663275/7578254 (8.8%)	Baseline	8.67% (8.65 to 8.69)
	In a Care Home	6230 / 216295 (2.9%)	0.89 (0.87 to 0.91)	4.74% (4.63 to 4.85)	18101/216295 (8.%)	1.18 (1.16 to 1.20)	10.00% (9.86 to 10.13)
IMD Deprivation Decile	Most Deprived	44759 / 515973 (8.7%)	Baseline	9.47% (9.39 to 9.56)	76750/515973 (14.9%)	Baseline	15.13% (15.03 to 15.23)
		47804 / 567221 (8.4%)	0.75 (0.74 to 0.76)	7.44% (7.38 to 7.50)	77905/567221 (13.7%)	0.76 (0.76 to 0.77)	12.19% (12.11 to 12.27)
		47565 / 627241 (7.6%)	0.64 (0.64 to 0.65)	6.54% (6.49 to 6.60)	77343/627241 (12.3%)	0.66 (0.66 to 0.67)	10.85% (10.78 to 10.93)
		45373 / 722661 (6.3%)	0.57 (0.57 to 0.58)	5.93% (5.87 to 5.98)	73905/722661 (10.2%)	0.59 (0.58 to 0.59)	9.75% (9.69 to 9.82)
		42635 / 796652 (5.4%)	0.51 (0.5 to 0.52)	5.34% (5.29 to 5.39)	70283/796652 (8.8%)	0.52 (0.52 to 0.53)	8.84% (8.78 to 8.9)
		40935 / 858303 (4.8%)	0.46 (0.45 to 0.46)	4.84% (4.79 to 4.88)	67766/858303 (7.9%)	0.47 (0.46 to 0.47)	8.06% (8.00 to 8.12)
		38086 / 894485 (4.3%)	0.42 (0.41 to 0.43)	4.48% (4.44 to 4.52)	63503/894485 (7.1%)	0.43 (0.43 to 0.44)	7.48% (7.42 to 7.53)
		36684 / 918054 (4.0%)	0.39 (0.39 to 0.4)	4.21% (4.16 to 4.25)	61723/918054 (6.8%)	0.41 (0.4 to 0.41)	7.09% (7.04 to 7.14)
		33833 / 934779 (3.6%)	0.35 (0.34 to 0.35)	3.77% (3.73 to 3.81)	56910/934779 (6.1%)	0.36 (0.36 to 0.37)	6.40% (6.35 to 6.44)
	Least Deprived	30264 / 947216 (3.2%)	0.31 (0.30 to 0.31)	3.40% (3.36 to 3.43)	51417/947216 (5.%)	0.32 (0.32 to 0.33)	5.79% (5.75 to 5.84)

8

	Unknown	2498 / 11964 (20.9%)	-	-	3871/11964 (32.4%)	-	-
Ethnicity	White	204842 / 6555567 (3.1%)	Baseline	3.23% (3.21 to 3.24)	409220/6555567 (6.2%)	Baseline	6.43% (6.41 to 6.45)
	Mixed/Multiple Ethnic	5446 / 34247 (15.9%)	4.38 (4.25 to 4.52)	12.44% (12.12 to 12.75)	7612/34247 (22.2%)	3.25 (3.17 to 3.34)	17.87% (17.50 to 18.25)
	Indian	11881 / 121720 (9.8%)	2.19 (2.14 to 2.23)	6.73% (6.61 to 6.85)	18257/121720 (15.0%)	1.82 (1.79 to 1.85)	11.02% (10.87 to 11.18)
	Pakistani	10528 / 52518 (20.0%)	5.26 (5.14 to 5.38)	14.47% (14.21 to 14.74)	18530/52518 (35.3%)	5.53 (5.42 to 5.63)	26.63% (26.28 to 26.97)
	Other Asian or Asian	13706 / 82251 (16.7%)	3.72 (3.65 to 3.79)	10.80% (10.62 to 10.98)	19797/82251 (24.1%)	3.04 (2.99 to 3.09)	16.93% (16.70 to 17.16)
	Black/African/Caribbean	29981 / 103294 (29.0%)	6.69 (6.58 to 6.79)	17.58% (17.37 to 17.79)	41162/103294 (39.8%)	5.36 (5.29 to 5.43)	26.06% (25.81 to 26.31)
	Other Ethnic Group	10227 / 58524 (17.5%)	4.16 (4.07 to 4.25)	11.89% (11.66 to 12.12)	13907/58524 (23%)	3.14 (3.07 to 3.2)	17.36% (17.09 to 17.64)
	Not stated/Unknown	123825 / 786428 (15.7%)	6.00 (5.95 to 6.04)	16.12% (16.03 to 16.2)	152891/786428 (19.4%)	3.69 (3.66 to 3.71)	19.73% (19.64 to 19.82)
Region	East of England	42261 / 971824 (4.3%)	Baseline	4.73% (4.69 to 4.78)	72699/971824 (7.5%)	Baseline	8.20% (8.15 to 8.26)
	London	108877 / 792575 (13.7%)	2.30 (2.27 to 2.33)	9.77% (9.70 to 9.83)	153166/792575 (19.3%)	1.96 (1.94 to 1.98)	14.39% (14.31 to 14.46)
	Midlands	69371 / 1515414 (4.6%)	0.97 (0.96 to 0.98)	4.60% (4.57 to 4.63)	120989/1515414 (8.0%)	0.97 (0.96 to 0.98)	7.98% (7.94 to 8.02)
	North East and Yorkshire	45147 / 1232540 (3.7%)	0.77 (0.76 to 0.78)	3.74% (3.71 to 3.78)	83505/1232540 (6.8%)	0.80 (0.79 to 0.81)	6.75% (6.71 to 6.8)
	North West	45973 / 973704 (4.7%)	0.95 (0.93 to 0.96)	4.51% (4.47 to 4.55)	82655/973704 (8.5%)	0.97 (0.96 to 0.98)	7.99% (7.94 to 8.04)
	South East	59447 / 1334389 (4.5%)	1.11 (1.09 to 1.12)	5.18% (5.14 to 5.22)	102275/1334389 (7.7%)	1.10 (1.09 to 1.11)	8.90% (8.85 to 8.96)
	South West	36862 / 962139 (3.8%)	0.90 (0.89 to 0.91)	4.30% (4.26 to 4.35)	62216/962139 (6.5%)	0.88 (0.87 to 0.89)	7.30% (7.25 to 7.36)
	Unknown	2498 / 11964 (20.9%)	-	-	3871/11964 (32.4%)	-	-
Sex	Female	217583 / 4279458 (5.1%)	Baseline	4.95% (4.93 to 4.97)	372475/4279458 (8.7%)	Baseline	8.60% (8.57 to 8.62)
	Male	192285 / 3510687 (5.5%)	1.16 (1.15 to 1.16)	5.62% (5.59 to 5.64)	305672/3510687 (8.7%)	1.03 (1.02 to 1.03)	8.78% (8.75 to 8.81)
	Unknown	568 / 4404 (12.9%)	0.94 (0.84 to 1.04)	4.67 (4.24 to 5.09)	3229/4404 (73.3%)	21.72 (19.92 to 23.69)	60.79% (58.88 to 62.7)

*The percent vaccinated may fall outside the range of the predictive margins, as they are based on the effect of the adjusted multivariable model.

9

Table 2. Number and proportion of individuals aged 50-69 years old not vaccinated for dose 1 of the COVID-19 vaccine between 8 December 2020 – 17 May 2021 in England and the odds of being unvaccinated from a multivariable logistic regression and mean adjusted prevalence from the model fit

	Characteristics	Dose 1 Not Vaccinated n/N (%)	Dose 1 Multivariable Regression Odds Ration and 95% CI	Dose 1 Predictive margins (%) and 95% CI*
Age	**50 to 54 years**	3018263 / 4214965 (71.6%)	Baseline	15.07% (15.04 to 15.10)
	55 to 64 years	4485055 / 7518324 (59.7%)	0.81 (0.81 to 0.82)	12.82% (12.8 to 12.85)
	65 to 69 years	561755 / 2891288 (19.4%)	0.51 (0.51 to 0.51)	8.72% (8.68 to 8.75)
Urban/ Rural status	**Urban areas**	6418686 / 11552097 (55.6%)	Baseline	13.17% (13.15 to 13.19)
	Rural areas	1632703 / 3052642 (53.5%)	0.75 (0.74 to 0.75)	10.39% (10.35 to 10.43)
	Other/ Unknown	13684 / 19838 (69.0%)	-	-
Clinically extremely vulnerable/ at risk (cohort 6)	**Not at risk**	6501682 / 10368328 (62.7%)	Baseline	14.18% (14.16 to 14.20)
	At Risk	1563391 / 4256249 (36.7%)	0.59 (0.59 to 0.59)	9.25% (9.22 to 9.28)
Health care worker	**Not Health Care Worker**	8003303 / 14162182 (56.5%)	Baseline	12.94% (12.93 to 12.96)
	Health Care Worker	61770 / 462395 (13.4%)	0.34 (0.34 to 0.35)	5.22% (5.16 to 5.28)
IMD Deprivation Decile	**Most Deprived**	760885 / 1290391 (59.0%)	Baseline	20.57% (20.50 to 20.65)
		782255 / 1339803 (58.4%)	0.74 (0.74 to 0.75)	16.52% (16.46 to 16.58)
		795155 / 1383303 (57.5%)	0.66 (0.65 to 0.66)	15.00% (14.95 to 15.06)
		803307 / 1437917 (55.9%)	0.59 (0.59 to 0.60)	13.88% (13.82 to 13.93)
		806095 / 1479989 (54.5%)	0.53 (0.53 to 0.53)	12.69% (12.64 to 12.74)
		816104 / 1522404 (53.6%)	0.47 (0.47 to 0.48)	11.60% (11.55 to 11.65)
		815712 / 1528345 (53.4%)	0.43 (0.43 to 0.43)	10.72% (10.67 to 10.77)
		816165 / 1543302 (52.9%)	0.40 (0.39 to 0.40)	9.97% (9.93 to 10.02)
		814550 / 1530600 (53.2%)	0.36 (0.35 to 0.36)	9.14% (9.10 to 9.19)
	Least Deprived	830441 / 1534627 (54.1%)	0.32 (0.31 to 0.32)	8.23% (8.19 to 8.28)
	Unknown	24404 / 33896 (72.0%)	-	-
Ethnicity	**White**	5532177 / 10821112 (51.1%)	Baseline	9.07% (9.05 to 9.08)
	Mixed/Multiple Ethnic	84371 / 135124 (62.4%)	2.60 (2.57 to 2.64)	19.97% (19.77 to 20.16)

10

	Indian	152271 / 325697 (46.8%)	1.19 (1.18 to 1.20)	10.55% (10.45 to 10.64)
	Pakistani	130526 / 197437 (66.1%)	2.48 (2.46 to 2.51)	19.26% (19.10 to 19.42)
	Other Asian or Asian	177291 / 305023 (58.1%)	1.56 (1.54 to 1.57)	13.24% (13.13 to 13.35)
	Black/African/Caribbean	306972 / 450853 (68.1%)	3.32 (3.29 to 3.34)	23.87% (23.75 to 23.98)
	Other Ethnic Group	139813 / 217886 (64.2%)	2.61 (2.59 to 2.64)	20.01% (19.86 to 20.16)
	Not stated/Unknown	1541652 / 2171445 (71.0%)	3.40 (3.38 to 3.41)	24.27% (24.21 to 24.32)
Region	East of England	966550 / 1721713 (56.1%)	Baseline	11.86% (11.81 to 11.91)
	London	1197210 / 2056938 (58.2%)	1.85 (1.84 to 1.86)	19.14% (19.09 to 19.19)
	Midlands	1508576 / 2758546 (54.7%)	0.98 (0.98 to 0.99)	11.69% (11.66 to 11.73)
	North East and Yorkshire	1245671 / 2284027 (54.5%)	0.80 (0.79 to 0.81)	9.85% (9.81 to 9.89)
	North West	967344 / 1865618 (51.9%)	0.99 (0.98 to 1.00)	11.77% (11.73 to 11.81)
	South East	1321417 / 2353321 (56.2%)	1.05 (1.05 to 1.06)	12.37% (12.32 to 12.41)
	South West	833901 / 1550518 (53.8%)	0.88 (0.88 to 0.89)	10.70% (10.65 to 10.76)
	Unknown	24404 / 33896 (72.0%)	-	-
Sex	Female	3659928 / 7229063 (50.6%)	Baseline	11.45% (11.42 to 11.47)
	Male	4388976 / 7376483 (59.5%)	1.27 (1.27 to 1.28)	13.87% (13.84 to 13.89)
	Unknown	16169 / 19031 (85.0%)	0.78 (0.75 to 0.81)	9.33% (9.01 to 9.65)

*The percent vaccinated may fall outside the range of the predictive margins, as they are based on the effect of the adjusted multivariable model.

