Covid-SMART Asymptomatic Testing Pilot in Liverpool City Region: Quantitative Evaluation

Institute of Population Health, University of Liverpool

for Liverpool City Region Covid-SMART Gold Command

20th December 2021
(updated 28th February 2022)

This Report

This is a response from the Institute of Population Health at the University of Liverpool to a request from the Liverpool City Region (LCR) Covid-SMART Gold Command to provide a quantitative evaluation report of the roll-out of asymptomatic SARS-CoV-2 antigen testing in the region since December 2020.

The analysis was led by Mark Green, David Hughes and Dimitrios Charalampopoulos, with inputs from Iain Buchan (editor), Ben Barr, Xingna Zhang, Marta García-Fiñana and others across the Departments of Public Health Policy and Systems and Health Data Science at the University of Liverpool. This work was also made possible by the collaboration of Public Health teams across Cheshire & Merseyside, including Emer Coffey, Lucy Marsden and Matt Ashton running the SMART-release pilot. We are also grateful for comments on drafts of this report by the DHSC Testing Initiatives Evaluation Board.

The report aims to describe the measurable effects of the LCR Covid-SMART service roll-out (~one month ahead of the rest of England) and estimate its impacts to help local authority officials and policymakers with community approaches to Covid-19 testing and future pandemic preparedness.

This study has been funded by the Department of Health and Social Care (DHSC) via the LCR Covid-SMART Gold Command, and by the National Institute for Health Research (NIHR) Health Protection Research Unit in Gastrointestinal Infections, a partnership between Public Health England (now UK Health Security Agency, UKHSA), the University of Liverpool and the University of Warwick. Grant No: NIHR ref NIHR200910. The views expressed are those of the authors and not necessarily those of the NIHR, UKHSA or DHSC.

Contents

Executive summary

On 3rd December 2020 “community testing” for SARS-CoV-2 antigen among people without symptoms of Covid-19 was expanded from Liverpool City to the wider Liverpool City Region (LCR). Between 3rd December 2020 and 31st July 2021, 668,243 (45%) LCR residents aged five years and older had a registered result from a SARS-CoV-2 rapid antigen lateral flow test (LFT) performed at a testing centre or via a universal access home test kit.

Fifty eight percent of all registered LFTs were taken at home. LFT uptake varied across the six local authorities of the region, ranging from 40% in Sefton to 50% in Liverpool. Socio-demographic inequalities posed a challenge. Uptake was lowest among young children (5-9 years) and older people (70+, particularly 80+ years), and in deprived areas, areas with a higher proportion of students, and areas with fewer digital resources or lower digital literacy.

Overall, 27,496 individuals declaring no symptoms were recorded as testing positive; 70% of them had a confirmatory PCR within two days. The average LFT positivity for the whole region was 0.9%, ranging from 0.7% in Halton and Wirral to just above 1.1% in Knowsley and Liverpool. Positivity was higher among males, those aged 15-34 years, people of Black, Mixed and Other ethnicity, and those living in deprived neighbourhoods.

Of the individuals with a positive LFT result, 3,629 were children aged 11–18 years, among whom lower uptake of confirmatory PCR was associated with higher deprivation, older age, and non-White ethnic background.

Implementation of daily LFTs as an alternative to quarantine for key workers in Liverpool (Test-to-Release scheme) was useful in sustaining essential services, saving 8,292 key worker workdays among those taking part in the pilot, with 71% of those eligible opting to participate.

In the initial month, when LCR had deployed community testing ahead of other regions, we estimated the impact was a 32% reduction (95% CI: -39% to -22%) in Covid-19 hospital admissions compared with other regions. We used synthetic control methodology and adjusted for regional differences in Covid-19 restrictions. There was no significant difference in hospitalisation rates between LCR and initial control areas thereafter when community testing had rolled out nationally. Case detection increased, with LCR detecting 28% (95% CI: 26% to 30%) more cases of SARS-CoV-2 infection than synthetic control areas, even after testing rolled out in control areas – equivalent to 17,401 (95% CI 16278 to 18505) additional cases of SARS-CoV-2 identified in LCR between 3rd December 2020 and 31st March 2021.

Introduction

On 6th November 2020, as a national lockdown started, the City of Liverpool (0.5m population) was selected by the UK Government to pilot large-scale community testing of asymptomatic individuals for SARS-CoV-2 antigen, since the City had the highest prevalence of Covid-19 in England in the preceding weeks.[1] Testing with the Innova SARS-CoV-2 rapid antigen test was made available to everyone without symptoms living or working in the City of Liverpool. Communications also drew attention to parallel (PCR) testing for people with symptoms. The aim of the pilot was to reduce or contain transmission of the virus while tackling the harms to health and social/economic wellbeing from Covid-19 restrictions. The decision to pilot asymptomatic testing in the community was an urgent public health response intended to generate understanding of: (i) how offering large-scale testing would be received by the local community; (ii) how lateral flow testing would perform in large-scale asymptomatic testing; and (iii) whether large-scale testing would help to contain the pandemic, reduce adverse health outcomes, such as hospital admissions, and support social and economic functions.

During the initial "mass testing" pilot period (6th November to 2nd December 2020) the scheme was advertised across different media and was rapidly deployed with the assistance of the British Army. The initial plan to test 75% of the asymptomatic population in two weeks proved infeasible, but local public health teams anticipated value and requested continuation of the pilot. The end of the national lockdown (2nd December) saw lower levels of Covid-19 and the service was handed over to the City Council on 3rd December 2020 as Liverpool opened into less stringent (Tier 2) local restrictions than most of the rest of England. At the same time, the scheme expanded to the wider Liverpool City Region (1.5m population). The approach was known as SMART (Systematic, Meaningful, Asymptomatic/agile, Repeated Testing) and had three components:

1. **'test-to-protect'** vulnerable people and settings (for example, people living in care homes)
2. **'test-to-release'** contacts of confirmed infected people sooner from quarantine than the stipulated period (for example, key workers in quarantine)
3. **'test-to-enable'** careful return to restricted activities to improve public health, social fabric, and the economy (for example, visits to care homes or sports events)

Net benefits were recently reported from the City of Liverpool pilot,[2] including an 18% increase in case-detection and a 21% decrease in case-rates up to mid-December 2020 when Liverpool was more easily compared with other regions, before the alpha wave hit. Targeted uses of this testing capacity had specific benefits, for example 8,318 workdays of key workers in a test-to-release scheme were saved from having to quarantine after contact with cases – instead they used a daily negative LFT as Covid certification to work. There is now a need to describe the effects of the larger scale programme among the 1.5m LCR resident population.

A qualitative evaluation of the LCR community testing pilot is reported separately,[3] showing that operational factors and strong communication between local authorities, local communities and external partners (military and NHS) were key to successful implementation. Recruitment and training of the testing workforce was challenging. Following the initial success, further delivery of the programme was disrupted by a third national lockdown, and by centralisation of some aspects of community testing.

October 2020

- (14) The new three-tier system of Covid-19 restrictions begins in England; with Liverpool City Region in Tier 3, the highest level of restrictions at the time
- (31) Government offers Liverpool mass testing with military assistance

November 2020

- (1) Liverpool City Council Covid-19 Strategic Coordination Group with Mersey Resilience Forum accepts in principle but with the freedom to develop a more targeted approach
- (2) Military arrive in Liverpool to establish test sites
- (5) National lockdown; a communications drive begins in Liverpool on testing
- (6) Six sites open for lateral flow testing (alongside mobile units for symptomatic PCR testing)
- (7) 16 sites open for lateral flow testing
- (10) First meeting of DHSC-convened Evaluation Steering Group; schools-based testing starts
- (11) Capacity increased: 37 community sites plus schools; home PCR kits delivered (one-off, unsolicited mailing to sample households); local evaluation group established
- (20) Re-configuration of resources: 15 popular testing sites kept; other resources were redeployed to smaller sites in low uptake areas
- (23) System for confirmatory PCR changed from national communication and delivery of a home test kit to swabbing at one designated local testing site (with outreach swabbing if needed) and an invitation message tailored to the local area

December 2020

- (2) Liverpool moved into Tier 2 with all surrounding regions in higher Tiers/restrictions
- (3) Handover of management of ATS from military to Liverpool City Council contractors; targeting becomes more focused as the pilot moves to Liverpool Covid-SMART brand and adapts to fewer Covid-19 restrictions
- (3) Liverpool care home visiting pilot begins; and the communications plan shifts priority to "test before you go" for implementation as the population returned to high transmission risk settings such as hairdressers
- (3) Liverpool City Region roll-out of Covid-SMART begins
- (4) Test-to-release for some key workers begins
- (17) More areas including Cheshire and Warrington move into Tier 2. Hotels in Liverpool booked heavily with people from London
- (31) Move back into Tier 3 with all surrounding regions in Tier 4

January 2021

(4) National lockdown

(4) National roll-out of community testing begins

March 2021

(8) Schools and colleges return with twice weekly rapid antigen testing nationally

Figure 1. Timeline of the Liverpool City then Liverpool City Region pilots

Data sources and methods

Data

Covid-19 testing and linked NHS records (Cheshire & Merseyside)

Combined Intelligence for Population Health Action (CIPHA) is a linked NHS, social care and public health data system for all individuals registered with a GP in Cheshire and Merseyside. CIPHA was established to support responses to Covid-19 and is now a core NHS led system detailed at www.cipha.nhs.uk. In our report, we focus on all testing records supplied as part of the NHS Test and Trace Pillar 2 service. An extract of the CIPHA data was taken on 6th August 2021. The file contained 8,037,280 observations.

During the data cleaning process, we identified substantial missing data for ethnicity (n = 839,833 or 10.4% of records were recorded as either 'prefer not to say' or were left blank). To address this, multiple imputation using chained equations was used to estimate the ethnicity of individuals based on age, sex, neighbourhood deprivation, the ethnicity profile of the LSOA where an individual lived (i.e., proportion of people who were Black, Asian, Mixed or Other), the proportion of full-time students in an area, and if there was a care home in the area. 8,939 records were unable to be imputed following this process, however following excluding records based on location, date and age there were no missing records in our analytical dataset. Imputation for sex, age and test result was not required due to high (>99.99%) or complete completion of records (where data were missing, we exclude them from analyses).

We defined the main study period as the start of SMART at 00:00 3rd December 2020 up to 23:59 31st July 2021. We extracted all tests for this period for individuals registered as living in the Liverpool City Region (one of Halton, Knowsley, Liverpool, Sefton, St. Helen's, and Wirral Local Authorities). The total analytical sample size was 4,529,194 and represents all tests taken (lateral flow device or PCR) within the region for this period. We primarily focus on LFTs representing 3,278,785 tests in total.

For the purposes of this report, we further excluded 17,581 tests (0.5%) where age was reported as less than five. LFTs should not have been conducted on individuals less than five. For most of the tests with age reported as 0, age was erroneously entered as the same date the test was taken. All statistics, analyses and plots use data for age five and older unless otherwise stated. Summary statistics for LFTs using all ages and not excluding those aged under five are presented in the Appendix.

Geospatial

The unit of analysis was selected as Lower Super Output Area (LSOA). LSOAs represent a small statistical zone for reporting data (~1500 people per LSOA) and are commonly used for understanding geographical inequalities both in research and policy. We aggregated testing records to LSOAs since we did not have information on people who did not receive a test, and therefore opt for describing ecological associations. To contextualise testing patterns, we used the data sources described below for LSOAs.

2019 mid-year population estimates were obtained by single year of age and sex (source: www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationesti

mates/datasets/lowersuperoutputareamidyearpopulationestimates). Data were needed as population denominators, to account for differences in population (overall size and age structure) between LSOAs. These data are estimated by the ONS and were the most recently available data on population estimates for LSOAs. Some aggregate summary tables had data for 2020, as the ONS have released estimates for higher geographical scales (i.e., Local Authorities). 2020 data for LSOAs was not available at the time of writing this report.

Neighbourhood deprivation was measured using 2019 Index of Multiple Deprivation (IMD) (source: www.gov.uk/government/statistics/english-indices-of-deprivation-2019). We used these data to investigate social inequalities in testing outcomes and IMD is commonly used by researchers and policy makers for measuring deprivation. Where quintiles are reported, we use the Local Authority specific quintiles rather than national ones.

Data on the location of care homes in 2019 was collected from the Care Quality Commission (source: www.cqc.org.uk/about-us/transparency/using-cqc-data). We included these data since care homes may have been the focus of targeted testing and therefore influence patterns.

We included data on the proportion of people in an area that were full-time students. These data were taken from the 2011 Census (source: www.nomisweb.co.uk) due to a lack of more recent data. These data were included to account for targeted testing (e.g., colleges or universities).

Finally, we used the 2018 Internet User Classification (IUC) as a proxy measure for digital exclusion or confidence in using the internet (source: data.cdrc.ac.uk/dataset/internet-user-classification). IUC is an area-based classification of areas utilising measures about confidence in internet technologies (e.g., ownership and use of internet technologies, infrastructure, online behaviours, use of social media). We include these data to account for any inequalities relating to testing procedures often being promoted or registered using smartphones. A full description of each area type profile has been included in the Appendix.

Hospital admissions (national)

For the synthetic control analysis, we used data on hospital admissions for Covid-19 (ICD codes UO7.1 or UO7.2) between 4th October 2020 and 4th April 2021 aggregated to Middle Layer Super Output Areas (MSOA). MSOAs are standard geographical units with an average population of 7,200 people which are nestled within the boundaries of local authorities. Hospital admission data were obtained from NHS digital under a data sharing agreement DARS-NIC-16656-D9B5T-V.4.2. Details of the DSA can be accessed here: app.powerbi.com/view?r=eyJrIjoiNzJjNGU4MDItMGIyZS00N2JhLTgzYzMtMDY4ZmUyYTIwZTRkIiwidCI6IjUwZjYwNzFmLWJiZmUtNDAxYS04ODAzLTY3Mzc0OGU2MjllMiIsImMiOjh9

Statistical methods

Descriptive

Descriptive statistics (e.g., mean values, percentages, frequencies) were calculated to present measures summarising overall patterns or trends. Data were presented in tables, as well as visualised in graphs.

Geospatial

A spatial regression framework was used to analyse testing outcome patterns for LSOAs. The benefit of this approach was to account for the spatial nature of the data since testing behaviours in one LSOA are likely to be similar to those in neighbouring areas. It also matches the same methodology used in the previous Liverpool City evaluation of SMART testing and associated analyses.[2,4]

Specifically, we examine associations between geospatial explanatory measures and four outcome variables: (i) overall LFT uptake, (ii) number of people who had more than one LFT, (iii) number of positive tests, and (iv) number of home tests. Here we estimated the expected numbers of each outcome based on the age, sex, and ethnic composition of each area (i.e., indirect standardisation). A Bayesian Hierarchical Poisson model was then fitted, modelling the observed numbers of each outcome, offset by the expected number, and accounting for spatial autocorrelation using a Besag, York and Mollie (BYM) model (fit using R-INLA). Continuous variables (proportion of students in a LSOA and deprivation score) were z-score standardised to account for scaling issues.

Synthetic control

We applied synthetic control methodology for microdata developed by Robbins et al.[5,6] to estimate the impact of community asymptomatic testing on hospital admissions for Covid-19 across the whole LCR. The synthetic control method is a generalisation of difference-in-difference methods, whereby an untreated version of the intervention areas (i.e., a synthetic control) is created using a weighted combination of areas that were not exposed to the intervention. To construct the synthetic control group, we derive calibration weights to match the MSOAs in LCR to areas outside the LCR across the five-week period prior to the intervention by local area characteristics described in the relevant section of the report. The weighting algorithm derives weights that meet three constraints. Firstly, the sum of weighted number of cases in the control group equals the number of cases in the intervention group. Secondly, the weighted average of each of the local area characteristics in the synthetic control group matches those in the intervention group. Lastly, the synthetic control and intervention group also match across all pre-intervention time points in terms of the numbers of hospital admissions. Synthetic control analysis was performed using R version 4.0.3 and the Microsynth package.[5]

Findings

Uptake of asymptomatic lateral flow testing

Regional variation

Between 3rd December 2020 and 31st July 2021, a total of 3,261,204 lateral flow tests were taken by 668,243 people aged five years or above across the six local authorities within the Liverpool City Region, representing 45.2% of its total population aged five years and older (see Table 1). The number of people tested varied from 51,942 (42.4%) in Halton to 237,482 (50.4%) in Liverpool. The highest mean number of tests per person was in Halton (5.75) and lowest in Liverpool (3.93). Overall uptake of LFTs by Local Authority without removing tests where age was under five years are presented in Appendix, Table 18.

Table 1. Overall lateral flow test uptake for individuals aged 5 years and older, tested at least once in Liverpool City Region by Local Authority, 3rd December 2020 – 31st July 2021.

Area	People tested	Total tests	Tests per person	Population (aged 5+)*	% Tested
Halton	51,942	298,722	5.75	122,385	42.4%
Knowsley	64,276	287,887	4.48	142,363	45.1%
Liverpool	237,482	934,444	3.93	471,638	50.4%
Sefton	105,864	600,316	5.67	262,110	40.4%
St. Helens	76,200	395,680	5.19	171,216	44.5%
Wirral	132,479	744,155	5.62	307,187	43.1%
Liverpool City Region	668,243	3,261,204	4.88	1,476,899	45.2%

*Note: *mid-2020 ONS estimates*

Exploring geographical patterns, at a small-area level, the estimated percentage of people who had an LFT result recorded was higher in more affluent areas such as Childwall, Woolton, Aigburth (all Liverpool), West Kirkby, and some rural parts of St. Helens and Knowsley (see Figure 2). Lower uptake was in urban areas and some deprived communities including Widnes, Birkenhead, Wallasey, North Liverpool, Waterloo and Runcorn. The LSOAs with high uptake were often target populations or areas with under-estimated population counts (e.g., student populations).

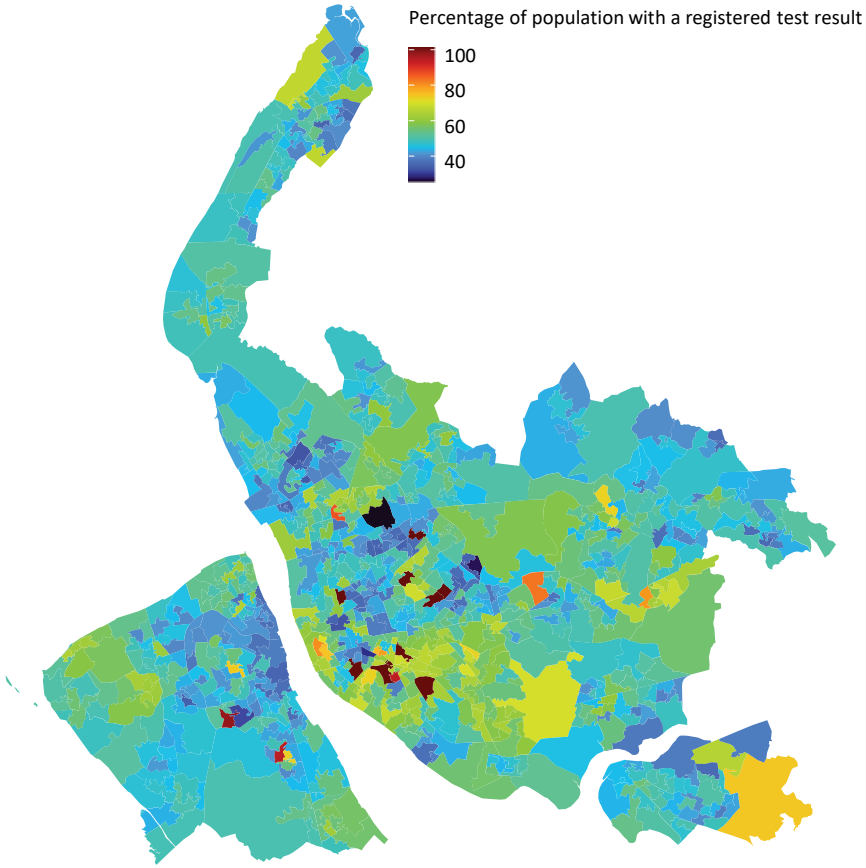

Figure 2. Percentage of people who received at least one lateral flow test and had a registered result by Lower Super Output Area for the Liverpool City Region

Time trends

Figure 3 shows trends over time in the number of LFTs as well as in the percentage of tests that were positive (i.e., positivity rate – described in separate section). There were increasing numbers of tests in the whole Liverpool City Region during December, peaking with high demand in the week before Christmas, likely reflecting people getting tested before meeting up in their Christmas Day bubbles or celebrating the holidays with friends and family more generally. The number of tests remained high and consistent during the national lockdown in January and February. A steep increase is observed in mid-March when schools re-opened due to the UK Government policy that all students must get tested regularly. Trends declined at the end of the month due to the Easter holidays where there were no school-related tests. When schools re-opened, the number of tests was not as high as pre-Easter, suggesting less engagement with testing. A small increase in test uptake was observed in late April/early May (~13,300 tests) due to the Events Research Programme involving audiences from LCR. A small decrease is observed at the end of May with half-term school holidays. Tests increased thereafter, before declining in mid-July with the end of the school year. Discussion of the positivity rate is presented later. Trends in LFT uptake don't follow trends in PCR uptake, which is largely more consistent, with fewer short-time fluctuations (see Appendix, Figure 19).

