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Influenza vaccine uptake in socially deprived areas: A multilevel retrospective population-based cross-sectional study using electronic health records in Liverpool, United Kingdom

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ABSTRACT

Background: Seasonal influenza causes around 15,000 deaths yearly in the UK. While vaccination is a useful prevention measure, uptake is low, related to factors such as deprivation, age, sex, and ethnicity. Liverpool is a diverse yet deprived city, with potentially interacting population-level factors which require examination prior to targeted intervention development.
Methods: A retrospective cross-sectional analysis of electronic health records in Liverpool used meta-analysis to examine associations between vaccine uptake and deprivation, sex, age group, and ethnicity.
Results: Overall prevalence rates for vaccination between September 2022 and March 2023 were 25·8 % (95 % CI: 23·8 % to 28·0 %). All factors were associated with uptake, which was lowest in: more deprived General Practices (family doctor; primary care physician), males, children aged 0–1, and in people identifying as Any Other ethnicity. Individuals identifying as White or Mixed/Multiple ethnic groups were most likely to be vaccinated, while those identifying as Black, Black British, Caribbean or African, and Asian or Asian British had lower uptake. Similarly, rates were higher in individuals aged 2–3, 4–10, and 65+ than 16–64, while no difference was found between the latter group and ages 11–15. Deprivation did not interact with age, sex, or ethnicity.
Conclusion: These findings support that deprivation, age, sex, and ethnicity influence influenza vaccine uptake, and that they do so uniquely in Liverpool. While deprivation did not interact with other characteristics, this may be due to the impact of inequality (large deprivation gap between richer and poorer areas) on the whole city, as this is as a social stressor that can impair health outcomes for all, not just those in more deprived areas. Future work should investigate experiences of people in areas with lower uptake in Liverpool, to understand potential barriers and enable targeted intervention.

1. Introduction

Seasonal influenza is an acute respiratory epidemic infection, typically occurring in colder seasons.[1] While primarily respiratory, influenza can affect other systems, such as the cardiovascular and nervous systems, [1] and worldwide there are an estimated yearly one billion cases, with respiratory complications alone causing 290,000–650,000 deaths [2]. Moreover, in the UK in 2022/2023, influenza activity was higher than in 2021/2022 [3]. Influenza-related mortality was estimated to be around 15,000 deaths in England during this period, around 200 % higher than the average of the previous four years [4]. Estimates by the International Longevity Centre – UK, suggest that influenza vaccination prevents between 200,000–600,000 cases and 6000–10,000 premature deaths yearly in England (primarily those aged 65+, but also those with underlying health conditions, and children) [5]. Furthermore, vaccinations protect both the receivers, and support development of herd immunity, which was not modelled in the above scenarios, suggesting that actual benefits are higher. In the UK, eligible individuals receive the flu vaccine for free at various locations including General Practice surgeries (GP; local primary healthcare practices/family doctor), pharmacies, maternity services, community clinics, and schools. Eligibility and access information is communicated by these services through various mediums, and via public health campaigns.

While vaccination reduces cases and deaths, low uptake of influenza

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vaccines, highlighted during the 2009/2010 influenza pandemic, when <50 % of the expected uptake was reported globally, is problematic [6]. Vaccine hesitance is defined by the World Health Organisation Strategic Advisory Group of Experts on Immunisation as refusal or delay in acceptance of vaccination, regardless of availability, [7] and its examination is important to understand (and ultimately reduce) barriers to uptake. Prior review-level research indicates vaccine uptake is influenced by various sociodemographic factors such as age, sex, ethnicity, pregnancy, employment, and education, as well as contextual factors, such as accessibility (including convenience, prioritisation of certain groups, knowledge of how to access, time taken to access, and number of sites offering the vaccine) and cost [8]. Regarding cost, this review was in the context of global healthcare, in which the influenza vaccine is not always free. In the UK, the vaccine is free for eligible individuals, though there may be indirect costs relating to transportation or time off work [9]. Regarding influenza vaccination, analysis of national household surveys of 11 European countries between 2001/2002 and 2007/2008 found that gender, education, household size, household income, and population size of living area, all significantly predicted uptake, though did so differently across countries [10]. Specifically, within the UK, being male, and living in a smaller or low-income household, associated with higher likelihood of influenza vaccination. However, inter and intra-country differences are not always consistent. For example, in two more recent studies in England, one studied health records and found Black at-risk patients less likely to receive the vaccine, [11] while another examined GP data and found people aged 16–64 in a clinical risk group from areas with high "Black or Minority Ethnic" populations were more likely to receive the vaccine [12]. Similarly, the health records study used an age-stratified analysis (ages 18–64 vs. 65+), and found higher vaccination in females (aged 18–64), [11] differing from the earlier national household survey study [10].

Inconsistency regarding how sociodemographic factors influence vaccine hesitance in the UK may be due to complex interactions between factors (intersectionality). Higher vaccination has been found in females aged 18–64, though no sex differences in 65+ year olds [11]. In the same study, the impact of ethnicity varied between ages, as in 18–64-year-olds rates were higher in White compared to Black patients, and highest in Asian patients, while rates were lowest across both age groups in Black patients [11]. In another study, the gap between sexes was wider in minority ethnic populations [13]. Furthermore, vaccination in different age groups seems to vary by deprivation of their local area, with lower rates in deprived areas for 2–4-year-olds, and 65+ year-olds, but no difference between areas in 16–64-year-olds in a clinical risk group [12]. This aligns with another finding that in patients aged 65+, greater deprivation associates with lower uptake [11]. Overall, these UK findings are consistent with those from the US that intersectionality of factors such as age, ethnicity, disability, or sexual orientation, impacts influenza and COVID-19 vaccination [14].

