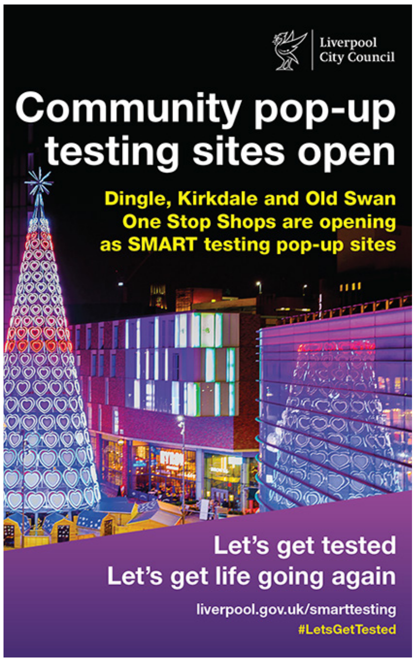
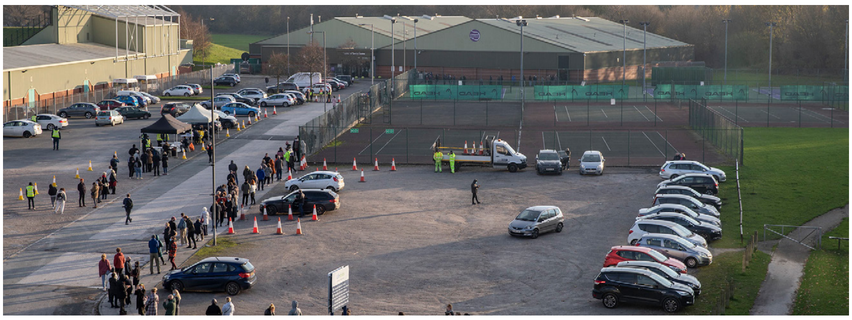
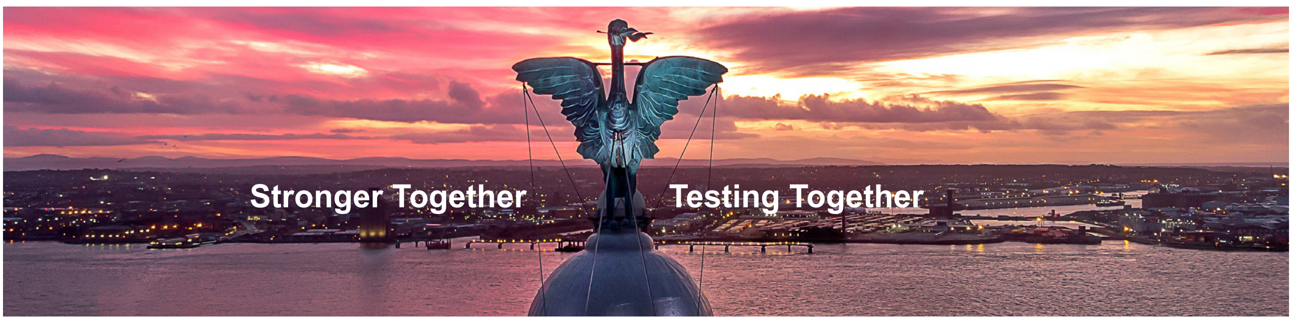
Liverpool Covid-SMART Community Testing Pilot

Evaluation Report | 17 June 2021







This report

This is the report from an evaluation led by the University of Liverpool into the Liverpool pilot of community open-access testing for the Covid-19 virus SARS-CoV-2 among those without symptoms. The evaluation was invited by the joint local and national command of the pilot and sponsored by the Department of Health and Social Care (DHSC).

This report extends an interim report published 23 December 2020,[1] and presents findings to help policymakers with community approaches to Covid-19 testing.

Inputs to the report have been combined from the pilot delivery partners and the evaluation group:

Pilot delivery partners: Liverpool City Council; NHS Test and Trace (DHSC); Army (8 Engineer Brigade); NHS Liverpool Clinical Commissioning Group; Merseycare NHS Trust; Cheshire & Merseyside Health & Care Partnership; Merseyside Local Resilience Forum; Liverpool Charity and Voluntary Services (LCVS).

Evaluation partners: The University of Liverpool; Public Health England; Joint Biosecurity Centre; Office for National Statistics (ONS); NHS Test and Trace; Scientific Advisory Group for Emergencies (SAGE) and its contributing universities.

ARMY BE THE BEST

Cheshire and Merseyside Health and Care Partnership

Department of Health & Social Care

LCVS TOGETHER FOR LIVERPOOL FOR GOOD

Liverpool City Council

MERSEYSIDE RESILIENCE FORUM

NHS Test and Trace

NHS Liverpool Clinical Commissioning Group

NHS Mersey Care NHS Foundation Trust

Public Health England

UNIVERSITY OF LIVERPOOL

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Military personnel instructing medical staff on Covid-19 testing procedure at Wavertree Tennis Centre

EXECUTIVE SUMMARY

The City of Liverpool and national agencies partnered to pilot community testing for SARS-CoV-2 antigen, open to all people without symptoms of Covid-19, living or working in the City.

Community testing was valuable as part of an agile, intelligence-led local public health intervention. We recommend a SMART (Systematic, Meaningful, Asymptomatic/Agile, Repeated Testing) approach:

- **Systematic:** end-to-end system-wide, from intention, to test, to adequately supported isolation
- **Meaningful:** clear, action-focused meaning and equity of access/use across the whole population
- **Asymptomatic/Agile:** plus (pauci-) symptomatic and rapid contact testing; flex to prevailing needs
- **Repeated:** fit testing regimens to transmission, consequences and the scale of testing
- **Testing:** quality assure end-to-end not just biological performance of lateral flow test (LFTs)

SMART targets: test-to-protect (vulnerable individuals/settings/services), test-to-release (sooner from quarantine), and test-to-enable (safer return to key activities for social fabric and the economy).

Between 6 November 2020 and 30 April 2021, 283,338 (57%) Liverpool residents took a test using the Innova SARS-CoV-2 antigen rapid antigen lateral flow device (LFD). Of these, 47% had more than one test (27% of residents), and in the same period, 152,609 residents were tested by PCR.

- **6,300 individuals declaring no symptoms tested positive by LFT** (case positivity 2.1%)

- 22,567 individuals declaring symptoms tested positive by PCR (case positivity 14.8%)

The estimated impacts (with 95% confidence intervals) of Liverpool's community testing compared with other areas were:

- **18%** (7% to 29%) increase in case detection vs control areas
- **21%** (12% to 27%) reduction in cases up to mid-December (after which the Kent variant surge made it difficult to compare areas) vs control areas
- Pessimistic model suggests 850 (500 to 1350) infections were prevented
- Optimistic model suggests 6600 (4840 to 9070) infections were prevented
- Small but non-significant reduction in hospital admissions

Socio-economic inequalities were a substantial challenge. Test uptake was lower and infection rates were higher in deprived areas, in areas with fewer digital resources or lower digital literacy, and among non-White ethnic groups. **Fear of income loss** from self-isolation was a key barrier to testing.

The **LFD worked as expected**, identifying most cases with high viral load, likely to be most infectious.

There was strong public awareness of, and a largely positive attitude toward community testing, motivated by shared identity, **civic pride and a wish to protect others.** Misinformation, particularly over test performance was a substantial problem needing intensive local communications to address.

Multiple national **testing initiatives in different contexts** from care homes to schools and workplaces made communication too complex and would have been **better integrated into a community testing** with integrated support from the local authority. **Shared data/intelligence** (e.g., www.cipha.nhs.uk) was vital for coordinating actions across NHS, local authority and public health agencies and their partners – informing multi-agency Gold/Silver/Bronze **command-and-control** structure. The role of the **Director of Public Health** was vital to effective coordination of services and engaging the public.

A low-cost, rapid, no-lab test of infectiousness saves time and extends the reach of health protection measures. SARS-CoV-2 antigen rapid **lateral flow testing meets this need** when coordinated by an effective local public health service. The end-to-end testing service was found valuable and has been continued beyond pilot as a core part of Liverpool's Covid-19 response.

THE PILOT

Background

The Department of Health and Social Care (DHSC) approached Liverpool City leaders on 31 October 2020 offering Covid-19 testing for everyone living or working in Liverpool, regardless of whether they had symptoms. The initial offer to test 75% of the asymptomatic population in two weeks with military assistance was renegotiated by the city to a serial testing approach, with value seen in having access to large-scale, flexible testing for coronavirus control and socio-economic recovery. Preparations started on 1 November 2020. Pre-publication information on the testing device (Innova SARS-CoV-2 lateral flow) that had already been purchased nationally was made available. The pilot plan was agreed on 5 November 2020 as national lockdown started, and testing commenced on 6 November 2020 as a collaboration between NHS Test & Trace, Liverpool City Council, NHS Liverpool Clinical Commissioning Group, the Army (8 Engineer Brigade), Cheshire & Merseyside Health & Care Partnership and Liverpool Charity and Voluntary Services, with evaluation led by The University of Liverpool with NHS Test and Trace, Public Health England (PHE), the Joint Biosecurity Centre (JBC) and Office for National Statistics (ONS).

Approach

The pilot was originally called MAST (mass, asymptomatic, serial testing), and the name was later changed to SMART (systematic, meaningful, asymptomatic/agile, repeated testing) to better reflect the partnership's approach to testing.

SMART has 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); and
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).

From 3 December 2020, a more targeted approach was taken to implementing SMART in response to changing Covid restrictions and infection levels and patterns.

Goals

Partners set a mission to:

"To identify the virus, wherever it is in the City, and empower local communities to suppress its transmission while being supported well when they need to isolate or quarantine. At the same time, to identify those who are needlessly self-isolating and empower them to return to usual activities."

The goals were

1. saved lives and improved health outcomes for the City's residents;
2. saved livelihoods and businesses, protecting the City's economy and social fabric; and
3. sooner and safer reopening of the City as a whole.

Governance

Partners established a Gold/ Silver/Bronze Command-and- Control system: Gold set the direction and was responsible for the pilot; Silver led the delivery and coordination of the pilot; Bronze provided operational control for the pilot, in collaboration with the Army. Bronze, Silver and Gold teams met daily to review situations, assess risks, make decisions, and deploy operations.

This Command-and-Control has delegated mandates from the Mayor of Liverpool and Liverpool Local Authority Chief Executive Officer, Merseyside Local Resilience Forum (LRF), Merseyside Test & Trace Cell, Cheshire & Merseyside Testing Cell, and Cheshire & Merseyside Health & Care Partnership Combined Intelligence for Population Health Action (CIPHA, www.cipha.nhs.uk) Governance Board. The Command-and Control structure sits within North West region's Incident Coordination Centre (ICC).

Military support maintained a parallel operational governance to the Command-and-Control structure, under a formal MACA (Military Aid to the Civil Authorities) protocol (to 6 December 2020). Military representatives were embedded in the MAST Command-and-Control at all three levels.

A STAC (Science and Technical Advice Cell) was established on 6 November 2020 as part of the Merseyside Local Resilience Forum governance structure and reported into the Command-and-Control system. STAC members were drawn from PHE, DHSC, NHS Test and Trace, University of Liverpool, University of Oxford, and Liverpool City Council. All testing operations conformed to NHS Test and Trace Clinical Framework Standard Operating Procedure (SOP), and queries about it were directed via STAC.

Figure 1: Command-and-control structure

GOLD

- Strategic leadership / national oversight
- Oversee / assure testing at high level
- Set objectives
- Make strategic decisions
- Define scope / approach

SILVER

- Manage Bronze operations
- Manage communications / messaging
- Inter-dependencies and organisational co-ordination
- Project governance
- Tactical/operational decisions
- Assurance to Gold
- Evaluation/lessons learnt
- Quality standards
- Options considered and preferred
- Recommend to Gold for decision

BRONZE

- Implement operational deliverables
- Manage inter-dependencies / relationships on the ground
- Co-ordinate lessons learned and produce how-to guide
- Identify and operationalise sites / workforce
- Develop sustainability and transition plans, and civilian operating procedures and processes
- Protect vulnerable groups

Multi-agency working within Liverpool

In March 2020, the Local Resilience Forum system, managed centrally by the Ministry of Housing Communities and Local Government (MHCLG), was operationalised in response to Covid-19. Strategic and Tactical Coordination Groups were stood up, and supporting cells created. These brought together representatives from local organisations responsible for service planning and delivery. Local Authorities, such as Liverpool City Council, also activated their own Covid-19 coordination groups. This is how Liverpool City Council responded quickly to the approach from DHSC outlined above.

Pilot planning was overseen by Liverpool City Council Covid-19 Strategic Coordination Group with DHSC ahead of the Command-and-Control system being activated on 6 November 2020.

The DHSC, as pilot sponsor, provided the initial directive to the military unit (8 Engineer Brigade) to establish 48 new asymptomatic testing sites (ATS) in the City of Liverpool using pre-purchased Innova lateral flow devices. Two military staff were seconded to DHSC to act as liaison. The role of the DHSC during the pilot was to approve the location of test sites, provide financial indemnity for site operators, approve costings, lead initial clinical governance, and establish an evaluation steering group.

Approximately 2,000 personnel from 8 Engineer Brigade arrived on Merseyside by 2 November and established an operational headquarters at HMS Eaglet in Liverpool. Liverpool City Council's Assistant Director for Supporting Communities was designated as military liaison officer, leading local negations over ATS and linking the military into the Command-and-Control structure.

Six initial ATS were in Liverpool City Council premises as these could be approved quickly. Military personnel took responsibility for the buildings and set up the testing infrastructure (signage; registration desks; testing booths; queueing systems) on 5 November 2020 for start the next day. The selection and confirmation of the second and third phases of further sites for ATS required more complex negotiation with site owners and DHSC. The process was informed by combined intelligence from the CIPHA system and analytic expertise from military, City Council and University partners.

Military personnel constructing a testing station

Following a briefing on Thursday 8 November 2020 for secondary school headteachers to prepare for testing at schools, an opt-in consent process was agreed. However, one school (not at the briefing) misunderstood their school would begin testing on the following Monday and sent an opt-out letter to parents on the Friday. Although this was recalled and replaced with an opt-in letter on Sunday, it fuelled negative discussion on social media, which damaged uptake of testing at schools.[1] Rates of consent varied considerably by school. An average of 52.6% of pupils at participating secondary schools (31 out of 33) were tested. A total of 32,411 tests (84% pupils; 16% staff) were done at schools in the period to 2 December 2020.