Comparing trends in uptake by Local Authority displays similar trends to the Liverpool City Region overall (Figure 3). For most of the period, the number of tests was highest in Liverpool, however by the end of the period there were more tests being undertaken in Wirral. Trends for positivity are described in the next section.

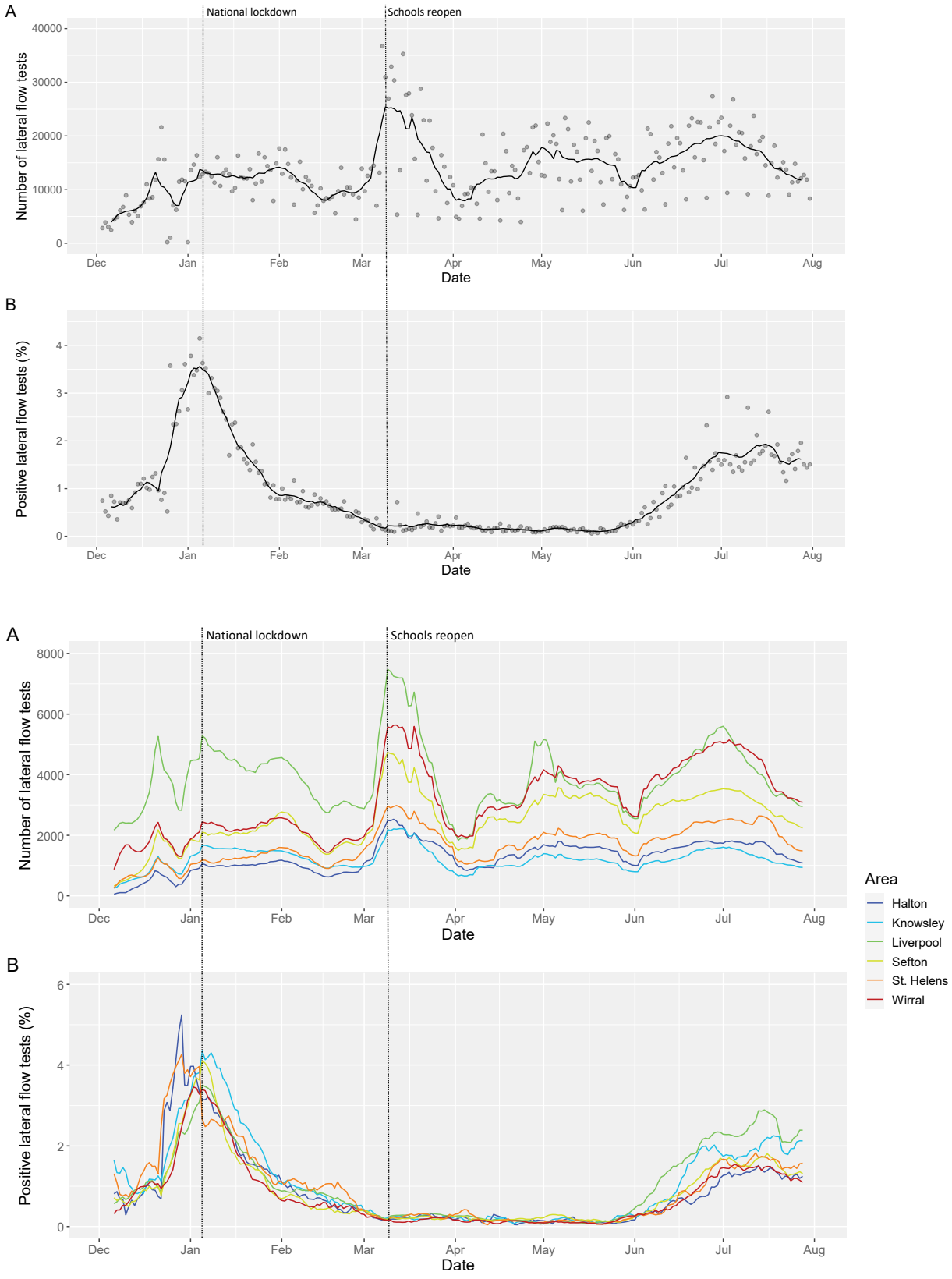

Figure 3. Trends in the total number of registered lateral flow tests (uptake) (A) and percentage of tests that were positive (B) for Liverpool City Region (top) and by Local Authority (bottom). Dots are raw daily values and the line is the 7 day moving average.

Variation by socio-demographic factors and area-level predictors

Summary statistics of who got tested are presented in Table 2. A greater percentage of females took an LFT (51% of all females in LCR) compared to males (47%). Uptake was highest in individuals aged 15-34 years (66%), and lowest in individuals aged 70+ years (26%). Differences by 10-year age bands are presented in Appendix, Figure 20. The highest percentage of people tested were aged 10-19, declining with increasing age band especially from age 60 years upwards. There were only small differences between Local Authorities for 10-year age bands (see Appendix, Figure 21).

Table 2. Number and proportion of people tested at least once with lateral flow devices, by demographic characteristics, 3rd December 2020 – 31st July 2021.

Theme	Characteristic	People tested (n)	Population (n)	% Tested
Sex	Female	407,782	798,742	51
	Male	358,037	765,273	47
Age	5-14	96,085	182,581	53
	15-34	268,419	409,598	66
	35-69	345,672	669,847	52
	70+	55,643	214,873	26
Ethnicity	Asian	19,839	34,937	57
	Black	13,625	17,237	79
	Mixed	9,486	28,310	34
	Other	5,757	12,263	47
	White	717,112	1,466,572	49
Deprivation	Least deprived	165,524	311,669	53
	Quintile 2	168,321	312,999	54
	Quintile 3	156,815	311,931	50
	Quintile 4	142,385	314,905	45
	Most deprived	132,774	307,816	43

Note: Deprivation quintile is defined using LA specific quintiles

There were variations in uptake between ethnic groups. Overall estimated LFT uptake was highest in the Black group (79%) and lowest in the Mixed ethnicity group (34%). Caution should be given to the ethnicity population estimates, which may have under-estimated some groups as the most recent ONS population estimates were for 2018. There were also social inequalities by neighbourhood deprivation. LFT uptake was highest in the least deprived areas (53%) than compared to the most deprived areas (43%). Local Authority specific summary statistics for the metrics presented in Table 2 can be found in Appendix, Table 19 and Table 20. Patterns largely follow those observed above, suggesting consistent demographic inequalities across each Local Authority.

Investigating the geographical predictors of test uptake revealed inequalities in uptake of testing (Figure 4, also see Appendix, Table 21 for raw values). Areas with a care home located within them had fewer tests than expected. In more deprived areas test uptake was also lower. Digital inequalities were evident. Areas characterised as 'e-Rational Utilitarians' (poor internet infrastructure and low mobile phone use), 'Digital Seniors' (older populations with average internet use) and 'settled offline communities' (limited use of internet and poor infrastructure) had lower test uptake than e-Veterans (areas with frequent internet use). Areas characterised as 'passive and uncommitted users' (limited internet use in rural or outer suburban areas) or 'e-Mainstream' (average internet usage) had higher numbers of tests compared to e-Veteran's areas.

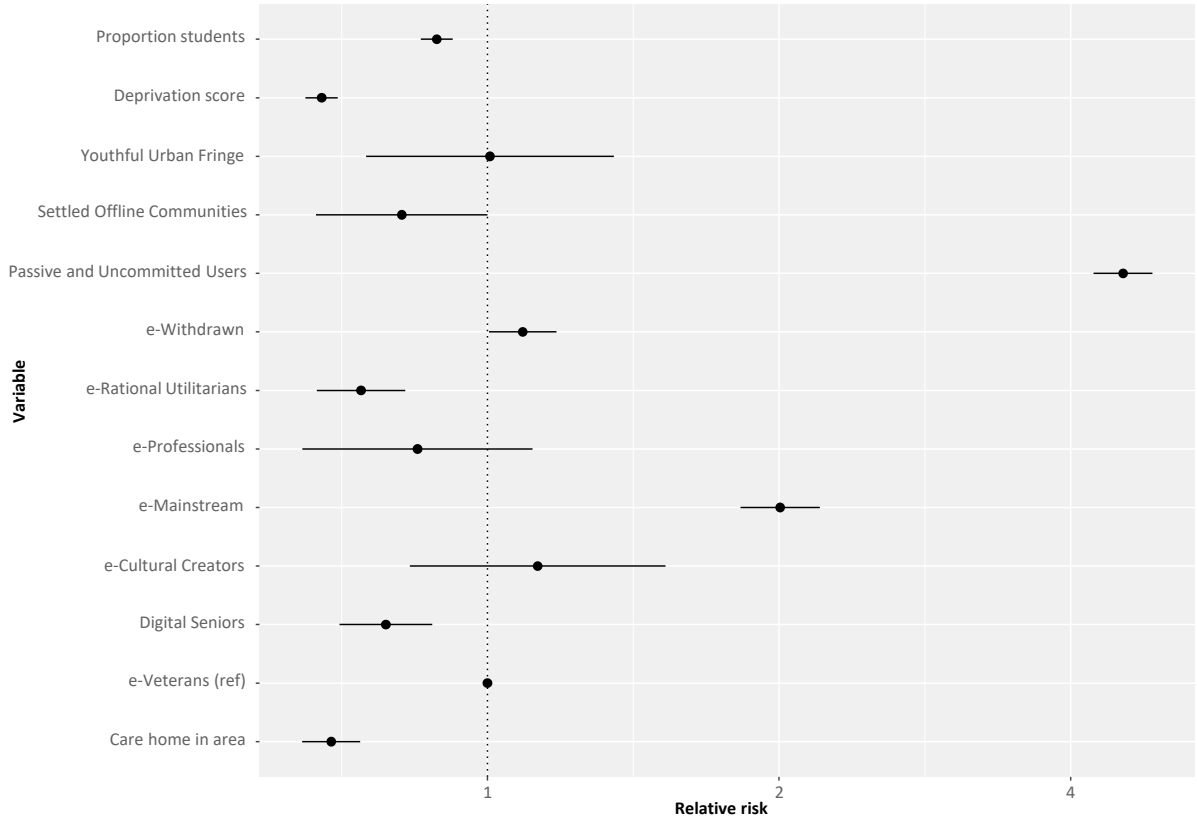

Figure 4. Relative risk estimates for associations detected in the Bayesian regression model for uptake of lateral flow tests in Liverpool City Region.

Note: The relative risk indicates whether uptake was higher (>1) or lower (<1) than expected for the age-sex-ethnic composition of an area. Points are the estimated value, and the lines represent 95% credible intervals. Details of estimates can be found in Appendix, Table 21.

A greater proportion of students in an area was associated with fewer tests. There are two main reasons likely for this. First, there may be under-representation of student populations in our denominators where students are counted at their non-term time residences. Second, there were fewer students in LCR over the study period. The UK government introduced a student travel window between 3rd and 9th December, designed to allow students to travel back to their non-term time homes safely prior to Christmas. Fewer students returned to the region initially in 2021, especially due to the continuation of university teaching remotely/online. This meant there were fewer students in the region, which resulted in lower uptake in these areas (rather than student populations opting not to engage in testing).

Positivity rates

Regional variation

Between 3rd December 2020 and 31st July 2021, testing identified 28,712 SARS-CoV-2 infections with LFT (0.88% of all LFT results) in LCR. The percentage of LFT that were positive (i.e., positivity rate) ranged from 0.69% in Halton and Wirral to just above 1.1% in Knowsley and Liverpool (see Table 3).

Table 3. Number and percentage of positive lateral flow tests in Liverpool City Region Local Authority areas, 3rd December 2020 – 31st July 2021.

Area	Total tests	Positive tests	Positive %
Halton	298,722	2,049	0.69
Knowsley	287,887	3,337	1.16
Liverpool	934,444	10,348	1.11
Sefton	600,316	4,735	0.79
St. Helens	395,680	3,089	0.78
Wirral	744,155	5,154	0.69
Liverpool City Region	3,261,204	28,712	0.88

Figure 5 shows how positivity rates varied at a small-area level (i.e., LSOAs). There is a distinct urban-rural pattern, with a higher percentage of tests being positive in urban areas especially in North Liverpool, Bootle and Speke/Garston. The high positivity rate for Speke/Garston is notable given the high uptake of testing in the area (~50%), in contrast to other neighbourhoods with high positivity that tend to have low uptake.

We note that these data on positivity rates are based on registered tests and non-reporting of tests (often negative LFTs) may affect the exact values.

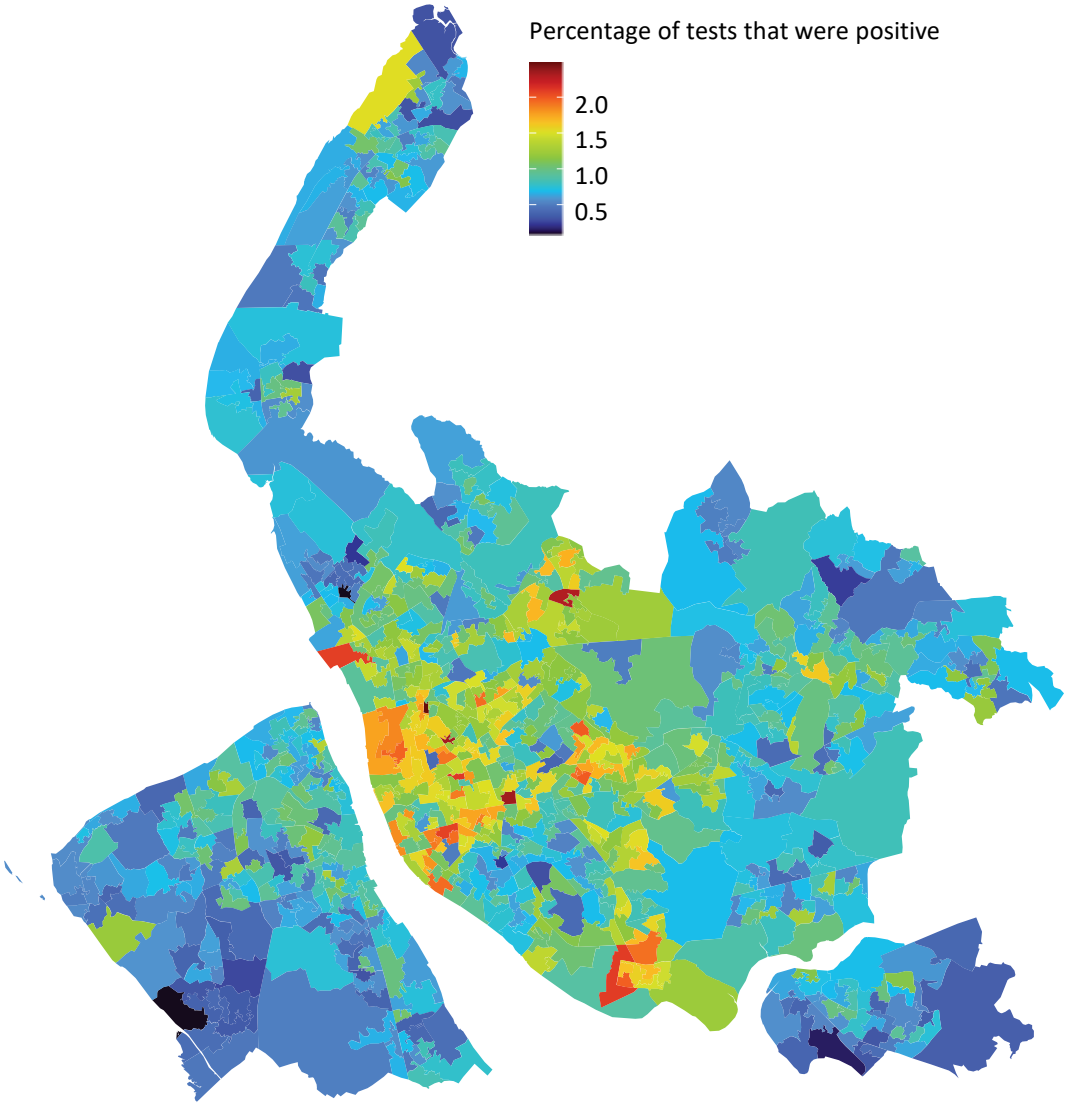

Figure 5. Percentage of lateral flow tests that were positive by Lower Super Output Area for Liverpool City Region, 3rd December 2020 – 31st July 2021.

Time trends

In Figure 3 we show trends in the positivity rate of LFTs over the study period. The percentage of positive tests is highest in January, reaching ~3.5% of LFTs. The positivity rate fell after January and remained low (<0.5%) between March and June, before rising thereafter. These trends mirrored trends for PCR positivity as well, albeit with PCR tests having a higher positivity rate since they are undertaken by symptomatic individuals (see Appendix, Figure 19). Comparing trends by Local Authority reveals close trends between areas during times of low prevalence (Figure 3). In January, the peak of positive tests is observed first in St. Helens and Halton before the other areas catch up. Noticeably, the peak in January lasts longest in Knowsley. The increased levels of Covid-19 in June and July occurs first in Liverpool, then Knowsley, before the other Local Authorities catch up (albeit remaining lower than Liverpool and Knowsley).

Variation by socio-demographic factors and area-level predictors

Positivity rates varied by socio-demographic factors and were higher among males, those aged 15-34 years, Black, Mixed and Other ethnicity groups, and people living in most deprived neighbourhoods (see Table 4). Local Authority specific summary statistics can be found in Appendix, Table 22 and Table 23. Patterns largely follow those described here.

Table 4. Number and percentage of lateral flow tests that were positive by demographic characteristics, 3rd December 2020 – 31st July 2021.

Theme	Characteristic	Positive tests (n)	Total tests (n)	Positive %
Sex	Female	14,751	1,946,506	0.76
	Male	13,905	1,310,738	1.06
Age	5-14	3,069	482,016	0.64
	15-34	12,924	994,091	1.30
	35-69	11,733	1,628,495	0.72
	70+	930	156,602	0.59
Ethnicity	Asian	633	80,419	0.79
	Black	557	51,795	1.08
	Mixed	400	38,239	1.05
	Other	242	19,237	1.26
	White	26,824	3,071,514	0.87
Deprivation	Least deprived	5,172	736,437	0.70
	Quintile 2	5,561	719,547	0.77
	Quintile 3	5,870	679,799	0.86
	Quintile 4	6,146	603,532	1.02
	Most deprived	5,907	521,889	1.13

Note: Deprivation quintile is defined using LA specific quintiles

Examining the geographical drivers of positivity rates also highlighted the importance of inequalities (Figure 6). Deprivation score was positively associated, suggesting that more deprived areas have more positive tests than expected. As the proportion of students in an area increased, positivity rate was lower. There was no association to the location of care homes. We did not include internet user classification in these analyses as we did not hypothesise that it would affect the likelihood of having a positive test.