11

Discussion:

As of 17 May 2021, 49.4% of the population aged 50 and above in England had received a first dose of the COVID-19 vaccine and 28.1% had their second dose. Vaccine coverage for dose 1 among those aged 50 years old, and for dose 2 for those aged 70 years old and above, have plateaued. A significant increase in the number of individuals aged 50-69 years old occurred in week 15 of the programme (the week commencing the 15 March 2021), when those aged 50 – 69 became eligible for the vaccine [14][15]. Individuals aged 50 to 69 vaccinated in earlier weeks were most likely to have been healthcare workers, individuals clinically extremely vulnerable/Cohort 6 at risk for severe coronavirus disease [16].

The overall proportion of individuals eligible for the vaccine but not vaccinated was highest in London, followed by areas in the Midlands and East of England. These results coincide with findings from studies assessing predictors associated with influenza and shingles vaccine coverage, prior to mass immunisation [9][10][17], which offered vaccines to individuals in similar populations, such as elderly individuals and those at risk, in which lower coverage in London and in urban areas is observed, despite differences in delivery of the programmes. For example, the shingles vaccine is delivered opportunistically in GP practices, while influenza vaccines are more widely available, including in pharmacies. Overall vaccine coverage for the first dose of a COVID-19 vaccine among those aged 65 years and older was higher for COVID-19 than for seasonal influenza vaccines delivered in the 2020/2021 winter season (90.9% vs 80.9%) [18].

Results from the multivariable logistic regression model and the predictive margins for two doses among those aged 70 years old and above, and for one dose among those aged 50-69, indicate increased odds and predicted margins of being unvaccinated with lower age groups. Should lower coverage among younger adults continue to be observed as the programme continues to roll-out, efforts must be made to address this. Moreover, after adjusting for all variables in the multivariable models, the odds of being unvaccinated was higher among males compared to females, in urban areas compared to rural areas, and highest in London compared to other regions in England among individuals aged 50 years old and above. Reduced odds of being unvaccinated was observed among those clinically extremely vulnerable/ at risk aged 50 years and above, and among healthcare workers aged 50 to 69 years old. These individuals were all eligible for the vaccine early in the programme.

Individuals aged 70 years old and above living in care homes had reduced odds of being unvaccinated for dose 1 compared to those not living in a care home. In contrast, care home residents had increased odds of being unvaccinated for the second dose compared to those living in a care home. The delivery of COVID-19 vaccines to care homes was primarily carried out by mobile teams that required a lot of logistics and coordination [19]. The delivery of second doses of COVID-19 vaccinations in care homes may be lower because it was difficult to follow up on individuals who were not vaccinated or partially vaccinated and moved into a care home after or between mobile vaccination unit visits. It is important to further investigate the increased odds of being unvaccinated with dose 2 in care homes, as residents have been disproportionately affected by SARS-CoV-2 [20]. It is unlikely that the death rates are associated with low coverage because deaths are recorded in a timely manner in the NIMS [21], though it is possible that care home residents might have had COVID-19 or another illness at the time of offer, thus causing a lag in the number of second doses received.

Both the highest odds and the predictive margins for being unvaccinated for dose 1 among all individuals in the study and for dose 2 among those aged 70 years old and above were observed in the most deprived and among the Black/African/Caribbean ethnicity. This coincides with findings

12

assessing COVID-19 vaccine coverage for those aged 70 years old and above using the 2011 ONS denominator population estimates [22] and using general practice records for population estimates based on registrations for two of the three GP IT System Suppliers in England [23]. Furthermore, among those aged 70 years old and above, the odds and prevalence of being unvaccinated among those of Pakistani ethnicity further increased for dose 2. Our findings highlight the structural and complex interplay of ethnicity and deprivation, which has also been observed with finding on SARS-CoV-2 infection, hospitalisations and mortality [24 25].

Strengths and Limitations of this study

Our study has several strengths. This is the is the first study assessing characteristics associated with COVID-19 vaccine coverage for all individuals aged 50 years and above in England, and one of the first studies globally assessing COVID-19 vaccine coverage. Our study also uses data from the NIMS, which is likely to be more complete than other datasets used to estimate COVID-19 vaccine coverage because it is based on all individuals in England with a registered NHS number. Furthermore, immunisation registers have proven to be fundamental when assessing and protecting the population, can be used for linkage to health-outcome databases, and can play a key role in the delivery of a national immunisation programme [26-28]. This is the first time England has developed a centralised national system capturing individual level data for both vaccination status and demographic characteristics. Previous studies assessing factors influencing vaccine coverage in England have been based on aggregate general practice-level data, in which estimates such as deprivation were based on the general practice post code. Having individual level data for frontline healthcare workers, care home residents, and others allowed us to link individual NHS numbers to properly account for these individuals. Such granular data are not available in similar studies or in general practice records.

We are unable to capture details on the total number of individuals without an NHS number and, of those who had not received a vaccine.Therefore, it is possible we have underestimated the number of vaccines delivered and odds of being unvaccinated for characteristics such as ethnic groups in which we have seen the greatest impact. The proportion of individuals aged 50 years and above with no NHS number is expected to be marginal. The NIMS population estimates are larger compared to the 2020 Office for National Statistics (ONS) mid-year population estimates (Supplementary Figure 1), thus possibly overestimating population estimates. However, ONS estimates are based on the 2011 census and do not take into account any changes or movements throughout the pandemic, which may be reflected in NHS records[29]. Furthermore, it is possible that there could be residual errors in data entry on the point of care apps at the vaccination sites, though these errors are not widespread. Though the NIMS was rapidly set up for monitoring COVID-19 vaccinations, it was piloted with influenza vaccinations delivered in the 2020/21 influenza season and the trends observed in our study align with other immunisation programmes.

Conclusions

This study provides evidence that in England, being male, being in a younger age group, belonging to certain minority groups, living in urban setting, or being a care home resident were associated with low COVID-19 vaccine coverage. The largest odds of being unvaccinated was observed among those of Black/African/Caribbean ethnicity and those in the most deprived decile. It is of utmost importance to reduce inequalities in vaccine coverage, particularly among Black, Asian and Minority Ethnic groups, and care home residents who have been most impacted by the SARS-CoV-2 infection. The delivery of the COVID-19 vaccination programme should continue to be investigated. Delivery strategies, such as the use of mass immunisation sites and mobile vaccination units for populations

13

where vaccine coverage is lower, should be evaluated to determine whether it could be applied to routine immunisations. As vaccine coverage increases in England, tailored strategies that consider barriers specific to under-vaccinated groups, such as vaccine hesitancy, [30]should be designed and implemented to improve COVID-19 vaccine coverage.

Acknowledgements

We would like to thank the Public Health England COVID-19 Data Science and ImmForm Teams, NHS England, NHS Digital and System C for their roles in developing and managing vaccination systems and datasets.

14

Contributor and guarantor information:
Elise Tessier is the guarantor of the paper and confirms that the manuscript is honest, accurate and transparent. There are no important aspects of the paper omitted.

Contributions: ET, JS, CC, MR, JLB, ME and JW provided overview of the project concept. ET, JS, YR, CT, CC, ME, JW, PR worked on the study design. AM, HH, TR, EC, CT, AL, ET, YR, JS and SL worked on acquiring and preparing the data for analysis. ET and NA prepared the statistical analyses and interpretation of the data. ET and JS prepared the manuscript and all authors reviewed the manuscript.

Competing interests declaration: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: funding from Public Health England for the submitted work; 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: Surveillance of covid-19 vaccination data is undertaken under Regulation 3 of The Health Service (Control of Patient Information) Regulations 2002 to collect confidential patient information (www.legislation.gov.uk/uksi/2002/1438/regulation/3/made) under Sections 3(i) (a) to (c), 3(i)(d) (i) and (ii) and 3(3).

Role and Funding source: There was no external funding for this study.

Data Sharing Statement: No additional data available.

Figure Legend/ Captions:

Figure 1. Number of individuals aged 70 years old and above vaccinated with dose 1 and dose 2 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.

Figure 2. Number of individuals aged 50 to 69 years old vaccinated with dose 1 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.

Figure 3. Proportion of individuals aged (a) 50-69 not vaccinated with dose 1 (b) 70 years old and above not vaccinated with dose 1 and (c) 70 years old and above not vaccinated with dose 2 of COVID-19 vaccine (1: London; 2: South East; 3: South West; 4: East of England; 5: Midlands; 6: North East and Yorkshire; 7: North West)
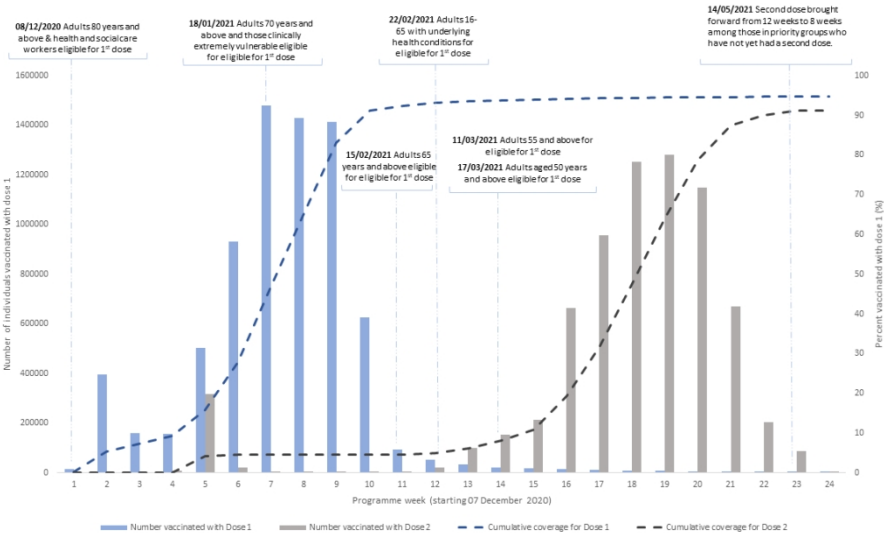
Supplementary Figure 1. The total number of individuals recoded in England by age group, based on roll out of the COVID-19 vaccine, in the 2020 mid-year population estimates and the NIMS.[1,2]

1. ONS mid-year population estimates are derived from the 2011 Census
2. NIMS estimates are based on the number of individuals with a National Health Service (NHS) record number
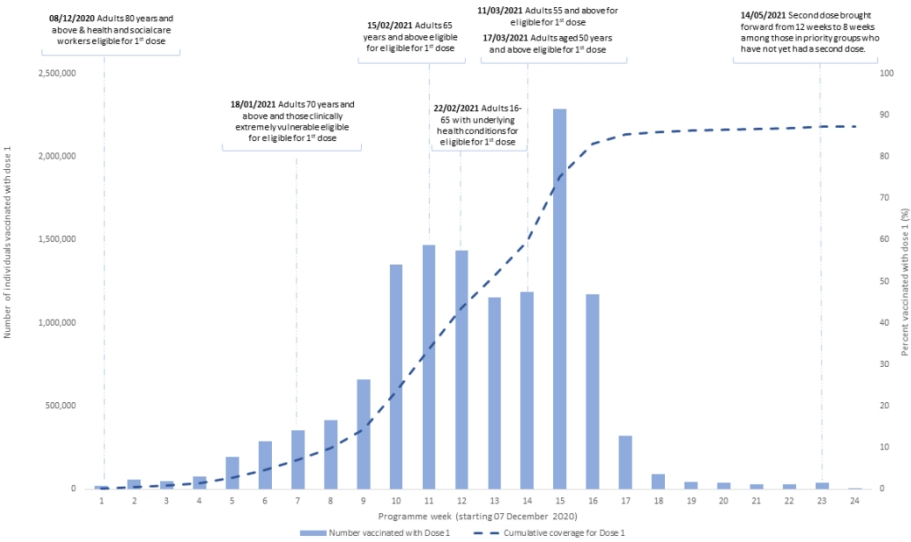
15

References:

1. Baraniuk C. Covid-19: How the UK vaccine rollout delivered success, so far. *BMJ* 2021;372:n421. doi: 10.1136/bmj.n421
2. Department of Health and Social Care. Statement from the UK Chief Medical Officers on the prioritisation of first doses of COVID-19 vaccines 2020 [Available from: https://www.gov.uk/government/news/statement-from-the-uk-chief-medical-officers-on-the-prioritisation-of-first-doses-of-covid-19-vaccines accessed 02 February 2021 2021.
3. Public Health England. COVID-19 - SARS-CoV-2 Chapter 14a 2021 [Available from: https://www.gov.uk/government/publications/covid-19-the-green-book-chapter-14a.
4. Public Health England. National protocol for COVID-19 Vaccine Moderna 2021 [Available from: https://www.gov.uk/government/publications/national-protocol-for-covid-19-vaccine-moderna accessed 25/05/2021.
5. Department of Health and Social Care. Optimising the COVID-19 vaccination programme for maximum short-term impact 2021 [Available from: https://www.gov.uk/government/publications/prioritising-the-first-covid-19-vaccine-dose-jcvi-statement/optimising-the-covid-19-vaccination-programme-for-maximum-short-term-impact accessed 03 February 2021 2021.
6. Care. DoHS. Joint Committee on Vaccination and Immunisation: advice on priority groups for COVID-19 vaccination, 30 December 2020 2020 [Available from: https://www.gov.uk/government/publications/priority-groups-for-coronavirus-covid-19-vaccination-advice-from-the-jcvi-30-december-2020/joint-committee-on-vaccination-and-immunisation-advice-on-priority-groups-for-covid-19-vaccination-30-december-2020 accessed 20/05/2021.
7. NHS England. Who is at high risk from coronavirus (COVID-19) 2021 [Available from: https://www.nhs.uk/conditions/coronavirus-covid-19/people-at-higher-risk/who-is-at-high-risk-from-coronavirus/ accessed 21/07/2021.
8. NHS Digital. COVID-19 Vaccinations 2021 [Available from: https://www.england.nhs.uk/statistics/statistical-work-areas/covid-19-vaccinations/ accessed 18/06/2021.
9. Ward C, Byrne L, White JM, et al. Sociodemographic predictors of variation in coverage of the national shingles vaccination programme in England, 2014/15. *Vaccine* 2017;35(18):2372-78. doi: 10.1016/j.vaccine.2017.03.042 [published Online First: 2017/04/02]
10. Tessier E, Warburton F, Tsang C, et al. Population-level factors predicting variation in influenza vaccine uptake among adults and young children in England, 2015/16 and 2016/17. *Vaccine* 2018;36(23):3231-38. doi: 10.1016/j.vaccine.2018.04.074 [published Online First: 2018/05/03]
11. Green HK, Andrews N, Letley L, et al. Phased introduction of a universal childhood influenza vaccination programme in England: population-level factors predicting variation in national uptake during the first year, 2013/14. *Vaccine* 2015;33(22):2620-8. doi: 10.1016/j.vaccine.2015.03.049 [published Online First: 2015/04/04]
12. Public Health England. Flu and flu vaccination 2019/20: A toolkit for care homes (South West), 2020.
13. NHS Digital. NHS Spine 2021 [Available from: https://digital.nhs.uk/services/spine accessed 27/05/2021.
14. NHS England. NHS England invites everyone aged 50 and over to be jabbed as NHS vaccination programme marks 100th day 2021 [Available from: https://www.england.nhs.uk/2021/03/nhs-england-invites-everyone-aged-50-and-over-to-be-jabbed-as-nhs-vaccination-programme-marks-100th-day/ accessed 05/06/2021.
15. NHS England. NHS invites people aged 56 to 59 for their COVID jab 2021 [05/06/2021]. Available from: https://www.england.nhs.uk/2021/03/56-59/.

16

16. NHS Digital. Vaccination of JCVI cohorts 5-6 and additional funding for vaccination in residential settings 2021 [Available from: https://www.england.nhs.uk/coronavirus/publication/vaccination-of-jcvi-cohorts-5-6-and-additional-funding-for-vaccination-in-residential-settings/ accessed 07/06/2021.

17. Bell S, Clarke R, Mounier-Jack S, et al. Parents' and guardians' views on the acceptability of a future COVID-19 vaccine: A multi-methods study in England. *Vaccine* 2020;38(49):7789-98. doi: 10.1016/j.vaccine.2020.10.027 [published Online First: 2020/10/29]

18. Public Health England. Seasonal influenza vaccine uptake in GP patients: winter season 2020 to 2021 2021 [Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/996033/Annual-Report_SeasonalFlu-Vaccine_GPs_2020_to_2021.pdf.

19. Mills MC, Salisbury D. The challenges of distributing COVID-19 vaccinations. *EClinicalMedicine* 2021;31 doi: 10.1016/j.eclinm.2020.100674

20. Gordon AL, Goodman C, Achterberg W, et al. Commentary: COVID in care homes—challenges and dilemmas in healthcare delivery. *Age and Ageing* 2020;49(5):701-05. doi: 10.1093/ageing/afaa113 %J Age and Ageing

21. NHS Digital. Mortality data review 2020 [Available from: https://digital.nhs.uk/coronavirus/coronavirus-data-services-updates/mortality-data-review accessed 22/06/2021.

22. Statistics. OfN. Coronavirus and vaccination rates in people aged 70 years and over by sociodemographic characteristic, England: 8 December 2020 to 9 May 2021, 2021.

23. Curtis HJ, Inglesby P, Morton CE, 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* 2021:2021.01.25.21250356. doi: 10.1101/2021.01.25.21250356

24. Mathur R, Rentsch CT, Morton CE, et al. Ethnic differences in SARS-CoV-2 infection and COVID-19-related hospitalisation, intensive care unit admission, and death in 17 million adults in England: an observational cohort study using the OpenSAFELY platform. *Lancet (London, England)* 2021;397(10286):1711-24. doi: 10.1016/S0140-6736(21)00634-6 [published Online First: 2021/04/30]

25. Robert W. Aldridge DL, Srinivasa Vittal Katikireddi, Rohini Mathur, Neha Pathak, Rachel Burns, Ellen B. Fragaszy, Anne M. Johnson, Delan Devakumar, Ibrahim Abubakar, Andrew Hayward Black, Asian and Minority Ethnic groups in England are at increased risk of death from COVID-19: indirect standardisation of NHS mortality data. *Wellcome Open Research* 2020;5(88)

26. Crowcroft NS, Levy-Bruhl D. Registries: An essential tool for maximising the health benefits of immunisation in the 21st century. 2017;22(17):30523. doi: doi:https://doi.org/10.2807/1560-7917.ES.2017.22.17.30523

27. Johansen K, Lopalco PL, Giesecke J. Immunisation registers – important for vaccinated individuals, vaccinators and public health. 2012;17(16):20151. doi: doi:https://doi.org/10.2807/ese.17.16.20151-en

28. Pebody R. Vaccine registers – experiences from Europe and elsewhere. 2012;17(17):20159. doi: doi:https://doi.org/10.2807/ese.17.17.20159-en

29. UK Health Security Agency Transparency and data – UKHSA's vaccines report 2021 [Available from: https://ukhsa.blog.gov.uk/2021/11/02/transparency-and-data-ukhsas-vaccines-report/.

30. Freeman D, Loe BS, Chadwick A, et al. COVID-19 vaccine hesitancy in the UK: the Oxford coronavirus explanations, attitudes, and narratives survey (Oceans) II. *Psychological medicine* 2020:1-15. doi: 10.1017/s0033291720005188 [published Online First: 2020/12/12]

17

Number of individuals aged 70 years old and above vaccinated with dose 1 and dose 2 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.

338x190mm (96 x 96 DPI)

Number of individuals aged 50 to 69 years old vaccinated with dose 1 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.

338x190mm (96 x 96 DPI)

Proportion of individuals aged (a) 50-69 not vaccinated with dose 1 (b) 70 years old and above not vaccinated with dose 1 and (c) 70 years old and above not vaccinated with dose 2 of COVID-19 vaccine (1: London; 2: South East; 3: South West; 4: East of England; 5: Midlands; 6: North East and Yorkshire; 7: North West)

338x190mm (96 x 96 DPI)

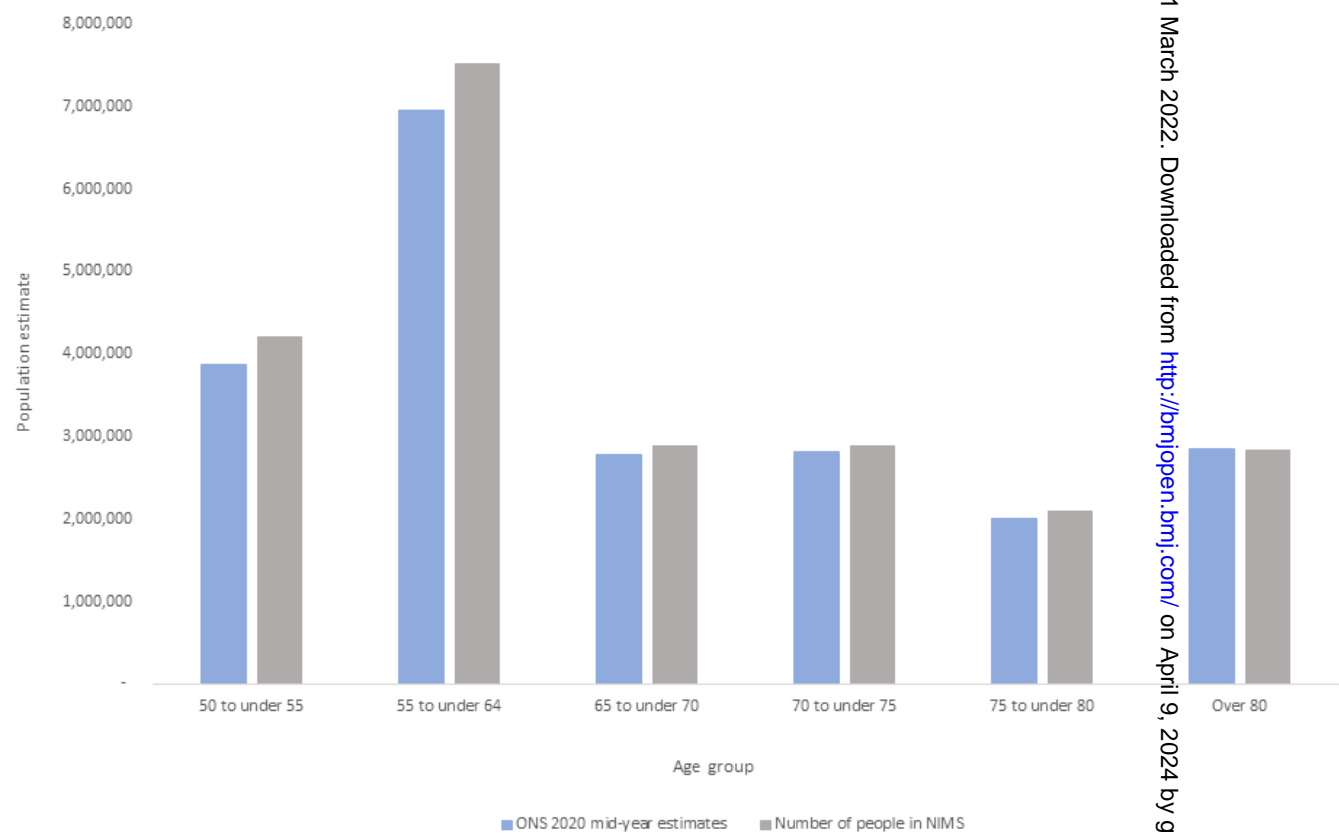**Supplementary Table 1.** Data fields provided by NIMS and other data sources used for vaccine coverage PHE for Vaccine Coverage

Data source	Data Field	Field explanations
Population denominator data file	First name	Limited to 50 characters
	Surname	Limited to 50 characters
	Date of birth	DD/MM/YYYY
	NHS number	10 Digit number without space
	Sex	Male; Female; Unknown
	Ethnicity	Based on the 2001 ethnic category codes: ETHNIC CATEGORY CODE 2001 (datadictionary.nhs.uk)
	Postcode	Post code with no spaces
	General practice code	Code of the individuals GP practice
	Flag for individuals clinically extremely vulnerable	
	Flag for frontline healthcare and social care workers	Based on the English Shielded Patient List Provided by NHS Business Services Authority for all staff who are directly employed by the NHS organisations using the Electronic Staff Record (ESR).
	Clinically Extremely Vulnerable	Provided by NHS Digital and is a record of vulnerable patients thought to be at high risk of complications from COVID-19. The data heavily relies on data linkage using the NHS number to extract data from the GP electronic health record (EHR), Hospital Episode Statistics (HES), and the QCOVID risk stratification assessment. Specific rule logic can be found here: https://digital.nhs.uk/coronavirus/shielded-patient-list/methodology/rule-logic
	Flag for individuals 16-65 at risk (Cohort 6)	Provided by NHS Digital and is based on a list of NHS numbers extracted from the EHR based on the national PHE PRIMIS SNOMED specification. This includes all those who are in a clinical risk group and coded as a carer within the EHR. For more information on the national specification can be found here: https://www.nottingham.ac.uk/primis/covid-19/covid-19.aspx
Vaccination events data file	NHS Number	10 Digit number without space
	Date of vaccination administration	DD/MM/YYYY
	Location Code	The unique code for the location where the vaccination event occurred
	Location Name	The name of the location where the vaccination event occurred
	Vaccine code	SNOMED CT concept code for the Vaccine Code

	Vaccine Procedure Code	SNOMED CT concept code for the Vaccination Procedure
	Route of vaccination	SNONED CT concept code for the route the vaccine was administered.
	Body Site	SNOMED CT concept code for the for the body site where the vaccination was administered
	Batch number	Vaccination's batch number (from the physical product)
	Manufacturer	Vaccination manufacturer name
Externally provided data sources	Index of Multiple Deprivation	From 2011 Census - linked by individuals post code.
	Care home status	Unique Property Reference Numbers and NHS-Addresses are used to link to the care home Care Quality Commission addresses. These are the used to linked to the Master Patient Index provided by NHS England and Improvement. The list of individuals in a care home is updated monthly.
Derived variables for coverage	Age as of 31 March 2021	Calculated based on DOB
	Manufacturer	Manufacturer is allocated using the first few characters of the Batch Number fields once any leading spaces and prefixes of Batch or BN are removed from the text string. Where it is not possible to identify the manufacturer using the first few characters of the trimmed Batch Number string, records where the batch number includes the string 'Pfizer' are allocated a Pfizer manufacturer code Pfizer, records including the strings 'AstraZeneca' (or 'Astra' and 'Zeneca') are allocated an AstraZeneca Code and records including the strings 'Moderna' are allocated a Moderna code. Finally, where manufacturer cannot be allocated using the above rules the manufacturer specific SNOMED codes are used to allocate manufacturer
	Dose number	Dose 1 should be on or after 08 December 2021. A completed course considered valid if dose 2 is a minimum of 20 days after dose 1
	Clinically Extremely Vulnerable/Cohort 6	This is a merged flag for those ages 16-65 that have been coded as at risk, anyone ages 16-69 clinically extremely vulnerable, or categorised as both.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