Crucially, such interactions may exacerbate health inequalities. As an example, Indigenous populations in Canada are disproportionately likely to experience cardiovascular disease morbidity/mortality, due to interactions between factors such as deprivation, higher prevalence of mental health and substance use disorders, undermining of a traditional healthy lifestyle, and barriers to accessing services, all of which will be experienced differently between sexes, ages and groups/geographical locations [15]. This suggests that considering uptake and predictors across/between entire countries may be somewhat misleading, as it could hide variation in localised populations that require intervention. It is therefore necessary to look at factors associated with uptake in smaller localised populations, enabling targeting of groups with lower uptake to investigate barriers/facilitators to vaccination.

The current study is conducted in Liverpool, a diverse city, in which 22·7 % of the population in the 2021 UK Census [16] identified as non-White English, Welsh, Scottish, Northern Irish or British (6·7 % identified as Other White, 5·8 % as Asian, 3·5 % as Black, 3·5 % as Mixed/Multiple, and 3·3 % as Any Other ethnic group (including Arab)). Of the 316 local authorities in England, Liverpool is the fourth most income-deprived (23·5 % of its population in 2019) [17]. Liverpool also has the 11th largest deprivation gap between neighbourhoods (50·4 percentage points between the most and least deprived), therefore likely great internal disparities. In the larger geographical area of Merseyside, which includes Liverpool, deprivation associated with hospitalisations for influenza-associated illnesses (more so in ages 15–39, 40–64, and 65+) and vaccine uptake [18]. Furthermore, in Manchester, a city comparable to Liverpool in diversity and deprivation, [16,17] wide inequalities have been found in both COVID-19 and influenza vaccinations for most ethnic groups compared to White British individuals, with particularly low uptake of COVID-19 vaccine in those identifying as Arab, or Black or Black British groups, and of influenza vaccine uptake in White and Black Caribbean, or White and Black African groups [13]. Interestingly, influenza vaccine uptake in Manchester was highest in those identifying as Bangladeshi, or 'other ethnic group'.

Additionally, pandemics can influence vaccine attitudes, as flu vaccine uptake correlates with COVID-19 vaccine attitudes [19]. Indeed, the gap in influenza vaccine uptake between the most and least deprived areas in Manchester (which has a similar deprivation gap to Liverpool)[17], has widened since COVID-19 in adults aged 65+ and children aged 4–9 (though decreased in children aged 2–3) [20]. Therefore, alongside studying local populations, it is important to examine factors associated with low influenza vaccine uptake *since* the COVID-19 pandemic, as experiences during this could have created a new pattern of uptake. The current study aims to identify sociodemographic factors associated with lower influenza vaccine uptake in GPs in Liverpool during a single UK flu season (September to March), to enable targeting for the winter influenza vaccination outreach.

2. Methods

2.1. Study design and setting

A cross-sectional analysis was conducted on anonymised Liverpool (UK) GP electronic health records in NHS Cheshire and Merseyside Integrated Care Board (ICB). The data was shared under the Liverpool Screening and Immunisation Oversight Group (SIOG) data sharing agreement. The Business Intelligence Team for the ICB provided summary data for routinely collected patient demographic data and influenza vaccination status (had influenza vaccine/did not have influenza vaccine) in the 2022–2023 influenza season (September 2022–March 2023), via data export from Egton Medical Information Systems.

2.2. Participants

Data was aggregated by the Business Intelligence Team according to GP surgery. Practices were excluded if they opted out of data sharing ($N = 3$) resulting in data being shared by 81 practices in total. All participants registered with a GP in Liverpool were included, regardless of age, which thus ranged from 0 to 100 years.

2.3. Procedures

After approval by the NHS Liverpool SIOG, which deemed the study exempt from requiring consent, anonymised summary data for influenza vaccinated and unvaccinated patients from each participating practice from 1st September 2022 – 31st March 2023 were extracted by NHS Liverpool ICB Business Intelligence Team into 64 separate CSV Microsoft Excel files and sent to a secure folder belonging to the principal investigator (CM). Variables extracted were: Sex; Age; Ethnicity; Postcode of registered GP practice; Lower Layer Super Output Area (LSOA) of the Indices of Multiple Deprivation (IMD; 2019) for patient residential address. The IMD is an overall relative measure of deprivation for small geographic areas (LSOAs), combining information from across seven broad domains: Income; Employment; Health Deprivation and

Disability; Education, Skills Training; Crime; Barriers to Housing and Services; Living Environment. LSOAs are ranked from most to least deprived, and grouped into deciles, with the 10 % most deprived in decile one, and the 10 % least deprived in decile ten. Data was stored on a secure server only accessible to the research team and downloaded to a password protected network drive at LJMU.