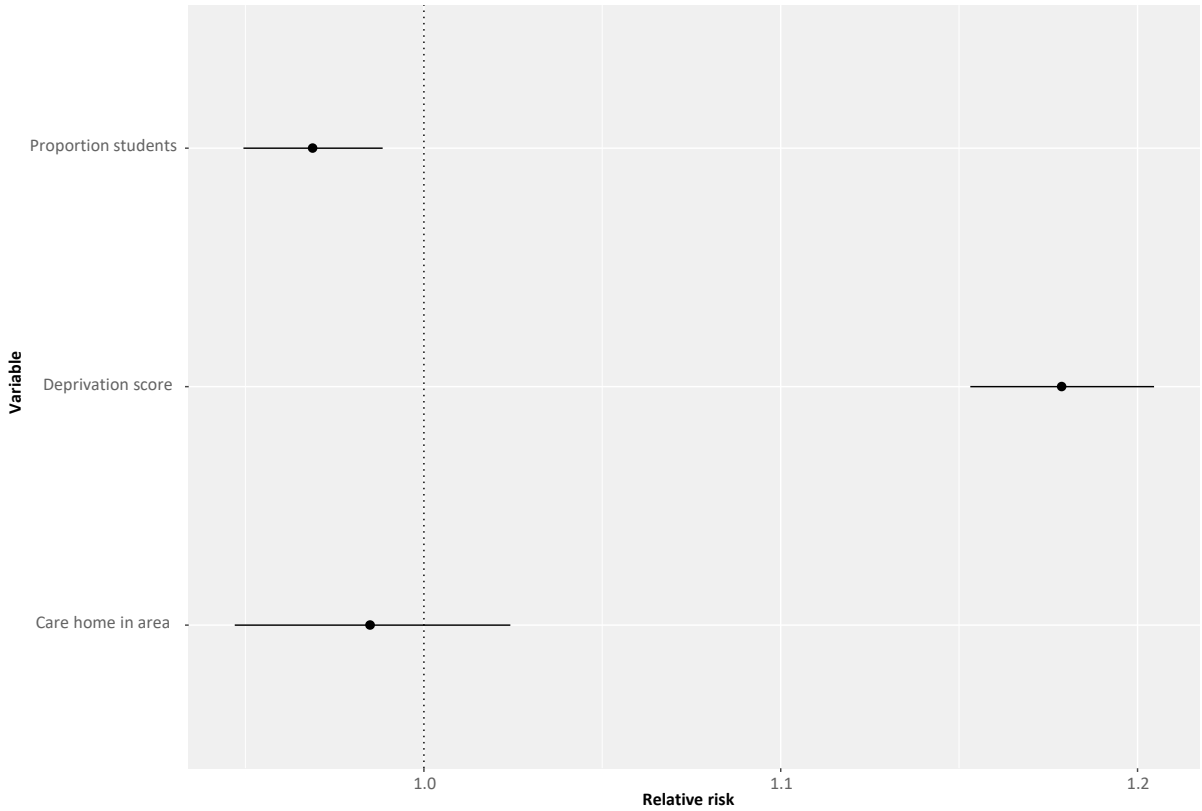

Figure 6. Relative risks estimated by factors in the Bayesian regression model for positive lateral flow tests in Liverpool City Region, 3rd December 2020 – 31st July 2021.

Note: The relative risk indicates whether positive tests were higher (>1) or lower (<1) than we would expect for the age-sex-ethnic composition of an area. Points are the estimated value, and the lines represent the 95% Credible intervals. Details of estimates can be found in Appendix, Table 24*.*

Repeat Lateral Flow testing: variation

A total of 391,862 people aged 5 years and over registered more than one test, representing 51.17% of all people tested in the Liverpool City Region (see Table 5). Females were more likely to have been tested more than once (53.58%) as compared to males (48.42%). There were small differences between ethnic groups, with the Other group being least likely to have had multiple tests (45.89%) and Mixed ethnicity group being most likely (53.14%). There was a social gradient with individuals from the least deprived quintiles being most likely to have had multiple tests (53.79%) than compared to individuals in the most deprived quintile (47.63%). Local Authority specific summary statistics can be found in Appendix, Table 25 and Table 26. Patterns largely follow those described here.

Table 5. Numbers and proportions of people who received multiple lateral flow tests by demographic characteristics, 3rd December 2020 – 31st July 2021.

Theme	Characteristic	People tested more than once (n)	People tested (n)	Multiple tests (%)
Sex	Female	218,508	407,782	54
	Male	173,354	358,037	48
Age	5-14	60,876	96,085	63
	15-34	140,815	268,419	52
	35-69	169,535	345,672	49
	70+	20,636	55,643	37
Ethnicity	Asian	10,205	19,839	51
	Black	6,760	13,625	50
	Mixed	5,041	9,486	53
	Other	2,642	5,757	46
	White	367,214	717,112	51
Deprivation	Least deprived	89,042	165,524	54
	Quintile 2	88,736	168,321	53
	Quintile 3	79,999	156,815	51
	Quintile 4	70,840	142,385	50
	Most deprived	63,245	132,774	48

Note: Deprivation quintile is defined using LA specific quintiles

Figure 7 shows the geographical pattern for the percentage of individuals who registered multiple tests (as proportion of total tests). Lower values can be observed in Southport, Northern Liverpool, Toxteth, Bootle, Seaforth, St. Helens and central Birkenhead. Patterns for higher values are often in suburban and rural areas, with the largest values observed in Formby and Bromborough.

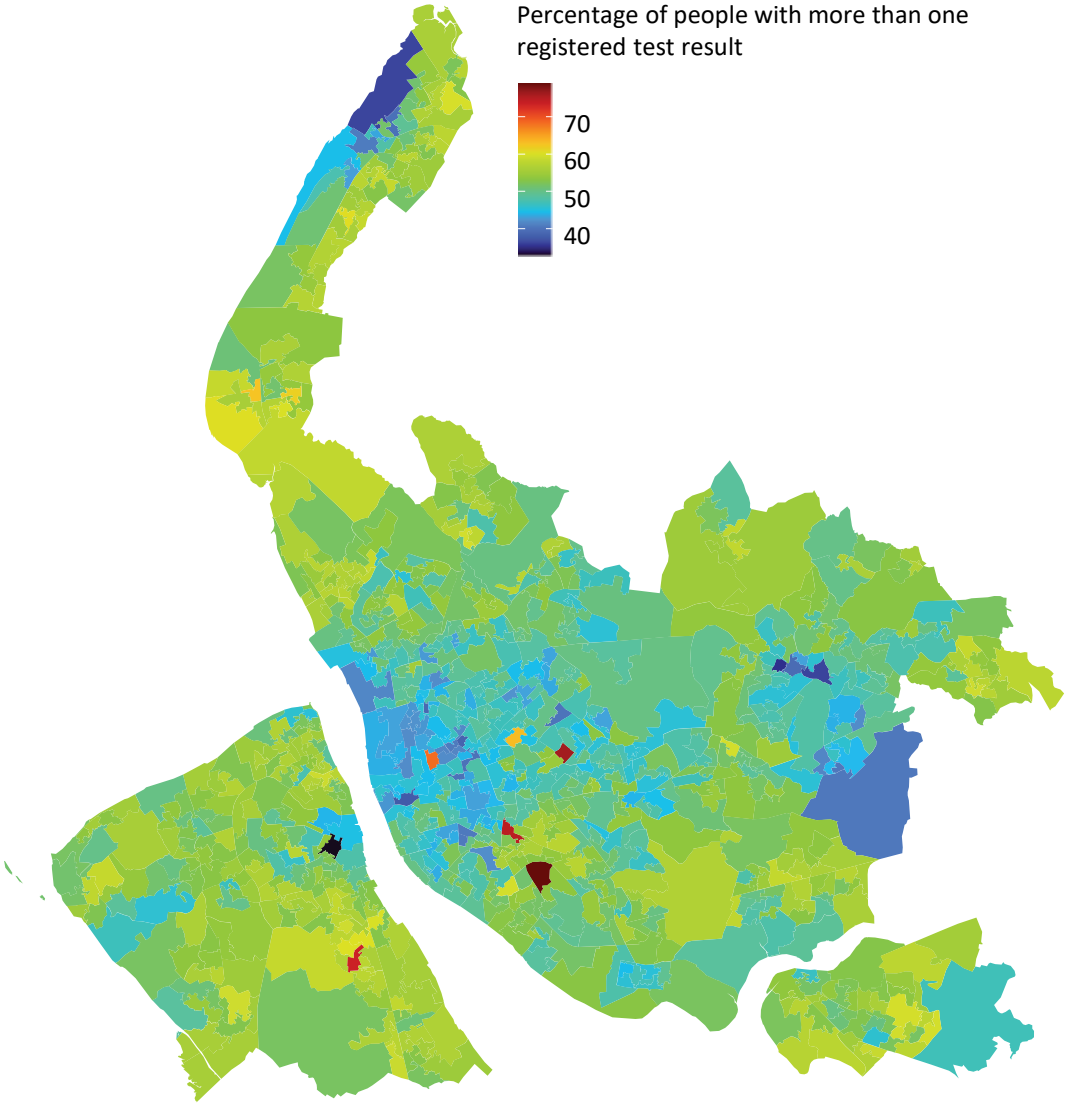

Figure 7. Spatial distribution of the percentage of people who received a lateral flow test who also received multiple tests for Lower Super Output Areas in Liverpool City Region.

Examining the geographical predictors of multiple test uptake demonstrated inequalities in multiple test patterns (see Figure 8, with actual values in Appendix, Table 27). Deprived areas, areas with a care home located within them, and areas with a greater proportion of students had fewer multiple tests than expected. There were also some digital inequalities. As compared to e-Veterans (areas with frequent internet use), 'e-Rational Utilitarian' areas (poor internet infrastructure and low mobile phone use) had fewer multiple tests, and areas characterised as 'passive and uncommitted users' (limited internet use in rural or outer suburban areas) or 'e-Mainstream' (average internet usage) had higher numbers of tests.

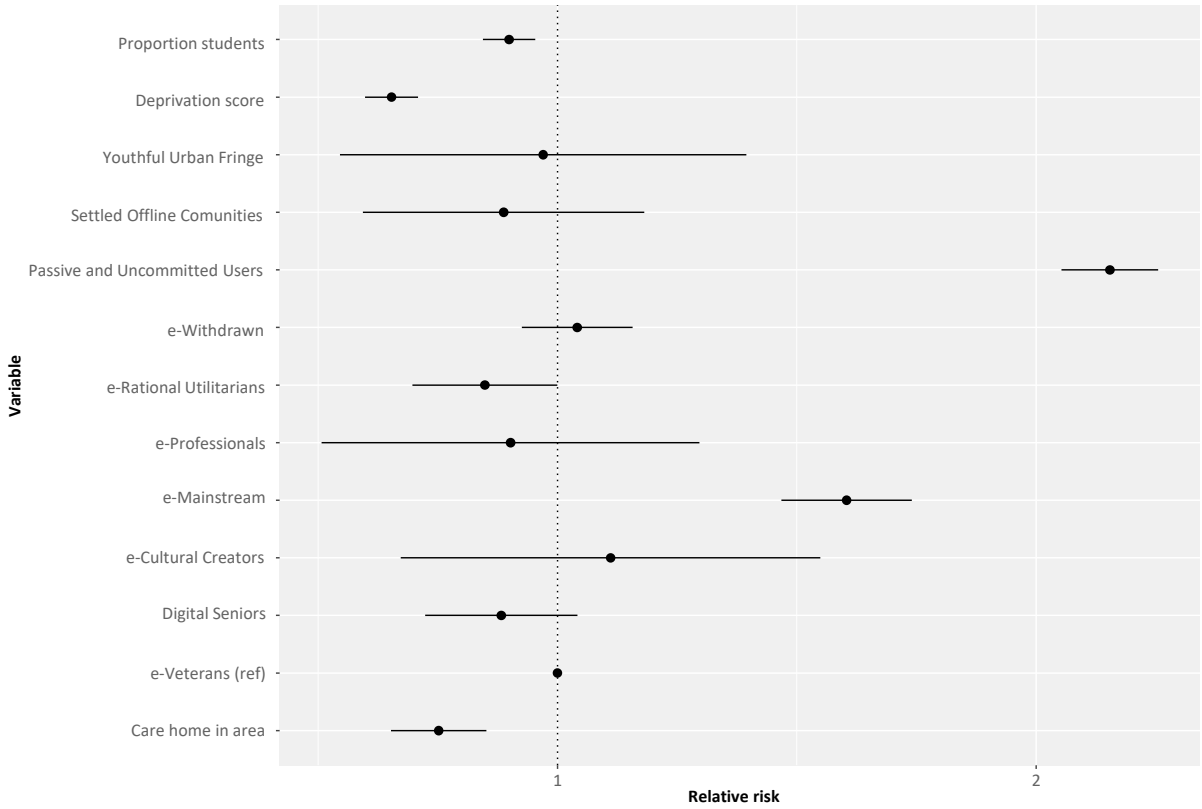

Figure 8. Relative risk estimates for associations detected in the Bayesian regression model for multiple lateral flow tests in Liverpool City Region, 3rd December 2020 – 31st July 2021.

Note: To interpret, the relative risk presents if multiple tests were higher (>1) or lower (<1) than we would expect for the age-sex-ethnic composition of an area. Points are the estimated value, and the lines represent the 95% Credible intervals. Raw values of estimates in the plot can be found in Appendix, Table 27*.*

Home lateral flow testing

Regional variation

Overall, there were 1,900,302 LFTs registered as taken at home representing 58% of all LFTs taken between 3rd December 2020 and 31st July 2021 in the Liverpool City Region (see Table 6). A total of 1,360,902 LFTs were registered at other locations (e.g., static and mobile test centres, workplaces, hospitals). There were more tests registered at home (~ 2/3rds) in Halton, Sefton, St. Helens and Wirral. Knowsley and Liverpool were the only Local Authorities where more people got tested outside of the home. The use of LFTs at home was higher than PCR tests where only 16% were conducted at home (see Appendix, Table 28) – note that this percentage was higher for Liverpool at 20%).

These data should be interpreted with caution since they are based on registered tests, and we hypothesise that people taking tests at home are less likely to register their test (especially negative LFTs) than compared to assisted sites.

Table 6. Summary statistics for lateral flow tests by location of test in the Liverpool City Region and by Local Authority, 3rd December 2020 – 31st July 2021.

Area	LFT at other location (n)	LFT at home (n)	Percentage of LFT at home (%)
Halton	103,716	195,006	65
Knowsley	148,677	139,210	48
Liverpool	507,996	426,448	46
Sefton	210,063	390,253	65
St. Helens	142,772	252,908	64
Wirral	247,678	496,477	67
Liverpool City Region	1,360,902	1,900,302	58

Exploring the geographical distribution for the percentage of home tests at a small-area level reveals distinct spatial patterns (Figure 9). Liverpool and Knowsley have far lower levels of home testing, and this is particularly low in the city centre of Liverpool.

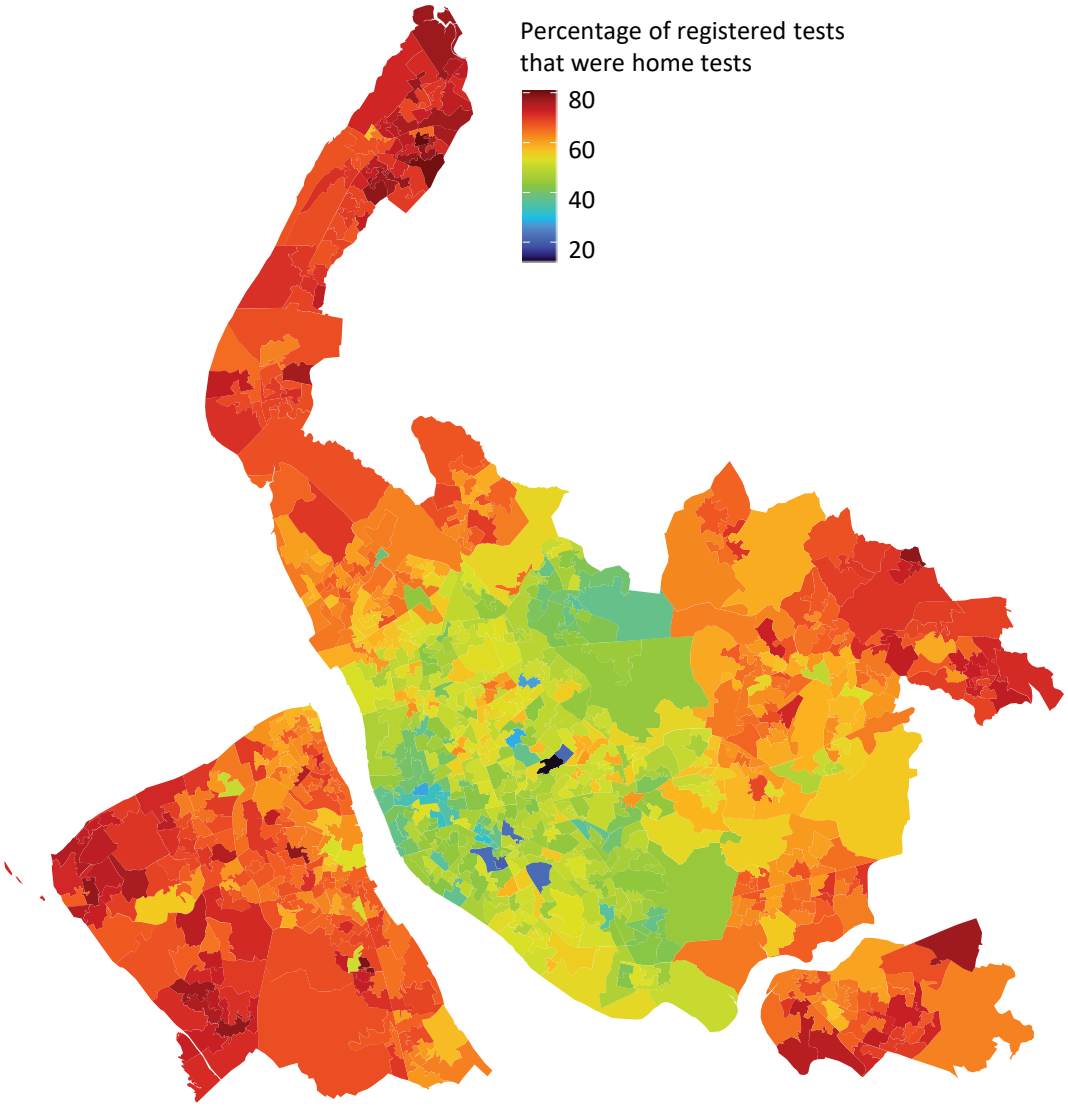

Figure 9. Percentage of tests that were completed at home for Lower Super Output Areas in the Liverpool City Region, 3rd December 2020 – 31st July 2021.

Time trends and positivity rates

Figure 10 presents trends in the uptake of home tests and related positivity rate. Initially, home testing uptake was uncommon due to low supply of home test kits, UK government policy and preference for testing out of the home. From mid-January, uptake for home tests begins to increase. Testing outside of the home represents a large proportion of all LFTs up until mid-March, but thereafter most LFTs were performed using home test kits. These trends were largely consistent when comparing trends for each Local Authority (right panel of Figure 10). Home testing was the most common location in each area from April 2021 onwards. 20th March 2021 is the first day the 7-day moving average for the number of tests at home in LCR exceeds those taken outside of the home. By the 1st July 2021, three quarters of all LFTs are conducted at home, suggesting large declines in the frequency of testing outside of the home. This is partly explained through lower availability of LFT test sites as well as increased use of home testing.

Trends in the positivity of LFTs by test location are largely similar. From December 2020 to February 2021 there is a peak in infections for both locations, although positivity rate is larger, and the trend is captured for longer, for tests outside of the home. This is likely to reflect the low numbers of tests conducted at home during this period and therefore comparisons should be made with caution. Between March and June, the low prevalence of positive tests remains similar for both test locations. In early June, there is an increasing trend for positive tests for both locations, the trend begins to diverge mid-June with the percentage of positive tests being higher for at home tests. For example, on 1st July 2021 the positivity rate was almost twice as high for home tests compared to those taken outside of the home (1.95% vs 1.08%). The positivity rate for home tests was higher in July across all LCR local authorities, however in Sefton the difference in the rate between home tests and tests from other locations was smaller. The higher rate for positive tests at home is likely to reflect under-reporting of negative tests, but may also be affected to some degree by pupils faking[7] positive tests to miss school or tests conducted correctly when done elsewhere (as empirically monitored).

We suggest some caution in making comparisons between trends for home tests and testing out of the home at assisted sites. Failure to register LFTs, often negative tests, at home is likely to be much more common than at assisted sites, which will affect denominators. This limitation applies to all analyses herein.

Figure 10. Trends in the number of tests taken (A) and percentage positive (B) between home tests and tests taken at other locations, for the whole Liverpool City Region (top) and by Local Authority (bottom), 3rd December 2020 – 31st July 2021. Dots are raw daily values and lines represent the 7-day moving average.

Variation by socio-demographic factors and area-level predictors

There were differences between those who used home tests or got tested elsewhere (Table 7). Females (65%), compared to males (49%), were more likely to use home tests. There were only small differences by age group, with the 35-69 age group having highest home test percentage (65%). There were few differences between most ethnic groups in preference, although the Other group were the only ethnicity who received more tests outside of the home (49%). Finally, there was not a distinct social gradient, with only a small difference (2.5%) between the least and deprived quintiles. Demographic descriptive statistics by Local Authority are presented in Appendix, Table 29 and Table 30.

Table 7. Number and proportion of people who were tested at home by demographic characteristics for Liverpool City Region, 3rd December 2020 – 31st July 2021.