Data and intelligence

Each person tested was asked questions and a record was created for getting result back to them, and for monitoring the programme. Registration involved linking individuals to test kits via a unique identifier (bar coded). For PCR, swabs were sent to laboratories and results returned around 24 hours later. LFTs were processed (see LFT Process) at the testing sites

Lime Street digital screen

and results sent approximately 30-60 minutes later by text message or email, including the required actions depending on whether the result is positive or negative. The national guidance for positive individuals was the same for LFT and PCR and did not change over the pilot. A supplementary local text message for LFT positives was added on 23 November 2020 to overcome logistical challenges with confirmatory PCR described later.

Test results flowed from NHS Test and Trace, via NHS Digital, into the regional combined NHS, local authority care and public health data/intelligence system CIPHA, which was established across Cheshire & Merseyside in May 2020 as a Covid-19 response from the NHS Out of Hospital and Hospital Cells with NHSX support. CIPHA aligns with NHS Covid Phase 3 directions on local integrated care data and is designed to support multi-agency working in the Cheshire & Mersey Health & Care Partnership.

Dashboards were established by CIPHA for the pilot, providing reports updated every 30 minutes on testing by sites and socio-demographic groups. In addition to on-line dashboards, summaries were emailed three times per day to the Command-and-Control members and field teams and used to inform the evolution of the testing site network.

Community engagement and communications

The aim to engage the city's whole population in the pilot drove DHSC's estimate of 48 test sites (20 bays testing 6 people per hour from 07:00 to 19:00 each day to generate a capacity of 69,120 tests – around 14% of the population per day).

A communications plan was developed and delivered by Liverpool City Council. This employed multimedia strategies and was updated in response to data on testing uptake, feedback from the military on engagement at ATS, analysis of social media and commissioned surveys. An interactive map of ATS was deployed on Liverpool City Council website to show waiting times at sites.

Discussion at Gold/Silver/Bronze command levels translated into communications plans for informing residents of uptake (daily press releases via the Liverpool Express website; regular media appearances by the Director of Public Health and other senior stakeholders).

In the third week of the pilot, Liverpool City Council liaised with Liverpool Charity and Voluntary Services [LCVS] organisation to target specific neighbourhoods with low attendance at ATS. A funding request for community involvement in co-creating testing engagement, incentives, and support, including tackling inequalities, was submitted to DHSC.

Timeline of the pilot

The preparation phase and three main implementation phases covered by this report map largely to the following months and public messages: 1) November 2020 “Let’s All Get Tested”; 2) December 2020, “Test Before You Go”; 3) January-April “Testing Our Front Line”.

OCTOBER

- (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

- (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
- (3) Liverpool accepts a MAST; an emergency response is stood up
- (5) National lockdown; a communications drive begins in Liverpool on MAST
- (6) Six ATS open for LFT testing (alongside mobile units for symptomatic PCR testing, which were already operating); QA teams for dual LFT PCR swabbing mobilised
- (7) 16 ATS open for LFT testing
- (10) First meeting of DHSC convened Evaluation Steering Group; schools-based testing starts
- (11) Capacity increased: 37 community ATS plus schools; home PCR kits delivered (one-off, unsolicited mailing to sample households); local evaluation group established
- (13) First meeting of the University of Liverpool evaluation group
- (20) Re-configuration of resources: 15 popular ATS kept; other resources were redeployed to smaller ATS 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

- (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 and adapts to fewer Covid-19 restrictions
- (3) Liverpool Covid-SMART 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
- (4) Liverpool Covid-SMART 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

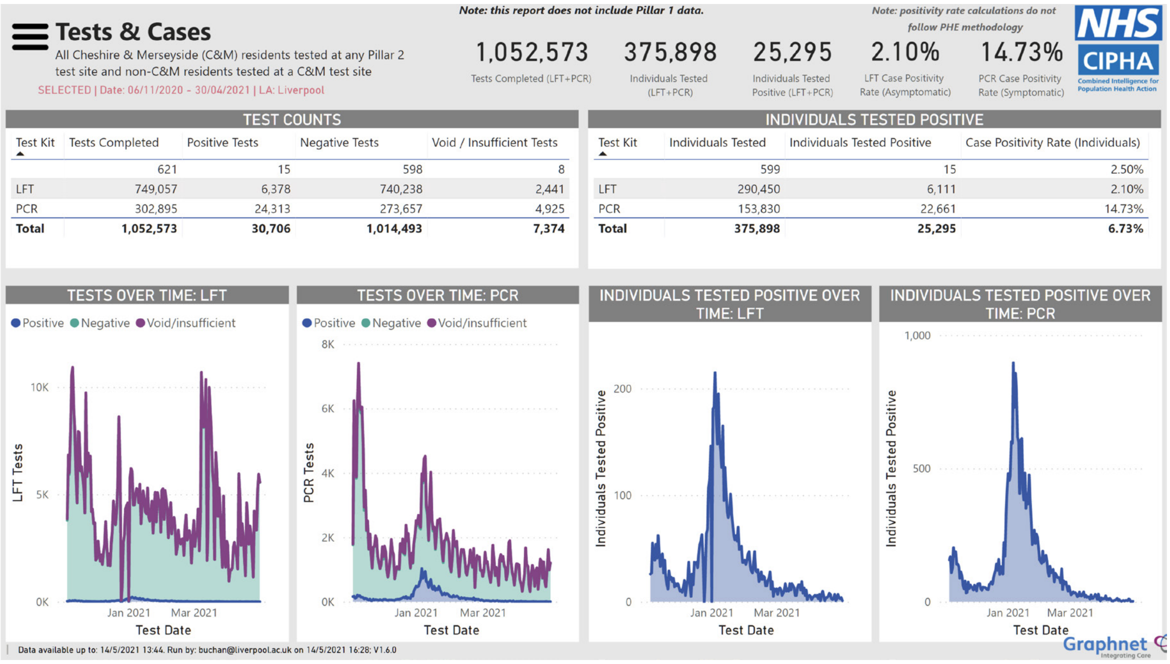
MARCH 2021

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

Summary of test numbers

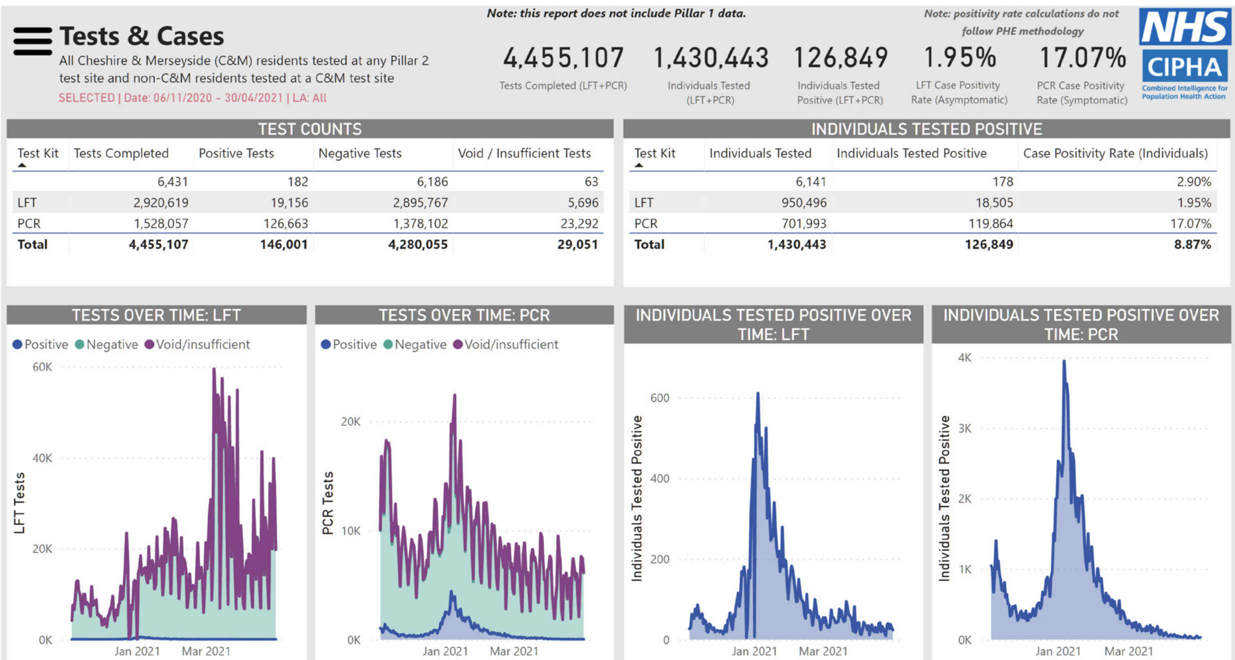
Test numbers for Liverpool City residents from 6 November 2020, the start of the pilot, until 30 April 2021 are shown in Figure 2. The PCR test numbers represent both symptomatic and asymptomatic uses, as a large one-off postal drop of home PCR kits was made from 11 to 16 November.

Figure 2: Summary testing dashboard for the City of Liverpool (0.5m population)



Equivalent numbers for the wider Cheshire & Merseyside region, where people working in Liverpool may live, are shown in Figure 3.

Figure 3: Summary testing dashboard for Cheshire and Merseyside (2.6m population)



The phases of the pilot dictated by prevailing infection patterns and changes to Covid-19 restrictions, as seen through the dashboards that the pilot teams used to coordinate actions are shown below (detailed results behind the captions are given later in the Public Health chapter):

Figure 4: Socio-demographic summary of testing in the pilot's first month from 6 November 2020

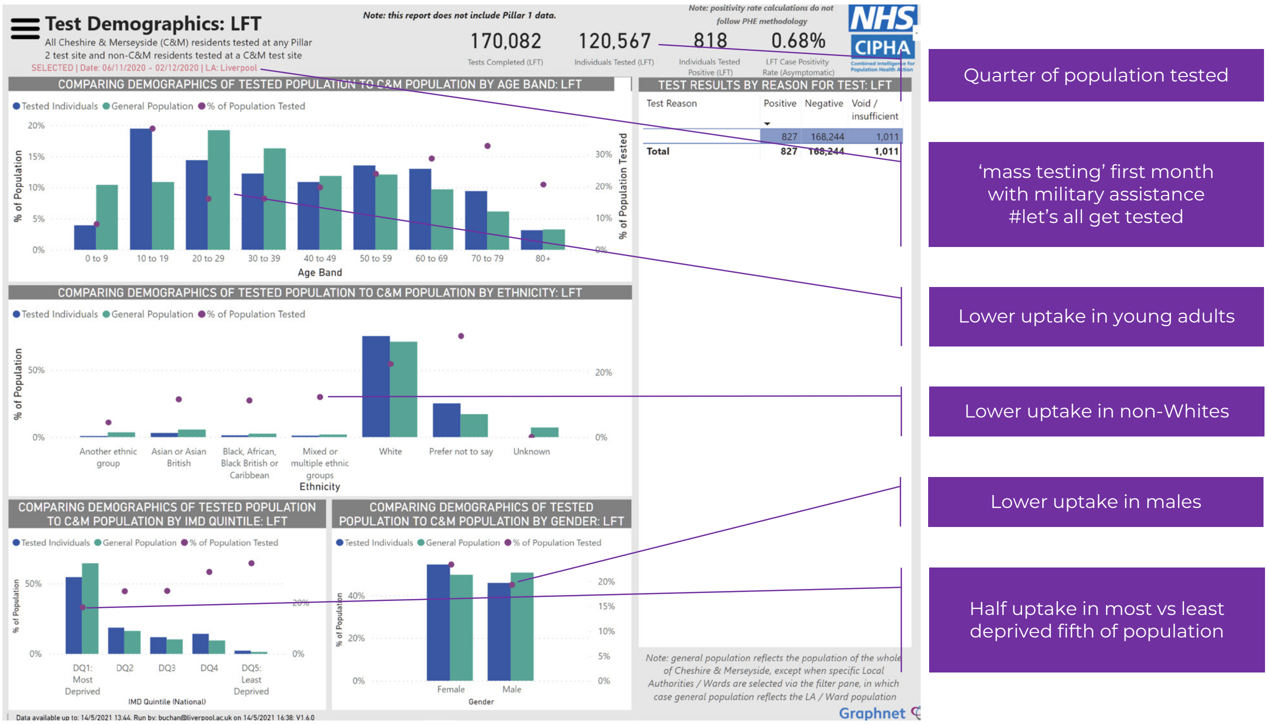


Figure 5: Socio-demographic summary of testing with Liverpool in Tier 2 in December 2020