Characteristics associated with COVID-19 vaccine uptake among adults in England (08 December – 17 May 2021)

	Item No	Recommendation	Section in manuscript	Page and Paragraph
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title	page 2 paragraph 6
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract	page 2
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction	Page 3
Objectives	3	State specific objectives, including any prespecified hypotheses	Introduction	Page 3 paragraph 4
Methods				
Study design	4	Present key elements of study design early in the paper	Methods	Page 5 paragraph 7 (subheading statistical analyses)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods	Page 5 paragraph 3 (subheading study population)
		Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	Methods	Page 5 paragraph 3 and 4 (subheading study population and vaccine coverage)
		For matched studies, give matching criteria and the number of controls per case	Methods	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Methods	Page 4 paragraph 5 (subheading data source) onto page 5.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Methods	Page 4 paragraph 5 (subheading data source) onto page 5. Also, in supplementary Table 1

				Page 5 paragraph 1 and 2 (statistical methods adjusting and mean prevalence margins)
Bias	9	Describe any efforts to address potential sources of bias	Methods	
Study size	10	Explain how the study size was arrived at	Methods	Page 5 paragraph 4 (under Vaccine coverage subheading). The total number of individuals vaccinated
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Methods	Page 4 paragraph 2 (subheading study population) Age groups based on the roll-out of the vaccination programme
		(*a*) Describe all statistical methods, including those used to control for confounding	Methods	Page 5 paragraph 7 (subheading statistical analyses)
		(*b*) Describe any methods used to examine subgroups and interactions	Methods	Page 5 paragraph 7 (statistical methods adjusting and mean prevalence margins)
	12	(*c*) Explain how missing data were addressed	methods/discussion	Page 5 paragraph 2 and page 13 paragraph 3. (age Individuals with no NHS number and DOB were excluded - this is addressed in the discussion)
		If applicable, explain how matching of cases and controls was addressed	N/A	N/A
Statistical methods		(*e*) Describe any sensitivity analyses	N/A	N/A
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—egg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Results	Page 6 paragraph 3 (under descriptive results subheading)
		(b) Give reasons for non-participation at each stage	Results	N/A

		(c) Consider use of a flow diagram	Results	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results	Pages 8 to 10 (Table 1 and Table 2)
		(b) Indicate number of participants with missing data for each variable of interest		N/A
		Report numbers in each exposure category, or summary measures of exposure	Results	Pages 8 to 10 (Table 1 and Table 2)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Results	Pages 8 to 10 (Table 1 and Table 2)
		(*b*) Report category boundaries when continuous variables were categorized	Results	Pages 8 -10 (Age groups shown in tables)
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		Pages 8 to 10 (Table 1 and Table 2) Predictive margins
Other analyses	17	Report other analyses done—egg analyses of subgroups and interactions, and sensitivity analyses	Results	N/A
Discussion				
Key results	18	Summarise key results with reference to study objectives	Discussion	Page 12 paragraph 1
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion	Page 13 paragraph 3
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion	Page 13 paragraph 4
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion	Page 13 paragraph 4
Other information				

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | | Page 14 |

BMJ Open

Characteristics associated with COVID-19 vaccine uptake among adults aged 50 years and above in England (08 December 2020 – 17 May 2021) – A population level observational study

	HEALTH SERVICES ADMINISTRATION & MANAGEMENT

SCHOLARONE™
Manuscripts

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](.).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](.) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Characteristics associated with COVID-19 vaccine uptake among adults aged 50 years and above in England (08 December 2020 – 17 May 2021) – A population level observational study

Elise Tessier	Epidemiologist [1]	Elise.Tessier@phe.gov.uk
Yuma Rai	Vaccine Tracking Officer [1]	Yuma.SangpangRai@phe.gov.uk
Eleanor Clarke	Scientist, Epidemiology [1]	Eleanor.Clarke@phe.gov.uk.uk
Anissa Lakhani	Scientist, Epidemiology [1]	Anissa.Lakhani@phe.gov.uk
Camille Tsang	Data Manager [1]	Camille.Tsang@phe.gov.uk
Ashley Makwana	Data Analyst[2]	Ashley.Makwana@phe.gov.uk
Heather Heard	Head of Data and Information Systems[3]	Heather.Heard@phe.gov.uk
Tim Rickeard	Head of Technical Services [2]	Tim.Rickeard@phe.gov.uk
Shreya Lakhani	Vaccine Tracking Officer [1]	Shreya.Lakhani@phe.gov.uk
Partho Roy	Consultant Epidemiologist [1]	Partho.Roy@phe.gov.uk
Michael Edelstein	Associate Professor [4]	michael.edelstein@biu.ac.il
Mary Ramsay	Deputy Director [1]	Mary.Ramsay@phe.gov.uk
Jamie Lopez-Bernal	Consultant Epidemiologist [1]	Jamie.LopezBernal2@phe.gov.uk
Joanne White	Senior Epidemiologist [1]	joannemshivji@gmail.com
Nick Andrews	Senior Statistician [1]	Nick.Andrews@phe.gov.uk
Colin Campbell	Consultant Epidemiologist [1]	Colin.NJ.Campbell@phe.gov.uk
Julia Stowe	Senior Epidemiologist [1]	Julia.Stowe@phe.gov.uk

Affiliations:

1. Immunisation and Countermeasures Division, Public Health England, 61 Colindale Avenue, London, NW9 5EQ UK
2. Vaccines and Countermeasures Division, Public Health England, 133-155, Waterloo Road, Lambeth SE1 8UG UK
3. Health Intelligence Division, Health Improvement Directorate, Public Health England, Station Rise, York, YO1 6GA
4. Faculty of Medicine, Bar Ilan University, Safed, Israel

Corresponding author: Elise.Tessier@phe.gov.uk

Immunisation and Countermeasures Division, Public Health England, 61 Colindale Avenue, London, NW9 5EQ UK

1

Abstract:

Objective: To determine characteristics associated with COVID-19 vaccine coverage among individuals aged 50 years and above in England since the beginning of the programme.

Design: Observational cross-sectional study assessed by logistic regression and mean prevalence margins.

Setting: COVID-19 vaccinations delivered in England from 08 December 2020 – 17 May 2021.

Participants: 30,624,257/ 61,967,781 (49.4%) and 17,360,045/ 61,967,781 (28.1%) individuals in England were recorded as vaccinated in the National Immunisation Management System with a first dose and a second dose of a COVID-19 vaccine, respectively.

Interventions: Vaccination status with COVID-19 vaccinations.

Main Outcome Measures: Proportion, adjusted odds ratios and mean prevalence margins for individuals not vaccinated with dose 1 among those aged 50- 69 years old and dose 1 and 2 among those aged 70 years old and above.

Results: Of individuals aged 50 years and above, Black/African/Caribbean ethnic group was the least likely of all ethnic groups to be vaccinated with dose 1 of the COVID-19 vaccine. However, of those aged 70 years and above, the odds of not having dose 2 was 5.53 (95% CI 5.42 to 5.63) and 5.36 (90% CI 5.29 to 5.43) greater among Pakistani and Black/African/Caribbean compared to White British ethnicity, respectively. The odds of not receiving dose 2 was 1.18 (95% CI 1.16 to 1.20) higher among individuals who lived in a care home compared to those who did not. This was the opposite to that observed for dose 1, where the odds of being unvaccinated was significantly higher among those not living in a care home (0.89 (95% CI 0.87 to 0.91)).

Conclusions: We found that there are characteristics associated with low COVID-19 vaccine coverage. Inequalities, such as ethnicity are a major contributor to suboptimal coverage and tailored interventions are required to improve coverage and protect the population from SARS-CoV-2.

2

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Article summary:

Strengths and Limitations of this study:

- This is the is the first study assessing characteristics associated with COVID-19 vaccine coverage for all individuals aged 50 years and above in England.
- This study uses data from the National Immunisation Management System (NIMS) which is based on all individuals in England with a registered NHS number.
- This centralised national system captures individual level data for both vaccination status and demographic characteristics and allows for linkage to other datasets such as health care worker and care home resident status.
- This study does not include those without an NHS number and, therefore, it is possible we have underestimated the number of vaccines delivered and odds of being unvaccinated for characteristics such as ethnic groups where we have seen the greatest impact.
- Residual errors in data entry on the point of care apps at the vaccination sites may have also occurred, though these errors are not likely to be widespread.

3

Background:

The United Kingdom (UK) was the world's first country to approve a COVID-19 vaccine for the pandemic, getting a head start on the roll-out of its COVID-19 vaccination programme [1]. On December 08 2020, the UK launched its COVID-19 vaccination programme with the aim of reducing COVID-19 mortality and hospitalisations among those at highest risk. There are currently three vaccines that the Medicines and Healthcare products Regulatory Agency (MHRA) have authorised; the Pfizer/BioNTech vaccine (offered from 08 December 2020), the AstraZeneca (Oxford) vaccine (offered from 04 January 2021) and the Moderna Tx (offered from 13 April 2021) [2-4].

To ensure the reduction of mortality from SARS-CoV-2 infection and protect the healthcare system, the Joint Committee on Vaccination and Immunisation (JCVI), an independent expert advisory committee that advises UK health departments on vaccination, initially recommended extending the interval between doses to as long as 12 weeks. Its goal was to vaccinate a greater number of people sooner with the first dose of the COVID-19 vaccine [5][6]. The JCVI also recommended that the vaccination programme be rolled out in phases beginning on 08 December 2021, for those aged 80 years old and above and for frontline healthcare workers. [6] The UK then opened eligibility to others, first among individuals identified as clinically extremely vulnerable, meaning they had been classified as at risk and advise to shield at home, and then in descending age groups.[7] By 17 March 2021, all adults aged 50 years and above were eligible for their first dose of a coronavirus vaccine.

NHS England, with support from Public Health England (PHE), the national public health agency, publishes COVID-19 vaccination counts and denominators by region, age, ethnicity and for care home residents using a tracker tool [8]. Previous research on characteristics for low vaccine coverage in England have shown that deprivation and ethnicity are associated with lower coverage for a range of routine immunisations delivered in England [9-11]. There is little to no data collected on vaccine coverage for routine vaccines such as shingles and influenza for individuals living in care homes, though evidence shows that barriers exist in achieving high influenza uptake in care homes. These barriers include care home size, geographical location, and working relationships with primary care and pharmacies [12]. These studies and guidance assess routine vaccines delivered in England, which are primarily delivered through general practices, pharmacies, and schools. With the ongoing COVID-19 pandemic, the rapid development of COVID-19 vaccines and the urgency to rapidly roll out the programme in various settings including mass immunisation sites, it is unknown whether the same characteristics associated with vaccine coverage for routine programmes are associated with low coverage for COVID-19 vaccines.

The aim of this study is twofold:

1. To describe the number of individuals eligible for a COVID-19 vaccine in the first phase of the roll-out that have been vaccinated with a single or two doses of COVID-19 vaccine by age, sex, geographical location, vaccine type, ethnicity, deprivation, urban, or rural setting and programme week.
2. To determine whether there are any characteristics independently associated with low vaccine coverage for dose 1 and dose 2 of COVID-19 vaccines.

Methods:

Data source

A National Immunisation Management System (NIMS) capable of recording any vaccination, regardless of point of delivery, has been used for the pandemic response to collect information

4

about COVID-19 vaccines delivered across England. Individuals who present to a vaccination site, such as general practice, pharmacy, or hospital provider and receive a COVID-19 vaccine will have their vaccine event information recorded on a Point of Care application. PHE receives data that is linked to demographic data obtained from the NHS (e.g., gender, date of birth), using the individual's unique NHS number [13]. PHE uses these data for monitoring vaccine safety, effectiveness, and coverage. All variables for vaccine coverage are described in Supplementary Table 1. Age was calculated for all individuals based on their age on 31 March 2021.

Patient and Public Involvement

No patients were involved in the design or execution of the study

Study population

NIMS data was extracted on 17 May 2021 to assess vaccination status of all individuals aged 50 to 69 years old for a first dose of COVID-19 vaccine, and of all individuals aged 70 years old and above vaccinated with a first and a second dose of a COVID-19 vaccine. The programme was still being rolled out among younger cohorts, so not all 50-59 years olds had been offered a second dose of a COVID-19 vaccine at the time of data extraction. Individuals recorded in the NIMS must have an NHS number in order to link the population denominator and vaccination event files. All individuals with a death recorded were excluded from the analyses for the purpose of calculating coverage in the living resident population aged 50 and above on 31 March 2021.