Theme	Characteristic	Home tests (n)	Total tests (n)	Percentage home (%)
Sex	Female	1,256,525	1,946,506	65
	Male	641,753	1,310,738	49
Age	5-14	259,866	482,016	54
	15-34	501,219	994,091	50
	35-69	1,050,152	1,628,495	64
	70+	87,041	156,602	56
Ethnicity	Asian	44,965	80,419	56
	Black	28,997	51,795	56
	Mixed	20,901	38,239	55
	Other	9,343	19,237	49
	White	1,794,072	3,071,514	58
Deprivation	Least deprived	433,996	736,437	59
	Quintile 2	408,116	719,547	57
	Quintile 3	405,333	679,799	60
	Quintile 4	356,206	603,532	59
	Most deprived	294,627	521,889	56

Note: Deprivation quintile is defined using LA specific quintiles

Looking at the geospatial correlates for home testing uptake (Figure 11), the only factor that we found to be significant was the proportion of students in an area, suggesting that areas with a larger share of student populations had lower uptake of home testing.

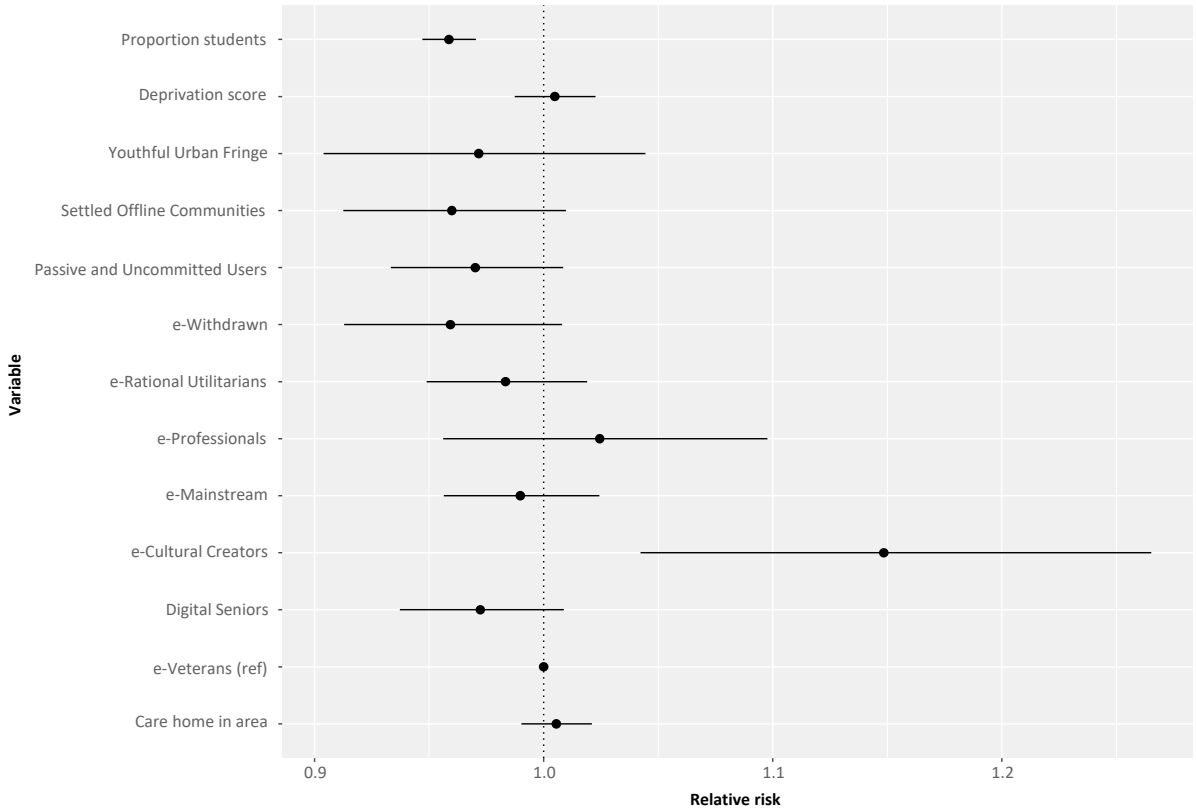

Figure 11. Relative risk/uptake estimates for associations detected in the Bayesian regression model for lateral flow tests conducted at home in Liverpool City Region, 3rd December 2020 – 31st July 2021.

Note: The relative risk indicates whether home tests were higher (>1) or lower (<1) than we would expect for the age-sex-ethnic composition of an area. Points are the estimated value, and the lines represent the 95% Credible intervals. Raw values of estimates in the plot can be found in Appendix, Table 31*.*

Confirmatory PCR testing after a positive lateral flow test

LFTs are not as sensitive as PCR tests but provide a result within 30 minutes compared with 2-3 days for PCR, enabling prompt actions such as isolation. As with any test, there are several factors that can affect the performance of LFTs, such as how the sample is taken. With home testing, there is the issue of whether the result was uploaded to national data systems. Although the LFTs have a high specificity (i.e., the proportion of non-infected individuals with a false positive result is low), during periods of low virus prevalence the chance that a positive result is false increases. To mitigate against the risk of false positives (resulting in unnecessary self-isolation), individuals who test positive using lateral flow devices are invited to book a confirmatory PCR test. Local messaging interventions at the end of November 2020 increased the uptake of confirmatory PCR tests in Liverpool, which had initially been poor. Confirmatory testing also allows surveillance of viral genetics to monitor new variants.

Regional variation

Using the CIPHA data resource we were able to monitor all positive LFTs across Liverpool City Region and determine how many individuals also had a PCR test within two days of the positive LFT. Between 3rd December 2020 and 31st July 2021, 19,283 individuals with a positive LFT also had a confirmatory PCR within 2 days (70.1%). There was some regional variation in the rates of uptake of confirmatory PCR tests ranging between 65.3% in Liverpool and 74.7% in Wirral (Table 8). However, we do not have access to Pillar 1 PCR tests (i.e., swab testing in Public Health England (PHE) labs and NHS hospitals for healthcare workers and those with a clinical need), so the numbers reported here may underestimate the true uptake of confirmatory PCR. For individuals with a confirmatory PCR test following a positive LFT, 17,305 PCRs were positive (89.7%), whilst 1775 (9.2%) were negative. Broadly similar rates of PCR agreement were observed in each region, with the disagreement between positive LFT and PCR varying between 7.7% in Knowsley and 10.7% in St. Helens (Table 8).

Table 8. Summary of Positive LFTs and confirmatory PCRs in Liverpool City Region between 3rd December 2020 and 31s July 2021.

Area	People with positive LFT	People with Confirmatory PCR within 2 days	Confirmatory PCR Positive	Confirmatory PCR Negative	Confirmatory PCR Void
Halton	1987	1466 (73.8%)	1306 (89.1%)	150 (10.2%)	10 (0.7%)
Knowsley	3191	2304 (72.2%)	2100 (91.1%)	176 (7.7%)	28 (1.2%)
Liverpool	9851	6434 (65.3%)	5816 (91.1%)	541 (8.4%)	77 (0.5%)
Sefton	4562	3230 (70.8%)	2917 (90.3%)	288 (8.9%)	25 (0.8%)
St. Helens	2979	2167 (72.7%)	1905 (87.9%)	231 (10.7%)	31 (1.4%)
Wirral	4926	3682 (74.7%)	3261 (88.6%)	389 (10.6%)	32 (0.8%)
Liverpool City Region	**27496**	**19283 (70.1%)**	**17305 (89.7%)**	**1775 (9.2%)**	**203 (1.1%)**

Variation by test location (home vs test centres)

Table 9 presents the monthly numbers of positive LFTs and confirmatory PCRs performed in Liverpool City Region between December 2020 and July 2021 by test location (home tests vs test centres). Figure 12 shows that individuals with a positive LFT obtained at home were, generally, more likely to obtain a confirmatory PCR, as compared to those with a positive test taken elsewhere. It is unclear why the uptake of confirmatory PCR testing for non-home tests dropped in February and March. In addition, the proportion of positive LFTs with a positive confirmatory PCR was observed to be quite similar in both tests taken at home and tests taken elsewhere, which is reassuring and suggests positives from home tests are reliable. The proportion of positive LFTs with a positive PCR was lowest between March and May (48.3% to 77%) but remained above 80% throughout the rest of the study period.

As shown in Figure 12, when the prevalence of Covid-19 was low (March-May 2021), the agreement between positive LFT and confirmatory PCR was lower. This agreement is not exactly equivalent to a standard positive predictive value (PPV), since there are several positive LFTs that we do not have a confirmatory PCR for, which may introduce bias into estimation of agreement. However, like PPV, the monthly proportions of agreement between positive LFT and PCR will depend on the underlying prevalence of Covid-19 at the time.

Table 9. Description of LFT testing characteristics in Liverpool City Region between December 2020 and July 2021 by month.

	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21
Registered LFTs	219928	387841	290860	566668	355532	463385	496119	481547
Individuals with at least one LFT	170043	239574	146075	221883	164892	157407	172825	174656
LFT positive individuals	2850 (1.7%)	8413 (3.5%)	1982 (1.4%)	1007 (0.5%)	479 (0.3%)	605 (0.4%)	4581 (2.7%)	7579 (4.3%)
Confirmatory PCR	2165 (76%)	6112 (72.6%)	869 (43.8%)	463 (46%)	264 (55.1%)	342 (56.5%)	3405 (74.3%)	5663 (74.7%)
Confirmatory PCR Positive	2004 (92.6%)	5800 (94.9%)	768 (88.4%)	343 (74.1%)	168 (63.6%)	212 (62%)	3026 (88.9%)	4984 (88%)
LFT Home Tests	2889 (1.3%)	62383 (16.1%)	98250 (33.8%)	222335 (39.2%)	277274 (78%)	399972 (86.3%)	427509 (86.2%)	410251 (85.2%)
Positive LFT home test with positive PCR	9 (81.8%)	324 (92%)	163 (81.9%)	209 (72.3%)	129 (62.3%)	198 (63.3%)	2772 (88.7%)	4691 (88.3%)
LFTs at test centres	217039 (98.7%)	325458 (83.9%)	192610 (66.2%)	344333 (60.8%)	78258 (22%)	63413 (13.7%)	68610 (13.8%)	71296 (14.8%)
Positive LFT from test centre with positive PCR	1995 (92.6%)	5476 (95.1%)	605 (90.3%)	134 (77%)	39 (68.4%)	14 (48.3%)	254 (90.4%)	293 (83.5%)

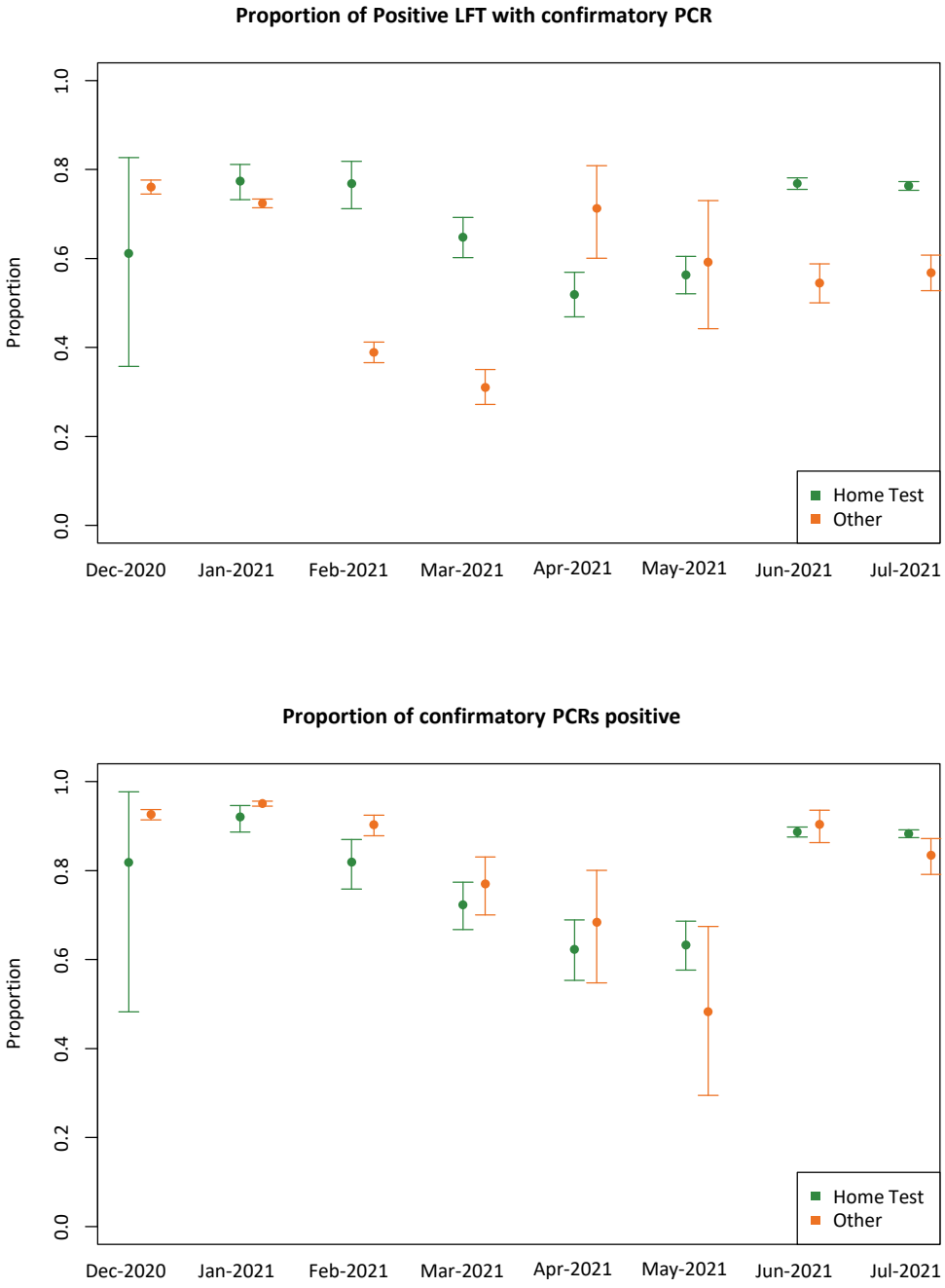

Figure 12. Proportion (with 95% confidence interval) of individuals with confirmatory PCR following positive LFT (top panel) and proportion (with 95% confidence interval) of positive LFTs with a positive confirmatory PCR (bottom panel).

We explored whether the observed discordant[1] positive rate (defined as 1 - specificity, i.e., the number of discordant positive LFTs divided by the total number of negatives) is consistent with the estimates of LFT specificity reported in the literature. We consider one test per individual to avoid the estimation being influenced by within-individual correlation. So, for individuals with multiple tests over the study period, the first test was used in this calculation. There were approximately 766,000 individuals for whom the first LFT had a negative result (with an average of 4.2 negative LFT's per person). 27,496 individuals had a positive LFT, with 19,283 (70%) having a confirmatory PCR within 2 days. Of these, 1,775 individuals had a negative confirmatory PCR. For the remaining 30% of individuals (8,213 individuals) with a positive LFT, who did not have a confirmatory PCR, we roughly expect 10% of these to be discordant positives (PPV ~ 90%).[9]

Assuming: (i) all 766,000 negative LFTs are truly negative (deviations from this are not expected to change the estimation significantly given the high negative predictive value), and (ii) 2,596 (=1775+821) discordant positive cases, the discordant positive rate is 2,596/(766,000+2,596) = 0.00338 (3.38 discordant positives per 1000 negative LFTs). This roughly corresponds to an estimate of specificity equal to 99.7%, which is close to the reported values of specificity in the literature (e.g., 99.9, 95%CI (99.8% to 99.99%).[9] Nevertheless, we acknowledge that limitations (the high proportion of missing confirmatory PCRs, selective non-reporting of negative LFT results, ability to produce fake positive results,[7] PCR accuracy,[11] etc., add uncertainty to this estimate).

[1] For any given pair of LFT and PCR results sampled from the same individual around the same time the swab may fail to sample a true infection in either test therefore we cannot say where the true/false result lies, only that the results are discordant. Most of the time, however, PCR is more likely than LFT to detect SARS-CoV-2 therefore we use it as a reference standard for confirmatory testing. We also recognise the limitation that PCR results may be positive when a person is no longer infectious. Diagnostic test statistics of sensitivity, specificity and predictive values should be interpreted with caution in Covid-19 given the multi-dimensional uncertainties.

Factors associated with confirmatory PCR testing uptake

We used generalised linear mixed models accounting for regional variability with random effects for region to explore factors associated with uptake of confirmatory PCR testing. Modelling suggests that non-White individuals and those living in the most deprived two fifths of Liverpool City Region were less likely to take a confirmatory PCR following a positive LFT (Table 10). Individuals who took a test at home were more likely to obtain a confirmatory PCR test. Age and sex were not significantly associated with the likelihood of obtaining a confirmatory PCR, nor was the number of LFTs taken in the two weeks prior to a positive LFT.

Table 10. Odds Ratios from logistic regression models showing the association with uptake of confirmatory PCR test after a positive LFT, 3rd December 2020 – 31st July 2021.

Explanatory Variable		Summary	Odds Ratio	95% CI	p-value
Intercept			3.09	(2.6, 3.66)	
Age		31 (21, 48)	1.00	(0.998, 1.001)	0.713
Sex	Female (Reference)	13707 (51.8%)			
	Male	12717 (48.2%)	1.05	(0.99, 1.1)	0.110
Ethnicity	White (Reference)	24765 (93.7%)			
	Asian	569 (2.2%)	0.51	(0.43, 0.6)	<0.001
	Black	499 (1.9%)	0.56	(0.47, 0.67)	<0.001
	Mixed or multiple ethnic groups	375 (1.4%)	0.86	(0.69, 1.08)	0.188
	Other	215 (0.8%)	0.36	(0.27, 0.47)	<0.001
IMD	1 (most deprived)	13522 (51.2%)	0.65	(0.57, 0.74)	<0.001
Deprivation	2	4263 (16.1%)	0.77	(0.67, 0.89)	<0.001
Quintile	3	3839 (14.5%)	0.87	(0.76, 1.01)	0.0703
	4	3334 (12.6%)	0.98	(0.85, 1.14)	0.827
	5 (least deprived) - Reference	1465 (5.6%)			
Total LFTs in previous 14 days		0.47 (0, 13)	1.01	(0.98, 1.04)	0.433
LFT self-reported home test?	No (Reference)	13503 (51.1%)			
	Yes	12920 (48.9%)	1.36	(1.28, 1.44)	<0.001

Note: For Categorical variables we report the number and percentage, whilst for age we report the median and interquartile range and for total number of LFTs in previous 14 days we report mean, minimum and maximum. 1073 individuals with missing age, sex or ethnicity data were omitted from these models

Factors associated with LFT-confirmatory PCR agreement

We also used generalised linear mixed models accounting for regional variability to explore factors associated with the agreement between a positive LFT and a confirmatory PCR (i.e., true positives). For individuals who had a confirmatory PCR test, home tests and tests on individuals with more LFTs in the two weeks prior to a positive LFT were less likely to produce a positive PCR, whilst tests on males were more likely to have a positive PCR (Table 11). There was no evidence of a significant association between ethnicity and the agreement between positive LFT and confirmatory PCR result.

It is worth mentioning that the discordance rate is linked to the prevalence at the time of tests with discordance less common at times of high prevalence. So, a potential confounder to these results is the fact that prevalence of Covid-19 changes over time which makes direct causal inference from these results challenging.

Table 11. Odds Ratios from multiple logistic regression models showing the association with agreement between positive LFT and confirmatory PCR result.

Explanatory Variable		Summary	Odds Ratio	95% CI	p-value
Intercept			16.60	(12.83, 21.48)	
Age		32 (21, 48)	0.999	(0.994, 0.999)	0.033
Sex	Female (Reference)	9801 (51.7%)			
	Male	9167 (48.3%)	1.32	(1.2, 1.46)	<0.001
Ethnicity	White (Reference)	18003 (94.9%)			
	Asian	322 (1.7%)	1.02	(0.71, 1.47)	0.921
	Black	286 (1.5%)	0.90	(0.62, 1.31)	0.596
	Mixed or multiple ethnic groups	261 (1.4%)	0.95	(0.64, 1.41)	0.798
	Other	96 (0.5%)	1.21	(0.58, 2.51)	0.612
IMD Deprivation Quintile	1 (most deprived)	9268 (48.9%)	0.74	(0.6, 0.93)	0.008
	2	3097 (16.3%)	0.83	(0.65, 1.05)	0.122
	3	2885 (15.2%)	0.80	(0.63, 1.01)	0.066
	4	2571 (13.6%)	0.99	(0.77, 1.27)	0.936
	5 (least deprived) - Reference	1147 (6.0%)			
Total LFTs in previous 14 days		0.48 (0, 13)	0.87	(0.84, 0.91)	<0.001
LFT self-reported home test?	No (Reference)	9305 (49.1%)			
	Yes	9663 (50.9%)	0.52	(0.47, 0.57)	<0.001

Note: For Categorical variables we report the number and percentage, whilst for age we report the median and interquartile range and for total number of LFTs in previous 14 days we report mean, minimum and maximum. 315 individuals with missing age, sex or ethnicity data were omitted from these models.