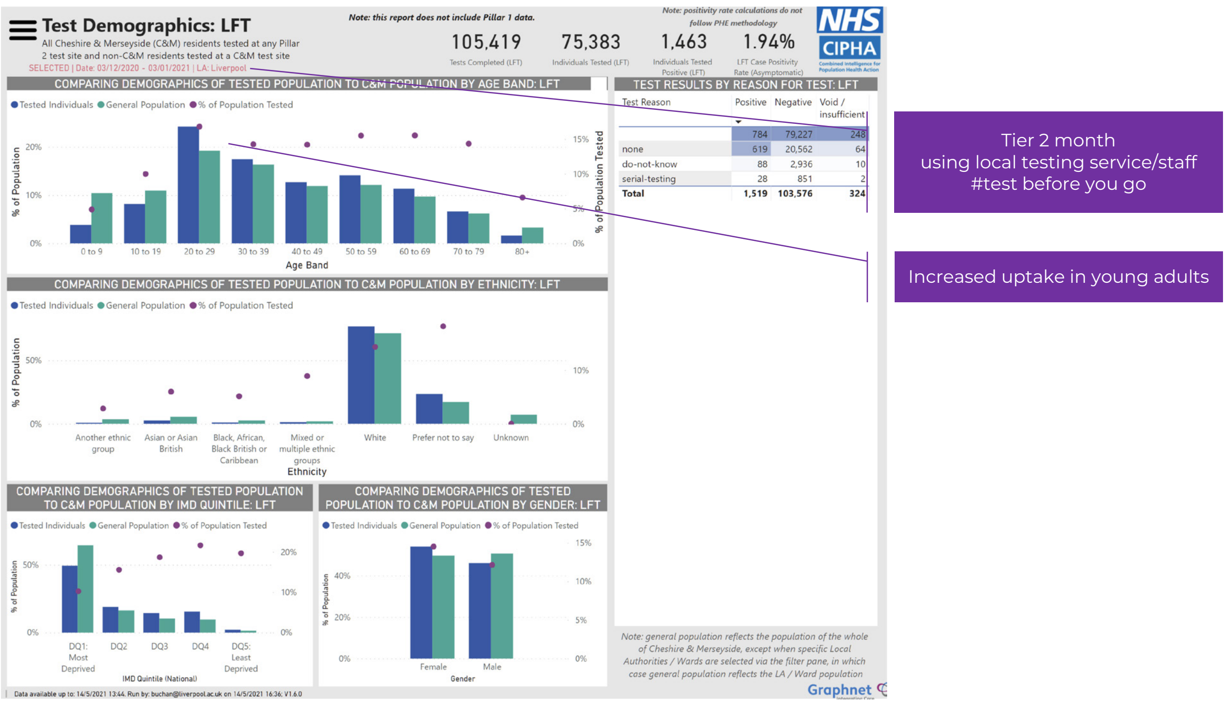


Figure 6: Socio demographic summary of Liverpool testing in Lockdown in early 2021

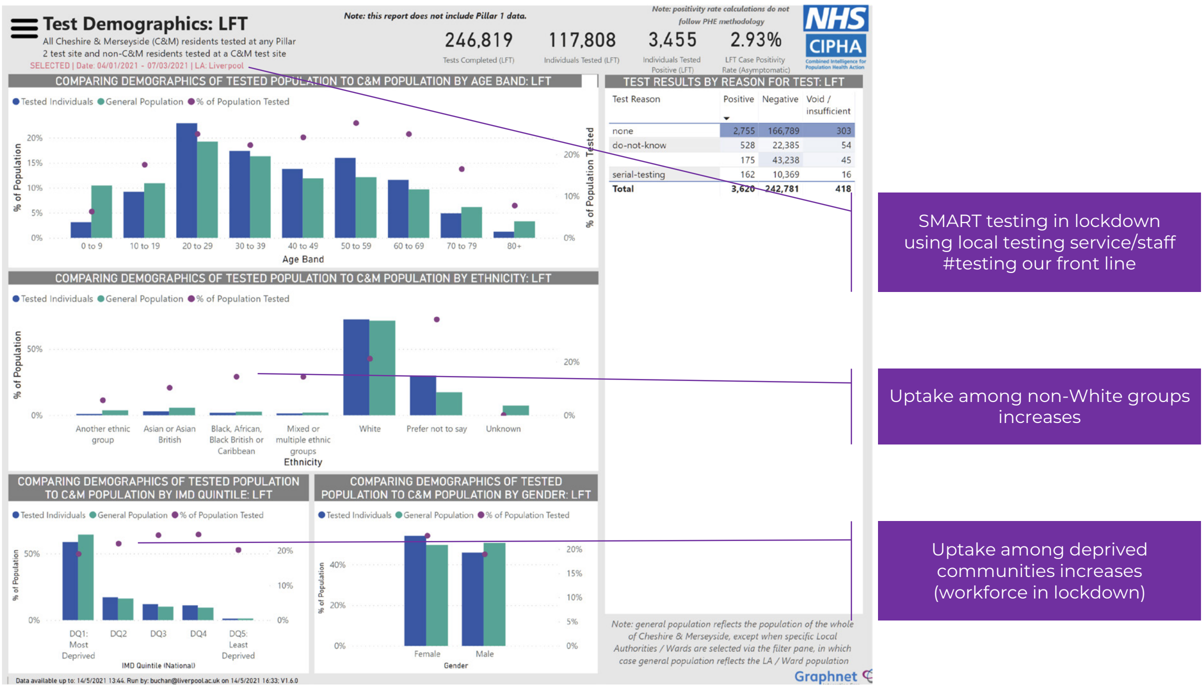
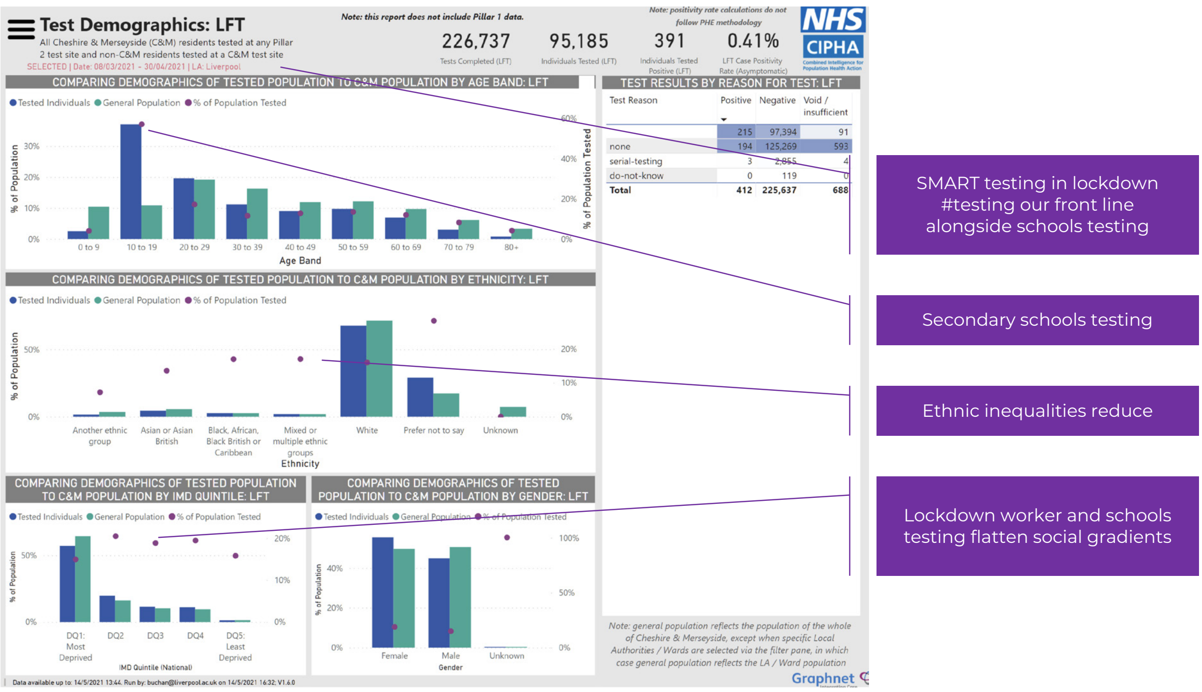


Figure 7: Socio demographic summary of Liverpool testing after schools return in March 2021



EVALUATION FRAMEWORK

The DHSC, as sponsor for the pilot, established an Evaluation Steering Group, which ran from November to December 2020 with inputs from SAGE, NHS Test and Trace, ONS, PHE, JBC, and academic specialists. The University of Liverpool was invited to lead the evaluation on 10 November 2020. The national Testing Initiatives Evaluation Board – formed in January 2021 – later reviewed outputs from the University of Liverpool evaluation team. A framework was adopted for evaluating four principal components of community testing: 1) operational systems, 1) biological meaning, 3) behavioural responses, and 4) public health impacts.

1. **SYSTEMS: Develop nationally generalisable systems for:**

a) establishing pathways - identifying who to test, communicating the need for a test, taking the test, carrying out the test, communicating the result to the person tested and to others who need to know, and ensuring that appropriate next steps happen

b) combining intelligence from NHS, local authority, and public health data sources for promoting and optimising access to testing for specific groups

c) multi-agency mutual aid to coordinate communications, public health responses and economic recovery activities

d) delivering strong community engagement

e) providing clear, impartial, and accurate information to the community, which explains the purpose of testing in this context

f) assessing the indirect effects of the pilot on other systems such as welfare support and clinical pathways

2. **BIOLOGY: To evaluate:**

a) the performance of the Innova LFT in context of use

b) the uptake and utility of PCR tests to confirm positive results from LFTs

c) repeated testing for test-to-protect (the vulnerable); test-to-release (from quarantine; isolation) and test-to-enable (safe return to usual activities)

3. **BEHAVIOURS: Understand the factors determining:**

a) uptake of tests on first and subsequent occasions, by socio-demographic groups

b) acceptance of the testing programme by the public in general and by specific vulnerable groups

c) drivers for accessing or declining testing for an individual and those they care for

d) responses to a positive test result

e) responses to a negative test result

f) effective and ethical incentives for participation

g) public trust, understanding, and cooperation

4. **PUBLIC HEALTH: Identify the public health impacts on:**

a) uptake overall and by gender, age, geographical area, deprivation, ethnicity, occupation, high risk and vulnerable groups

b) tackling inequalities in the uptake of testing and its effects

c) virus transmission during the pilot and beyond

d) protecting vulnerable groups

e) contact-tracing of cases and their contacts

f) the proportion of the population who isolate or quarantine

g) compliance with isolation, and consequently transmission

h) unintended consequences, such as a potential reduction in Covid-safe behaviours after a negative test

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This was a rapid evaluation of a developing pilot with after-action, continuous learning at the forefront. It was not always possible to examine and mitigate systematic biases from data collection.

Qualitative and survey work on the ground was targeted at explaining differences in test uptake therefore it should not be interpreted as representative of the general population. ONS survey work was undertaken to generate a representative sample.

The timing of the pilot meant that it was not possible to design a priori, sophisticated control comparisons or establish randomised testing patterns to build strong causal inferences on impacts of the testing on public health outcomes or behavioural processes.

This evaluation used routinely collected data and field observations, which might be replicated in other localities. The framework is intended for formative use in guiding implementations of similar testing in other localities, and for providing immediate summative policy evidence.

ETHICS AND APPROVALS

This work was invited as a service evaluation not research. DHSC/NHS Test and Trace wrote confirming the status as service evaluation and liaised with the Medicines and Healthcare Devices Regulatory Authority (MHRA) over the use of the Innova lateral flow device in this post-validation pilot service.

Whether MAST/SMART was 'a screening process' or 'an emergency public health intervention during an extraordinary event' was discussed by the evaluation team and with DHSC.[2,3] A distinction was drawn between identification of cases of non-communicable disease dispersed in the community and primarily impacting the person tested (e.g., cervical cancer), and identification of cases of a highly infectious disease that by its nature amplifies within a community with wider societal impacts. It was agreed without dissent that MAST and SMART were urgent public health interventions subject to the legal and ethical provisions of a health protection activity and Covid-19 specifically.

With reference to the Health Research Authority decision tool, the secondary analysis of data provided in a health protection activity is not classified as research, and so does not require research ethics committee review.[4]

The quality assurance sample of dual LFT and PCR swabs was run as quality management of the service of NHS Test and Trace, with the data provided to the evaluation team for secondary analysis of data provided in a health protection activity.

Where additional information required interactions that were not a routine part of the pilot service, local research ethics committee approvals were obtained.

SYSTEMS

Aim

The aim was to understand the human and technical systems required to deliver community testing in an end-to-end, civic operation as part of wider Covid-19 measures.

Key findings

The handover period from the military in December 2020 was extremely tight. The transition team should have been engaged much earlier.

The management of clinical waste was not included in the SOP and local registered waste contractors had to be brought in and outlets found at short notice.

Signage for the ATS, in terms of quantity and timeliness of delivery, was a problem from the start. It was a large and complex requirement, which after internal delays had to be re-allocated to an external contractor.

Although site accessibility was considered when sites were selected, further issues needed to be addressed such as wheelchair access, availability of sign language trained staff and translators.

Questions about occupation in test booking forms were often left unanswered, which hindered the ability to monitor uptake of LFTs by key worker groups.

Training in the use of LFTs for the pilot extensions (schools, MFRS, Police, prison staff) was initially managed by ATS personnel. Training co-ordination was later taken over by Liverpool City Council (LCC) who had important local contextual knowledge of each setting.

Financial management was ad hoc in the first two months. It would have been preferable to have appointed a dedicated finance officer at the start of the pilot.

Anecdotal feedback from LCVS partners suggests that their support activities mobilised an increased number of LFTs in hard-to-reach communities, and their practical support (food hampers, collection services) reduced the demand on LCC services (evidenced by a reduction in the number of calls to the LCC helpline compared with the first lockdown period).

The VCF [Voluntary, Charity and Faith] sector organisations agreed to participate in expectation of prompt reimbursement through the LCVS/LCC contract. However, no payment was made to LCVS during the period to 31 March 2021. Many VCF organisations operate on very small financial margins and struggled to support their members during the pilot.

The CIPHA integrated data and shared analytics system was vital as a single source of truth across NHS, public health, local authority and academic organisations in coordinating and evolving the pilot.

Sources and methods

The governance and operations systems were evaluated using material created by the Command-and-Control structure, and with reference to individual discussions with key stakeholders.

Multi-agency working

Governance and operations

The speed with which the pilot was established (seven days from agreement to opening of first ATS) created logistical challenges. The initial DHSC estimate of 48 geographically spread sites had to be revised with reference to local intelligence on Liverpool's neighbourhoods and practical issues such as site ownership and access.

The governance structure was responsive to the fast-moving process. Verbal agreements were accepted for some actions to enable site set-up. Command-and-Control action logs were not fully operational until 11 November 2020 and governance frameworks were not finalised until 13 November 2020. The military command logged every operational decision within their own system.

Local organisations were already working together effectively and efficiently through the Cheshire & Merseyside joint Covid-19 cells across the two constituent LRFs. The governance and operational structures for the pilot therefore drew on existing knowledge and networks. The co-chairs of the Gold/Silver/Bronze levels were drawn from different organisations, resulting in smooth identification and solution of emerging issues.

Adapting operations according to intelligence

An early adaptation was the rapid deployment of clinical staff from local NHS organisations to the ATS to ensure compliance with the clinical standard operating procedures and surveillance of attendees for vulnerable and potentially symptomatic individuals. The initial queues at the ATS on 6 and 7 November were effectively managed by the Council, who used their external stewarding contractor to supply additional staff.