2.4. Statistical analysis

Prevalence meta-analysis was conducted to determine the pooled prevalence rates of vaccination status, using the 'metafor', 'tidyverse' and 'ggplot2' packages in R Studio [21–23]. When analysing moderation by demographic factors, multilevel meta-analysis was used to account for variance within GP surgeries, [24] using random effects models with a restricted maximum likelihood estimator. Logit transformed proportions were calculated in line with recommendations, [25] before back transformation for interpretation. To determine heterogeneity, I^2 is reported.

Moderation effects were examined by IMD of the GP surgery and ethnicity, age, and sex. Ethnicity was recoded according to the UK 2021 Census categories, though with White collapsed into one category (therefore categories assessed were a) Asian, Asian British or Asian Welsh, b) Black, Black British, Black Welsh, Caribbean or African, c) Mixed or Multiple ethnic groups, d) White, and e) Any Other ethnicity). For age, we used ages 0–1; 2–3; 4–10; 11–15; 16–64; 65+, in accordance with age groupings recommended for vaccination in the UK, in which ages 2–3, 4–10, and ages 65+ were recommended in the 2022–2023 flu season. Ages 0–1, 11–15, and 16–64 were also included in the current study, to enable comparison in uptake between ages that were and were not recommended for vaccination [26].

IMD scores based on GP surgeries ranged from 1 to 8, however a large percentage of these scores were 1 ($N = 52$, 64 %). As such IMD was treated as both a continuous and a binary variable (IMD 1 vs. IMD 2–8), in line with previous research [27].

2.5. Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

3. Results

In total, summary data was shared for 553,678 people (282,462 male). See Table 1 for summary demographic data for participants.

Across 81 GP surgeries, the pooled prevalence rate of vaccination was 0·258 [95 % CI: 0·238 to 0·280], $I^2 = 99$ %, tau2 = 0·263. The largest prevalence rate was 0·551 [95 % CI: 0·539 to 0·564] and the smallest was 0·031 [95 % CI: 0·030; 0·033. Removal of either did not substantially influence the pooled rate (range 0·255 to 0·264).

There was a significant association between prevalence rates of vaccination and GP IMD scores (B = 0·106 [95 % CI: 0·040 to 0·172], p = ·002: see Fig. 1), which explained approximately 10·2 % of heterogeneity in rates ($R^2 = 10{\cdot}2$). Examination of IMD as a binary predictor demonstrated that GP surgeries with the highest deprivation (IMD = 1: 0·231 [95 % CI: 0·208 to 0·256) was associated with significantly lower vaccination prevalence than less deprived surgeries (IMD2–8: 0·314 [95 % CI: 0·280 to 0·351]).

There was a significant difference across age groups (X^2 [5] = 5631, p < ·001). Compared to age 16–64 (0·163 [95 % CI: 0·152 to 0·175]), there was a significantly lower prevalence in age 0–1 (0·006 [95 % CI: 0·005 to 0·008]: p < ·001), a significantly higher prevalence in age 2–3 (0·188 [95 % CI: 0·170 to 0·208]: p < ·001), ages 4–10 (0·311 [95 % CI: 0·284 to 0·339]: p < ·001) and age 65+ (0·728 [95 % CI: 0·712 to 0·744]: p < ·001). There was no significant difference for age 11–15 (0·0169 [95 % CI: 0·152 to 0·187]: p = ·306). See Fig. 2.

There were no significant interactions between age group and IMD

Table 1
Descriptives of variables of interest: deprivation of GP surgery, and patient age, sex, and ethnicity.

Deprivation of GP Surgery*	N (%)
IMD 1	52 (65·0 %)
IMD 2	8 (10·0 %)
IMD 3	2 (2·5 %)
IMD 4	6 (7·5 %)
IMD 5	11 (13·8 %)
IMD 8	1 (1·3 %)
Age of patients	N (%)
0–1	9846 (1·8 %)
2–3	10,628 (1·9 %)
4–10	41,415 (7·5 %)
11–15	28,943 (5·2 %)
16–64	383,410 (69·3 %)
65+	79,156 (14·3 %)
Sex of patients	N (%)
Male	282,462 (51·0 %)
Female	271,216 (49·0 %)
Ethnicity of patients	N (%)
Asian	46,491 (8·6 %)
Black	20,415 (3·7 %)
Mixed	61,866 (11·1 %)
Other	16,600 (3·0 %)
White	333,556 (60·2 %)
Unknown	74,808 (13·5 %)

* *Note – IMD for one GP surgery was not provided.*

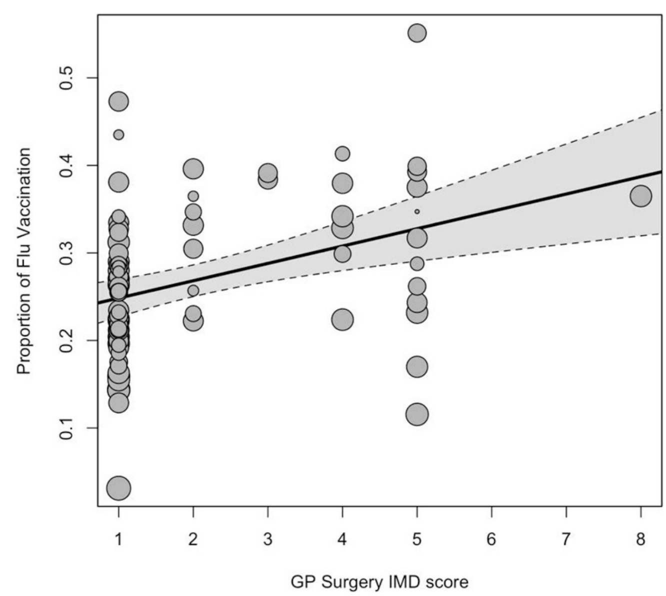

Fig. 1. Scatter plot showing the relationship between prevalence of flu vaccination in individual GP surgeries against the IMD for that surgery.