Uptake of LFT in secondary school-aged children

Secondary school-aged children provide an interesting group on which to examine the uptake of LFTs. This is because not only a child testing positive needs to isolate but also their school class contacts may need to quarantine which can substantially impair children's' education. The UK government advised[2] twice weekly testing using LFTs for all secondary school pupils from 8th March as schools reopened. However, the uptake of LFT testing and the agreement between positive LFT and confirmatory PCR in school-aged children is not well understood.

Regional variation

Between 3rd December 2020 and 31st July 2021, 701,951 LFTs were taken by 134,166 11-18-year-olds across the six Local Authorities within the Liverpool City Region; 3,629 individuals were identified with a positive LFT among 11–18-year-olds (Table 12). Not all children with a positive LFT undertook a confirmatory PCR, with 70.7% of 12-18-year-olds taking a PCR test within 2 days of a positive LFT.

Table 12. Summary of Lateral Flow testing in 12–18-year-old children in Liverpool City Region between 3rd December 2020 and 31st July 2021 by Local Authority.

	Liverpool City Region	Halton	Knowsley	Liverpool	Sefton	St. Helens	Wirral
Number of individuals with LFT test	134166	11699	9775	49367	20999	15258	27068
Number of LFT tests	701951	76828	49195	179471	128907	90507	177043
Number of PCR tests	63361	6189	6230	17430	13025	6615	13872
Number of individuals with a positive LFT test	3629	275	368	1091	650	423	822
Number of individuals with a confirmatory PCR (% of individuals with positive LFT)	2565 (70.7%)	205 (74.5%)	251 (68.2%)	675 (61.9%)	469 (72.2%)	332 (78.5%)	633 (77.0%)
Confirmatory PCR positive (%)	2249 (87.7%)	186 (90.7%)	221 (88.0%)	575 (85.2%)	416 (88.7%)	280 (84.3%)	571 (90.2%)
Confirmatory PCR negative (%)	290 (11.3%)	19 (9.3%)	23 (9.2%)	89 (13.2%)	52 (11.1%)	49 (14.8%)	58 (9.2%)
Confirmatory PCR void (%)	26 (1.0%)	0 (0%)	7 (2.8%)	11 (1.6%)	1 (0.2%)	3 (0.9%)	4 (0.6%)

[2] From 16th August 2021, people fully vaccinated or aged under 18 years were no longer required to self-isolate if identified as a close contact of a positive Covid-19 case. This is after the study period of this report.

Time trends

Figure 13 shows that there was a substantial increase in the use of LFTs in secondary school-aged children at the beginning of March, coinciding with the return to school for most children in the UK. After the initial period of schools-based testing (two weeks), uptake of LFT dropped substantially. At this point lateral flow testing in secondary school aged children switched more to home testing. The pattern was similar across all Local Authorities.

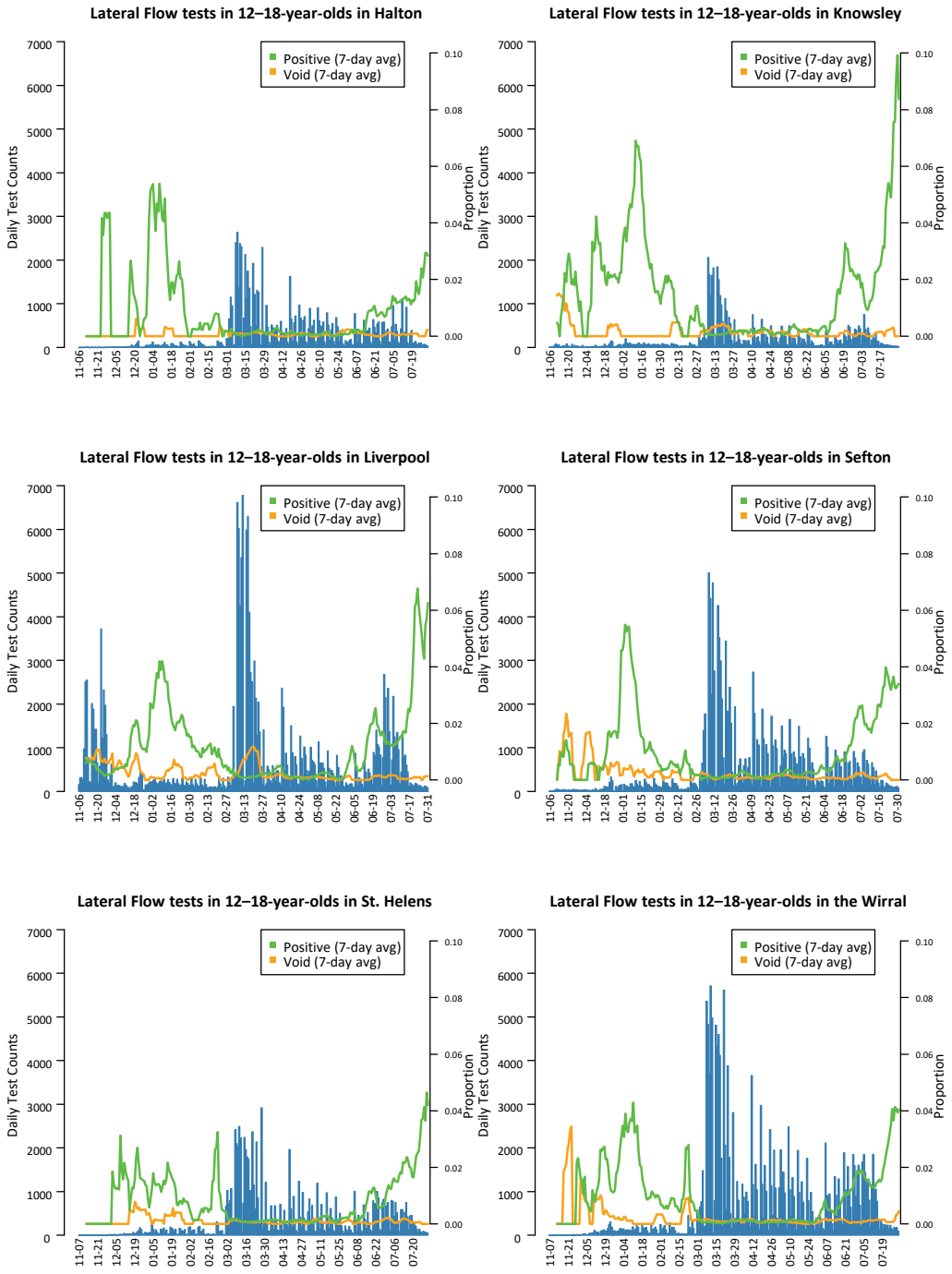

Figure 13. Uptake of Lateral Flow testing in 12-18-year-olds by Local Authority. Blue bars show the daily counts of lateral flow tests taken. The proportion of all LFT tests on a day that are positive is shown in green and the proportion of tests void is shown in orange.

LFT vs confirmatory PCR disagreement: variations by local authority and over time

As show in Table 12, the overall disagreement between a positive LFT and a confirmatory PCR was 11.3%, ranging from 9.2-9.3% in Wirral, Knowsley, and Halton to 14.8% in St. Helens. There was substantial variability across the study period with higher proportions of disagreement when the prevalence of Covid-19 was lower (top panel, Figure 14). The proportion of discordant positive LFTs (i.e., linked to a negative PCR) was higher when the proportion of positive tests was lower implying lower prevalence (bottom right of Figure 14). This emphasises the need for confirmatory PCR testing, especially when prevalence is low.[10]

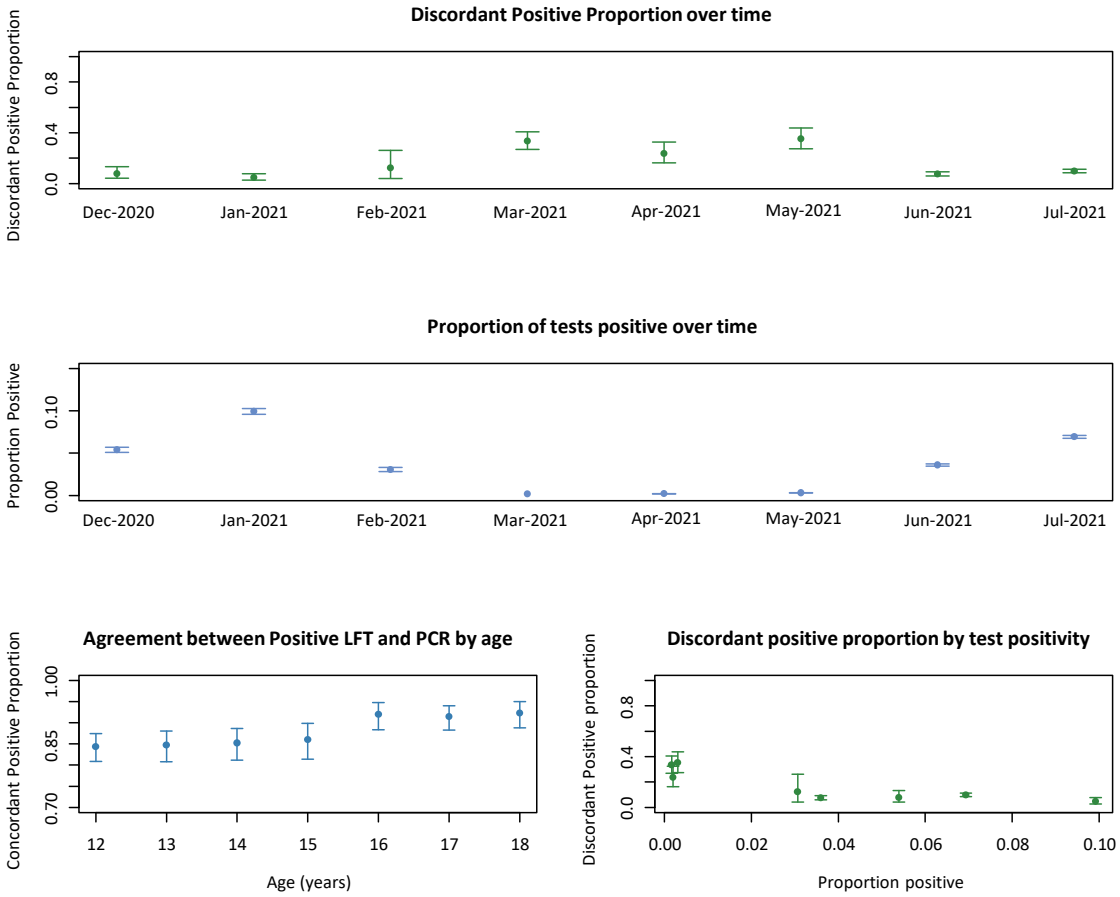

Figure 14. Proportion of disagreement (with 95% confidence intervals) between positive LFT and confirmatory PCR, over time (top panel), proportion of all tests positive over time (middle panel), concordant positive proportion by age (bottom left) and the relationship between discordant positive proportion and proportion of all tests positive (bottom right). Confirmatory PCR was determined as a PCR within a 2-day window of the positive LFT. The proportion of tests positive was calculated as all positives (either PCR or LFT) divided by all tests taken within the month for each age group. We have assumed, conservatively, that all void PCR results are discordant positives.

Factors associated with uptake of confirmatory PCR

We used multifactorial logistic regression to assess factors influencing the uptake of confirmatory PCR tests following positive LFT in 12-18-year-olds. Table 13 presents the findings. Positive LFTs from non-White children, from individuals living in the two most deprived quintiles of Liverpool City Region areas, and from older secondary school-aged children were less likely to have a confirmatory PCR. Also, self-reported positive LFTs were more likely to obtain a confirmatory PCR than supervised tests. An individual's sex, and the number of LFTs taken in the last 14 days were not significant predictors of whether an individual would get a confirmatory PCR following a positive LFT. A small association was observed for age, with older children slightly less likely to get confirmatory PCR. This contrasts with the findings for the whole population (Table 10) in which no evidence was found of an association between age and likelihood of obtaining a confirmatory PCR. The reasons for this apparent discrepancy are unclear, although the association is small in any case.

Table 13. Odds Ratios from multiple logistic regression models showing the association with uptake of confirmatory PCR test after a positive LFT for 12–18-year-olds.

Explanatory Variable		Summary	Odds Ratio	95% CI	p-value
Intercept			4.33	(2.2, 8.54)	<0.001
Age		15 (13, 17)	0.96	(0.92, 0.999)	0.030
Sex	Female (Reference)	1918 (53.0%)			
	Male	1701 (47%)	1.10	(0.94, 1.27)	0.173
Ethnicity	White (Reference)	2988(82.6%)			
	Asian	87 (2.4%)	0.42	(0.27, 0.65)	<0.001
	Black	62 (1.7%)	0.38	(0.23, 0.64)	<0.001
	Mixed or multiple ethnic groups	102 (2.8%)	0.73	(0.48, 1.14)	0.160
	Other	17 (0.5%)	0.25	(0.09, 0.67)	0.006
	Prefer not to say	363 (10.0%)	0.76	(0.6, 0.97)	0.028
IMD Deprivation Quintile	5 (least deprived) - Reference	288 (8.0%)			
	1 (most deprived)	1775 (49.0%)	0.52	(0.38, 0.7)	<0.001
	2	523 (14.5%)	0.65	(0.46, 0.92)	0.015
	3	530 (14.6%)	0.86	(0.6, 1.22)	0.404
	4	503 (13.9%)	0.94	(0.65, 1.35)	0.749
Total LFTs in previous 14 days		0 (0, 1)	0.99	(0.92, 1.06)	0.700
LFT self-reported home test?	No (Reference)	1198 (33.1%)			
	Yes	2421 (66.9%)	2.28	(1.93, 2.69)	<0.001

Note: For categorical variables we report the number and percentage, whilst for continuous variables we report the median and interquartile range.

Factors associated with LFT-confirmatory PCR agreement

We also used multifactorial logistic regression to assess factors associated with the agreement between positive LFTs and confirmatory PCR in 12-18-year-olds. As shown in Table 14, positive LFTs on older children were more likely to be confirmed with a positive PCR, with an increase in odds of 16% (OR: 1.16; 1.09 to 1.24) per year of age in 12-18-year-olds. Moreover, self-reported positive LFTs were more likely to agree with the PCR compared to testing site supervised tests. Finally, deprivation and the number of LFTs in the 14 days prior to a positive LFT did not appear to be significant predictors of whether the confirmatory PCR would agree with the original positive LFT in secondary school-aged children.

Table 14. Odds ratios for a multiple logistic regression showing the association with agreement between positive LFT and confirmatory PCR for 12-18-year-olds.

Explanatory Variable		Summary	Odds Ratio	95% CI	p-value
Intercept			0.50	(0.18, 1.42)	0.195
Age		15 (13, 17)	1.16	(1.09, 1.24)	<0.001
Sex	Female (Reference)	1918 (53.0%)			
	Male	1341 (52.4%)			
IMD Deprivation Quintile	5 (least deprived) - Reference	229 (9.0%)			
	1 (most deprived)	1162 (45.4%)	1.05	(0.67, 1.58)	0.831
	2	367 (14.3%)	1.02	(0.62, 1.65)	0.943
	3	407 (15.9%)	1.26	(0.76, 2.06)	0.368
	4	394 (15.4%)	1.57	(0.93, 2.64)	0.087
Total LFTs in previous 14 days		0 (0, 1)	0.92	(0.84, 1.01)	0.062
LFT self-reported home test?	No (Reference)	693 (27.1%)			
	Yes	1866 (72.9%)	1.55	(1.19, 2.01)	0.001

Note: For categorical variables we report the number and percentage, whilst for continuous variables we report the median and interquartile range.

Times that people got tested

This section aims to explore weekly and daily variations in the uptake of asymptomatic LFT in Liverpool City Region during the study period. Figure 15 presents patterns for LFT behaviour by day of the week and by hour of the day. Testing was most common on Monday and lowest on Saturday. Weekly patterns in the number of tests varied by differences in testing behaviours between home and other site tests (see Appendix, Figure 22). Home tests were more common on Sunday, Monday, Wednesday and Thursday, with little difference on other days. Positivity rates were highest on Saturday (e.g., 1.40% on Saturday vs 0.81% on Friday). LFT uptake was most common in the morning, especially between 8 and 11am. There were declining numbers of tests following this period. While there were higher values of positive tests between 0 and 4am, caution should be made in interpreting these data due to small number issues (<100 positive tests over the study period). There were differences in patterns throughout the day between home and other site testing behaviours, with home testing most commonly occurring outside of the working day (see Appendix, Figure 22 and Figure 23).

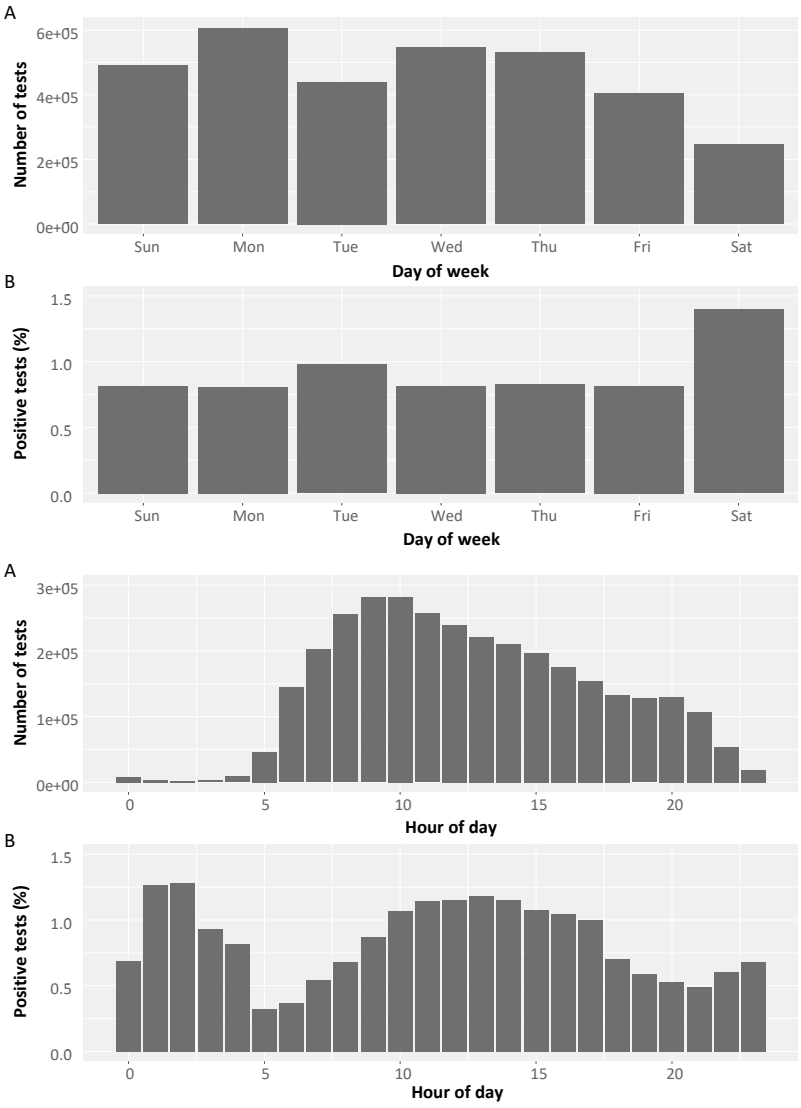

Figure 15. Lateral flow device patterns by day of the week (top) and by hour of the day (bottom) in Liverpool City Region for (A) total number of tests, and (B) percentage of tests that were positive, 3rd December 2020 – 31st July 2021.

Test-to-release scheme for key workers in Liverpool

A specific aspect of the Liverpool pilot aimed to evaluate the use of serial daily LFTs as an alternative to quarantine (Test-to-Release[12] scheme) for key workers in Liverpool who had been identified as a close contact of a confirmed positive SARS-CoV-2 case. The pilot was first implemented with Merseyside Police in November 2020, and later with Merseyside Fire and Rescue Service (MFRS) in December 2020. Alder Hey Children's Hospital, Adult Social Care (primarily Domiciliary Care Providers) and Liverpool City Council joined in February 2021. Other organisations contributed smaller numbers of individuals. The number of individuals recruited per organisation, and a summary of the number of tests per day since original exposure is shown in Appendix, Table 32.

Between 4th December 2020 and 16th August 2021, 1,657 individuals enrolled on this key-worker-release scheme. The reasons for non-participation were not systematically recorded by organisations, however based on feedback from organisational leads, most opt-outs from the scheme were due to travel difficulties. Participants carried out supervised daily testing with Innova lateral flow devices from point of identification until day seven post exposure with an evaluatory PCR test on day six or seven. Basic demographic features of participants from Mersey Police, Mersey Fire and Alder Hey are shown in Table 15 (information from organisations with fewer participants is not shown to assure anonymity).