At the start, existing Mobile Testing Units (MTUs) for symptomatic testing and the pilot ATS were managed separately. This was quickly identified as a discoordination risk, so the two systems were integrated at local level via Bronze Command, with clearer signage for the three out of 37 community venues where there were both types of testing available. The communications plan was adapted to clarify the purpose of each type of site, their location, and opening hours.

The DHSC approvals were streamlined by bringing the Senior Regional Coordinator North West into the local Command-and-Control structure (from the second week) and identifying DHSC staff to act as conduits. This enabled operational issues to be quickly addressed, including facilitating the use of local telephone numbers for follow-up PCR test bookings for positive LFT cases, and alerting DHSC to a communications failure on the postal drop of PCR kits to Liverpool Households.

NHS Test and Trace introduced a home PCR test delivery to addresses that were more than 800m from a testing site. This was centrally directed, and the local authority were advised of the postal districts chosen by DHSC via their national delivery partner company. The provision of home PCR test kits was preceded by a letter with guidance sent by NHS Test and Trace up to two days in advance of the Home Test kits being delivered by Amazon. Three home test kits were sent in each parcel, with a total of 85,062 kits being delivered to 28,354 households over 4 ‘Sprints’. The postal districts were L16, L25, L12, L24 and L14, but did exclude addresses which were within the radius of a testing centre.

As the completed home test kits had to be submitted through post boxes, to mitigate Royal Mail boxes being overwhelmed, Liverpool was asked to provide ‘collection points’ for the test kits for the day of delivery and the day following the delivery. At the busiest point 12 vans were provided in the identified areas to collect kits from residents between 08:30 and 17:00 and were then taken to a single point to transfer to Royal Mail who then delivered them to a Lighthouse laboratory.

Of the 85,062 kits delivered, 8,914 (10.5%) were registered by residents and 7,024 (8.3%) results were provided. Of the kits registered 3,428 were collected over the four sprints by the collection vans, all other completed kits would have been submitted via the post boxes. In response to the low registration numbers, a change was made centrally from 17 November 2020 to only send a letter to household occupiers informing them of how to request a home test kit.

Sustainability and knowledge transfer

The decision to continue LFT testing beyond the agreed period of military support placed a considerable strain on local partners to finalise procurement processes with external contractors. This involved proceeding at risk, with parallel negotiations with DHSC on the costing and agreement of a devolved budget; taking over equipment leases and liaison with the military command to produce guidance for the incoming staff. The Sustainability Plan was submitted and private sector providers in place by 30 November 2020 for a start date of 3 December 2020. Supply chain assurance (for LFTs and waste management) was a key issue for the transition period.

Mobilisation of a pilot for visitor testing in twelve Liverpool care homes (using multiple LFTs and a PCR test) was complicated by the announcement of a national pilot. There was a delay in the supply of kits, and public confusion over which care homes were included – nationally vs locally selected.

Liverpool City Council managed a 'Lessons Learned' process, in collaboration with military personnel in the format of 7-, 14- and 21-day reviews. A summary was published on Resilience Direct on 7 December and disseminated via a workshop for Local Resilience Forum partners.

In May 2021, Gold/Silver/Bronze command remains operational, coordinating testing across the City of Liverpool, complemented by an equivalent Liverpool City Region command structure. This structure has supported further national Covid-19 response pilots including the Events Research Programme.

Digital access, dataflows and intelligence

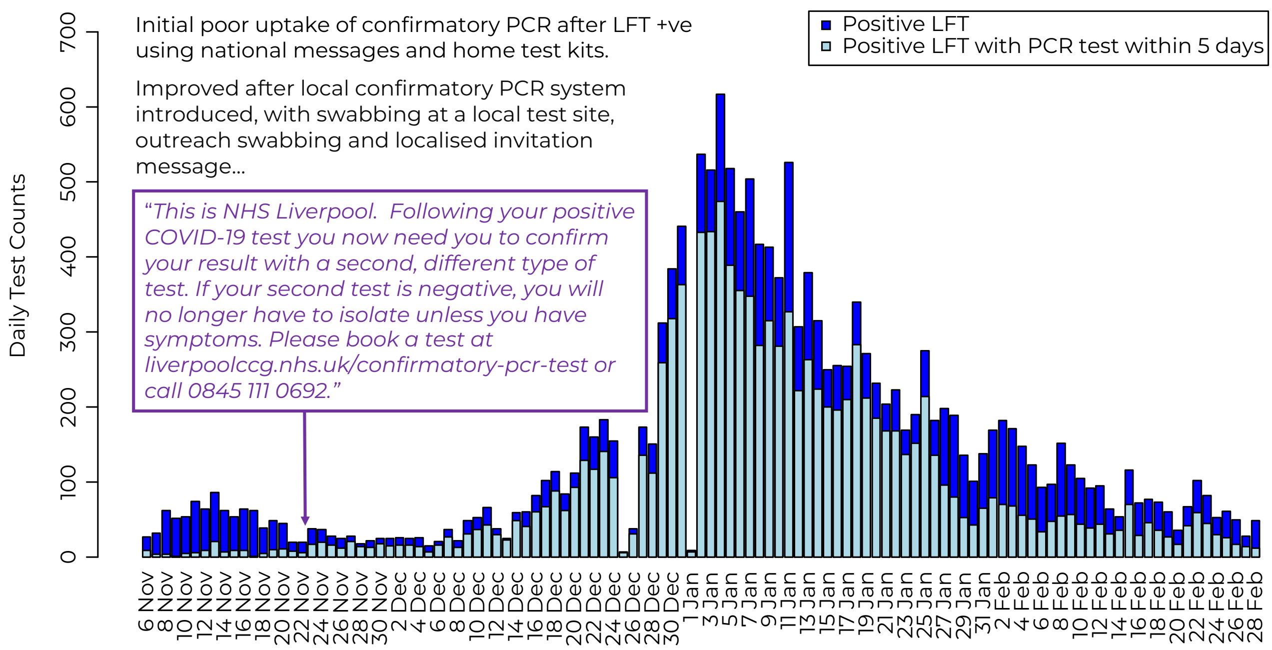
Digital registration proved to be a key determinant for attendance and 'flow rate' through the ATS. The initial plan for pre-registration online was abandoned after it proved impractical to manage alongside the walk-in option. Individuals presenting at ATS were asked to self-register on their personal devices. However, some ATS reported up to 40% of attendees did not have suitable devices or the ability to operate them, and military personnel were required to complete the registration process on ATS/NHS devices.

Dataflows from national and local systems into a combined intelligence facility, CIPHA (www.cipha.nhs.uk), were important as a single source of truth for agile command-and-control. The necessary Pillar 2 test result dataflows were granted to Cheshire and Merseyside on 5 November 2020. Analysts from NHS Liverpool Commissioning Group, Merseycare and The University of Liverpool joined an extended CIPHA team to inform and evaluate the pilot by working on anonymised data extracts from the information system provider Graphnet.

CIPHA was also used under NHS Information Governance to guide testing workflows, including intercepting positive LFT results to offer a local confirmatory PCR service when it became apparent that take up of the national system was low. A digital workflow from NHS Test and Trace via CIPHA to NHS Liverpool was put in place on 23 November, offering a local testing site dedicated to confirmatory PCR testing, and rapid sample processing at Liverpool Clinical Laboratories, which quickly improved confirmatory PCR uptake from 19% to 79% (from 6 November to 22 November 140/736 individuals receiving positive LFT results received a PCR test within 5 days, from 23 November to 12 December these numbers were 184/234).

CIPHA dashboards, including maps and socio-demographic summaries, showed wide variation in uptake across the City, not all in

Figure 8: Change in uptake, following local intervention, of PCR testing within 5 days of a positive LFT



the expected patterns of NHS and social care utilisation inequities. Geospatial analysis was refined to include 15-minute walking times to ATS and consideration of Covid-19 prevalence, deprivation, and digital exclusion. This highlighted areas that were not well-served, and enabled the roll-out of temporary sites, and the closure of some sites with unviable attendance.

CIPHA dashboards for the first phase of testing were expanded and improved for the subsequent SMART roll-out across the wider Liverpool City Region in December 2020. Related dashboards for vaccination, NHS capacity management and were built and CIPHA has become a core population health management tool for NHS, local authority and academic organisations in across the region. CIPHA is now expanding to other regions including the whole of the NW and parts of the SE England.

Communications and community engagement

Consultation with residents (via surveys and focus groups) identified that the "MAST" (Mass, Asymptomatic, Serial Testing) term was not well understood. 'Asymptomatic' and 'serial' proved especially challenging terms to communicate. There was insufficient attention to briefing those attending for testing that they should return within five to seven days for another test.

Misinformation may have affected public confidence and uptake in the first phase of the pilot. Misinformed issues included perception of the risk of infection at test sites, suspicion around Government use of data collected (especially 'DNA'), and the need to have physical contact with centre staff. The communications team responded through a page on the Council website, daily stakeholder emails; Facebook messages targeted by postcodes and regular press briefings and contact with ward councillors and community leaders. Public figures from the football and entertainment communities provided short influencer videos which were disseminated via social media channels.

Distribution of leaflets via pharmacy prescriptions bags was first discussed on 19 November. Targeted initiatives such as this would have been beneficial earlier in the pilot.

Following the planned review on 19 November 2020 the programme was re-branded as 'SMART' (Systematic Meaningful Asymptomatic Repeat Testing) – and colloquially 'smart'. This acknowledged the emerging scientific evidence on the sensitivity of LFTs and responded to analysis that specific population sectors that were less likely to engage with testing. It facilitated the development of three target-based plans for the use of LFTs:

1. Test-to-protect

Testing to protecting the vulnerable and wider society against direct harms from SARS-CoV-2 and indirect harms from Covid-19 control measures)

2. Test-to-release

Testing to release contacts of cases from having to quarantine, especially key-workers with major societal consequence of absence from work – now termed "DCT: Daily Contact Testing"

3. Test-to-enable

Testing to allow abeyance of restrictions affecting health, social fabric, and economy, for example enabling attendance at music, theatre, business and sports events

In the early months, community engagement proved challenging without an existing city-wide Voluntary Plan. Although the Liverpool Charity and Voluntary Services (LCVS) had some capacity to act as a liaison service, and knowledge of charities and neighbourhood groups, it proved impractical to mobilise these at such short notice to provide a community activation service. Liverpool City Council began a leafleting drop to targeted neighbourhoods on 20 November 2020, after the main publicity drive, missing the opportunity for a critical mass of 'push-pull' communications.

Discussions around deploying third party vehicles as testing centres (Red Cross; St John's Ambulance; Arriva buses) were hindered by health and safety/protocol/sign-off concerns and did not proceed. These would have been a very effective route into the hardest-to-reach communities that have poor digital engagement.

Focus groups and surveys suggested the community reception of the military personal was very positive and welcoming (see Behaviours chapter).

Visualisation of the mobile testing unit

System developments from 3 December 2020

The City Council assumed direct management of the ATS from the military on 3 December 2020 and was rebranded Covid-SMART (Systematic, Meaningful, Asymptomatic/Agile, Repeated Testing). Testing became more targeted in response to move of Liverpool into a lower tier of restrictions when the public messaging moved from “let’s all get tested” to “test before you go” (going to the hairdresser, restaurant, shops etc.). The planned opening and closure of ATS was informed by a review of usage data at Bronze Command. By 31 March 2021, the number of fixed sites had been reduced to six. After the imposition of national lockdown on 5 January 2021 the public messaging on use of the ATS changed to prioritise use by workers who could not work from home, with “testing our front line”.

On 10 December 2020, a new rapid response vehicle was brought into action, with an initial site in Sefton Park, an area of relatively low engagement with the LFT pilot. This was moved around the city, informed by data on testing uptake and data on areas of increased Covid-19 positive cases.

As part of SMART-reopening, training for school staff in how to conduct LFTs commenced on 29 January 2021 at Wavertree ATS. The full implementation of this pilot was dependent on the lifting of the national lockdown. This happened on 8 March 2021, by which time all schools in England and Wales were required to implement a LFT protocol.

Further SMART-reopening initiatives included the provision of training for businesses within the LCC area from early February 2021. A pilot of late-night ATC opening at Anfield (LFC) did not prove effective and was discontinued.

‘Test-to-Release’ pilots commenced on 4 December 2020, initially with Merseyside Police Force, and subsequently extended to Mersey Fire and Rescue, and HMP Liverpool. A protocol was developed in collaboration with scientific advisers, on the appropriate regime of daily testing following contact with a positive case, to reduce the period of self-isolation. Staff were trained in how to conduct LFTs at home and how to submit their results. By 3 March 2021 there were 709 participants in the Keyworker SMART Release scheme (655 were from Merseyside Police); 3,263 days of isolation had been saved.

A programme of targeted community engagement was commissioned from LCVS in December 2020 (although the contract between LCVS and LCC was not in place until January 2021). LCVS identified several Local Trusted Organisations in areas of the city with lower testing uptake and worked through their members to deliver information on testing and support for self-isolation. This was achieved through doorstep conversations, online contact (Zoom sessions, social media such as WhatsApp groups), and the delivery of food hampers and prescription collection. Local community leaders were involved with identifying hard-to-reach people. Information on testing was also disseminated through the Positive About Play Christmas and February Half term programmes and the Health and Wellbeing Network. Feedback from LCVS partners was collated through a Survey Monkey and focus groups.

Sector specific arrangements

As the pilot evolved, asymptomatic testing schemes emerged across different sectors and settings that Gold and Silver Command had to integrate into a civic whole, which involved working with different Government organisations, including Department of Health and Social Care (DHSC), Department for Education (DfE), Department for Culture Media and Sport (DCMS), Cabinet Office, Department for Business, Energy and Industrial strategy (BEIS) and Ministry of Housing, Communities and Local Government.

University testing was devolved to universities whereas schools' testing was driven directly by DfE. Some Universities, including University of Liverpool, were asked to build capacity to deliver an alternative testing method, LAMP (loop-mediated isothermal amplification), which did not take off as it was too labour-intensive. Lateral flow device supplies to Universities and local authorities were managed separately at national level but needed re-integration locally, and the University CAMPUS Shield programme across Liverpool was represented in local Command-and-Control.