(p > ·054).

There was a significant difference in prevalence rates between sexes (X^2 [1] = 649, p < ·001). Males had significantly lower prevalence rates (0·235 [95 % CI: 0·218 to 0·253]) than females (0·283 [95 % CI: 0·264 to 0·302]). See Fig. 3.

There was no interaction between sex and IMD score as either raw score or binary (ps > ·090).

Prevalence rates were calculated for each ethnic group. There was a significant difference in these prevalence rates (X^2 [4] = 131·24, *p* < ·001). Compared to White ethnicity (0·291 [95 % CI: 0·271 to 0·311]), Black, Black British, Caribbean or African ethnicity had significantly lower vaccination rates (0.167 [95 % CI: 0·154 to 0·181]: p < ·001). Asian or Asian British also had significantly lower vaccination rates (0·213 [95 % CI: 0·194 to 0·234]: p < ·001) and Other ethnic grouping

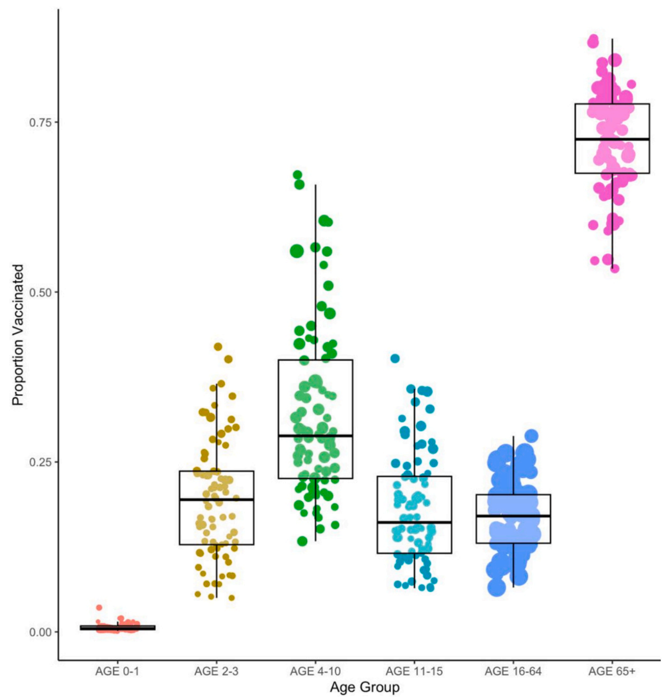

Fig. 2. Prevalence of Flu vaccination across GP surgeries by age groups. Size of individual points is relative to the size of that sample across surgeries.

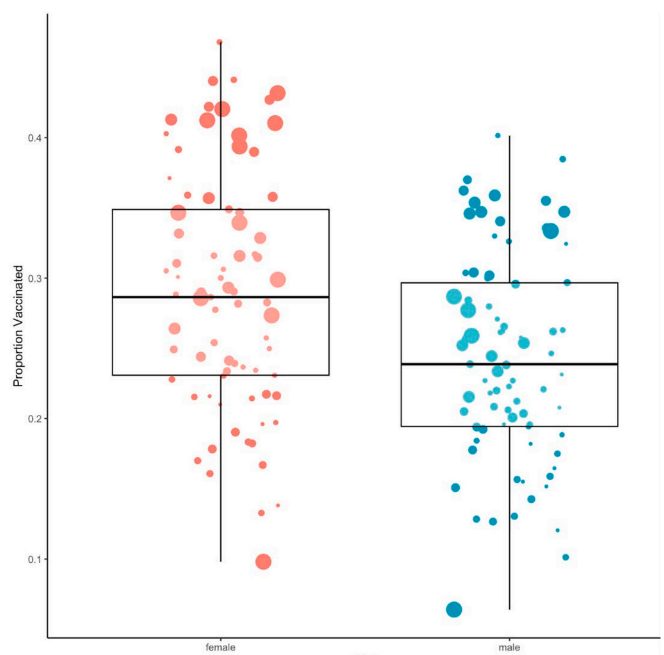

Fig. 3. Prevalence of Flu vaccination across GP surgeries by sex. Size of individual points is relative to the size of that sample across surgeries.

also had significantly lower vaccination rates (0.137 [95 % CI: 0.124 to 0·151]: p < ·001). There was no significant difference with Mixed or Multiple ethnic groups (0·284 [95 % CI: 0·231 to 0·343], p = ·968. Black, Black British, Caribbean or African ethnicity (p = ·040), Asian or Asian British (p < ·001) and Mixed or Multiple ethnicity (p < ·001) had significantly greater prevalence rates than Any Other ethnicities. See Fig. 4.

Inclusion of GP surgery IMD as a raw or binary score did not lead to any interactions with ethnic groups (ps > ·073).