Table 15. Demographic features of individuals enrolled in the pilot from Mersey Police, Mersey Fire and Alder Hey. Smaller organisations, contributing less than 20 individuals to the SMART release scheme were not included in this table to preserve anonymity (27 individuals across six organisations).

Organisation	Mersey Police	Mersey Fire	Alder Hey
Number of Individuals	1358	90	182
Age	36 (27, 46)	41 (32, 51.75)	34.5 (28, 45)
Males	899 (66.2%)	Not available	Not available
Females	459 (33.8%)	Not available	Not available
White	1315 (96.8%)	85 (94.5%)	157 (86.3%)
Non-white (Black, Asian, Mixed)	43 (3.2%)	3 (3.0%)	11 (6.0%)
Not given	0	2 (2.2%)	14 (7.7%)

Note: percentages may not add up to 100 due to rounding.

Test-to-release or daily contact testing appeared to be useful for sustaining services during the pandemic, with a total of 34 positive Covid cases identified and only three of these missed by daily LFTs in a total of 1657 participants. Figure 16 shows a graphical representation of when each of these 34 individuals was identified and their testing history, and demonstrates that most individuals who tested positive were identified by the scheme.

Table 16 summarises the concordance of serial lateral flow testing with seven PCR results.

Adherence with the daily testing scheme was good overall and allowed key services to remain staffed during the pandemic. For such schemes to continue going forward, organisations would benefit from increased support in maintaining data records of participants' test results.

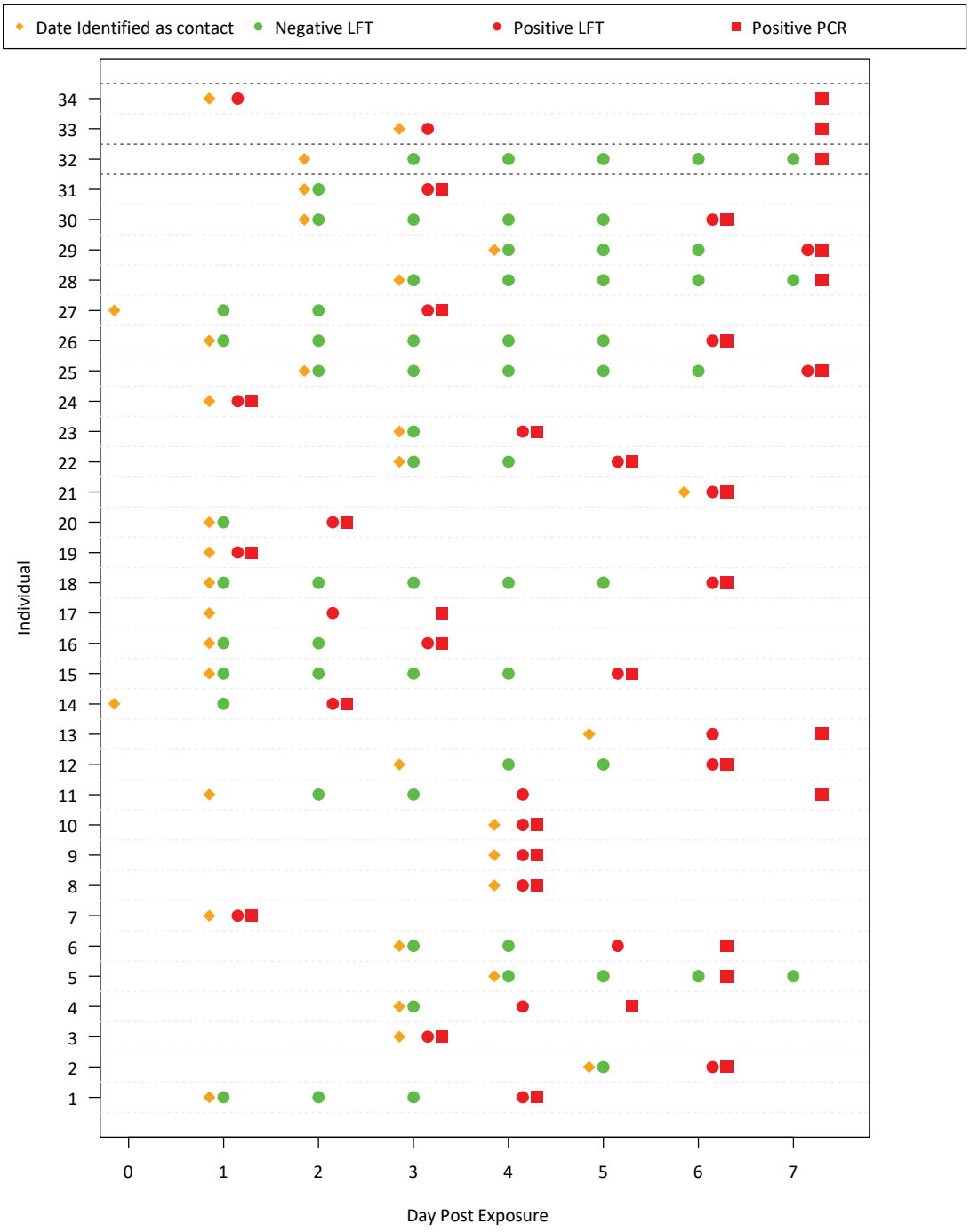

Figure 16. Graphical representation of the testing history of 34 individuals testing positive by PCR. Individuals 1-31 worked for Mersey Police, individual 32 worked for Mersey Fire and individuals 33 and 34 worked for Alder Hey.

Table 16. PCR-concordance of serial LFT testing in Police workers. A positive is defined as an individual who had at least one positive LFT at any point during their seven days of observation. The "No result" column denotes individuals with a missing PCR result.

			PCR Result			
			Void	**Negative**	**Positive**	**No Result**
Serial LFT	**Police**	All negative	1	1269	2	57
		Positive	0	0	29	0
	Mersey Fire	All Negative	0	83	1	6
		Positive	0	0	0	0
	Alder Hey	All Negative	0	167	0	13
		Positive	0	0	2	0

Impact of LCR community asymptomatic testing on Covid-19 hospital admissions

On 3rd December 2020 community asymptomatic testing for SARS-CoV-2 was expanded from Liverpool City to the wider LCR. This means that LCR was 1-2 months ahead in the adoption of asymptomatic testing compared to most LAs in England. As part of the current report, we therefore aimed to estimate the impact of asymptomatic testing on hospital admissions for Covid-19 across the whole LCR until the 21st of March 2021 (NHS Digital have not yet provided data for synthetic control areas beyond this date, however, the main period of interest is the initial month where LCR rolled out community testing ahead of other areas). We used synthetic control methods to compare trends in hospital admissions for Covid-19 between MSOAs (total of 200) within the 6 local authorities comprising the LCR (i.e., intervention area) and a combination of other MSOAs in local authorities that did not undergo similar testing (i.e., synthetic controls). We used hospital admissions as the main outcome for this analysis because this outcome is less affected by changes in levels of case detection than other outcomes such as case rates. This is because information on reported Covid-19 cases usually underestimates the number of actual infections as it is influenced by changes in testing practices, public behaviour and testing capacity.

Construction of the synthetic control areas and adjustment for Tier 3 restrictions

We excluded MSOAs from the control group if they were within local authorities with an LFT testing rate of more than 1 per 100 population per week during the 1st month of the intervention period (i.e., 3rd December 2020 – 3rd January 2021) to minimise the potential impact of similar asymptomatic pilot programmes elsewhere. To construct the synthetic control group, we derived calibration weights to match the MSOAs in LCR to areas outside the LCR (across the five-week period prior to the intervention) by local area characteristics representing established Covid-19 risk factors; these included deprivation using the 2019 IMD, percentage of population aged 7-11 and >70 years using 2019 mid-year ONS estimates, average number of care home beds per head of population from the Care Quality Commission, population density (i.e., people per hectare), the proportion of the population from Black, Asian and Minority Ethnic (BAME) groups and the proportion of students (both obtained from the 2011 Census). To account for differences in the prevalence of the Alpha variant B.1.1.7, we included the proportion of positive tests with S-gene target failure on comparable PCR testing for each LA from Public Health England. We also matched the synthetic control group on preintervention trends in hospital admissions for Covid-19 (main outcome) to minimise potential differences in unobserved characteristics. Figure 17 shows the geographical location of the intervention and control areas.

In addition to constructing the synthetic control group, we adjusted our analysis to remove the effect of the Tier 3 restrictions in the synthetic control group. This is because on 3rd December 2020, the whole LCR moved to less stringent (Tier 2) local restrictions, while most of the rest of England entered Tier 3 restrictions. Based on previous analysis[7] we found that Tier 3 restrictions reduced hospital admission rates, on average, by 15% (95% CI 11% to 19%) relative to Tier 2 restrictions and that these effects started around the 17th December 2020 and extended to the 21st February 2021. We therefore adjusted the cases in Tier 3 areas upwards by this percentage during this period, before deriving weights as outlined above to provide a synthetic control group reflecting transmission conditions that were experienced in LCR at that time. This adjustment assumes the effect of Tier 2 restrictions on transmission in

LCR was the same as the average effect across Tier 2 areas in England. The effect could have, however, been greater in LCR, because unlike other Tier 2 areas, most of the areas surrounding the LCR were in Tier 3.

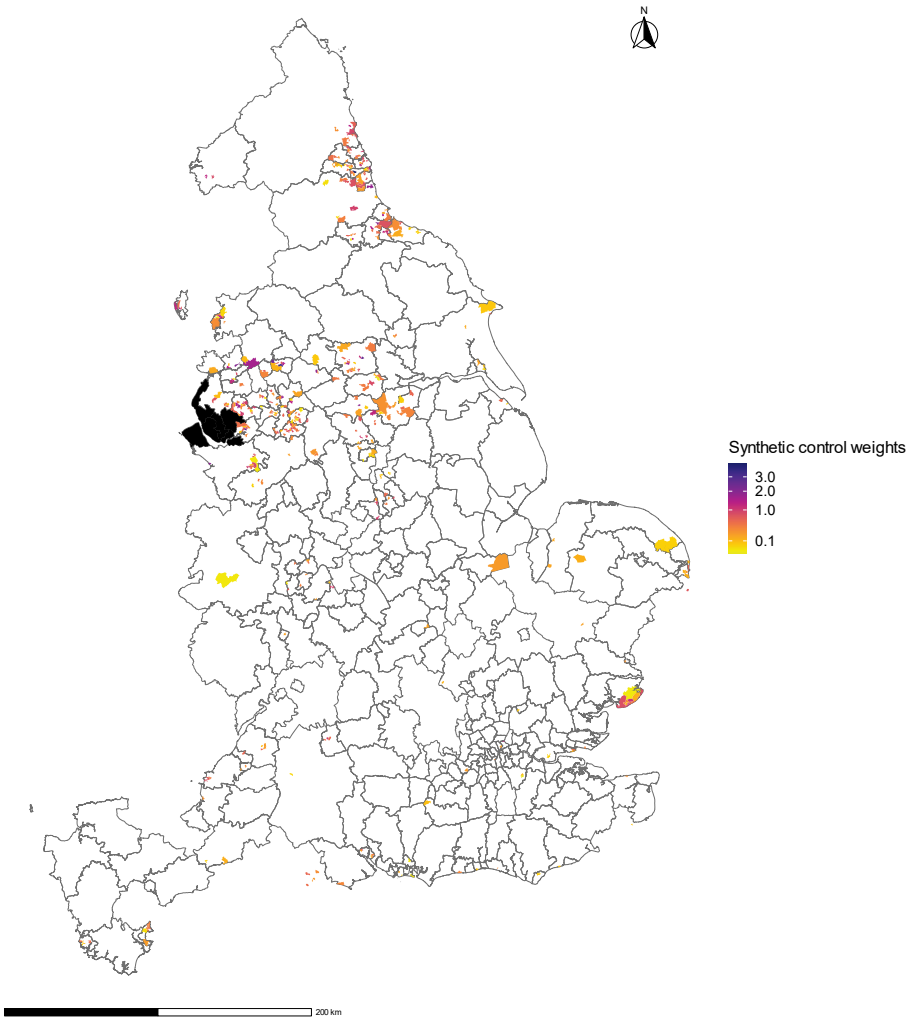

Figure 17. Location of intervention areas (LCR) (black) and synthetic control areas that did not introduce community testing (yellow to purple with increasing weights).

Trends in Covid-19 hospital admission rates

We analysed the trend in hospital admissions in LCR, eight weeks before the 3rd December 2020 (i.e., when the City of Liverpool pilot expanded to LCR) and from that period to the 21st March 2021 compared to the control group. The main intervention-control contrast period was in the first month when LCR had rolled out community testing ahead of the rest of England. Figure 18 shows the trend in weekly Covid-19 hospital admission rates, from early October 2020 to end of March 2021 in LCR and the synthetic control group, adjusted for the effect of reduced transmission resulting from stricter restrictions in Tier 3 areas. Due to an exact match in calibration weights, the synthetic control and intervention groups were identical in hospitalisation rates in the pre-intervention period. However, trends began to diverge at the end of November 2020, with hospitalisations being lower in LCR than in the synthetic control. Since expansion of asymptomatic testing in the LCR started only in early December, we expect most of the divergence observed in November to be driven by the

earlier implementation of the scheme in Liverpool City (6th November). However, part of this early effect may be attributed to spill-over effects in the wider region since, for example, some participants in the Liverpool pilot were working in Liverpool but residing in neighbouring areas. The lower trend in LCR continued throughout December with 95% confidence intervals not overlapping at each time point, before sharply rising in early January 2021 to match the synthetic control. At this point Alpha variant was spreading rapidly and national lockdown was in place. The synthetic control areas at this point also started to roll-out community testing so became less of a control to LCR other than a potential hangover effect of early adoption. The trend in LCR then raised above that of the synthetic control with non-overlapping 95% confidence intervals from mid-January to early February 2021. Thereafter, trends remain similar until early March 2021 before the trend in Liverpool City Region alongside the surrounding 95% confidence intervals declined below those of the synthetic control from 8th March 2021 to the end of that month, with both areas declining following the national lockdown.

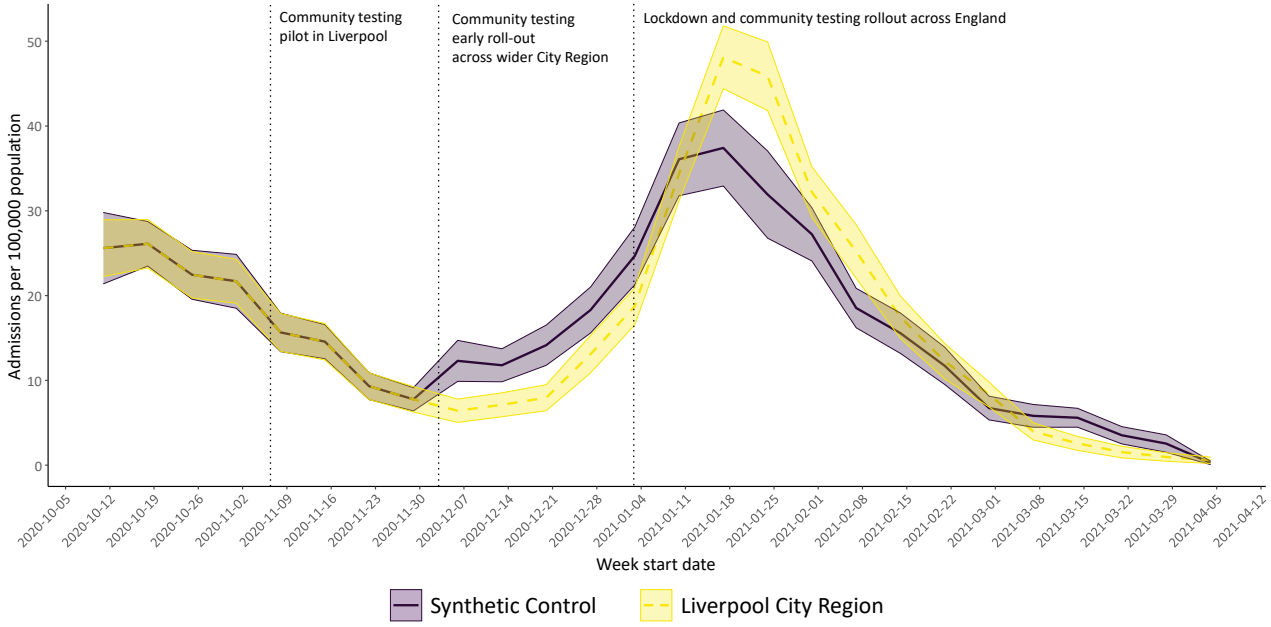

Figure 18. The trend in weekly Covid-19 hospital admission rates in MSOAs in Liverpool City Region compared to a synthetic control group constructed from the weighted average of MSOAs outside Liverpool City Region without community testing. Dotted vertical lines represent start of Liverpool community testing pilot on 6th November 2020, followed by expansion to Liverpool City Region on 3rd December 2020, before national roll-out.

Impact of community testing on hospital admissions

We estimated the average treatment effect for the treated as the difference in cumulative number of hospital admissions in the post intervention period in LCR, compared to the weighted number of admissions in the synthetic control group. We applied a permutation procedure to estimate the 95% confidence intervals and p-values (analysis repeated through 250 permutations). We estimated the effect of the community testing programme on Covid-19 hospital admissions both throughout the whole study period (until 21st March 2021) and during the first month of implementation (until 3rd January 2021). For the estimation of these effects, we assumed Tier 3 restrictions reduced admissions by 15% compared to Tier 2 restrictions. This corresponds to our central estimate of the average effect estimated across Tier 2 and 3 areas in England.

For the entire observation period (model 1, Table 17) we found no significant difference in hospital admission rates in LCR compared to the synthetic control group, which is unsurprising considering the control group deployed community testing six weeks after LCR. We assumed that the effect on transmission in LCR of entering Tier 2 from Tier 3 was 15% (central estimate). Table 17 also shows the intervention effect at the upper and lower bound of our tier effect estimate (19% and 11% respectively). When analysis was restricted to the first month of implementation (model 4), when LCR rolled out community testing ahead of the control areas, we found asymptomatic testing in LCR was associated with a 32% reduction in hospital admissions and this effect was statistically significant (95% CI from -39% to -22%, p-value<0.001). It should be noted that overall admissions were lower during that period. In absolute numbers, this 32% reduction is the equivalent of 391 fewer admissions.

Table 17. Estimated effect of community testing programme on Covid-19 hospital admissions from synthetic control analysis, under alternative assumptions related to the effect of the introduction of less stringent restrictions in Liverpool City Region in December 2021.

Model	Period	Assumed reduction in Covid-19 hospital admissions related to Tier 3 Vs Tier 2 restrictions	% difference in hospital admissions	Lower CL	Upper CL	P-value
1	3/12/20 – 21/3/21 (control data span)	15% (central estimate)	1%	-7%	9%	0.876
2		19%	-5%	-13%	3%	0.216
3		11%	7%	-2%	16%	0.119
4	3/12/20 – 2/1/21 (testing region vs non-testing control areas)	Nil	-32%	-39%	-23%	<0.001
5		15% (central estimate)	-34%	-42%	-25%	<0.001

Supplementary analysis: Impact of community testing on case detection

In supplementary analysis we estimated the effect of the introduction of the community testing during the whole study period (until 31st March 2021) on the case detection rate – i.e., the proportion of SARS-CoV-2 infections in the population detected through the testing. If we assume that the trend in Covid-19 admissions in the intervention and synthetic control populations broadly reflects the trend in infections (~1 week prior), then comparing the ratio in cases to the lagged number of admissions gives an approximation of the relative difference in the case detection rate between the intervention and synthetic control populations. We can therefore model the relative change in case detection rates before and after the introduction of community testing in LCR compared to the change in case detection rates in the synthetic control group as a log linear Poisson regression model with confirmed cases as the outcome and the log of the number of Covid-19 admissions, 1 week later, as an offset. This analysis assumes that the Infection Hospitalisation Rate (i.e., proportion of infected admitted) follows the same trend in the intervention and synthetic control areas over time. Based on the Poisson regression model, we estimated that community testing led to a relative increase in the case detection rate of 28% (RR = 1.30, 95% CI 1.28 to 1.33). This is equivalent to an additional 17,874 cases (95% CI 16,807 to 18,923) of SARS-CoV-2 being identified between 3rd December 2020 and 31st March 2021 than would have been identified without community testing.

Appendix: Supplementary findings

Table 18. Number of lateral flow device tests undertaken by Local Authority (without removing tests with age less than 5).