Vaccine coverage

Vaccine coverage was calculated by dividing the total number of individuals with a recorded NHS number in the dataset who were vaccinated with 1 dose and 2 doses of COVID-19 vaccine since the beginning of the vaccine roll-out on 08 December 2020 (numerator) by the total number of individuals with a recorded NHS number in the dataset (denominator).

Proportion of unvaccinated individuals

The proportion of individuals not vaccinated for dose 1 and/or not vaccinated with dose 2 was calculated by dividing the total number of individuals unvaccinated or with a single dose of the COVID-19 vaccine since the beginning of the vaccine roll-out on 08 December 2020 (numerator) by the total number of individuals with a recorded NHS number in the dataset (denominator).

Descriptive analyses:

The proportion of individuals vaccinated and unvaccinated was described by programme week, starting at week 1 (beginning on 07 December 2020). Cumulative vaccine uptake has been calculated by programme week. Furthermore, the number of and proportion of individuals unvaccinated were aggregated by age groups, region, rural/urban classification, ethnicity, for individuals clinically extremely vulnerable, for individuals over 65 years old living in a care home, for individuals less than 65 years old, and a healthcare worker.

Statistical analyses:

Statistical analyses were conducted for individuals eligible for a COVID-19 vaccine in England in Phase 1, at the beginning of the roll out. The analyses were conducted for those vaccinated with dose 1 and dose 2 for individuals aged 70 years old and above, and for dose 1 among individuals aged 50 to 69 years old.

5

To assess the odds of being unvaccinated or being unvaccinated with dose 2, univariable logistic regression models for each characteristic were fitted with the binary outcome of vaccination status (not vaccinated/ vaccinated with a single dose and vaccinated with dose 1/ vaccinated with two doses). A multivariable logistic regression model was conducted adjusting for all other characteristics.

The adjusted mean prevalence margins and 95% confidence intervals of being unvaccinated for each characteristic within the multivariable model fit were calculated using the adjusted ratios. All statistical analyses were conducted using Stata 15.1.

Ethics Statement: Surveillance of covid-19 vaccination data was undertaken under Regulation 3 of The Health Service (Control of Patient Information) Regulations 2002 to collect confidential patient information (www.legislation.gov.uk/uksi/2002/1438/regulation/3/made) under Sections 3(i) (a) to (c), 3(i)(d) (i) and (ii) and 3(3).

Results

Descriptive results

From 17 March 2021 all individual ages 50 and above were eligible for a COVID-19 vaccine. As of 17 May 2021, a total of 30,624,257/ 61,967,781 (49.4%) and 17,360,045/ 61,967,781 (28.1%) individuals were vaccinated with a first dose and a second dose of a COVID-19 vaccine, respectively. A total of 90.9% of individuals aged 65 years and older had received at least one dose of the COVID-19 vaccine. The number of individuals vaccinated varied by programme week, plateauing at weeks 11 and 24 for dose 1 and 2 among those aged 70 years old and above, and week 23 for dose 1 among those aged 50 to 69 years old (Figures 1 and 2). Those aged 50 to 69 were still eligible for their second dose and had not yet plateaued at the time the data was extracted.

The proportion of individuals unvaccinated varied by age, dose and region; London consistently had the highest proportion of individuals being unvaccinated (Figure 3). Among the total population aged 50 and older, the North East of England had the lowest proportion of unvaccinated individuals (Figure 3).

70-year olds and above unvaccinated

Of individuals aged 70 years old and above, all characteristics were significantly associated with being unvaccinated in both the univariable and multivariable logistic regression analyses.

The odds of being unvaccinated was higher among males and those aged 75-79 and 80 years old and above than the baseline of 70-74 years old (Table 1). The odds of being unvaccinated with 1 or 2 doses was higher in urban areas; particularly in London with an increased odds of 2.30 (2.27 to 2.33) and 1.96 (1.94 to 1.98) odds for being unvaccinated for both dose 1 and dose 2, respectively (Table 1).

Among those clinically extremely vulnerable, the odds of being unvaccinated was reduced (OR 0.61 (95% CI 0.61 to 0.62)) and (OR 0. 88 (95% CI 0.87 to 0.89)) for dose 1 and dose 2, respectively compared to those with no significant underlying health conditions.

The odds of being unvaccinated among those living in a care home was also reduced for dose 1 (OR 0.89 (95% CI 0.87 to 0.91)) compared to those not living in a care home. However, the odds of being unvaccinated for dose 2 was 1.18 (95% CI 1.16 to 1.20) greater.
The greatest odds of being unvaccinated among 70 years olds was among those living in the most deprived areas and among Black/African/Caribbean ethnicities. Among the Black/African/Caribbean

6

ethnicity, the odds of not having a first dose was 6.69 (95% CI 6.58 to 6.79) greater than White British ethnicity. The odds of being unvaccinated with a second dose was 5.53 (95% CI 5.42 to 5.63) greater among the Pakistani ethnicity, followed by the Black/African/Caribbean ethnicity with an odds of 5.36 (95% CI 5.29 to 5.43).

The mean prevalence of being unvaccinated for each characteristic within the adjusted multivariable model showed increased prevalence among the characteristics with the highest odds of being unvaccinated. The highest prevalence was among the Black/African/Caribbean ethnic group for dose 1 with a mean prevalence of 17.6% unvaccinated. The prevalence among those unvaccinated with dose 1 was 26.6% and 26.1% among the Pakistani and Black/African/ Caribbean ethnicities, though the 95% confidence intervals do overlap between the two ethnicities (Table 1).

50-69-year olds unvaccinated

Of those aged 50-69 years old, all the characteristics were significantly associated with being unvaccinated in both the univariable and multivariable logistic regression analyses.

Similarly to those aged 70 and above, the odds of being unvaccinated was higher among males and increased in the younger populations (Table 1). The odds of being unvaccinated was higher in urban areas and particularly in London where there was an increased odds of 1.85 (95% CI 1.84 to 1.86) (Table 2).

The greatest odds of being unvaccinated with dose 1 among 50-69 year olds was highest among those with an unknown or not stated ethnicity and Black/African/Caribbean ethnicity which had a 3.40 (95% CI 3.38 to 3.41) and 3.32 (95% CI 3.29 to 3.34) increased odds of being unvaccinated compared those of White British ethnicity (Table 2).

Both the clinically extremely vulnerable/ at risk and healthcare workers had decreased odds of being unvaccinated than those that were not in these groups (OR 0.59 (95% CI 0.59 to 0.59) and 0.34 (95% CI 0.34 to 0.35), respectively) (Table 2), showing a protective effect among those at highest risk of SARS-CoV-2 disease.

The highest predictive margin for being unvaccinated after adjusting for all variables in the multivariable logistic regression model was among the Unknown/Not Stated and Black/African/Caribbean ethnic groups with a prevalence of 24.7% and 23.9% unvaccinated, respectively (Table 2).

7

Table 1. Number and proportion of individuals aged 70 years old and above not vaccinated for dose 1 and dose 2 of the COVID-19 vaccine between 8 December 2020 – 17 May 2021 in England and the odds of being unvaccinated from a multivariable logistic regression and mean adjusted prevalence from the model fit

Characteristics		Dose 1 Not Vaccinated n/N (%)	Dose 1 Multivariable Regression Odds Ratio and 95% CI	Dose 1 Predictive margins	Dose 2 Not Vaccinated n/N (%)	Dose 2 Not vaccinated / those with Dose 1 n/n(%)	Dose 2 Multivariable Regression Odds Ration and 95% CI*	Dose 2 Predictive margins (%) and 95% CI**
Age	70 to 74 years	169173 / 2877391 (5.9%)	Baseline	5.42% (5.39 to 5.44)	271998/2877391 (9.5%)	102872 / 271998 (37.8%)	Baseline	9.14% (9.11 to 9.17)
	75 to 79 years	100478 / 2086215 (4.8%)	0.86 (0.85 to 0.87)	4.74% (4.72 to 4.77)	161503/2086215 (7.7%)	61025 / 161503 (37.8%)	0.82 (0.82 to 0.83)	7.76% (7.72 to 7.79)
	Over 80 years	140785 / 2830943 (5.0%)	1.00 (1.00 to 1.01)	5.44% (5.41 to 5.46)	247875/2830943 (8.8%)	107059 / 247875 (43.2%)	0.98 (0.97 to 0.98)	8.95% (8.92 to 8.98)
Urban/ Rural status	Urban areas	348992 / 5906988 (5.9%)	Baseline	5.46% (5.44 to 5.47)	571598/5906988 (9.7%)	222605 / 571598 (38.9%)	Baseline	9.00% (8.98 to 9.02)
	Rural areas	60218 / 1880742 (3.2%)	0.77 (0.76 to 0.77)	4.31% (4.28 to 4.35)	108020/1880742 (5.7%)	47802 / 108020 (44.3%)	0.81 (0.80 to 0.81)	7.50% (7.45 to 7.54)
	Other/ Unknown	1226 / 6819 (18.0%)	-	-	1758/6819 (25.8%)	532 / 1758 (30.3%)	-	-
Clinically extremely vulnerable	Not clinically extremely vulnerable	333971 / 6158381 (5.4%)	Baseline	5.75% (5.73 to 5.77)	523938/6158381 (8.5%)	189967 / 523938 (36.3%)	Baseline	8.93% (8.91 to 8.95)
	Clinically extremely vulnerable	76464 / 1636167 (4.7%)	0.61 (0.61 to 0.62)	3.72% (3.70 to 3.75)	157437/1636167 (9.6%)	80973 / 157437 (51.4%)	0.88 (0.87 to 0.89)	8.01% (7.97 to 8.05)
Care home status	Not in a Care Home	404206 / 7578254 (5.3%)	Baseline	5.25% (5.24 to 5.27)	663275/7578254 (8.8%)	259069 / 663275 (39.1%)	Baseline	8.67% (8.65 to 8.69)
	In a Care Home	6230 / 216295 (2.9%)	0.89 (0.87 to 0.91)	4.74% (4.63 to 4.85)	18101/216295 (8.4%)	11871 / 18101 (65.6%)	1.18 (1.16 to 1.20)	10.00% (9.86 to 10.13)
IMD Deprivation Decile	Most Deprived	44759 / 515973 (8.7%)	Baseline	9.47% (9.39 to 9.56)	76750/515973 (14.9%)	31992 / 76750 (41.7%)	Baseline	15.13% (15.03 to 15.23)
		47804 / 567221 (8.4%)	0.75 (0.74 to 0.76)	7.44% (7.38 to 7.50)	77905/567221 (13.7%)	30105 / 77905 (38.6%)	0.76 (0.76 to 0.77)	12.19% (12.11 to 12.27)
		47565 / 627241 (7.6%)	0.64 (0.64 to 0.65)	6.54% (6.49 to 6.60)	77343/627241 (12.3%)	29778 / 77343 (38.5%)	0.66 (0.66 to 0.67)	10.85% (10.78 to 10.93)
		45373 / 722661 (6.3%)	0.57 (0.57 to 0.58)	5.93% (5.87 to 5.98)	73905/722661 (10.2%)	28532 / 73905 (38.6%)	0.59 (0.58 to 0.59)	9.75% (9.69 to 9.82)