4. Discussion

This paper aimed to identify sociodemographic factors associated with lower influenza vaccine uptake in GPs in Liverpool, UK. The pooled prevalence rate of vaccination was 25·8 %, ranging from 3·1 % to 55·1 % across surgeries, and GP deprivation (IMD) explained 10·2 % of the overall variance. All factors (deprivation, sex, age, and ethnicity) impacted prevalence, which was lowest in: more deprived GPs, males, children aged 0–1, and individuals identifying as Any Other ethnicities. Individuals identifying as White or Mixed/Multiple ethnic groups were most likely to be vaccinated, while those identifying as Black, Black British, Caribbean or African, and Asian or Asian British had a lower uptake. Rates were higher in individuals aged 2–3, 4–10, and 65+ than ages 16–64, while no difference was found between the latter group and those aged 11–15. Deprivation did not interact with any other factor.

When compared to national rates during the same influenza season for people registered at GPs in England, [28] overall prevalence in Liverpool is low (25·8 % (95 % CI: 23·8 % to 28·0 %) compared to 33·8 %). Similarly, compared to national data regarding age (ages 2–3, 16–64, and 65+), prevalence is also lower in Liverpool, though the same overall pattern is found. Specifically, prevalence is highest in 65+ (72·8 % in Liverpool vs. 79·9 % nationally), lower in 2–3-year-olds (18·8 % in Liverpool vs. 43·7 % nationally), and lower still for 16–64-year-olds (16·3 % in Liverpool vs. 20·6 % nationally). Additionally, while sex data cannot be compared directly due to national data being stratified by age and risk, the national data does show higher prevalence in at-risk females aged 16–64. Likewise, national ethnicity data cannot be directly compared, but suggests similar patterns, in which individuals who identified as White British had the highest uptake in at-risk 16–64-year-olds and those aged 65+, though in pregnant women the highest uptake was in “Other ethnic groups – Chinese”. Furthermore, lower than average national uptake in at-risk 16–64-year-olds, 65+ year olds and pregnant women, was found in individuals identifying within the Black and Mixed Black groups, indicating vulnerabilities consistent with the current study. Therefore, compared to national influenza vaccination uptake, Liverpool demonstrates similar patterns, but lower prevalence, possibly due to deprivation being a predictor, in current and previous work [10,12,18,20].

Interestingly, these findings both complement and contradict existing UK literature. For example, lower uptake in males is consistent with one previous study, [11] but not another [10]. Lower deprivation-related uptake is inconsistent with the prior finding of higher uptake in lower income households, [10] but consistent with the finding that lower deprivation predicts lower uptake [11,12,18]. Similarly, that deprivation explained 10.2 % of variance, but did not interact with age is inconsistent with two studies, [11,12] which found deprivation associates with lower uptake only in certain ages (2–4[11] and 65+) [11,12]. Furthermore, deprivation in these studies was measured similarly to the current study, using IMD of practice, therefore would be expected to find comparable results, though one also used IMD of patient, which displayed the age interaction [11]. Importantly, cost has been previously noted as a barrier to vaccination, [8] and while the influenza vaccine is free to those eligible, indirect costs (such as transportation or time off work) likely contribute to patients’ perceived cost-benefit of the vaccine, [9] and thus may relate to the current finding of lower uptake in more deprived GP practices.

Furthermore, the finding that individuals who identify as Black, Black British, Caribbean or African, had lower uptake (thereby demonstrating health inequalities in Liverpool relating to influenza) is consistent with one previous finding low uptake in Black patients, [11] but not with another of higher uptake in 16–64-year-olds in areas with larger “Black or Minority Ethnic” populations [12]. Additionally, in the current study, White and Mixed/Multiple ethnicity groups had the highest uptake, with Asian patients less likely to be vaccinated, while in a prior study, Asian patients aged 16–64 had the highest uptake [12]. Moreover, that in the current study, Mixed/Multiple ethnicity had high