Area	People tested	Total tests	Total positive tests	Positivity rate (%)
Halton	52,843	300,270	2,078	0.69
Knowsley	65,565	289,985	3,378	1.16
Liverpool	241,303	940,813	10,453	1.11
Sefton	107,505	603,061	4,796	0.80
St. Helens	77,500	397,939	3,136	0.79
Wirral	134,046	746,717	5,210	0.70
Liverpool City Region	678,762	3,278,785	29,051	0.89

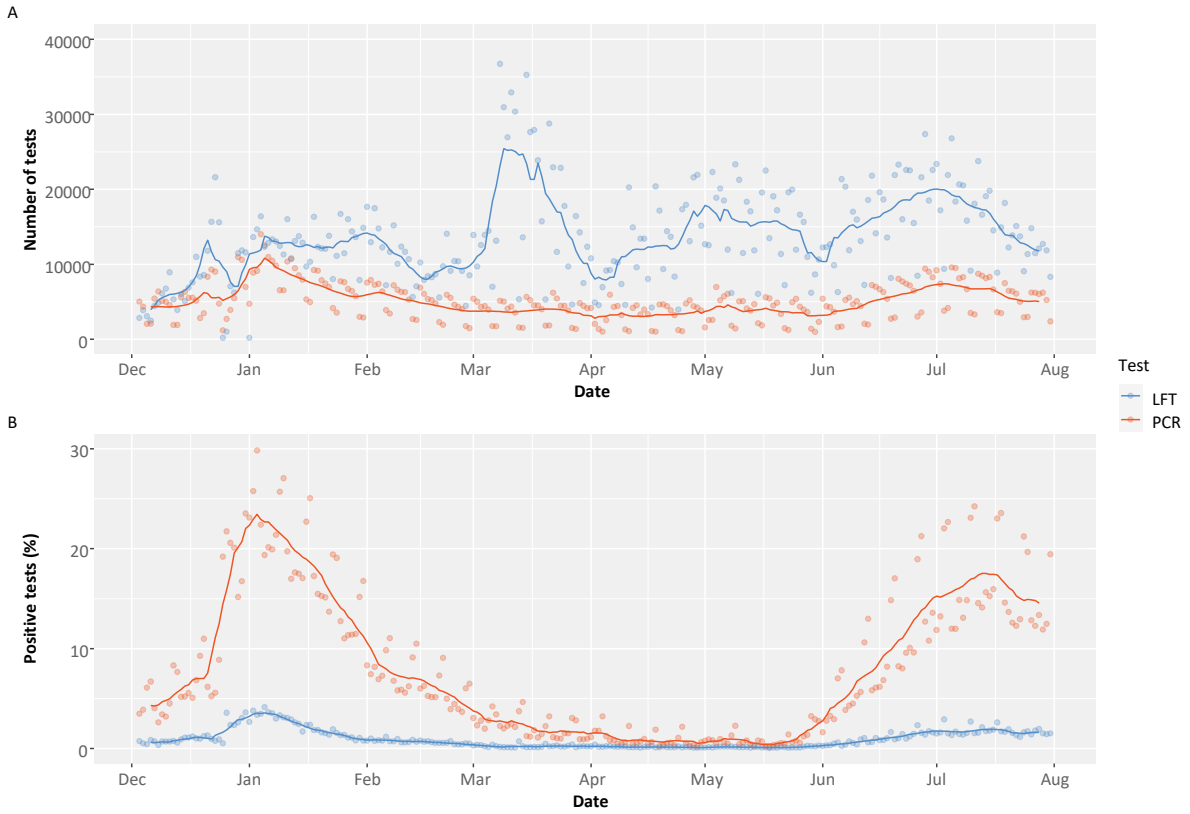

Figure 19. Trends in people aged 5 years and above receiving a test (A) and percentage of tests that were positive (B) by test type for the Liverpool City Region.

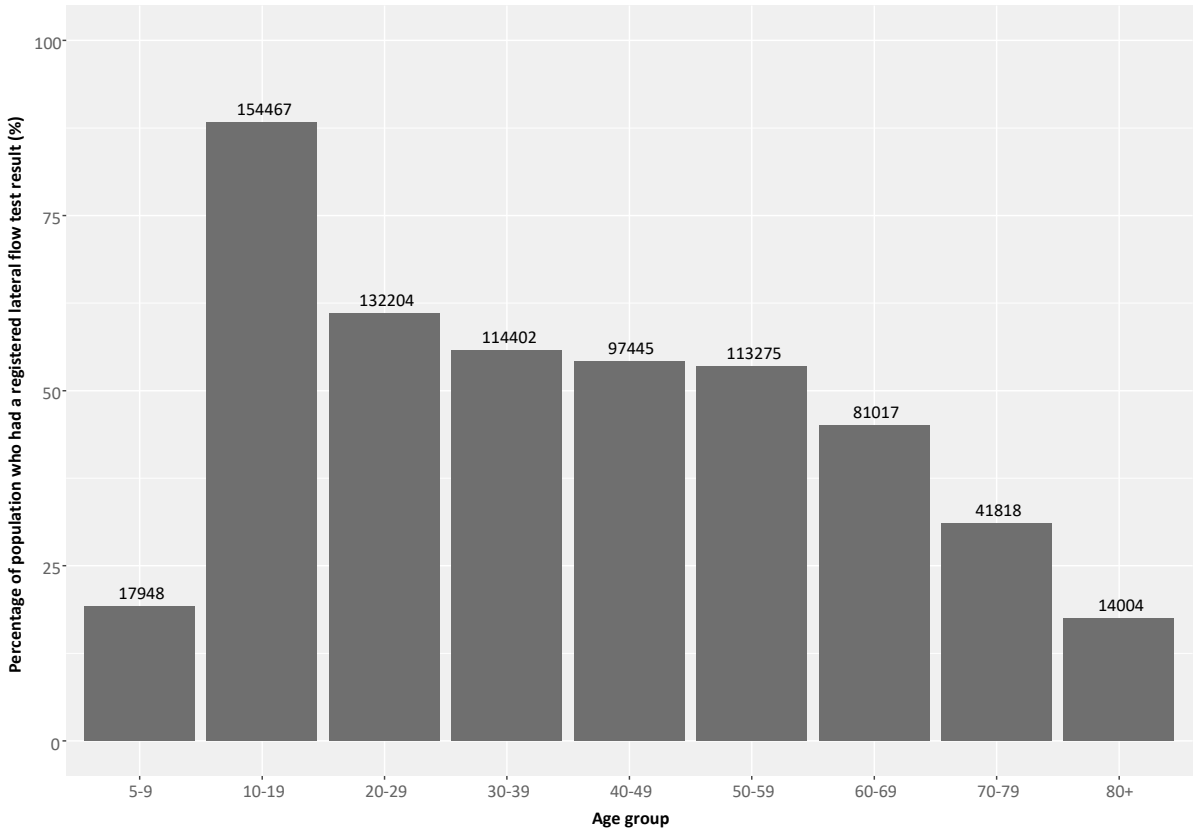

Figure 20. Percentage of population who had a registered lateral flow test result by 10-year age band for Liverpool City Region (raw numbers for update are presented by each bar).

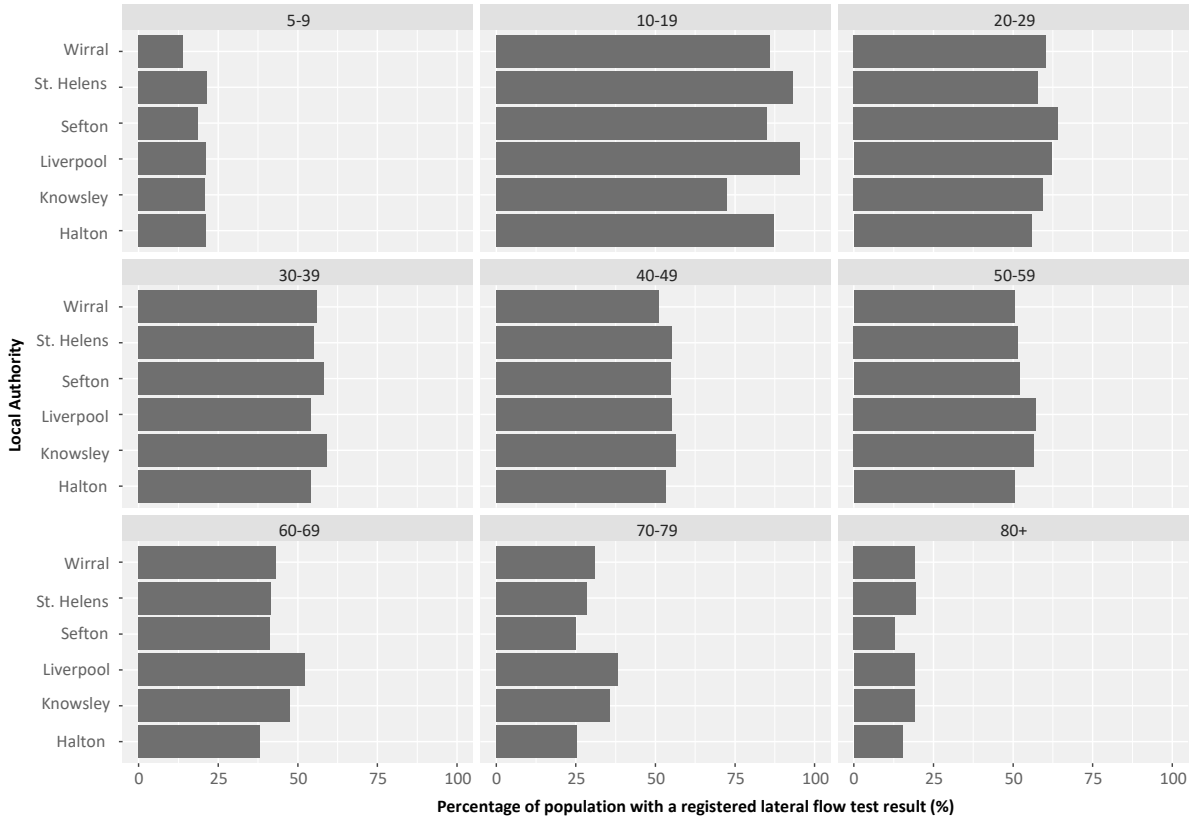

Figure 21. Percentage of people by 10-year age groups who had a registered lateral flow test result by Local Authority.

Table 19. Summary statistics for test uptake by demographic characteristics for Halton, Knowsley and Liverpool.

		Halton			Knowsley			Liverpool		
Theme	**Characteristic**	**People tested**	**Estimated population**	**Percentage tested (%)**	**People tested**	**Estimated population**	**Percentage tested (%)**	**People tested**	**Estimated population**	**Percentage tested (%)**
Sex	Female	32,805	66,464	49.36	39,300	79,964	49.15	140,490	250,078	56
	Male	27,537	63,295	43.51	34,835	72,488	48.06	125,039	250,396	50
Age	"5-14"	8,928	17,012	52.48	8,370	19,270	43.44	31,636	54,176	58
	15-34	19,498	30,514	63.90	24,381	38,732	62.95	110,278	169,003	65
	35-69	28,258	58,207	48.55	36,037	66,058	54.55	107,512	196,444	55
	70+	3,658	16,652	21.97	5,347	18,303	29.21	16,103	52,015	31
Ethnicity	Asian	710	1,031	68.87	1,001	1,673	59.83	11,955	21,681	55
	Black	532	270	197.04	866	527	164.33	8,934	14,620	61
	Mixed	499	1,766	28.26	606	2,299	26.36	5,046	14,949	34
	Other	225	171	131.58	245	241	101.66	3,911	10,201	38
	White	58,376	126,172	46.27	71,417	146,123	48.87	235,683	436,591	54
Deprivation	Least deprived	15,194	29,706	51.15	17,850	32,977	54.13	58,281	98,071	59
	Quintile 2	11,110	22,927	48.46	15,005	29,054	51.65	66,150	105,159	63
	Quintile 3	12,668	27,640	45.83	15,752	31,003	50.81	52,084	94,136	55
	Quintile 4	10,860	24,419	44.47	13,556	28,953	46.82	44,253	100,407	44
	Most deprived	10,510	24,718	42.52	11,972	28,875	41.46	44,761	100,269	45

Note 1: Deprivation quintile is defined using LA specific quintiles. Caution should therefore be given to making comparisons between areas.
Note 2: Population estimates for ethnicity should be interpreted with caution as we have more people tested than estimated for most areas.

Table 20. Summary statistics for test uptake by demographic characteristics for Sefton, St. Helens and Wirral.

		Sefton			St. Helens			Wirral		
Theme	**Characteristic**	**People tested**	**Estimated population**	**Percentage tested (%)**	**People tested**	**Estimated population**	**Percentage tested (%)**	**People tested**	**Estimated population**	**Percentage tested (%)**
Sex	Female	68,233	143,031	47.71	46,455	91,984	50.50	80,499	167,221	48
	Male	59,494	132,868	44.78	40,532	89,111	45.48	70,600	157,115	45
Age	"5-14"	16,012	31,539	50.77	12,123	21,278	56.97	19,016	39,306	48
	15-34	39,732	58,125	68.36	27,329	42,418	64.43	47,201	70,806	67
	35-69	62,192	123,932	50.18	40,611	80,222	50.62	71,062	144,984	49
	70+	9,791	48,514	20.18	6,924	27,298	25.36	13,820	52,091	27
Ethnicity	Asian	1,749	2,976	58.77	1,149	1,963	58.53	3,275	5,614	58
	Black	1,242	854	145.43	686	253	271.15	1,365	714	191
	Mixed	1,111	3,773	29.45	595	1,456	40.87	1,629	4,067	40
	Other	540	849	63.60	318	236	134.75	518	565	92
	White	123,085	267,957	45.93	84,239	176,677	47.68	144,312	313,051	46
Deprivation	Least deprived	25,465	53,462	47.63	16,964	34,606	49.02	31,770	62,847	51
	Quintile 2	25,957	54,630	47.51	19,300	37,848	50.99	30,799	63,381	49
	Quintile 3	27,429	58,763	46.68	16,236	34,411	47.18	32,646	65,978	49
	Quintile 4	25,518	56,199	45.41	18,645	38,284	48.70	29,553	66,643	44
	Most deprived	23,358	53,356	43.78	15,842	35,436	44.71	26,331	65,162	40

Note: Deprivation quintile is defined using LA specific quintiles. Caution should therefore be given to making comparisons between areas.

Note 2: Population estimates for ethnicity should be interpreted with caution as we have more people tested than estimated for most areas.

Table 21. Summary results from the Bayesian regression model examining spatial patterns in overall lateral flow test uptake.

Variable	Relative Risk	95% Credible Interval	
		Lower	Upper
Deprivation score (z-score)	0.67	0.65	0.70
Proportion students (z-score)	0.89	0.85	0.92
Care home in LSOA	0.69	0.64	0.74
Internet User Classification			
e-Veterans	Reference		
Digital Seniors	0.79	0.70	0.88
e-Cultural Creators	1.13	0.83	1.53
e-Mainstream	2.01	1.82	2.20
e-Professionals	0.85	0.64	1.11
e-Rational Utilitarians	0.74	0.67	0.82
e-Withdrawn	1.09	1.00	1.18
Passive and Uncommitted Users	4.53	4.22	4.86
Settled Offline Communities	0.82	0.67	1.00
Youthful Urban Fringe	1.01	0.75	1.35

Table 22. Summary statistics for people who tested positive by demographic characteristics for Halton, Knowsley and Liverpool

		Halton			Knowsley			Liverpool		
Theme	**Characteristic**	**Positive tests (n)**	**Total tests (n)**	**Percentage positive (%)**	**Positive tests (n)**	**Total tests (n)**	**Percentage positive (%)**	**Positive tests (n)**	**Total tests (n)**	**Percentage positive (%)**
Sex	Female	1,064	182,786	0.58	1,698	168,768	1.01	5276	538,408	0.98
	Male	982	115,739	0.85	1,634	118,655	1.38	5040	394,581	1.28
Age	"5-14"	248	56,193	0.44	318	35,738	0.89	940	108,460	0.87
	15-34	848	82,367	1.03	1,402	85,438	1.64	5217	353,457	1.48
	35-69	887	148,538	0.60	1,510	151,747	1.00	3872	427,633	0.91
	70+	63	11,427	0.55	102	14,500	0.70	287	43,439	0.66
Ethnicity	Asian	15	3,533	0.42	39	4,408	0.88	391	39,994	0.98
	Black	11	2,518	0.44	33	3,145	1.05	386	30,819	1.25
	Mixed	21	2,357	0.89	32	2,248	1.42	218	16,880	1.29
	Other	4	760	0.53	12	984	1.22	190	10,645	1.78
	White	1,995	289,357	0.69	3,216	276,638	1.16	9131	834,651	1.09
Deprivation	Least deprived	425	77,806	0.55	683	75,119	0.91	1902	219,976	0.86
	Quintile 2	362	56,967	0.64	662	59,558	1.11	2184	234,587	0.93
	Quintile 3	433	61,530	0.70	716	60,614	1.18	2005	182,564	1.10
	Quintile 4	395	52,796	0.75	709	48,835	1.45	2104	153,360	1.37
	Most deprived	431	49,426	0.87	562	43,297	1.30	2121	142,502	1.49

Note: Deprivation quintile is defined using LA specific quintiles. Caution should therefore be given to making comparisons between areas.

Table 23. Summary statistics for people who tested positive by demographic characteristics for Sefton, St. Helens and Wirral.

		Sefton			St. Helens			Wirral		
Theme	**Characteristic**	**Positive tests (n)**	**Total tests (n)**	**Percentage positive (%)**	**Positive tests (n)**	**Total tests (n)**	**Percentage positive (%)**	**Positive tests (n)**	**Total tests (n)**	**Percentage positive (%)**
Sex	Female	2417	364,565	0.66	1631	240,974	0.68	2665	451,005	0.59
	Male	2312	235,111	0.98	1456	154,327	0.94	2481	292,325	0.85
Age	"5-14"	503	92,694	0.54	370	67,814	0.55	690	120,561	0.57
	15-34	1983	159,053	1.25	1313	108,650	1.21	2161	203,533	1.06
	35-69	2091	318,057	0.66	1300	200,570	0.65	2073	380,336	0.55
	70+	152	29,872	0.51	104	18,267	0.57	222	38,900	0.57
Ethnicity	Asian	59	9,156	0.64	32	5,474	0.58	97	17,690	0.55
	Black	44	5,284	0.83	29	2,848	1.02	54	7,051	0.77
	Mixed	39	5,501	0.71	27	2,876	0.94	63	8,322	0.76
	Other	24	3,248	0.74	5	1,201	0.42	7	2,361	0.30
	White	4563	576,487	0.79	2994	382,902	0.78	4925	707,906	0.70
Deprivation	Least deprived	848	125,238	0.68	506	80,593	0.63	808	157,079	0.51
	Quintile 2	815	126,208	0.65	581	89,791	0.65	957	151,573	0.63
	Quintile 3	975	135,752	0.72	586	74,648	0.79	1155	163,786	0.71
	Quintile 4	1031	118,318	0.87	756	83,200	0.91	1151	146,307	0.79
	Most deprived	1060	94,160	1.13	658	67,069	0.98	1075	124,585	0.86

Note: Deprivation quintile is defined using LA specific quintiles. Caution should therefore be given to making comparisons between areas.

Table 24. Summary results from the Bayesian regression model examining spatial patterns in positivity rate for lateral flow test.

Variable	Relative Risk	95% Credible Interval	
		Lower	Upper
Deprivation score (z-score)	1.18	1.15	1.20
Proportion students (z-score)	0.97	0.95	0.99
Care home in LSOA	0.98	0.95	1.02

Table 25. Summary statistics for people who received multiple tests by demographic characteristics for Halton, Knowsley and Liverpool.

		Halton			Knowsley			Liverpool		
Theme	**Characteristic**	**People tested >1 (n)**	**People tested (n)**	**Multiple tests (%)**	**People tested >1 (n)**	**People tested (n)**	**Multiple tests (%)**	**People tested >1 (n)**	**People tested (n)**	**Multiple tests (%)**
Sex	Female	18,242	32,805	55.61	20,630	39,300	52.49	72,362	140,490	52
	Male	13,901	27,537	50.48	16,772	34,835	48.15	58,368	125,039	47
Age	"5-14"	5,819	8,928	65.18	5,129	8,370	61.28	18,663	31,636	59
	15-34	10,744	19,498	55.10	12,752	24,381	52.30	55,728	110,278	51
	35-69	14,248	28,258	50.42	17,556	36,037	48.72	50,430	107,512	47
	70+	1,332	3,658	36.41	1,965	5,347	36.75	5,909	16,103	37
Ethnicity	Asian	377	710	53.10	516	1,001	51.55	6,013	11,955	50
	Black	263	532	49.44	442	866	51.04	4,427	8,934	50
	Mixed	278	499	55.71	319	606	52.64	2,574	5,046	51
	Other	94	225	41.78	106	245	43.27	1,739	3,911	44
	White	31,131	58,376	53.33	36,019	71,417	50.43	115,977	235,683	49
Deprivation	Least deprived	8,381	15,194	55.16	9,457	17,850	52.98	30,706	58,281	53
	Quintile 2	6,087	11,110	54.79	7,676	15,005	51.16	34,380	66,150	52
	Quintile 3	6,615	12,668	52.22	7,865	15,752	49.93	25,199	52,084	48
	Quintile 4	5,608	10,860	51.64	6,704	13,556	49.45	20,635	44,253	47
	Most deprived	5,452	10,510	51.87	5,700	11,972	47.61	19,810	44,761	44

Note: Deprivation quintile is defined using LA specific quintiles. Caution should therefore be given to making comparisons between areas.