8

		42635 / 796652 (5.4%)	0.51 (0.5 to 0.52)	5.34% (5.29 to 5.39)	70283/796652 (8.8%)	27648 / 70283 (39.3%)	0.52 (0.52 to 0.53)	8.84% (8.78 to 8.9)
		40935 / 858303 (4.8%)	0.46 (0.45 to 0.46)	4.84% (4.79 to 4.88)	67766/858303 (7.9%)	26831 / 67766 (39.6%)	0.47 (0.46 to 0.47)	8.06% (8.00 to 8.12)
		38086 / 894485 (4.3%)	0.42 (0.41 to 0.43)	4.48% (4.44 to 4.52)	63503/894485 (7.1%)	25417 / 63503 (40.0%)	0.43 (0.43 to 0.44)	7.48% (7.42 to 7.53)
		36684 / 918054 (4.0%)	0.39 (0.39 to 0.4)	4.21% (4.16 to 4.25)	61723/918054 (6.7%)	25039 / 61723 (40.6%)	0.41 (0.4 to 0.41)	7.09% (7.04 to 7.14)
		33833 / 934779 (3.6%)	0.35 (0.34 to 0.35)	3.77% (3.73 to 3.81)	56910/934779 (6.1%)	23077 / 56910 (40.5%)	0.36 (0.36 to 0.37)	6.40% (6.35 to 6.44)
	Least Deprived	30264 / 947216 (3.2%)	0.31 (0.30 to 0.31)	3.40% (3.36 to 3.43)	51417/947216 (5.4%)	21153 / 51417 (41.1%)	0.32 (0.32 to 0.33)	5.79% (5.75 to 5.84)
	Unknown	2498 / 11964 (20.9%)	-	-	3871/11964 (32.4%)	1373 / 3871 (35.5%)	-	-
Ethnicity	White	204842 / 6555567 (3.1%)	Baseline	3.23% (3.21 to 3.24)	409220/6555567 (6.2%)	204373 / 409220 (49.9%)	Baseline	6.43% (6.41 to 6.45)
	Mixed/Multiple Ethnic	5446 / 34247 (15.9%)	4.38 (4.25 to 4.52)	12.44% (12.12 to 12.75)	7612/34247 (22.2%)	2166 / 7612 (28.5%)	3.25 (3.17 to 3.34)	17.87% (17.50 to 18.25)
	Indian	11881 / 121720 (9.8%)	2.19 (2.14 to 2.23)	6.73% (6.61 to 6.85)	18257/121720 (15.0%)	6376 / 18257 (34.9%)	1.82 (1.79 to 1.85)	11.02% (10.87 to 11.18)
	Pakistani	10528 / 52518 (20.0%)	5.26 (5.14 to 5.38)	14.47% (14.21 to 14.74)	18530/52518 (35.3%)	8002 / 18530 (43.2%)	5.53 (5.42 to 5.63)	26.63% (26.28 to 26.97)
	Other Asian or Asian	13706 / 82251 (16.7%)	3.72 (3.65 to 3.79)	10.80% (10.62 to 10.98)	19797/82251 (24.1%)	6091 / 19797 (30.8%)	3.04 (2.99 to 3.09)	16.93% (16.70 to 17.16)
	Black/African/Caribbean	29981 / 103294 (29.0%)	6.69 (6.58 to 6.79)	17.58% (17.37 to 17.79)	41162/103294 (39.8%)	11181 / 41162 (27.2%)	5.36 (5.29 to 5.43)	26.06% (25.81 to 26.31)
	Other Ethnic Group	10227 / 58524 (17.5%)	4.16 (4.07 to 4.25)	11.89% (11.66 to 12.12)	13907/58524 (23.8%)	3680 / 13907 (26.5%)	3.14 (3.07 to 3.2)	17.36% (17.09 to 17.64)
	Not stated/Unknown	123825 / 786428 (15.7%)	6.00 (5.95 to 6.04)	16.12% (16.03 to 16.2)	152891/786428 (19.4%)	29066 / 152891 (19%)	3.69 (3.66 to 3.71)	19.73% (19.64 to 19.82)
Region	East of England	42261 / 971824 (4.3%)	Baseline	4.73% (4.69 to 4.78)	72699/971824 (7.5%)	30438 / 72699 (41.9%)	Baseline	8.20% (8.15 to 8.26)
	London	108877 / 792575 (13.7%)	2.30 (2.27 to 2.33)	9.77% (9.70 to 9.83)	153166/792575 (19.3%)	44289 / 153166 (28.9%)	1.96 (1.94 to 1.98)	14.39% (14.31 to 14.46)
	Midlands	69371 / 1515414 (4.6%)	0.97 (0.96 to 0.98)	4.60% (4.57 to 4.63)	120989/1515414 (8.0%)	51618 / 120989 (42.7%)	0.97 (0.96 to 0.98)	7.98% (7.94 to 8.02)
	North East and Yorkshire	45147 / 1232540 (3.7%)	0.77 (0.76 to 0.78)	3.74% (3.71 to 3.78)	83505/1232540 (6.8%)	38358 / 83505 (45.9%)	0.80 (0.79 to 0.81)	6.75% (6.71 to 6.8)

9

	Characteristic							
	North West	45973 / 973704 (4.7%)	0.95 (0.93 to 0.96)	4.51% (4.47 to 4.55)	82655/973704 (8.5%)	36683/ 82655 (44.4%)	0.97 (0.96 to 0.98)	7.99% (7.94 to 8.04)
	South East	59447 / 1334389 (4.5%)	1.11 (1.09 to 1.12)	5.18% (5.14 to 5.22)	102275/1334389 (7.7%)	42828/ 102275 (41.9%)	1.10 (1.09 to 1.11)	8.90% (8.85 to 8.96)
	South West	36862 / 962139 (3.8%)	0.90 (0.89 to 0.91)	4.30% (4.26 to 4.35)	62216/962139 (6.5%)	25354/ 62216 (40.8%)	0.88 (0.87 to 0.89)	7.30% (7.25 to 7.36)
	Unknown	2498 / 11964 (20.9%)	-	-	3871/11964 (32.4%)	1373/3871 (35.5%)	-	-
Sex	Female	217583 / 4279458 (5.1%)	Baseline	4.95% (4.93 to 4.97)	372475/4279458 (8.7%)	154892 / 372475 (41.6%)	Baseline	8.60% (8.57 to 8.62)
	Male	192285 / 3510687 (5.5%)	1.16 (1.15 to 1.16)	5.62% (5.59 to 5.64)	305672/3510687 (8.7%)	113387 / 305672 (37.1%)	1.03 (1.02 to 1.03)	8.78% (8.75 to 8.81)
	Unknown	568 / 4404 (12.9%)	0.94 (0.84 to 1.04)	4.67 (4.24 to 5.09)	3229/4404 (73.3%)	2661/3229 (82.4%)	21.72 (19.92 to 23.69)	60.79% (58.88 to 62.7)

*The odds of having a complete course of COVID-19 vaccine compared to having an incomplete (1 dose) or zero vaccines

**The percent vaccinated may fall outside the range of the predictive margins, as they are based on the effect of the adjusted multivariable model.

Table 2. Number and proportion of individuals aged 50-69 years old not vaccinated for dose 1 of the COVID-19 vaccine between 8 December 2020 – 17 May 2021 in England and the odds of being unvaccinated from a multivariable logistic regression and mean adjusted prevalence from the model fit

	Characteristics	Dose 1 Not Vaccinated n/N (%)	Dose 1 Multivariable Regression Odds Ration and 95% CI	Dose 1 Predictive margins (%) and 95% CI*
Age	50 to 54 years	3018263 / 4214965 (71.6%)	Baseline	15.07% (15.04 to 15.10)
	55 to 64 years	4485055 / 7518324 (59.7%)	0.81 (0.81 to 0.82)	12.82% (12.8 to 12.85)
	65 to 69 years	561755 / 2891288 (19.4%)	0.51 (0.51 to 0.51)	8.72% (8.68 to 8.75)
Urban/ Rural status	Urban areas	6418686 / 11552097 (55.6%)	Baseline	13.17% (13.15 to 13.19)
	Rural areas	1632703 / 3052642 (53.5%)	0.75 (0.74 to 0.75)	10.39% (10.35 to 10.43)
	Other/ Unknown	13684 / 19838 (69.0%)	-	-
Clinically extremely	Not at risk	6501682 / 10368328 (62.7%)	Baseline	14.18% (14.16 to 14.20)

10

vulnerable/ at risk (cohort 6)	**At Risk**	1563391 / 4256249 (36.7%)	0.59 (0.59 to 0.59)	9.25% (9.22 to 9.28)
Health care worker	**Not Health Care Worker**	8003303 / 14162182 (56.5%)	Baseline	12.94% (12.93 to 12.96)
	Health Care Worker	61770 / 462395 (13.4%)	0.34 (0.34 to 0.35)	5.22% (5.16 to 5.28)
IMD Deprivation Decile	**Most Deprived**	760885 / 1290391 (59.0%)	Baseline	20.57% (20.50 to 20.65)
		782255 / 1339803 (58.4%)	0.74 (0.74 to 0.75)	16.52% (16.46 to 16.58)
		795155 / 1383303 (57.5%)	0.66 (0.65 to 0.66)	15.00% (14.95 to 15.06)
		803307 / 1437917 (55.9%)	0.59 (0.59 to 0.60)	13.88% (13.82 to 13.93)
		806095 / 1479989 (54.5%)	0.53 (0.53 to 0.53)	12.69% (12.64 to 12.74)
		816104 / 1522404 (53.6%)	0.47 (0.47 to 0.48)	11.60% (11.55 to 11.65)
		815712 / 1528345 (53.4%)	0.43 (0.43 to 0.43)	10.72% (10.67 to 10.77)
		816165 / 1543302 (52.9%)	0.40 (0.39 to 0.40)	9.97% (9.93 to 10.02)
		814550 / 1530600 (53.2%)	0.36 (0.35 to 0.36)	9.14% (9.10 to 9.19)
	Least Deprived	830441 / 1534627 (54.1%)	0.32 (0.31 to 0.32)	8.23% (8.19 to 8.28)
	Unknown	24404 / 33896 (72.0%)	-	-
Ethnicity	**White**	5532177 / 10821112 (51.1%)	Baseline	9.07% (9.05 to 9.08)
	Mixed/Multiple Ethnic	84371 / 135124 (62.4%)	2.60 (2.57 to 2.64)	19.97% (19.77 to 20.16)
	Indian	152271 / 325697 (46.8%)	1.19 (1.18 to 1.20)	10.55% (10.45 to 10.64)
	Pakistani	130526 / 197437 (66.1%)	2.48 (2.46 to 2.51)	19.26% (19.10 to 19.42)
	Other Asian or Asian	177291 / 305023 (58.1%)	1.56 (1.54 to 1.57)	13.24% (13.13 to 13.35)
	Black/African/Caribbean	306972 / 450853 (68.1%)	3.32 (3.29 to 3.34)	23.87% (23.75 to 23.98)
	Other Ethnic Group	139813 / 217886 (64.2%)	2.61 (2.59 to 2.64)	20.01% (19.86 to 20.16)
	Not stated/Unknown	1541652 / 2171445 (71.0%)	3.40 (3.38 to 3.41)	24.27% (24.21 to 24.32)
Region	**East of England**	966550 / 1721713 (56.1%)	Baseline	11.86% (11.81 to 11.91)
	London	1197210 / 2056938 (58.2%)	1.85 (1.84 to 1.86)	19.14% (19.09 to 19.19)
	Midlands	1508576 / 2758546 (54.7%)	0.98 (0.98 to 0.99)	11.69% (11.66 to 11.73)
	North East and Yorkshire	1245671 / 2284027 (54.5%)	0.80 (0.79 to 0.81)	9.85% (9.81 to 9.89)
	North West	967344 / 1865618 (51.9%)	0.99 (0.98 to 1.00)	11.77% (11.73 to 11.81)
	South East	1321417 / 2353321 (56.2%)	1.05 (1.05 to 1.06)	12.37% (12.32 to 12.41)
	South West	833901 / 1550518 (53.8%)	0.88 (0.88 to 0.89)	10.70% (10.65 to 10.76)

11

	Unknown	24404 / 33896 (72.0%)	-	-
	Female	3659928 / 7229063 (50.6%)	Baseline	11.45% (11.42 to 11.47)
Sex	**Male**	4388976 / 7376483 (59.5%)	1.27 (1.27 to 1.28)	13.87% (13.84 to 13.89)
	Unknown	16169 / 19031 (85.0%)	0.78 (0.75 to 0.81)	9.33% (9.01 to 9.65)

*The percent vaccinated may fall outside the range of the predictive margins, as they are based on the effect of the adjusted multivariable model.

12

Discussion:

As of 17 May 2021, 49.4% of the population aged 50 and above in England had received a first dose of the COVID-19 vaccine and 28.1% had their second dose. Vaccine coverage for dose 1 among those aged 50 years old, and for dose 2 for those aged 70 years old and above, have plateaued. A significant increase in the number of individuals aged 50-69 years old occurred in week 15 of the programme (the week commencing the 15 March 2021), when those aged 50 – 69 became eligible for the vaccine [14][15]. Individuals aged 50 to 69 vaccinated in earlier weeks were most likely to have been healthcare workers, individuals clinically extremely vulnerable/Cohort 6 at risk for severe coronavirus disease [16].

The overall proportion of individuals eligible for the vaccine but not vaccinated was highest in London, followed by the Midlands and East of England areas. These results coincide with findings from studies assessing predictors associated with influenza and shingles vaccine coverage, prior to mass immunisation [9][10][17], which offered vaccines to individuals in similar populations, such as elderly individuals and those at risk, in which lower coverage in London and in urban areas is observed, despite differences in delivery of the programmes. For example, the shingles vaccine is delivered opportunistically in GP practices, while influenza vaccines are more widely available, including in pharmacies. Overall vaccine coverage for the first dose of a COVID-19 vaccine among those aged 65 years and older was higher for COVID-19 than for seasonal influenza vaccines delivered in the 2020/2021 winter season (90.9% vs 80.9%) [18].

Results from the multivariable logistic regression model and the predictive margins for two doses among those aged 70 years old and above, and for one dose among those aged 50-69, indicate increased odds and predicted margins of being unvaccinated with lower age groups. Should lower coverage among younger adults continue to be observed as the programme continues to roll-out, efforts must be made to address this. Moreover, after adjusting for all variables in the multivariable models, the odds of being unvaccinated was higher among males compared to females, in urban areas compared to rural areas, and highest in London compared to other regions in England among individuals aged 50 years old and above. Reduced odds of being unvaccinated was observed among those clinically extremely vulnerable/ at risk aged 50 years and above, and among healthcare workers aged 50 to 69 years old. These individuals were all eligible for the vaccine early in the programme.