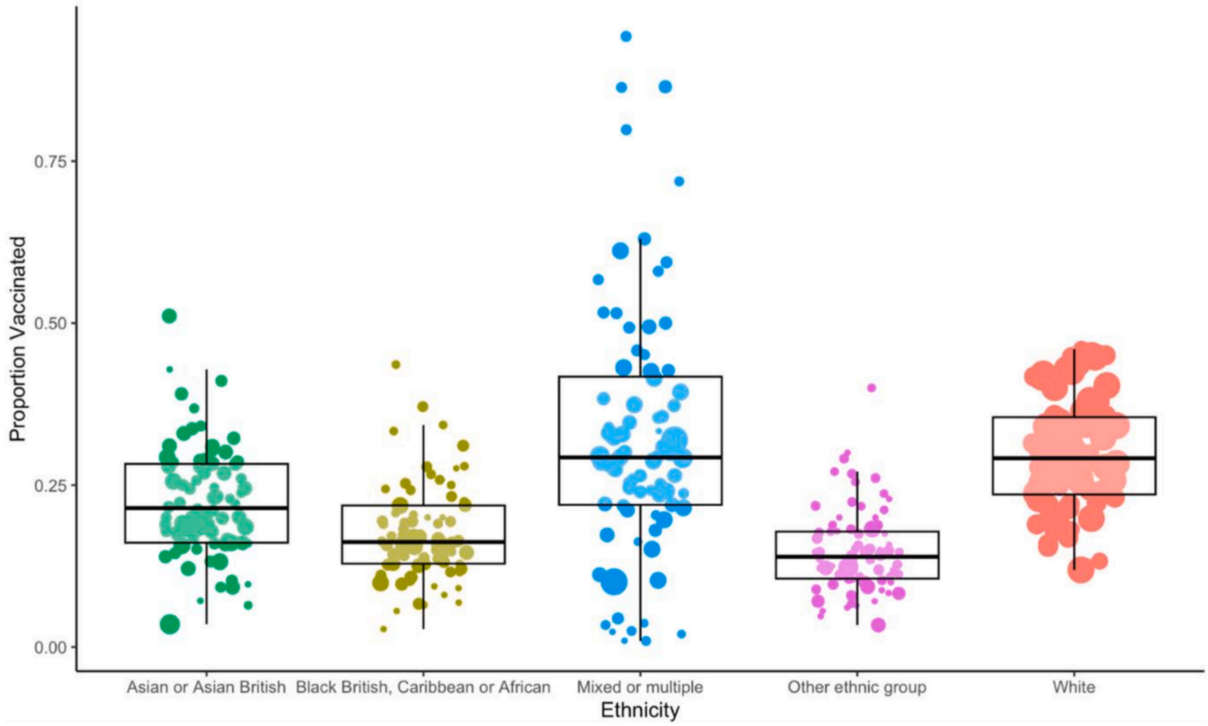

Fig. 4. Prevalence of Flu vaccination across GP surgeries by ethnicity. Size of individual points is relative to the size of that sample across surgeries.

uptake, and Any Other ethnicities had the lowest uptake, suggests that methods used previously to collapse these two groups together, [11] may be problematic. Interestingly, lower uptake here within those identifying as Black, Black British, Caribbean or African is generally consistent with findings in Manchester, though low uptake here in Any Other ethnicities is contradictory [13]. That deprivation did not interact with ethnicity was unexpected, given the clear intersectionality demonstrated in Manchester [13]. Regarding uptake among age groups in the current study, this is generally consistent with expectations, as the ages with higher uptake (2–3, 4–10, and 65+) were recommended for vaccination during the 2022–2023 influenza season, while those with lower uptake, ages 0–1, 11–15, and 16–64, were not (though 11–15-year-olds have been added to the 2023–2024 influenza immunisation programme) [26].

Overall, these findings support that sociodemographic characteristics have an impact on influenza vaccine uptake, and that their pattern of influence is unique to a location. However, it is surprising that there was no interaction between deprivation and other factors. One possibility is that the characteristics assessed, age, sex, and ethnicity, are such entrenched predictors of health behaviours in the Liverpool city region, that even the support/advantages of a less deprived area does not reduce their impact. Indeed, health outcomes are poorest in societies where income differences are largest, possibly driven by these societies not only having higher levels of deprivation, but by inequality being socially corrosive: lowering trust, social cohesion, involvement in community life, and increasing violence, which all in turn impact physiological stress and health-related behaviour, at both ends of the social status scale [27]. This phenomenon is particularly evident in health outcomes that are more prevalent when social status is low, including respiratory diseases [29]. Therefore, with deprivation an important predictor in the current study, and with Liverpool having such a large deprivation gap, it is possible that these results relate to the impact of inequality as experienced by the whole city.

Regardless, vaccine hesitance is a growing issue across a variety of conditions, and in 2019, was listed as one of the top ten global health threats [30]. Furthermore, within this, influenza is unique, as it requires individuals to undergo repeated, seasonal vaccination. Systematic reviews of global research find that individuals cite a variety of reasons for influenza vaccine hesitance, including concerns about safety and effectiveness, lack of trust in healthcare, misinformation or lack of information, and low worry and perceived risk/severity of influenza, [6,8] in addition to cultural reasons such as expectations around racial fairness, prior experience of discrimination within healthcare settings, trust in natural remedies and prayer/God, and concerns about halal status of vaccines and impact on fertility [31]. It is possible that individuals with the demographic characteristics associated here with lower uptake, may be more likely to experience these barriers. For example, individuals from areas with higher levels of deprivation may complete fewer years of education, thus making them more vulnerable to misinformation [32]. Similarly, individuals from ethnically minoritised groups may experience discrimination in healthcare settings, leading to lowered trust and concerns about racial fairness [33]. Additionally, since the COVID-19 pandemic, vaccine fatigue has been demonstrated as impacting influenza vaccine intentions, and new drivers of this have appeared, such as political affiliation [19]. The current paper identifies sociodemographic factors that influence vaccine uptake in Liverpool. Future work should investigate reasons for hesitance in Liverpool, as like patterns of uptake, experiences/views are likely to be unique to the city, with priority ideally given to groups that have been identified as low uptake.