Table 26. Summary statistics for people who received multiple tests by demographic characteristics for Sefton, St. Helens and Wirral.

		Sefton			St. Helens			Wirral		
Theme	**Characteristic**	**People tested >1 (n)**	**People tested (n)**	**Multiple tests (%)**	**People tested >1 (n)**	**People tested (n)**	**Multiple tests (%)**	**People tested >1 (n)**	**People tested (n)**	**Multiple tests (%)**
Sex	Female	37,811	68,233	55.41	24,312	46,455	52.33	45,151	80,499	56
	Male	29,541	59,494	49.65	18,851	40,532	46.51	35,921	70,600	51
Age group	"5-14"	10,386	16,012	64.86	7,588	12,123	62.59	13,291	19,016	70
	15-34	21,500	39,732	54.11	13,750	27,329	50.31	26,341	47,201	56
	35-69	31,640	62,192	50.87	19,360	40,611	47.67	36,301	71,062	51
	70+	3,826	9,791	39.08	2,465	6,924	35.60	5,139	13,820	37
Ethnicity	Asian	954	1,749	54.55	556	1,149	48.39	1,789	3,275	55
	Black	597	1,242	48.07	325	686	47.38	706	1,365	52
	Mixed	645	1,111	58.06	301	595	50.59	924	1,629	57
	Other	317	540	58.70	131	318	41.19	255	518	49
	White	64,839	123,085	52.68	41,850	84,239	49.68	77,398	144,312	54
Deprivation quintile	Least deprived	14,065	25,465	55.23	8,953	16,964	52.78	17,480	31,770	55
	Quintile 2	14,193	25,957	54.68	9,815	19,300	50.85	16,585	30,799	54
	Quintile 3	14,679	27,429	53.52	7,988	16,236	49.20	17,653	32,646	54
	Quintile 4	13,125	25,518	51.43	9,056	18,645	48.57	15,712	29,553	53
	Most deprived	11,290	23,358	48.33	7,351	15,842	46.40	13,642	26,331	52

Note: Deprivation quintile is defined using LA specific quintiles. Caution should therefore be given to making comparisons between areas.

Table 27. Summary results from the Bayesian regression model examining spatial patterns in multiple lateral flow test uptake.

Variable	Relative Risk	95% Credible Interval	
		Lower	Upper
Deprivation score (z-score)	0.79	0.76	0.82
Proportion students (z-score)	0.93	0.90	0.97
Care home in LSOA	0.84	0.79	0.90
Internet User Classification			
e-Veterans	Reference		
Digital Seniors	0.92	0.83	1.03
e-Cultural Creators	1.08	0.80	1.46
e-Mainstream	1.52	1.38	1.67
e-Professionals	0.93	0.71	1.23
e-Rational Utilitarians	0.90	0.81	1.00
e-Withdrawn	1.03	0.95	1.11
Passive and Uncommitted Users	2.23	2.07	2.39
Settled Offline Communities	0.93	0.75	1.13
Youthful Urban Fringe	0.98	0.73	1.31

Table 28. Number of PCR tests conducted at home or outside the home at another location by Local Authority.

Area	Tests at other location	Tests at home	Percentage of tests at home
Halton	79,275	11,341	13.5
Knowsley	96,971	15,665	13.9
Liverpool	272,429	69,192	20.3
Sefton	223,364	41,567	15.7
St. Helens	110,246	18,295	14.2
Wirral	229,929	42,561	15.6
Liverpool City Region	1,012,214	198,621	16.4

Table 29. Summary statistics for people who received home tests by demographic characteristics for Halton, Knowsley and Liverpool.

		Halton			Knowsley			Liverpool		
Theme	**Characteristic**	**Home tests (n)**	**Total tests (n)**	**Percentage home (%)**	**Home tests (n)**	**Total tests (n)**	**Percentage home (%)**	**Home tests (n)**	**Total tests (n)**	**Percentage home (%)**
Sex	Female	129,207	182,786	70.69	94,262	168,768	55.85	277480	538,408	52
	Male	65,639	115,739	56.71	44,736	118,655	37.70	148382	394,581	38
Age	"5-14"	35,605	56,193	63.36	15,780	35,738	44.15	40722	108,460	38
	15-34	48,088	82,367	58.38	38,565	85,438	45.14	141803	353,457	40
	35-69	103,498	148,538	69.68	79,659	151,747	52.49	226148	427,633	53
	70+	7,655	11,427	66.99	4,994	14,500	34.44	17189	43,439	40
Ethnicity	Asian	2,266	3,533	64.14	2,605	4,408	59.10	17877	39,994	45
	Black	1,528	2,518	60.68	1,727	3,145	54.91	15842	30,819	51
	Mixed	1,440	2,357	61.09	1,124	2,248	50.00	7363	16,880	44
	Other	449	760	59.08	513	984	52.13	3947	10,645	37
	White	189,163	289,357	65.37	133,029	276,638	48.09	380833	834,651	46
Deprivation	Least deprived	51,010	77,806	65.56	36,748	75,119	48.92	101102	219,976	46
	Quintile 2	37,187	56,967	65.28	30,340	59,558	50.94	97774	234,587	42
	Quintile 3	40,028	61,530	65.05	29,112	60,614	48.03	84607	182,564	46
	Quintile 4	34,801	52,796	65.92	22,196	48,835	45.45	74971	153,360	49
	Most deprived	31,820	49,426	64.38	20,602	43,297	47.58	67408	142,502	47

Note: Deprivation quintile is defined using LA specific quintiles. Caution should therefore be given to making comparisons between areas.

Table 30. Summary statistics for people who received home tests by demographic characteristics for Sefton, St. Helens and Wirral.

		Sefton			St. Helens			Wirral		
Theme	**Characteristic**	**Home tests (n)**	**Total tests (n)**	**Percentage home (%)**	**Home tests (n)**	**Total tests (n)**	**Percentage home (%)**	**Home tests (n)**	**Total tests (n)**	**Percentage home (%)**
Sex	Female	261227	364,565	71.65	168352	240,974	69.86	325997	451,005	72
	Male	128656	235,111	54.72	84396	154,327	54.69	169944	292,325	58
Age	"5-14"	54247	92,694	58.52	38608	67,814	56.93	74904	120,561	62
	15-34	87829	159,053	55.22	63778	108,650	58.70	121156	203,533	60
	35-69	226021	318,057	71.06	139970	200,570	69.79	274856	380,336	72
	70+	21786	29,872	72.93	10392	18,267	56.89	25025	38,900	64
Ethnicity	Asian	6225	9,156	67.99	3729	5,474	68.12	12263	17,690	69
	Black	3554	5,284	67.26	1639	2,848	57.55	4707	7,051	67
	Mixed	3548	5,501	64.50	1775	2,876	61.72	5651	8,322	68
	Other	2287	3,248	70.41	667	1,201	55.54	1480	2,361	63
	White	374269	576,487	64.92	244938	382,902	63.97	471840	707,906	67
Deprivation	Least deprived	83876	125,238	66.97	53023	80,593	65.79	108237	157,079	69
	Quintile 2	83473	126,208	66.14	57303	89,791	63.82	102039	151,573	67
	Quintile 3	91366	135,752	67.30	49334	74,648	66.09	110886	163,786	68
	Quintile 4	76113	118,318	64.33	52419	83,200	63.00	95706	146,307	65
	Most deprived	55055	94,160	58.47	40669	67,069	60.64	79073	124,585	63

Note: Deprivation quintile is defined using LA specific quintiles. Caution should therefore be given to making comparisons between areas.

Table 31. Summary results from the Bayesian regression model examining spatial patterns in home lateral flow test uptake.

Variable	Relative Risk	95% Credible Interval	
		Lower	Upper
Deprivation score (z-score)	1.00	0.99	1.02
Proportion students (z-score)	0.96	0.95	0.97
Care home in LSOA	1.01	0.99	1.02
Internet User Classification			
e-Veterans	Reference		
Digital Seniors	0.97	0.94	1.01
e-Cultural Creators	1.15	1.04	1.27
e-Mainstream	0.99	0.96	1.02
e-Professionals	1.02	0.96	1.10
e-Rational Utilitarians	0.98	0.95	1.02
e-Withdrawn	0.96	0.91	1.01
Passive and Uncommitted Users	0.97	0.93	1.01
Settled Offline Communities	0.96	0.91	1.01
Youthful Urban Fringe	0.97	0.90	1.04

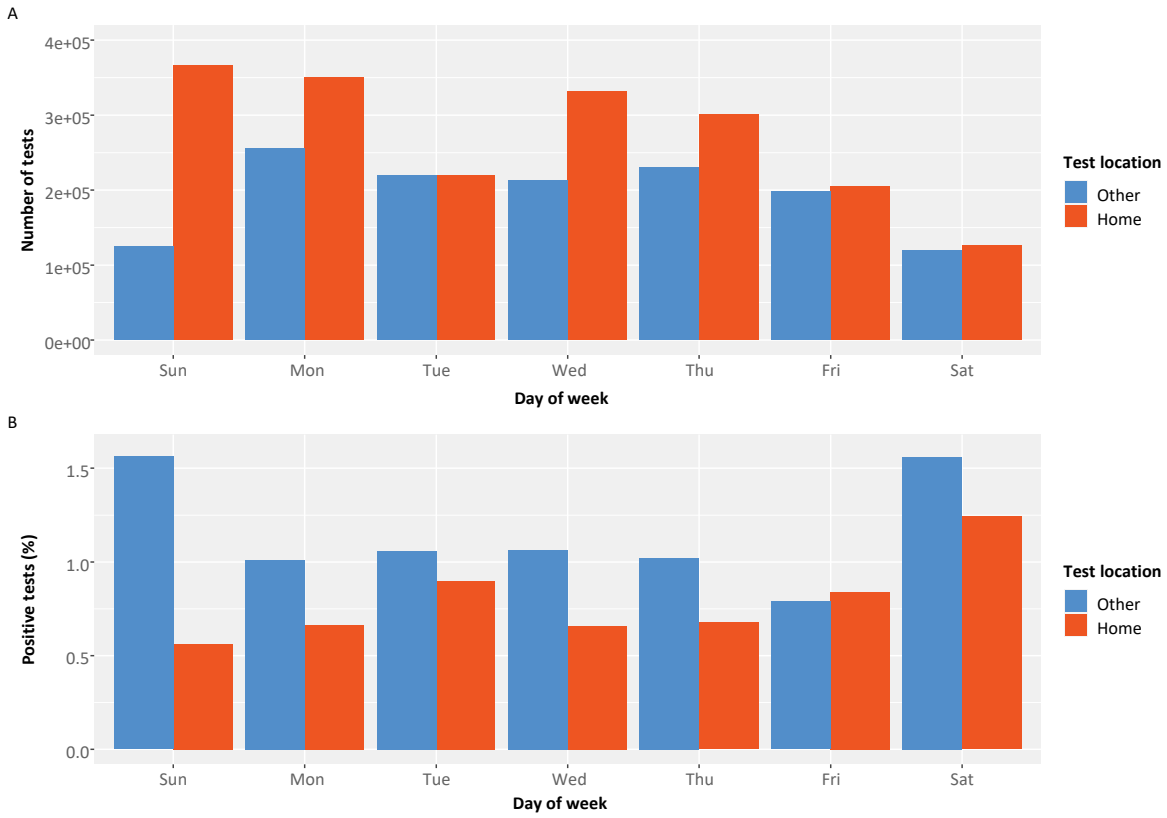

Figure 22. Variations in test uptake (A) and positivity rate (B) between tests taken at home and at other locations by weekday in Liverpool City Region.

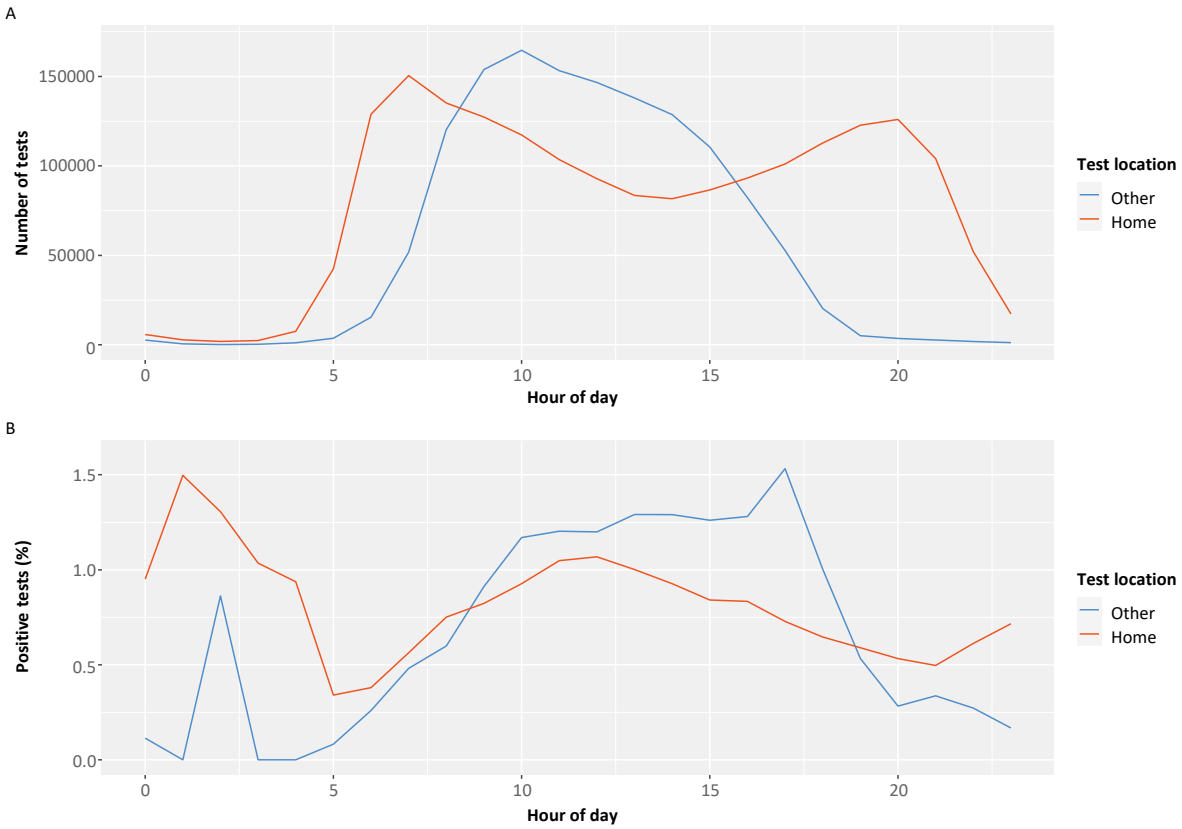

Figure 23. Variations in test uptake (A) and positivity rate (B) between tests taken at home and at other locations by time of day for Liverpool City Region.

Table 32. Summary of testing details for each organisation enrolled in the key-worker-release scheme.

Organisation	Number invited	Number of Participants (%)	Total number of LFTs per day							PCR	Number of individuals with a given total number of tests							
			Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 6/7	0	1	2	3	4	5	6	7
Mersey Police		1358	392	673	887	1080	1202	1385	1310	1301	2	52	95	142	199	215	281	372
Merseyside Fire & Rescue		90	40	45	57	67	72	83	82	84	2	4	11	6	12	10	11	34
Alder Hey		183	40	71	102	129	153	161	164	170	4	11	16	26	31	32	26	37
Wings Care	12	12	7	10	11	12	11	11	11	11	0	0	0	1	1	1	2	7
Carers		1	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	0
Local Government LSSL	7	4	4	4	4	4	4	4	4	4	0	0	0	0	0	0	0	4
LCC		7	0	1	3	6	7	7	6	7	1	0	0	2	2	2	1	0
Autism Initiative	2	2	1	1	2	2	2	2	2	2	0	0	0	0	0	5	0	1
Rodney House Residential Home		1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0

Note 1: There were 57 missing PCRs for Mersey Police, consisting of three who were removed mid-pilot due to missing LFT, three who withdrew as a household member tested positive, four who withdrew due to developing symptoms, three who decided to withdraw and self-isolate, eight who were enrolled too close to the end of the scheme and 36 who reported doing a PCR but no result was received.

Note 2: There were six missing PCRs for Mersey Fire consisting of three who withdrew during the pilot and three who reported doing a PCR but no result was received.

Note 3: There were 13 missing PCRs for Alder Hey consisting of four who withdrew due to a household member testing positive, one who stopped working for Alder Hey mid pilot, one who withdrew consent mid-pilot, one who developed symptoms and chose to isolate, one who was isolating for a different medical condition, three who were withdrew from the pilot due to non-compliance and two who reported doing a PCR, but no result was received.

Glossary

CIPHA	Combined Intelligence for Population Health Action
IMD	Index of Multiple Deprivation
IUC	Internet User Classification
LA	Local Authority
LCR	Liverpool City Region
LFT	Lateral Flow Test (for SARS-CoV-2 antigen)
LSOA	Lower Super Output Area
MSOA	Middle Layer Super Output Area
ONS	Office for National Statistics
PCR	Reverse Transcription Polymerase Chain Reaction (for SARS-CoV-2 nucleic acid)

References

1. Department of Health and Social Care. Liverpool to be regularly tested for coronavirus in first whole city testing pilot 2020 [Available from: https://www.gov.uk/government/news/liverpool-to-be-regularly-tested-for-coronavirus-in-first-whole-city-testing-pilot.
2. University of Liverpool for Department of Health and Social Care. Liverpool coronavirus (Covid-19) community testing pilot: full evaluation report summary 2021 [Available from: https://www.gov.uk/government/publications/liverpool-coronavirus-covid-19-community-testing-pilot-full-evaluation-report-summary.
3. A qualitative evaluation of asymptomatic Covid-19 testing (SMART) in the Liverpool City Region. Liverpool John Moores University; 2021.
4. Green MA, Garcia-Finana M, Barr B, Burnside G, Cheyne CP, Hughes D, et al. Evaluating social and spatial inequalities of large scale rapid lateral flow SARS-CoV-2 antigen testing in Covid-19 management: An observational study of Liverpool, UK (November 2020 to January 2021). Lancet Reg Health Eur. 2021;6:100107.
5. Robbins MW, Davenport S. microsynth: Synthetic Control Methods for Disaggregated and Micro-Level Data in R. 2021. 2021;97(2):31.
6. Robbins MW, Saunders J, Kilmer B. A Framework for Synthetic Control Methods With High-Dimensional, Micro-Level Data: Evaluating a Neighborhood-Specific Crime Intervention. Journal of the American Statistical Association. 2017;112(517):109-26.
7. Oni L, Hawcutt D, Buchan I, Semple M. Soft drinks can be misused to give false "false positive" SARS-CoV-2 lateral flow device results. medRxiv 2021.07.05.21260003 2021; doi: https://doi.org/10.1101/2021.07.05.21260003
8. Zhang X, Owen G, Green M, Buchan I, Barr B. Evaluating the impacts of tiered restrictions introduced in England, during October and December 2020 on Covid-19 cases: A synthetic control study. medRxiv. 2021:2021.03.09.21253165.
9. García-Fiñana M, Hughes DM, Cheyne CP, Burnside G, Stockbridge M, Fowler TA, Fowler VL, Wilcox MH, Semple MG, Buchan I. Performance of the Innova SARS-CoV-2 antigen rapid lateral flow test in the Liverpool asymptomatic testing pilot: population based cohort study. BMJ. 2021 Jul 6;374:n1637. doi: 10.1136/bmj.n1637.
10. Bird SM. Covid tests in secondary schools: A statistical cause celebre. Signif (Oxf). 2021;18(3):42-5.
11. Mina MJ, Peto TE, García-Fiñana M, Semple MG, Buchan IE. Clarifying the evidence on SARS-CoV-2 antigen rapid tests in public health responses to COVID-19. Lancet. 2021 Apr 17;397(10283):1425-1427. doi: 10.1016/S0140-6736(21)00425-6.
12. Crozier A, Rajan S, Buchan I, McKee M. Put to the test: use of rapid testing technologies for covid-19. BMJ. 2021 Feb 3;372:n208. doi: 10.1136/bmj.n208. PMID: 33536228.