Individuals aged 70 years old and above living in care homes had reduced odds of being unvaccinated for dose 1 compared to those not living in a care home. In contrast, care home residents had increased odds of being unvaccinated for the second dose compared to those living in a care home. The delivery of COVID-19 vaccines to care homes was primarily carried out by mobile teams that required a lot of logistics and coordination [19]. The delivery of second doses of COVID-19 vaccinations in care homes may be lower because it was difficult to follow up on individuals who were not vaccinated or partially vaccinated and moved into a care home after or between mobile vaccination unit visits. It is important to further investigate the increased odds of being unvaccinated with dose 2 in care homes, as residents have been disproportionately affected by SARS-CoV-2 [20]. It is unlikely that the death rates are associated with low coverage because deaths are recorded in a timely manner in the NIMS [21], though it is possible that care home residents might have had COVID-19 or another illness at the time of offer, thus causing a lag in the number of second doses received.

Both the highest odds and the predictive margins for being unvaccinated for dose 1 among all individuals in the study and for dose 2 among those aged 70 years old and above were observed in the most deprived and among the Black/African/Caribbean ethnicity. This coincides with findings

13

assessing COVID-19 vaccine coverage for those aged 70 years old and above using the 2011 ONS denominator population estimates [22] and using general practice records for population estimates based on registrations for two of the three GP IT System Suppliers in England [23]. Furthermore, among those aged 70 years old and above, the odds and prevalence of being unvaccinated among those of Pakistani ethnicity further increased for dose 2.

Our findings highlight the structural and complex interplay of ethnicity and deprivation, which has also been observed with findings on SARS-CoV-2 infection, hospitalisations and mortality [24 25] This also concurs with a study assessing households in the UK that found individuals of an ethnic minority and a lower socioeconomic status were associated with greater COVID-19 vaccine hesitancy[26].

Strengths and Limitations of this study

Our study has several strengths. This is the first study assessing characteristics associated with COVID-19 vaccine coverage for all individuals aged 50 years and above in England, and one of the first studies globally assessing COVID-19 vaccine coverage. Our study also uses data from the NIMS, which is likely to be more complete than other datasets used to estimate COVID-19 vaccine coverage because it is based on all individuals in England with a registered NHS number. Furthermore, immunisation registers have proven to be fundamental when assessing and protecting the population, can be used for linkage to health-outcome databases, and can play a key role in the delivery of a national immunisation programme [27-29]. This is the first time England has developed a centralised national system capturing individual level data for both vaccination status and demographic characteristics. Previous studies assessing factors influencing vaccine coverage in England have been based on aggregate general practice-level data, in which estimates such as deprivation were based on the general practice postcode. Having individual level data for frontline healthcare workers, care home residents, and others allowed us to link individual NHS numbers to properly account for factors relating to these individuals. Such granular data are not available in similar studies or in general practice records.

We are unable to capture details on the total number of individuals without an NHS number and, of those who had not received a vaccine. Therefore, it is possible we have underestimated the number of vaccines delivered and odds of being unvaccinated for characteristics such as ethnic groups in which we have seen the greatest impact. The proportion of individuals aged 50 years and above with no NHS number is expected to be marginal. The NIMS population estimates are larger compared to the 2020 Office for National Statistics (ONS) mid-year population estimates (Supplementary Figure 1), thus possibly overestimating population estimates. However, ONS estimates are based on the 2011 census and do not take into account any changes or movements throughout the pandemic, which may be reflected in NHS records[30]. Furthermore, it is possible that there could be residual errors in data entry on the point of care apps at the vaccination sites, though these errors are not widespread. Though the NIMS was rapidly set up for monitoring COVID-19 vaccinations, it was piloted with influenza vaccinations delivered in the 2020/21 influenza season and the trends observed in our study align with other immunisation programmes.

Conclusions

This study provides evidence that in England, being male, being in a younger age group, belonging to certain minority groups, living in urban setting, or being a care home resident were associated with low COVID-19 vaccine coverage. The largest odds of being unvaccinated was observed among those of Black/African/Caribbean ethnicity and those in the most deprived decile. It is of utmost importance to reduce inequalities in vaccine coverage, particularly among Black, Asian and Minority Ethnic groups, and care home residents who have been most impacted by the SARS-CoV-2 infection.

14

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

The delivery of the COVID-19 vaccination programme should continue to be investigated. Delivery strategies, such as the use of mass immunisation sites and mobile vaccination units for populations where vaccine coverage is lower, should be evaluated to determine whether it could be applied to routine immunisations. As vaccine coverage increases in England, tailored strategies that consider barriers specific to under-vaccinated groups, such as vaccine hesitancy, [31]should be designed and implemented to improve COVID-19 vaccine coverage.

Acknowledgements

15

Contributor and guarantor information:
Elise Tessier is the guarantor of the paper and confirms that the manuscript is honest, accurate and transparent. There are no important aspects of the paper omitted.

Contributions: ET, JS, CC, MR, JLB, ME and JW provided overview of the project concept. ET, JS, YR, CT, CC, ME, JW, PR worked on the study design. AM, HH, TR, EC, CT, AL, ET, YR, JS and SL worked on acquiring and preparing the data for analysis. ET and NA prepared the statistical analyses and interpretation of the data. ET and JS prepared the manuscript and all authors reviewed the manuscript.

Competing interests declaration: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: funding from Public Health England for the submitted work; 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: Surveillance of covid-19 vaccination data is undertaken under Regulation 3 of The Health Service (Control of Patient Information) Regulations 2002 to collect confidential patient information (www.legislation.gov.uk/uksi/2002/1438/regulation/3/made) under Sections 3(i) (a) to (c), 3(i)(d) (i) and (ii) and 3(3).

Role and Funding source: There was no external funding for this study.

Data Sharing Statement: No additional data available.

Figure Legend/ Captions:

Figure 1. Number of individuals aged 70 years old and above vaccinated with dose 1 and dose 2 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.

Figure 2. Number of individuals aged 50 to 69 years old vaccinated with dose 1 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.

Figure 3. Proportion of individuals aged (a) 50-69 not vaccinated with dose 1 (b) 70 years old and above not vaccinated with dose 1 and (c) 70 years old and above not vaccinated with dose 2 of COVID-19 vaccine (1: London; 2: South East; 3: South West; 4: East of England; 5: Midlands; 6: North East and Yorkshire; 7: North West)

Supplementary Figure 1. The total number of individuals recoded in England by age group, based on roll out of the COVID-19 vaccine, in the 2020 mid-year population estimates and the NIMS.[1,2]

1. ONS mid-year population estimates are derived from the 2011 Census
2. NIMS estimates are based on the number of individuals with a National Health Service (NHS) record number

16

References:

1. Baraniuk C. Covid-19: How the UK vaccine rollout delivered success, so far. *BMJ* 2021;372:n421. doi: 10.1136/bmj.n421

2. Department of Health and Social Care. Statement from the UK Chief Medical Officers on the prioritisation of first doses of COVID-19 vaccines 2020 [Available from: https://www.gov.uk/government/news/statement-from-the-uk-chief-medical-officers-on-the-prioritisation-of-first-doses-of-covid-19-vaccines accessed 02 February 2021 2021.

3. Public Health England. COVID-19 - SARS-CoV-2 Chapter 14a 2021 [Available from: https://www.gov.uk/government/publications/covid-19-the-green-book-chapter-14a.

4. Public Health England. National protocol for COVID-19 Vaccine Moderna 2021 [Available from: https://www.gov.uk/government/publications/national-protocol-for-covid-19-vaccine-moderna accessed 25/05/2021.

5. Department of Health and Social Care. Optimising the COVID-19 vaccination programme for maximum short-term impact 2021 [Available from: https://www.gov.uk/government/publications/prioritising-the-first-covid-19-vaccine-dose-jcvi-statement/optimising-the-covid-19-vaccination-programme-for-maximum-short-term-impact accessed 03 February 2021 2021.

6. Care. DoHS. Joint Committee on Vaccination and Immunisation: advice on priority groups for COVID-19 vaccination, 30 December 2020 2020 [Available from: https://www.gov.uk/government/publications/priority-groups-for-coronavirus-covid-19-vaccination-advice-from-the-jcvi-30-december-2020/joint-committee-on-vaccination-and-immunisation-advice-on-priority-groups-for-covid-19-vaccination-30-december-2020 accessed 20/05/2021.

7. NHS England. Who is at high risk from coronavirus (COVID-19) 2021 [Available from: https://www.nhs.uk/conditions/coronavirus-covid-19/people-at-higher-risk/who-is-at-high-risk-from-coronavirus/ accessed 21/07/2021.

8. NHS Digital. COVID-19 Vaccinations 2021 [Available from: https://www.england.nhs.uk/statistics/statistical-work-areas/covid-19-vaccinations/ accessed 18/06/2021.

9. Ward C, Byrne L, White JM, et al. Sociodemographic predictors of variation in coverage of the national shingles vaccination programme in England, 2014/15. *Vaccine* 2017;35(18):2372-78. doi: 10.1016/j.vaccine.2017.03.042 [published Online First: 2017/04/02]

10. Tessier E, Warburton F, Tsang C, et al. Population-level factors predicting variation in influenza vaccine uptake among adults and young children in England, 2015/16 and 2016/17. *Vaccine* 2018;36(23):3231-38. doi: 10.1016/j.vaccine.2018.04.074 [published Online First: 2018/05/03]

11. Green HK, Andrews N, Letley L, et al. Phased introduction of a universal childhood influenza vaccination programme in England: population-level factors predicting variation in national uptake during the first year, 2013/14. *Vaccine* 2015;33(22):2620-8. doi: 10.1016/j.vaccine.2015.03.049 [published Online First: 2015/04/04]

12. Public Health England. Flu and flu vaccination 2019/20: A toolkit for care homes (South West), 2020.

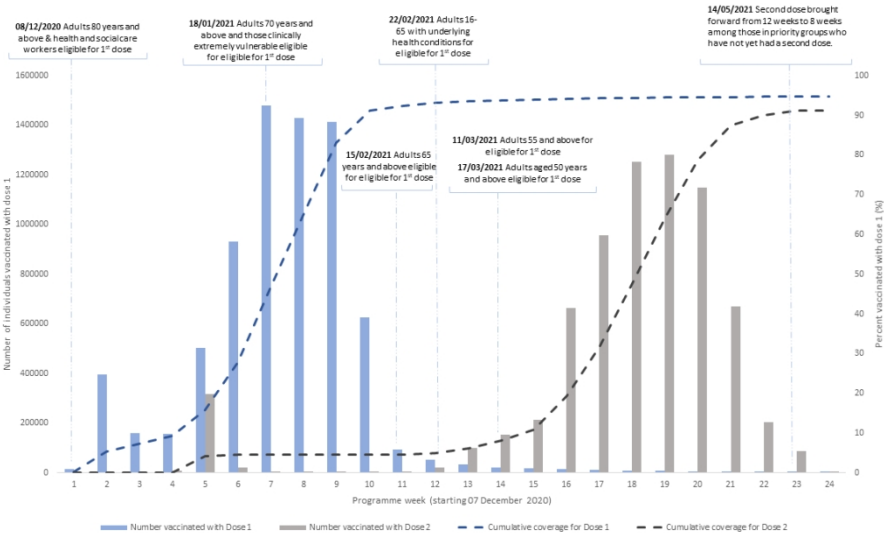13. NHS Digital. NHS Spine 2021 [Available from: https://digital.nhs.uk/services/spine accessed 27/05/2021.

14. NHS England. NHS England invites everyone aged 50 and over to be jabbed as NHS vaccination programme marks 100th day 2021 [Available from: https://www.england.nhs.uk/2021/03/nhs-england-invites-everyone-aged-50-and-over-to-be-jabbed-as-nhs-vaccination-programme-marks-100th-day/ accessed 05/06/2021.

15. NHS England. NHS invites people aged 56 to 59 for their COVID jab 2021 [05/06/2021]. Available from: https://www.england.nhs.uk/2021/03/56-59/.

17

16. NHS Digital. Vaccination of JCVI cohorts 5-6 and additional funding for vaccination in residential settings 2021 [Available from: https://www.england.nhs.uk/coronavirus/publication/vaccination-of-jcvi-cohorts-5-6-and-additional-funding-for-vaccination-in-residential-settings/ accessed 07/06/2021.

17. Bell S, Clarke R, Mounier-Jack S, et al. Parents' and guardians' views on the acceptability of a future COVID-19 vaccine: A multi-methods study in England. *Vaccine* 2020;38(49):7789-98. doi: 10.1016/j.vaccine.2020.10.027 [published Online First: 2020/10/29]

18. Public Health England. Seasonal influenza vaccine uptake in GP patients: winter season 2020 to 2021 2021 [Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/996033/Annual-Report_SeasonalFlu-Vaccine_GPs_2020_to_2021.pdf.

19. Mills MC, Salisbury D. The challenges of distributing COVID-19 vaccinations. *EClinicalMedicine* 2021;31 doi: 10.1016/j.eclinm.2020.100674

20. Gordon AL, Goodman C, Achterberg W, et al. Commentary: COVID in care homes—challenges and dilemmas in healthcare delivery. *Age and Ageing* 2020;49(5):701-05. doi: 10.1093/ageing/afaa113 %J Age and Ageing

21. NHS Digital. Mortality data review 2020 [Available from: https://digital.nhs.uk/coronavirus/coronavirus-data-services-updates/mortality-data-review accessed 22/06/2021.