The current study was not without limitations. Due to restrictions within the data received, it was not possible to specifically examine individuals in clinical risk groups (except for age group), so while the analysis highlights factors with disproportionate influence on vaccine uptake, it is not clear how risk status plays a role. However, higher uptake in those aged 65+, indicates that risk status as determined by age, did support uptake. Additionally, due to limitations in summary data as opposed to individual patient level data, it was not possible to examine multilevel modelling of intersectionality between all factors. Furthermore, deprivation was measured at the GP level, rather than also at the individual level, which is a limitation given prior indications of interactions between patient level IMD and age [11]. Moreover, there was extensive variability in the coding of ethnicity in the raw data prior to recoding, which reduces the certainty of result interpretation, and indicates the importance of action to improve ethnicity data recording at the source. Finally, study results may not be generalisable to areas with a different demographic distribution. However, England and Wales Census data shows that the majority (74·4 %) of people identify as White British, 6·2 % as Other White, 9·3 % as Asian, 4·0 % as Black, 2·9 % as Mixed/Multiple and 2·1 % as Any Other ethnic group (including Arab), so the profile of Liverpool is not dissimilar to elsewhere in the UK [34].

In conclusion, Liverpool is a diverse and multicultural city, with its own unique population, and high levels of deprivation and inequality. It is unsurprising therefore, that the city has a unique pattern of influenza vaccine uptake, which is lower than the national average. Deprivation, age, sex, and ethnicity, all associated with uptake, with the lowest uptake found in GP surgeries with high deprivation, and in patients not recommended for a vaccine based on age, or who identified as male, or as Any Other ethnicity. The lack of an interaction between deprivation and other factors likely reflects the impact of inequality on Liverpool as a whole, as a social stressor. Future research should now consider the reasons, experiences, and views behind vaccine hesitance/acceptance within Liverpool, which likely contribute to these patterns of uptake, and could be used to guide intervention.

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CRediT authorship contribution statement

Anna Powell: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis. **Andrew Jones:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Marie-Claire Van Hout:** Methodology, Funding acquisition, Conceptualization. **Catharine Montgomery:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Catharine Montgomery reports financial support was provided by CSL Seqirus. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data and analysis code can be found on osf.io using link in manuscript.

References

[1] Moghadami M. A narrative review of influenza: a seasonal and pandemic disease. Iran J Med Sci 2017;42(1):2–13. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5337761/.

[2] World Health Organisation. Global influenza strategy 2019 to 2030. Prevent Control Prepare 2019:2–3. https://iris.who.int/bitstream/handle/10665/311184/9789241515320-eng.pdf?sequence=18 [accessed 26th January 2024].

[3] UK Health Security Agency. Seasonal influenza vaccine uptake in GP patients: monthly data, 2022 to 2023. 2023. https://www.gov.uk/government/statistics/seasonal-influenza-vaccine-uptake-in-gp-patients-monthly-data-2022-to-2023. accessed 29th January 2024.

[4] Andrews N, Clare T, Sinnathamby M, Watson C. Estimating the contribution of influenza, COVID-19 and extreme cold weather to excess mortality – A working paper. https://khub.net/documents/135939561/174090236/Contribution+of+influenza%2C+COVID-19+and+cold+weather+to+excess+mortality+winter+of+2022_23+using+adapted+FluMOMO+model.pdf/dd36fbb9-c7fe-546e-00f2-41ec268b6526; 2023.

[5] Franklin B, Hochlaf D. An Economic analysis of Flu vaccination. In: The international longevity centre - UK; 2018. https://ilcuk.org.uk/wp-content/uploads/2018/07/An_economic_analysis_of_flu_vaccination_-_ILC-UK.pdf. accessed 26th January 2024.

[6] Schmid P, Rauber D, Betsch C, Lidolt G, Denker M-L. Barriers of influenza vaccination intention and behavior–a systematic review of influenza vaccine hesitancy, 2005–2016. PLoS One 2017;12(1):e0170550. https://doi.org/10.1371/journal.pone.0170550.

[7] MacDonald NE. Vaccine hesitancy: definition, scope and determinants. Vaccine 2015;33(34):4161–4. https://doi.org/10.1016/j.vaccine.2015.04.036.

[8] Truong J, Bakshi S, Wasim A, Ahmad M, Majid U. What factors promote vaccine hesitancy or acceptance during pandemics? A systematic review and thematic analysis. Health Promot Int 2022;37(1):daab105. https://doi.org/10.1093/heapro/daab105.

[9] Lee BY, Bacom KM, Donohue JM, Wiringa AE, Bailey RR, Zimmerman RK. From the patient perspective: the economic value of seasonal and H1N1 influenza vaccination. Vaccine 2011;29(11):2149–58. https://doi.org/10.1016/j.vaccine.2010.12.078.

[10] Endrich MM, Blank PR, Szucs TD. Influenza vaccination uptake and socioeconomic determinants in 11 European countries. Vaccine 2009;27(30):4018–24. https://doi.org/10.1016/j.vaccine.2009.04.029.

[11] Loiacono MM, Mahmud SM, Chit A, et al. Patient and practice level factors associated with seasonal influenza vaccine uptake among at-risk adults in England, 2011 to 2016: an age-stratified retrospective cohort study. Vaccine: X 2020;4:100054. https://doi.org/10.1016/j.jvacx.2020.100054.

[12] 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):3231–8. https://doi.org/10.1016/j.vaccine.2018.04.074.

[13] Watkinson RE, Williams R, Gillibrand S, Sanders C, Sutton M. Ethnic inequalities in COVID-19 vaccine uptake and comparison to seasonal influenza vaccine uptake in greater Manchester, UK: a cohort study. PLoS Med 2022;19(3):e1003932. https://doi.org/10.1371/journal.pmed.1003932.