Workplace testing was driven by BEIS and DHSC in two pilots: regular testing and Daily Contact Testing (as an alternative to quarantine). This cut across earlier organised elements of the Liverpool pilot on test-to-release contacts of cases from quarantine if they were key workers. Similarly, DHSC introduced a service directly to care homes, cutting across care home specific elements of the Liverpool pilot, which caused confusion for participants. Large organisations such as Fire, Police and NHS could cope with this confusion and put their own systems in place to coordinate locally but smaller organisations had fewer resources to manage this. These agencies, rather than work with the national programme structures chose to work through the local Director of Public Health. NHS Test and Trace offered LFD supplies to Directors of Public Health for use in this way, under local clinical governance – this was the preferred model in Liverpool.

A DHSC project, Encore, for reopening events, was planned with Liverpool then moved to DCMS. Successful delivery of testing and protocols for events required local Command-and-Control.

Scale and sustainability

From November 2020 to May 2021, an increasing number of sectors and organisation have been invited into LFT pilots and many families and individuals have been asked to engage with these overlapping schemes. The overlaps have caused confusion where guidance for testing is different between settings, or where testing is duplicated when a person has multiple roles.

During surges of the pandemic, testing supplies, coordination and communication needed local authority and DHSC intervention to bring cross-sector activities into a greater whole. For example, at one point the Police faced abstractions from quarantine that put the force's ability to provide some frontline services at risk if they could not ramp up daily testing.

As national support for ATS venues reduced, so did the accessibility to some high need/risk communities. In May 2021, the Liverpool ATS are reducing from 6 to 2 or 3. This will impact some sectors more than others, for example 41% of the domestic care sector staff in Liverpool do not have a car (LCC social care workforce survey, 2021). Home testing may compensate for this lack of access to testing, however, home testing requires a lot of digital interaction and many in this sector have low digital resources or literacy.

As society reopens in Summer 2021 the scale of testing will grow, with a potential combinatorial explosion of requirements for sector or setting based testing. For example, a care home worker going to a football match may be asked to test twice within a day. At the population level, residents will soon return to clusters of large and small mixing events, from a music festival to working the afternoon in a crowded coffee shop. Twice weekly community wide LFT (with follow-up PCR and viral sequencing for positives), alongside efficient symptomatic and

"Blossoms At Sefton Park" - part of the 2021 Events Research Programme surge testing, may be the only practical solution to combining multiple SARS-CoV-2 testing requirements, for as long as they are needed.

BIOLOGY

Aim

The aim was to quality assure the biological performance of Innova SARS-CoV-2 antigen rapid lateral flow devices and the asymptomatic testing process, including the uptake and utility of repeat LFTs and confirmatory PCR tests.

Key findings

1) The Innova lateral flow device (LFD) performed as expected, identifying most SARS-Cov-2 cases without classical symptoms but with high viral load – those likely to be the most infectious.
2) To maximise the value of lateral flow tests (LTFs) care should be taken to:
   a) Train test operatives;
   b) Clearly and accurately communicate how to interpret test results;
   c) Target testing with reference to background case rates;
   d) Avoid single lateral flow tests for access to vulnerable settings.
3) Local messaging interventions appeared to be important for uptake of PCR tests to confirm positive results from lateral flow tests.
4) From late December 2020 the UK Variant VOC 202012/01 dominated SARS-CoV-2 transmissions detected in this pilot.

Performance of the Innova SARS-CoV-2 Antigen Rapid Lateral Flow Test

Sources and methods

We conducted a quality assurance (QA) exercise to assess the performance and appropriate implementation of the Innova SARS-CoV-2 rapid antigen LFT in Liverpool. Asymptomatic individuals attending ATS between 8 and 29 November were asked to participate in a QA process and given the opportunity to opt out. The sample of around 6,000 attendees received a LFT and a reverse-transcriptase quantitative polymerase chain reaction test, a 'PCR' test. Two supervised, self-administered swabs were taken at the same appointment within minutes. The first swab was analysed by LFT, the second by the standard PCR test used in lighthouse laboratories. The PCR results were sent from NHS Test and Trace to CIPHA and analysed by an independent team at the University of Liverpool.

The primary analysis compared classifications of SARS-CoV-2 infection status made by Innova LFT with PCR from supervised, self-swab sample collection at general population scale. The secondary analysis investigates the influence of viral load on the paired LFT-PCR classifications, using PCR cycle threshold (Ct) as a proxy for sample viral load.

Accuracy parameters (sensitivity, specificity, and predictive values) were estimated, and 95% confidence intervals were generated using the Clopper-Pearson method. Analyses were carried out in R (version 3.6.1 or later) and checked by a second statistician using SAS software (version 9.4). Initial results from this QA evaluation have been reported in our interim report,[1,6] and in national media.[7-14] Our full analysis has been submitted to a scientific journal for publication.[15]

Findings

The QA dataset consists of data from n = 5,869 individuals from 48 ATS in Liverpool. A comparison of the LFT results recorded on site and the paired QA PCR results is shown in Table 1. PCR results included 5.8% voids (343/5,869) and LFT results included 0.4% voids (22/5,869).

Table 1: Results of the LFT and RT-qPCR tests obtained from 5869 participants.

QA dataset	RT-qPCR Result				
LFT Result		Negative	Positive	Void	Total (%)
	Negative	5431	42	341	5814 (99.1%)
	Positive	3	28	2	33 (0.6%)
	Void	18	4	0	22 (0.4%)
	Total (%)	5452 (92.9%)	74 (1.3%)	343 (5.8%)	5869

Accuracy of LFT assessed against PCR, excluding void results, showed that the overall sensitivity of the Innova LFT was 40%. It is important to note that this statistic can be misleading if the PCR test is detecting a large proportion of post-infectious individuals, which is true of a large proportion of PCR positives when the epidemic curve is in late decline or steady state. We also found:

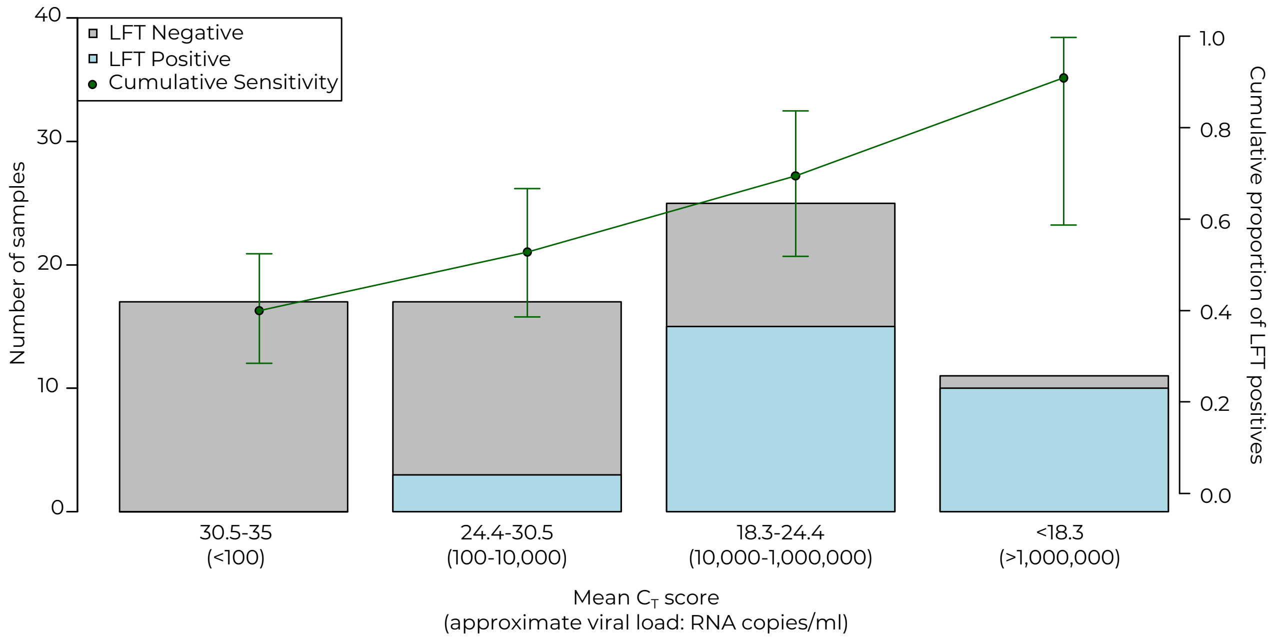
- Specificity (true negative rate) = 99·9% (99·8 to 99·99; 5431/5434);
- Positive predictive value (likelihood a LFT test-positive case is PCR positive) = 90·3% (74·2 to 98·0; 28/31);
- Negative predictive value (likelihood a LFT test-negative case is PCR negative) = 99·2% (99·0 to 99·4; 5431/5473).

In our study, LFT achieved 90% relative sensitivity vs PCR positive cases with high viral load >10^6 RNA copies/ml. The corresponding 95% confidence interval (CI) indicated that LFT is likely to detect at least three fifths and at most 998 in every 1000 of RT-qPCR positive cases with high viral load (Figure 9).

PPV and NPV were directly estimated using a 1·3% prevalence, derived from the QA dataset. This value is consistent with the prevalence reported by the Office for National Statistics for the period the QA study was conducted.

We conclude that Innova LFD worked as expected and is a valuable tool – within a wider public health response – for identifying individuals with higher viral loads, who are more likely to be infectious, but who do not report classical symptoms. We recommend that to maximise the value of LFT testing, care should be taken to (i) train test operatives; (ii) achieve clear and accurate communication with the public about how to interpret test results; (iii) target testing with reference to background case rates; (iv) avoid single LFT for access to vulnerable settings where the consequences of infection are severe (unless comprehensive additional risk reduction measures are in place). Further studies are needed to understand the full relationship between LFT results and infectiousness.

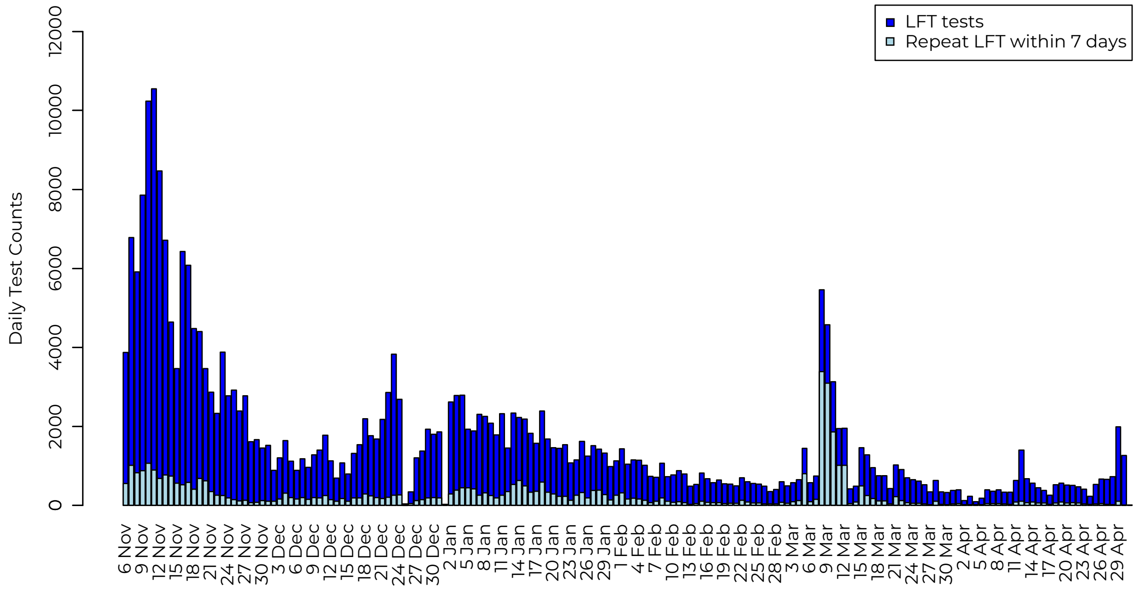
Figure 9: Number of negative and positive LFT cases by RT-qPCR viral load (based on mean CT score across three gene targets). Intervals show the 95% CI for the cumulative sensitivity to detect viral loads >1, >10^2, >10^4, and >10^6 RNA copies/ml, with the axis on the right-hand side



Repeated lateral flow testing

Twice weekly testing was the target. Between 6 November 2020 and 30 April 2021, 290,161 residents had an LFT test. Of these 54% did not return for a second test (as of 30 April 2021), whilst 16%, 27% and 33% returned for another test within 7 days, 14 days and 28 days of their first test, respectively. Figure 10 shows uptake over time and counts of individuals returning for a second LFT within a week.