22. Statistics. OfN. Coronavirus and vaccination rates in people aged 70 years and over by sociodemographic characteristic, England: 8 December 2020 to 9 May 2021, 2021.

23. Curtis HJ, Inglesby P, Morton CE, 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* 2021:2021.01.25.21250356. doi: 10.1101/2021.01.25.21250356

24. Mathur R, Rentsch CT, Morton CE, et al. Ethnic differences in SARS-CoV-2 infection and COVID-19-related hospitalisation, intensive care unit admission, and death in 17 million adults in England: an observational cohort study using the OpenSAFELY platform. *Lancet (London, England)* 2021;397(10286):1711-24. doi: 10.1016/S0140-6736(21)00634-6 [published Online First: 2021/04/30]

25. Robert W. Aldridge DL, Srinivasa Vittal Katikireddi, Rohini Mathur, Neha Pathak, Rachel Burns, Ellen B. Fragaszy, Anne M. Johnson, Delan Devakumar, Ibrahim Abubakar, Andrew Hayward Black, Asian and Minority Ethnic groups in England are at increased risk of death from COVID-19: indirect standardisation of NHS mortality data. *Wellcome Open Research* 2020;5(88)

26. Robertson E, Reeve KS, Niedzwiedz CL, et al. Predictors of COVID-19 vaccine hesitancy in the UK household longitudinal study. *Brain, Behavior, and Immunity* 2021;94:41-50. doi: https://doi.org/10.1016/j.bbi.2021.03.008

27. Crowcroft NS, Levy-Bruhl D. Registries: An essential tool for maximising the health benefits of immunisation in the 21st century. 2017;22(17):30523. doi: doi:https://doi.org/10.2807/1560-7917.ES.2017.22.17.30523

28. Johansen K, Lopalco PL, Giesecke J. Immunisation registers – important for vaccinated individuals, vaccinators and public health. 2012;17(16):20151. doi: doi:https://doi.org/10.2807/ese.17.16.20151-en

29. Pebody R. Vaccine registers – experiences from Europe and elsewhere. 2012;17(17):20159. doi: doi:https://doi.org/10.2807/ese.17.17.20159-en

30. UK Health Security Agency Transparency and data – UKHSA's vaccines report 2021 [Available from: https://ukhsa.blog.gov.uk/2021/11/02/transparency-and-data-ukhsas-vaccines-report/.

31. Freeman D, Loe BS, Chadwick A, et al. COVID-19 vaccine hesitancy in the UK: the Oxford coronavirus explanations, attitudes, and narratives survey (Oceans) II. *Psychological medicine* 2020:1-15. doi: 10.1017/s0033291720005188 [published Online First: 2020/12/12]
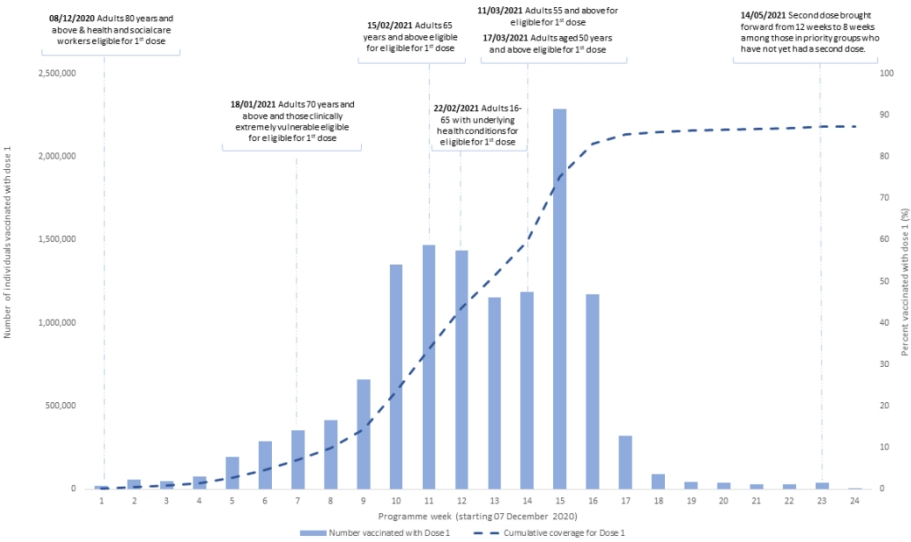
18

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
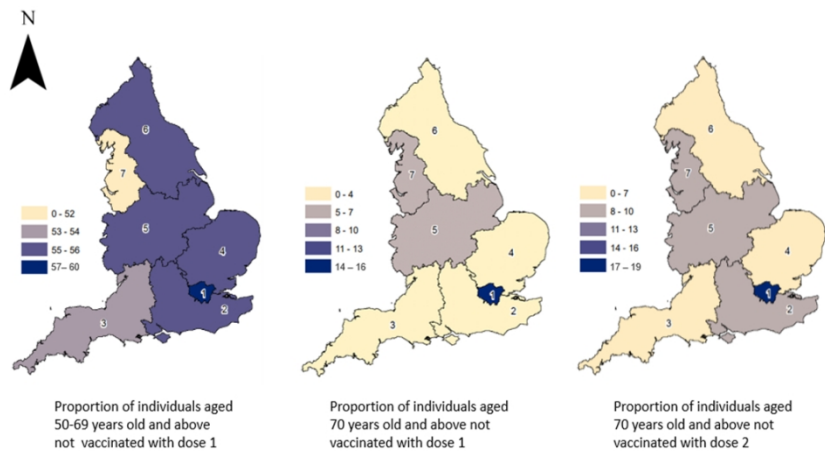47
48
49
50
51
52
53
54
55
56
57
58
59
60

19

Number of individuals aged 70 years old and above vaccinated with dose 1 and dose 2 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.

338x190mm (96 x 96 DPI)

Number of individuals aged 50 to 69 years old vaccinated with dose 1 of the COVID-19 vaccine and cumulative vaccine uptake by programme week (starting the week of 07 December 2020), England.

338x190mm (96 x 96 DPI)

Proportion of individuals aged (a) 50-69 not vaccinated with dose 1 (b) 70 years old and above not vaccinated with dose 1 and (c) 70 years old and above not vaccinated with dose 2 of COVID-19 vaccine (1: London; 2: South East; 3: South West; 4: East of England; 5: Midlands; 6: North East and Yorkshire; 7: North West)

338x190mm (96 x 96 DPI)

Supplementary Table 1. Data fields provided by NIMS and other data sources used for vaccine coverage PHE for Vaccine Coverage

Data source	Data Field	Field explanations
Population denominator data file	First name	Limited to 50 characters
	Surname	Limited to 50 characters
	Date of birth	DD/MM/YYYY
	NHS number	10 Digit number without space
	Sex	Male; Female; Unknown
	Ethnicity	Based on the 2001 ethnic category codes: ETHNIC CATEGORY CODE 2001 (datadictionary.nhs.uk)
	Postcode	Post code with no spaces
	General practice code	Code of the individuals GP practice
	Flag for individuals clinically extremely vulnerable	
	Flag for frontline healthcare and social care workers	Based on the English Shielded Patient List Provided by NHS Business Services Authority for all staff who are directly employed by the NHS organisations using the Electronic Staff Record (ESR).
	Clinically Extremely Vulnerable	Provided by NHS Digital and is a record of vulnerable patients thought to be at high risk of complications from COVID-19. The data heavily relies on data linkage using the NHS number to extract data from the GP electronic health record (EHR), Hospital Episode Statistics (HES), and the QCOVID risk stratification assessment. Specific rule logic can be found here: https://digital.nhs.uk/coronavirus/shielded-patient-list/methodology/rule-logic
	Flag for individuals 16-65 at risk (Cohort 6)	Provided by NHS Digital and is based on a list of NHS numbers extracted from the EHR based on the national PHE PRIMIS SNOMED specification. This includes all those who are in a clinical risk group and coded as a carer within the EHR. For more information on the national specification can be found here: https://www.nottingham.ac.uk/primis/covid-19/covid-19.aspx
Vaccination events data file	NHS Number	10 Digit number without space
	Date of vaccination administration	DD/MM/YYYY
	Location Code	The unique code for the location where the vaccination event occurred
	Location Name	The name of the location where the vaccination event occurred
	Vaccine code	SNOMED CT concept code for the Vaccine Code

	Vaccine Procedure Code	SNOMED CT concept code for the Vaccination Procedure
	Route of vaccination	SNONED CT concept code for the route the vaccine was administered.
	Body Site	SNOMED CT concept code for the for the body site where the vaccination was administered
	Batch number	Vaccination's batch number (from the physical product)
	Manufacturer	Vaccination manufacturer name
Externally provided data sources	Index of Multiple Deprivation	From 2011 Census - linked by individuals post code.
	Care home status	Unique Property Reference Numbers and NHS-Addresses are used to link to the care home Care Quality Commission addresses. These are the used to linked to the Master Patient Index provided by NHS England and Improvement. The list of individuals in a care home is updated monthly.
Derived variables for coverage	Age as of 31 March 2021	Calculated based on DOB
	Manufacturer	Manufacturer is allocated using the first few characters of the Batch Number fields once any leading spaces and prefixes of Batch or BN are removed from the text string. Where it is not possible to identify the manufacturer using the first few characters of the trimmed Batch Number string, records where the batch number includes the string 'Pfizer' are allocated a Pfizer manufacturer code Pfizer, records including the strings 'AstraZeneca' (or 'Astra' and 'Zeneca') are allocated an AstraZeneca Code and records including the strings 'Moderna' are allocated a Moderna code. Finally, where manufacturer cannot be allocated using the above rules the manufacturer specific SNOMED codes are used to allocate manufacturer
	Dose number	Dose 1 should be on or after 08 December 2021. A completed course considered valid if dose 2 is a minimum of 20 days after dose 1
	Clinically Extremely Vulnerable/Cohort 6	This is a merged flag for those ages 16-65 that have been coded as at risk, anyone ages 16-69 clinically extremely vulnerable, or categorised as both.

Characteristics associated with COVID-19 vaccine uptake among adults aged 50 years and above in England (08 December 2020 – 17 May 2021) – A population level observational study

	Item No	Recommendation	Section in manuscript	Page and Paragraph
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title	Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract	page 2
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Background	Page 4
Objectives	3	State specific objectives, including any prespecified hypotheses	Background	Page 3 paragraph 5
Methods				
Study design	4	Present key elements of study design early in the paper	Methods	Page 5 paragraph 7 (subheading statistical analyses)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Methods	Page 5 paragraph 3 (subheading study population)
		Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	Methods	Page 5 paragraph 3 and 4 (subheading study population and vaccine coverage)
		For matched studies, give matching criteria and the number of controls per case	Methods	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Methods	Page 4 paragraph 5 (subheading data source) onto page 5.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Methods	Page 4 paragraph 5 (subheading data source) onto page 5. Also, in supplementary Table 1

Bias	9	Describe any efforts to address potential sources of bias	Methods	Page 5 paragraph 1 and 2 (statistical methods adjusting and mean prevalence margins)
Study size	10	Explain how the study size was arrived at	Methods	Page 5 paragraph 4 (under Vaccine coverage subheading). The total number of individuals vaccinated
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Methods	Page 4 paragraph 2 (subheading study population) Age groups based on the roll-out of the vaccination programme
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Methods	Page 5 paragraph 7 (subheading statistical analyses)
		(*b*) Describe any methods used to examine subgroups and interactions	Methods	Page 5 paragraph 7 (statistical methods adjusting and mean prevalence margins)
		(*c*) Explain how missing data were addressed	methods/discussion	Page 5 paragraph 2 and page 13 paragraph 3. (age Individuals with no NHS number and DOB were excluded - this is addressed in the discussion)
		If applicable, explain how matching of cases and controls was addressed	N/A	N/A
		(*e*) Describe any sensitivity analyses	N/A	N/A
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—egg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Results	Page 6 paragraph 3 (under descriptive results subheading)
		(b) Give reasons for non-participation at each stage	Results	N/A

		(c) Consider use of a flow diagram	Results	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Results	Pages 8 to 10 (Table 1 and Table 2)
		(b) Indicate number of participants with missing data for each variable of interest		N/A
		Report numbers in each exposure category, or summary measures of exposure	Results	Pages 8 to 10 (Table 1 and Table 2)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Results	Pages 8 to 10 (Table 1 and Table 2)
		(*b*) Report category boundaries when continuous variables were categorized	Results	Pages 8 -10 (Age groups shown in tables)
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		Pages 8 to 10 (Table 1 and Table 2) Predictive margins
Other analyses	17	Report other analyses done—egg analyses of subgroups and interactions, and sensitivity analyses	Results	N/A
Discussion				
Key results	18	Summarise key results with reference to study objectives	Discussion	Page 12 paragraph 1
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Discussion	Page 13 paragraph 3
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion	Page 13 paragraph 4
Generalisability	21	Discuss the generalisability (external validity) of the study results	Discussion	Page 13 paragraph 4
Other information				

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based		Page 14

For peer review only