[14] Breaux RD, Rooks RN. The intersectional importance of race/ethnicity, disability, and age in flu vaccine uptake for U.S. adults. SSM – Population Health 2022;19:101211. https://doi.org/10.1016/j.ssmph.2022.101211.

[15] Kapilashrami A, Hankivsky O. Intersectionality and why it matters to global health. Lancet 2018;391(10140):2589–91. https://doi.org/10.1016/S0140-6736(18)31431-4.

[16] Office for National Statistics. Ethnic group. 2022. England and Wales: Census; 2021. https://www.ons.gov.uk/peoplepopulationandcommunity/culturalidentity/ethnicity/bulletins/ethnicgroupenglandandwales/census2021#ethnic-groups-in-england-and-wales [accessed 26th January 2024].

[17] Office for National Statistics. Exploring local income deprivation: A detailed picture of disparities within English local authorities to a neighbourhood level. 2021. https://www.ons.gov.uk/visualisations/dvc1371/#/E07000223. accessed 26th January 2024.

[18] Hungerford D, Ibarz-Pavon A, Cleary P, French N. Influenza-associated hospitalisation, vaccine uptake and socioeconomic deprivation in an English city region: an ecological study. BMJ Open 2018;8(12). https://doi.org/10.1136/bmjopen-2018-023275.

[19] Skyles TJ, Stevens HP, Obray AM, et al. Changes in attitudes and barriers to seasonal influenza vaccination from 2007 to 2023. J Community Health 2023. https://doi.org/10.1007/s10900-023-01277-7.

[20] Watkinson RE, Williams R, Gillibrand S, Munford L, Sutton M. Evaluating socioeconomic inequalities in influenza vaccine uptake during the COVID-19 pandemic: a cohort study in greater Manchester, England. PLoS Med 2023;20(9):e1004289. https://doi.org/10.1371/journal.pmed.1004289.

[21] Viechtbauer W. Conducting meta-analyses in R with the metafor package. J Stat Softw 2010;36:1–48. https://doi.org/10.18637/jss.v036.i03.

[22] Wickham H, Averick M, Bryan J, et al. Welcome to the Tidyverse. J Open Source Software 2019;4(43):1689. https://doi.org/10.21105/joss.01686.

[23] Wickham H. Ggplot2: Elegant graphics for data analysis. New York: Springer-Verlag; 2016. https://doi.org/10.1007/978-3-319-24277-4.

[24] Moeyaert M, Ugille M, Natasha Beretvas S, Ferron J, Bunuan R, Van den Noortgate W. Methods for dealing with multiple outcomes in meta-analysis: a comparison between averaging effect sizes, robust variance estimation and

multilevel meta-analysis. Int J Soc Res Methodol 2017;20(6):559–72. https://doi.org/10.1080/13645579.2016.1252189.

[25] Barker TH, Migliavaca CB, Stein C, et al. Conducting proportional meta-analysis in different types of systematic reviews: a guide for synthesisers of evidence. BMC Med Res Methodol 2021;21(1):189. https://doi.org/10.1186/s12874-021-01381-z.

[26] UK Health Security Agency. National flu immunisation programme 2023 to 2024 letter. 2023. https://www.gov.uk/government/publications/national-flu-immunisation-programme-plan/national-flu-immunisation-programme-2023-to-2024-letter#cohort-eligibility. accessed 26th January 2024.

[27] Montgomery C, Schoetensack C, Saini P, Owens L, Van Ginneken N, Rice M, et al. Prevalence and incidence of alcohol dependence: cross-sectional primary care analysis in Liverpool, UK. BMJ Open 2023;13(4):e071024. https://doi.org/10.1136/bmjopen-2022-071024.

[28] UK Health Security Agency. Seasonal influenza vaccine uptake in GP patients: Winter season 2022 to 2023, https://assets.publishing.service.gov.uk/media/64d21e33a4045e000da84be5/GP-patients-flu-annual-report-2022-2023.pdf; 2023. accessed 29th January 2024.

[29] Pickett KE, Wilkinson RG. Income inequality and health: a causal review. Soc Sci Med 2015;128:316–26. https://doi.org/10.1016/j.socscimed.2014.12.031.

[30] World Health Organisation. Ten threats to global health in 2019. 2019. https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019. accessed 26th January 2024.

[31] Kumar S, Shah Z, Garfield S. Causes of vaccine hesitancy in adults for the influenza and Covid-19 vaccines: a systematic literature review. Vaccines 2022;10(9):1518. https://doi.org/10.3390/vaccines10091518.

[32] Reis M, Michalski N, Bartig S, et al. Reconsidering inequalities in COVID-19 vaccine uptake in Germany: a spatiotemporal analysis combining indiviudal educational level and area-level socioeconomic deprivation. Sci Rep 2024;14(1):23904. https://doi.org/10.1038/s41598-024-75273-9.

[33] Paul E, Fancourt D, Razai M. Racial discrimination, low trust in the health system and COVID-19 vaccine uptake: a longitudinal observation study of 633 adults from ethnic minority groups. J R Soc Med 2022;115(11):439–47. https://doi.org/10.1177/01410768221095241.

[34] Office for National Statistics. Population of England and Wales by ethnicity. GOV.UK. 2022 https://www.ethnicity-facts-figures.service.gov.uk/uk-population-by-ethnicity [accessed 28th January 2025].