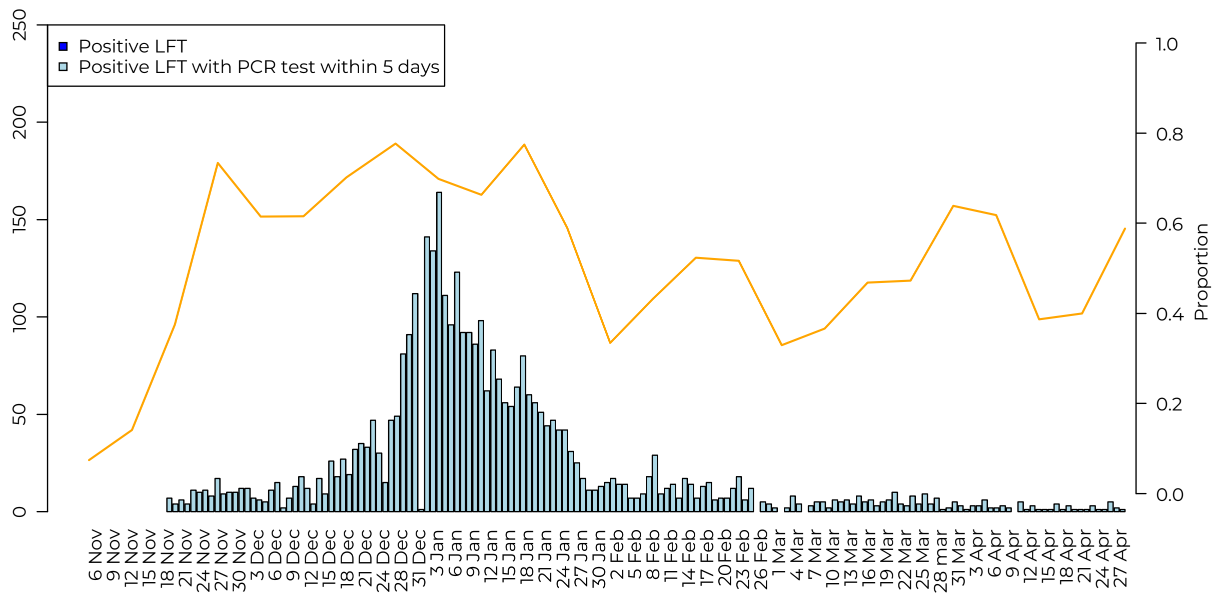
Figure 10: Number of first time LFT testers by day, and the numbers who return within a week



Confirmatory PCR tests

Individuals who tested positive with LFT were invited to book a confirmatory PCR test. Initial uptake of confirmatory PCRs was poor. After a local messaging intervention at the end of November 2020, the uptake of confirmatory PCR improved, although a reduction was observed from the end of January. Figure 11 shows the uptake of confirmatory PCRs over time. In total there were 6,109 individuals who tested positive via LFT between 6 November 2020 and 30 April 2021, and 3,547 of these received a PCR test within 5 days (58%). This number represents a lower bound on the number of confirmatory PCRs since some individuals may have been tested within Pillar 1 and not been detected within Pillar 2 data. For individuals with a confirmatory PCR within 5 days of a positive LFT, 3216 had a positive PCR (90.7%), 295 were negative (8.3%) and 36 were void (1.0%).

Figure 11: Number of individuals with positive LFT test by date. The number of individuals who have a PCR test within 5 days of a positive LFT is shown in the light blue, with the proportion of all individuals with a positive LFT shown by the orange line



Symptomatic individuals

Only 14/5980 individuals who reported no symptoms at their first positive LFT, had a subsequent test (either PCR or LFT) where they reported symptoms. This is unlikely to be a reliable picture of how many individuals with positive LFT went on to develop symptoms, since such individuals may not seek a further test after a positive result. In addition, the recording of symptomatic status is likely to be prone to errors. We do not have data to assess whether individuals with a positive LFT subsequently contacted NHS 111, their GP or were admitted to hospital, which would be a better indication of symptom status.

New variants

During the last months of 2020, a new UK Variant (VOC 202012/01) started to spread rapidly across the UK. Exact detection of this variant requires genetic sequencing, but a proxy of its presence can be obtained by observing the dropout of Spike protein (S gene) in the PCR cycle thresholds. Figure 12 shows the proportion of all positive PCRs in the region that showed S gene dropout, and the proportion of PCR positives with all three target genes recorded (N gene, S gene and ORF1ab). We have discounted 10,531 Covid positive cases whose tests were taken at the Immensa, Randox or Accora-Quade labs since they did not target S gene in their PCR assays. This represented 2.8% of all individuals with Covid within our analysis. Our analysis of S-gene dropout reveals that the rise in cases beginning in mid-December was largely, and increasingly driven by the new variant.

Figure 12: Number of positive PCR tests by day, and the proportions of positive tests with all three target genes reported (purple), and those with S gene dropout (red)

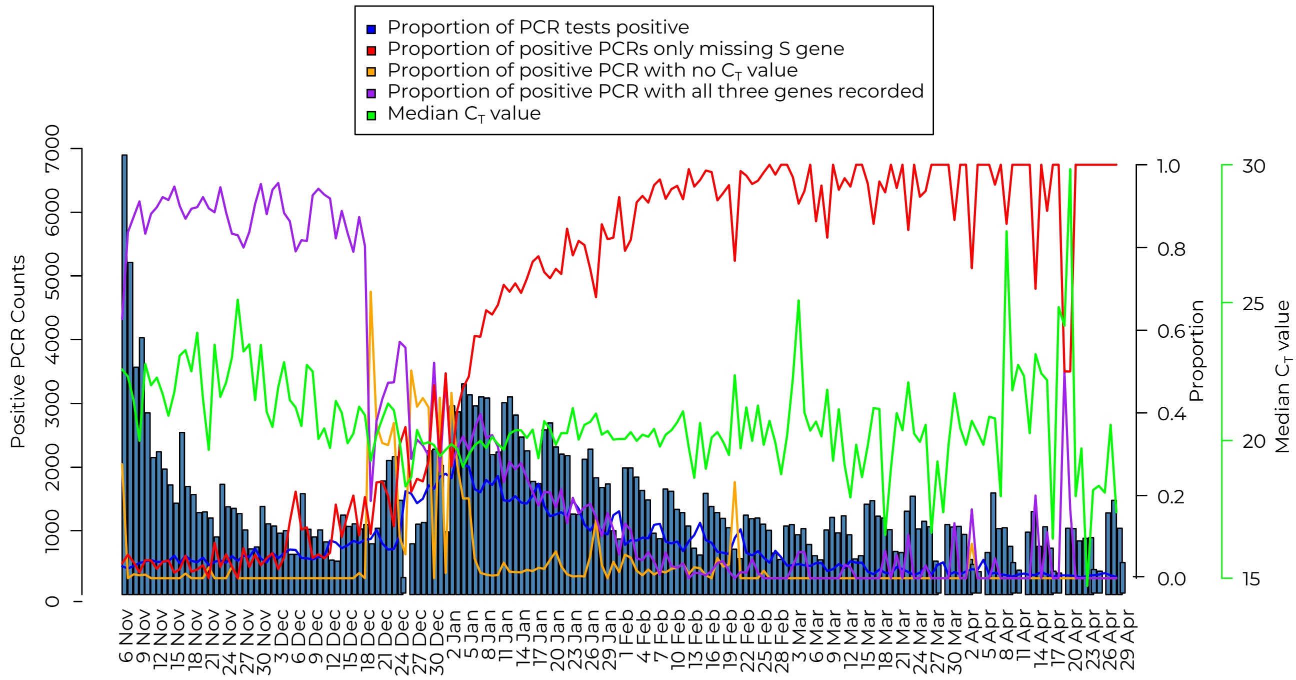
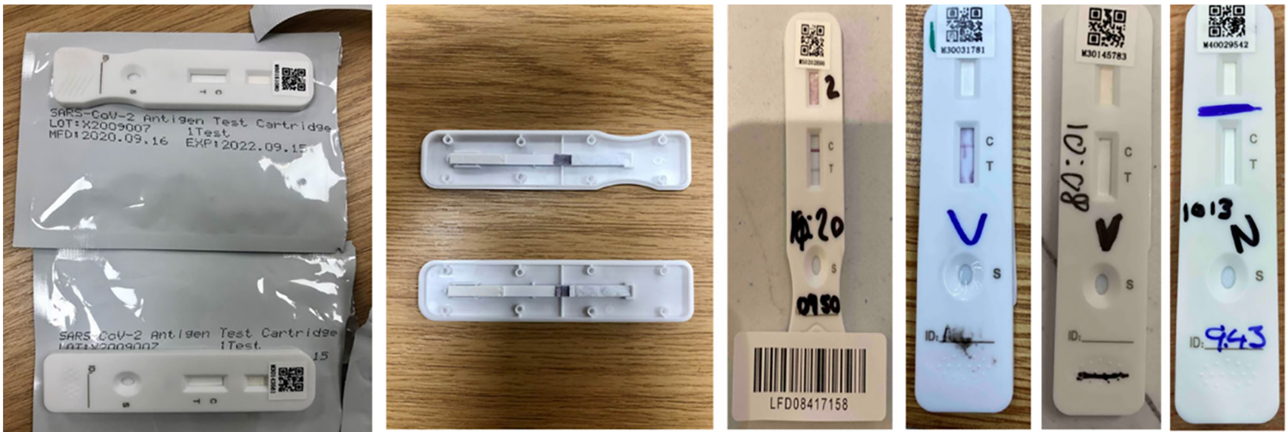


Figure 13: Examples of device build differences and reading/labelling issues



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Schools testing and plausibility of self-reported results

From 3 March 2021, LFT testing in secondary schools was recommended. We report summary results of lateral flow tests in 5–11-year-olds (primary school aged children) and 12–18-year-olds (secondary school aged children) in the Liverpool region between 6 November 2020 and 30 April 2021.

There were 26,880 LFTs conducted on 5–11-year-olds, identifying 162 positive tests. Of these, 91 had a confirmatory PCR within 5 days, yielding 86 positives (94.5%) and 5 negatives (5.5%)

There were 129,657 LFTs conducted on 12–18-year-olds, detecting 454 positives tests. 262 of these had a confirmatory PCR within 5 days (57.7%), yielding 228 positive PCRs (87.0%) and 33 negatives (13.0%).

For test results entered at home there is no confirmed link between LFD device code and outcome and the result appearing in Pillar 2 dataflows, the user just reports the result into a web form. Future AI-based reading of LFD ID and result may give more objective data comparable to ATS results.

Device handling, reading and labelling

Manufacturer's Quality Control (QC) certificates and batch certification were not provided for the lateral flow devices used in the Liverpool pilot. These may have been retained centrally. At least four different LFT builds were provided for use in the pilot. The shape and size of the sample windows varied between LFT devices. There is a concern that build could affect performance of the LFTs. When asked about this, the NHS Test and Trace team report "Each batch of Innova devices underwent QC testing using antigen control sets provided by Innova. This testing was performed centrally by Intertek before the batch was released for use. Reports are produced on an exceptions basis, with quarantine of specific lots or products that fail QC tests to prevent them entering circulation."

Test performance may have varied with build quality, temperature in transport, swabbing, device use, result reading, labelling and data entry. It was later learned that the batch numbers of tests can be traced by the logistics team from the QR code on the (images of) devices. However, the batch numbers were not recorded against individual test. Good practice is to include batch numbers in QA datasets and to link the batch number with a QC certificate for the corresponding batch.

The substantial mislabelling of LFDs indicates the need for an AI test reading process on uploaded images, provided the image classification can outperform typical ATS operatives.

The sample of 5,869 LFDs reported here have been used for training AI that is expected to be deployed across NHS Test and Trace shortly.

Repeated testing

To understand the value of repeated rapid testing for SARS-CoV-2 antigen, it is important to consider the dynamics of SARS-CoV-2 infection and viral shedding (as distinct from viral load) within individuals, and to reflect the changes in meaning of summaries of test positivity for populations at different stages of the epidemic curve. We encountered a lack of understanding of the asymmetrical nature of test positivity and viral dynamics at individual and population levels. So, we wrote the series of articles listed in the Appendix to help clarify the evidence for policymakers and public health practitioners.

Repeated testing in the Liverpool pilot was infrequent in the general population. From February 2021, some workplace groups such as construction workers took up twice-weekly testing, but systematic study of repeated testing focused on enhanced testing for care homes and daily contact testing for keyworkers in critical services. The main determinants of the outcomes were behavioural therefore the results are presented in the Behaviours chapter.

BEHAVIOURS

Aim

The aim was to understand behavioural responses to community testing overall and in specific settings.

Key findings

1. There was strong public awareness of, and a largely positive attitude toward community testing, motivated by shared identity, civic pride and a wish to protect others.
2. The main barrier to testing was fear of losing income if having to self-isolate.
3. Although most survey respondents reported an intention to comply with guidance if testing positive, the completeness of adherence to self-isolation was unclear.
4. Misinformation in news and social media over test accuracy damaged public trust and was a barrier to testing uptake – intensive local communications were needed to rebuild trust.
5. Messages about targeted testing were less well understood than messages to all get tested, but some target audiences were more motivated by targeting.
6. Test-to-release or Daily Contact Testing was best received where the employer had existing support for testing and contact tracing.
7. School-to-school communication and co-creation of testing facilities with the local authority generated more positive attitudes to schools' testing.
8. Concurrent local and national policies for pilots such as care homes, schools and workplace testing caused confusion and reduced engagement.
9. There was only sparse evidence of a negative test result licensing Covid-unsafe behaviours.

10. Introducing enhanced staff testing in care homes saw poor adherence due to high workload, low morale and lack of resources to support the additional workload of testing; so, unsurprisingly the pilot scheme did not reduce the number and size of outbreaks.

Overall testing

Sources and methods

Testing site attendance survey

An online public survey with the City Council was aimed at individuals attending ATS. The survey focused on people's experiences of the process, any barriers to their attendance, general understanding of the government guidance and comments on their views on overall communication. The survey was distributed via social media channels and posters with QR codes at sites for people to complete while they waited for their results.

A first survey iteration (30 November to 17 December 2020) collected more open-ended answers, looking to capture an initial picture of the public's perceptions and views. This initial dataset was reviewed, and prevalent themes identified, which informed a relaunched version (17 December to 14 February 2021) focusing on more discrete and quantified answers.

A total of 984 individuals responded to the survey:

- Ages ranged from 10-77, mean 45 years (402 respondents)
- 783 respondents provided a gender, 469 female, 302 male, 6 non-binary
- 791 respondents provided ethnicity: 714 White/British/Irish
- 787 respondents provided residence status: 180 lived alone; 607 lived with others (236 with children; 365 with other adults)

News and social media analysis

We analysed a sample of news and social media responses to community testing in and around Liverpool to gather insights from people who may not engage in other standard evaluation techniques, targeting Facebook, Twitter, and the Liverpool Echo.

We used the CrowdTangle platform to collect all Facebook posts containing the keyword 'testing' published from 6 November 2020 to 1 March 2021 on the public pages Wirral Council (46), Liverpool City Council (89), Sefton Council (17) St Helens Council (18).

Through the RISJbot we crawled all news articles published by Liverpool Echo on its official webpage and related users' comments for the time range 1 November 2020 to 21 January 2021, gathering 5547 articles.

Through the Twitter Premium API, we collected the tweets from 1 January 2020 to 1 March 2021 linked to accounts geolocated in Liverpool City Region.

News and social media coverage concentrated more on some phases of the pilot than on others. Relevant Twitter activity was concentrated in the 'mass testing' month, with the top tweeted day being the first day, 6 November 2020. Similarly, filtering headlines for the Liverpool Echo through the keyword "testing" we obtained a sample of 1843 articles with a highly skewed distribution – November: 1712 articles; December: 114 articles; January: 17 articles.

We applied a mixed methods approach to investigate: i) lines and trends of local information diffusion; and ii) public reactions to official communication with a focus on perceived facilitators and barriers.

The qualitative rapid thematic analysis of local narratives was based on:

- 132 comments from the Liverpool Echo
- 767 comments from Facebook pages (Liverpool City Council, Wirral Council, Sefton Council, BBC North West, Liverpool Echo news)

- 271 Tweets

Thematic analysis was extended (with new themes) from the interim analysis previously reported [1].

Interviews with those who did vs did not take part in testing

Participants who chose not to participate in the Liverpool pilot were recruited via social media (n=12). Potential 'non-tested' interviewees contacted the research team, and we used a convenience sample. We also recruited 21 'tested' participants using a questionnaire distributed at testing sites. A purposive sample was targeted (age, gender, deprivation, ethnicity). Participants were offered a £15 voucher as compensation for their time. Focus groups were held with 17 adults and 5 young people (aged 16-18) including representatives from ethnic minorities, people with chronic health conditions and/or their careers, and residents of a disadvantaged inner-city area. The adults had not gone for testing and did not intend to for fear of income loss if they needed to self-isolate. The focus groups ran from 30 November to 17 December 2020.

Findings

The section starts by discussing the perception of the community testing pilot by the public, and motivators and barriers to participation in asymptomatic community testing. We then consider behavioural responses to positive and negative LFT results.

Awareness of and attitudes towards testing

- *High awareness and positive attitudes towards testing*

There were notable differences in attitudes towards testing. Differences were particularly strong between those who did vs did not participate, and (social) media showed a variety of attitudes. Focus groups with Liverpool residents from early to mid-December showed that attitudes toward the pilot and getting tested were very positive. All groups emphasised that the Army were doing a good job and there was strong belief that asymptomatic testing helped take Liverpool out of Tier 3. Quantitative analysis of social media also indicated positive or neutral attitudes towards testing. We identified 919 Tweets with relevant hashtags during the study period (#liverpooltesting, #masstesting #liverpooltesting, #masstesting, #lpoolcouncil, #liverpoolcouncil, #LetsGetTested, #CovidSafe, #asymptomatic, #stay CovidSafe, #stay Covid Safe, #Lets get tested, #StaySafe Liverpool, #Stay Safe Liverpool, #lateral flow test, #lateral flow tests, #lateral flow testing, #mass testing, #smart testing). These tweets concentrated on during the first phase of mass testing, with a peak on 6 November 2020. The most-used hashtag was #LetsGetTested and sentiment analysis showed an overall positive sentiment (37.4% positive, 16.8% negative and 45.7% neutral).

- *Hesitancy reflected concerns over test accuracy and the value of results*

Our sample non-participants revealed specific hesitancy issues. Participants were sceptical about test accuracy and the utility of a negative test result. Similar scepticism was reflected in local online narratives, for example, a belief that tests were "only 40% accurate – as good as meaningless". There was also concern that tests could also result in false negatives: "Even if you get a negative test result, there is a 5% chance it could be false negative… I'm not sure why so many are rushing to get it. Just take the precautions you've already been told to, to reduce chance of infection", resulting in misunderstanding of the role of testing.

Interviews with individuals who did not take part highlighted the perception that there was no need for a test since they were either not in contact with others (e.g., working from home), they were being vigilant, or that their children were being tested (considered a proxy for parents also being negative). Amongst those working at home, some held the perception that testing would put strain on the NHS,

" me and my partner, we work from home, so we did not want to put more strain on the NHS because... we do not see my family, we do not see friends, so we do not expose ourselves in an unnecessary way."

This indicated a need for public education over the difference between clinical and public health testing in Covid-19 responses.

- *Information overload about testing*

Focus group discussions revealed gaps in knowledge about the testing protocols and sometimes people felt overwhelmed by the amount of information. There was some Covid fatigue associated with potential de-motivation. It was felt that local information / communications were the best and most useful, for example local radio was considered a good way to keep up with 'what's going on'. Schools were also felt to be a good source of information.

In addition, although focus groups were positive towards testing there was a lack of trust of Government. It was felt that trust would improve with greater involvement of local councillors, community leaders and local trusted organisations. Local TV programmes were also suggested for demystify the testing process, particularly for older people.

Motivators, facilitators and barriers to participation

- *Testing motivated by civic pride and a desire to protect others*

Decisions to participate in the pilot reflected various motivations and expectations. Factors influencing participation were strongly pro-social with a sense of shared identity and an ethical drive to take part. In the ONS survey, an approximately equal number of respondents stated that they participated in the pilot due to 'civic duty' (240, 17%), 'desire to protect family and vulnerable members of their household' (216, 15%), or because they 'felt it was the right thing to do to reduce spread' (219, 15%). Similarly, across social media, qualitative analysis showed that social identity was a key motivator to get tested, along with a sense of pride in the city. For example, the most "liked" Facebook post, made on 24 December 2020 stated:

"Hopefully, the media will show that us scousers are sensible and caring and educated enough to act together like this before we see our families tomorrow. Well done all,..."

...referring to pre-Christmas testing. Protecting the community was also identified as a facilitator in qualitative analysis of social media, however as the testing was rolled out to a wider Liverpool City Region, tensions between wanting to protect the local community and feeling protective over the local community and case rates between local authority districts within the region arose.

The most frequent response to the ONS survey question on why individuals had taken part in the pilot (269, 19%) stated that they were looking for reassurance and wanted to know if they had the virus. Further, interviewees said they wanted to help reduce transmission by knowing their virus status,

"Well the obvious one is just to know that I'm, for all intents and purposes at the time of the test, negative for Covid and that I am not... potentially infecting other people"

ONS survey respondents listed a wide range of factors they would highlight and promote others to attend. They pointed to the ease of the testing process (410, 32%) and the staff assisting them throughout (156, 12%). Reinforcing again the collective effort, some highlighted the importance of protecting others (269, 21%) and the desire to control the virus to return to normal (231, 18%), while also acknowledging the peace of mind test results provide (210, 16%). These responses reflect the core purpose of community testing and the potential for lasting positive impact on the region.

- *Testing motivated by social duty and/or individual needs*

In the ONS survey some also mentioned being tested as a requirement for work (131, 9%), whereas others were drawn to it by convenience (93, 7%). Lastly, a small number of respondents went for a test as they were recently exposed to somebody with Covid-19 (35, 2%).

Liverpool City Council Facebook pages included a post:

“Santa is getting tested before he gets ready to make his deliveries this Christmas… Be like Santa, and get your #Covid19 test before you go out and about this week.”

The post can be interpreted as permission to ‘go out and about’ during the Christmas break without warning that a negative test does not license abandonment of social distancing. However, the ONS survey showed that only 4% of respondents intended to carry out social activities following a negative test – and it should be noted that Liverpool was in Tier 2 for the second half of December when some social activities were permitted. The LFT process could be used to reinforce messages about the need to maintain Covid-safe behaviours after a negative test.

- *Hesitancy driven by concerns over inconvenience or perceived risks*

Concerns were raised over perceived inconvenience, personal safety and the consequences of testing positive. Focus groups emphasised the risks of travelling to the test centre, as did those who did not participate in the pilot. People were discouraged by the inconvenience of testing, queues and crowding. There were perceived safety issues over being outside on cold, dark nights, and over catching SARS-CoV-2 in queues. About crowding, there appeared to be subtle differences between those who did vs did not participate in the pilot. The only negative feedback received from those who chose to participate concerned the length of the queues, especially at Christmas:

“But I would say that the only off-putting thing is the giant queues I think sometimes, especially over the Christmas period there was a lot of testing going on for this testing in those sites, and reduced hours in other sites so I think a lot of people went to different sites, so the queues were quite large”

In contrast for those who chose not to be tested emphasis was also placed on the potential for exposure to the virus in a crowded area:

“Yes, only because I think obviously when it first came out there were lots of people going to have the test themselves and because you don’t know who has and who hasn’t got it, I’m very wary about keeping a safe distance and everything else, but not everybody is, so that put me off”

An ‘angry’ Facebook post (23 December 2020) stated,

“The irony being people with no symptoms are standing with a crowd of others for hours waiting to be tested….if you didn’t have covid before, you probably do now!”

In the ONS survey, only 29% of responses described reasons people might be deterred from attending an ATS, whilst 71% could not think of any reason why people might not attend. This is unsurprising as the survey was delivered to those who had chosen to participate in the pilot. It is notable, however, that 59% of the responses that were made related to inconvenience, referring to: being deterred by potential crowd sizes (68, 23%) the time the process would take (57, 19%) and the inconvenience of the site (51, 17%). Beyond optimising the geographical distribution of sites, focusing on convenient nodes and heavy-traffic areas, improvements on reporting how busy sites were and expected wait times addressed some of these concerns.

- *Hesitancy driven by fear of self-isolation consequences*

Survey respondents also indicated that having to isolate following a positive result would influence the decision to attend an ATS (75, 25%). This was identified as an important barrier across our study. Focus groups noted both the financial consequences following a positive test result and the risk of children missing school. The online survey also asked whether respondents knew why other people said that they would not participate in the pilot. Although only a small percentage of respondents (293, 30%) knew people who would not come, they shared various reasons others offered. The main reason related to government distrust (53, 14%) and conspiratorial thinking (83, 22%), while others pointed to an overall lack of knowledge and misconceptions (60, 16%). A smaller number highlighted increasing sense of apathy (82, 21%) and efforts in the process (27, 7%), with others raising fundamental concerns about the impact a positive result would have on their lives (81, 21%). The contrast with views expressed in our qualitative work by those who did not participate in testing is marked. The responses here likely represent a more extreme spectrum of hesitancy examples, capturing more vocal and active views amongst respondents' immediate social circle.

Perceptions of access to testing

- *Unpopular changes to popular testing*

Interviewees commented on how well the processes and procedures were implemented. From other lines of inquiry, there was evidence of room to improve communication. Focus group noted poor communication around changing ATS locations and opening times, which made fitting testing into daily routine difficult. Analysis of public engagement with LCC Facebook public pages from 6 November 2020 to 1 March 2021 shows similar results: out of the most popular' posts (posts with highest number of Likes x Shares x Comments x Love x Wow x Haha x Sad x Angry), negative sentiment (Sad/Angry reactions) were triggered by posts reporting on sudden changes of plans for testing and access hours trigger negative sentiment, while thank you notes and stress on positive results consistently triggered positive sentiment.

The shift from MAST to SMART branding and from "let's all get tested" to "test before you go" marketing resulted in some confusion around accessibility and who was able to get a test. This was expressed, for example, on Facebook and in the Liverpool Echo respectively:

"Can you confirm if I am able to still have a lateral flow test or is it only for keyworkers / carers. The information going around on FB is confusing. Also do you need to book online or queue?"

A resident in the neighbouring district of Sefton complaining about not being able to access testing available only to people living or working in Liverpool said,

"I wasn't aware my job made me not a genuine person. These tests are for asymptomatic people living in Sefton. I am asymptomatic, and I live in Sefton. I fail to see what I've done wrong."

Response to a positive test result

The initial version of the ONS survey captured a range of open answers, reflecting people's understanding of steps to take if they tested positive. As illustrated in Figure 14, Most respondents (724, 55%) outlined actions in line with government guidance: self-isolate, stay at home, work from home. Others highlighted the need to notify recent contacts or employer (177, 13%) as well as the NHS (123, 9%). A small percentage (133, 10%) also suggested the need for further testing, which highlights some discrepancy between guidance and adherence to restrictions.

Response to a negative test

On the ONS survey question about behaviour following a negative test, as illustrated in Figure 15, the highest number of respondents highlighted the need to consider following guidance (442, 39%) and abide restrictions at work (99, 9%). Liverpool's position in Tier 2 during the second half of December was reflected in some answers pointing to the ability to maintain some activity if they complied with restrictions. Nonetheless, the increased infections and lockdown restrictions reduced this activity, as reflected in people's responses. A small number of respondents (118, 10%) also pointed to the desire of encouraging others to attend, reinforcing the notion of civic duty in the area.

Considering the requirement of regular testing as a key component of the pilot programme, the majority recognised the need to go for further tests, although 20% of the respondents did not say that they would come back for another one

Figure 14. Intentions around a positive test result reported in ONS survey

What do you intend to do if you test positive?

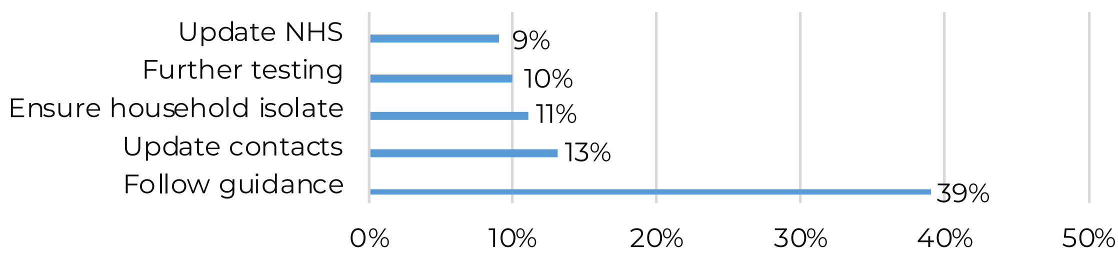
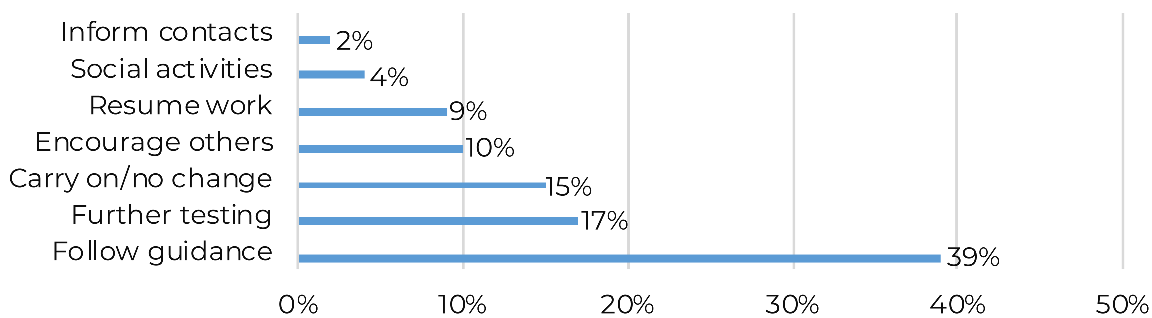


Figure 15. Intentions around a negative test result reported in ONS survey

What do you intend to do if you test negative?



Behavioural responses to testing in specific contexts

Enhanced test-to-protect in care homes

Sources and methods

Through focus groups we explored the perceptions of friends or relatives of care home residents: 5 participants were recruited via Liverpool City Council: 2 from care homes taking part in a pilot of enhanced testing, and 3 from homes with usual testing. We also carried out 15 semi-structured interviews with members of staff across nine care homes to: a) explore care home staff's experiences of integrating LFTs into routine practice for visitor and staff testing; and b) understand behavioural, usability, administrative and organisational factors that might affect adherence to the testing protocol. We conducted 450 minutes of interview, followed by thematic analysis.

Findings

- *Staff testing*

Staff expressed frustration at the inconvenience of having to test at their workplace and lack of monetary compensation for arriving earlier or staying later than their paid shifts to get tested. This implies that testing regimes face significant barriers that will likely amplify existing frustrations with current employment practices, contributing to work-related stressors.

Pandemic induced work stressors played a role in staff hesitancy to take on additional testing. Staff were already experiencing exhaustion from taking on heavier caseloads and learning new roles outside the scope of their training, together with feeling demoralised because of the lack of public recognition for their work in social care.

Misinformation in the news and social media about LFD accuracy was also a barrier. Care homes managers were fearful about losing staff due to the mandatory self-isolation protocols. Equally, staff members were worried about losing income. There was fear of losing staff members to false-positive tests and increasing the strain on other, already stretched staff.

- *Visitor testing*

Staff felt that lateral flow testing could 'restore a sense of normality for residents' – especially restoring non-verbal communication and lifting restrictions that would limit families from otherwise engaging in positive expressions of affection and nurturing important emotional connections. Testing was seen to have the potential to reduce relational disruptions, support the emotional well-being of residents and reduce the risks of social disconnect from the world outside care homes.

We also identified barriers to realising these benefits. Staff members expressed concerns over the extra time beyond testing needed to follow infection prevention and control procedures (PPE, deep cleaning, disinfection etc.) – consuming up to three hours of staff time. Cleaning tasks can lead to staff frustrations due to the redistribution of workload that then takes time away from providing direct resident care. Managing social distancing in the corridors of old buildings was also time-consuming. These time pressures amplify the existing situation where inadequate staffing has meant that carers are already struggling to find time to provide direct care.

- *Real-world vs theoretical protocols*

Despite care homes' eagerness to participate, testing protocols were challenging to implement for the reasons outlined above. So, staff were less willing to increase from weekly to twice weekly testing. Pressured staff also had anxieties about self-swabbing for LFT, before it was socialised publicly. Formal training from the Army, followed by cascade training within homes was conducted. Not all staff members were confident in conducting the test; trained staff members did not have the chance to directly trial the device during training and no instruction material was left.

There were two themes from focus group participants who had family or friends in the care home pilot: benefits of care home testing; perceptions of care home testing and visiting. The benefits of being able to visit included the importance of being able to visit a loved one and having some physical contact along with the peace of mind of not spreading the virus unknowingly. On the other hand, there were some less positive perceptions of visiting. For example, participants were worried about contracting the virus while visiting. There was also disappointment at the time allowed for visits and perceived inconsistencies in rules that had to be followed during the visit.

Key themes for focus group participants whose relatives did not live in the pilot care homes included feelings of exclusion from the pilot and that wider participation in SMART should have enabled visiting. Participants again stressed the advantages of testing for visiting.

Test-to-release for key workers

Sources and methods

Focus groups were held on 5 and 12 March 2021 with directed discussion about the involvement of key worker organisations in the SMART Release pilot (testing as an alternative to quarantine for contacts of cases). Organisations and sectors involved included the Police Force, Fire & Rescue, Domiciliary Care providers, Liverpool Street Scene Limited, Alder Hey Children's Hospital NHS Trust, and Liverpool City Council. The first meeting focussed on the organisations who had established SMART Release schemes – the Police and Fire and Rescue, which contributed most data (N = ~980 staff) and have had SMART release in place since November 2020. The second meeting focussed on the involvement of smaller organisations that were earlier on in the process or who have so far recruited fewer to SMART Release. The objective was to explore initial set up and challenges.

Findings

- *Facilitators*

Workers in large organisations, that ran their own test and trace systems, such as NHS, Police, Fire & Rescue and some Universities, found it easier to engage with the SMART release alternative to quarantine than those in smaller organisations. An implementation pack devised by LCC helped cross-fertilise learning and improved communication and staff engagement with the scheme.

- *Discordant national and local policies and communication*

Domiciliary care providers emphasised initial anxiety about whether the local pilot conflicted with the emerging national approach and policy. They were re-assured that the pilot was approved by DHSC. The same sector reported difficulty understanding the national guidance and regulations, which deterred them from participating in the local pilot. The confusion was to do with whether contacts of contacts could return to work as normal. Staff isolating seriously impacted domiciliary care services and engagement with SMART release. A big benefit of SMART release was that the protocol was clear and over-rode other communications and messages that the domiciliary care sector felt overwhelmed by: "too much guidance on everything" and people "don't have time to digest it all".

- *Appropriate adjustments for sector needs*

After issuing Implementation Packs, LCC met with 35 organisations and 17 signed up to the scheme. These meetings were felt to be very helpful, providing detail and enabling discussion about specific organisation's needs. Liverpool Street Scene Ltd (LSS) provided insight into how they had to make adaptations to the scheme using leaflets in accessible language that were delivered in information boxes collected by refuse truck drivers daily. Communications needed to be different in this setting as many of the staff do not have access to a computer or smart phone. Throughout the pandemic LSS communications were sent out in this way in the form of frequently asked questions.

Support needed for the scheme to take root

The SMART release initiative was felt to be "a really good lever" for employers. Having the system up and running in readiness for a subsequent outbreak felt important. However, some issues were highlighted that need addressing to establish then scheme: 1) standard reporting system; 2) simpler directive for shift-workers e.g., negative test before work rather than every 24 hours; 3) streamlined enrolment into the scheme.

Test-to-enable in schools

Sources and methods

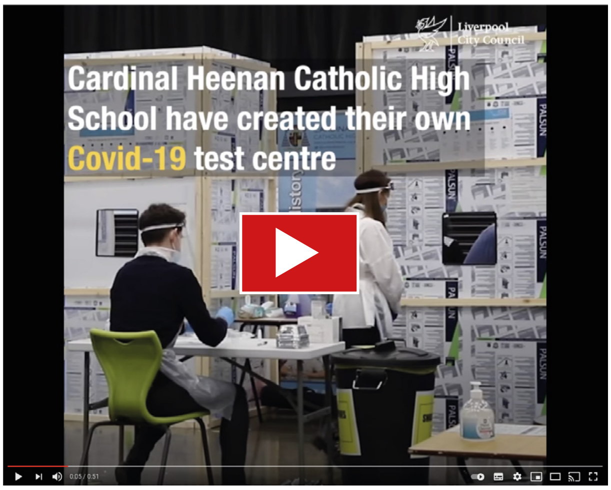
Two focus groups were held to gather perceptions on regular testing enabling the re-opening of schools. The first focus group was held on 8 February 2021 and the second on 10 February2021. Nine school staff, including teachers, administration and support roles, and 2 parents participated.

Findings

The need for testing in schools was well understood. The Liverpool schools' pilot was welcomed. All staff felt testing was less disruptive than anticipated. The military were praised by staff and parents.

Staff reported that the administration associated with testing was burdensome, particularly re-registering each student each time they were tested with LFDs. However, schools implemented home-grown approaches to overcome with these challenges including re-registering by the army the day before testing; pupils registering themselves via phones; developing pre-registration forms.

All the schools represented in the focus group reported 70-80% parents consenting. All agreed



Video 1: Cardinal Heenan School Covid 19 testing

that most non-consent was due to failure to return opt-in consent on time. Other reasons for non-consent included that the child thought it would be unpleasant. A minority of parents were reportedly anti-testing, and some were worried about the repercussions of a positive test result.

It was agreed by all focus group participants that the biggest barrier to testing is the financial one – the loss of income (and mobility) associated with positive test result. This is particularly problematic for single parent families. Removing the bureaucracy around the £500 claim to support self-isolation was felt to be a way to address this. Seeing teachers get tested was felt to incentivise pupils.

Using schools as local testing sites open to parents was mentioned as a potential way to get more people involved in testing. It was felt that fuller engagement of non-consenting parents/ staff would be critical to efficacy.

When the national schools testing programme (termed "test-to-find") rolled out across secondary schools on 8 March 2021, several Liverpool schools created local testing regimes, and the City Council introduced a three-level support scheme for schools. An example can be seen in Video 1.

Behaviours impacting systems of testing in specific settings

Care homes

Aim

The aim was to evaluate the feasibility, usability and effectiveness of additional LFT testing for care home staff and of new testing to re-admit visitors.

Sources and methods

We designed two protocols utilising LFTs and confirmatory PCRs aiming to reduce entrance of SARS-CoV-2 into care homes.

Staff were asked to take two self-administered LTFs per week with a simultaneous PCR at the second LFT for quality control and in concordance with the statutory national weekly PCR for staff at the time. Protocol adherence was measured by both the proportion of staff taking part and the frequency of testing. Full adherence would have been 12 LFT over 6 weeks. Holidays, sick days, and shift work was expected to preclude full adherence. We therefore considered the proportion of staff achieving 75% (1.5 tests a week), and 50% (1 test a week).

Visitors required two negative LFTs within 24-hours before visiting. They had to wear PPE and maintain social distance; they could hold a resident's hand with outstretched arms, but hugs and skin to skin contact were not permitted. The first test was at one designated ATS where LFT and PCR were taken. If the LFT was negative they could go to a care home within the next 24 hours. At the care home they would receive a second LFT and if negative could visit a resident. If either LFT result was positive, the visitor was asked to immediately self-isolate according to Government guidelines.

Liverpool's 87 care homes were approached to take part; 11 Covid-19 outbreak free care homes enrolled. Training on LFD use was initiated by the Army then cascaded by trained to untrained care home staff. The pilot ran between 1 December 2020 and 10 January 2021.

Data were compiled to compare case rates and outbreaks in pilot versus with non-pilot homes.

Findings

- *Cases rates and outbreaks*

The study period coincided with a national surge in cases driven by the Kent variant in the general population, which likely affected care homes. Over this time, seven out of the eleven homes identified Covid-19 positive individuals in residents or staff, with six homes entering outbreak (two or more cases within a 14-day period among either residents or staff).

There was no statistical difference in the proportion of outbreaks observed during the study period (odds ratio 2.1; 95% CI 0.5 to 9.8) between care homes in the pilot (54.5%; 6/11) and those outside (35.6%; 26/73). Three care homes were excluded from comparison as they were in outbreak at the start of the pilot. There was no statistical difference in the mean size of outbreak amongst residents and staff (p=0.39) between pilot homes (6.7%, range 0-38.8%, n=6) and non-pilot homes (5.0%, range: 0-64.8%, n=26). The two groups were not matched by design, for example by prior outbreak patterns, so may not be directly comparable.

- *Test confirmation*

During the pilot, 407 staff members were tested as part of the protocol. The resultant prevalence was 0.31 (95% CI 0.10-0.71) positive tests per 100 LFTs performed, and 1.23 (95% CI 0.40-2.84) LFT positive staff members per 100 staff tested. 1638 LFD tests were performed, of which 828 had matched PCR tests. All five positive LFD test results were subsequently confirmed positive by PCR. No false negative LFD test results were identified. There were no voided or unreadable LFD results recorded.

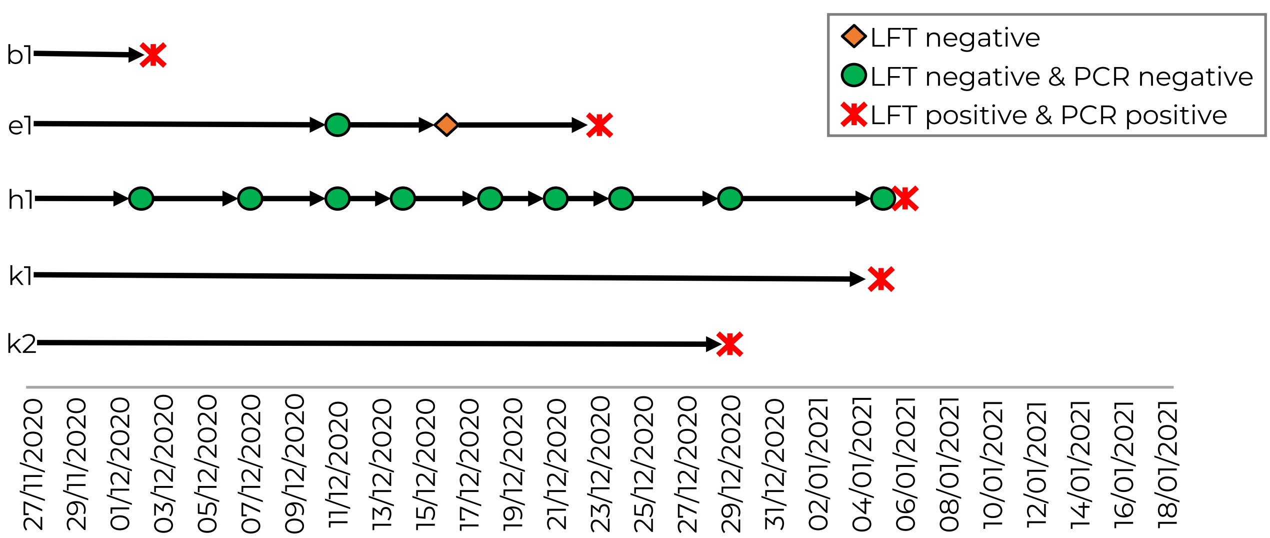
- *Adherence to protocol*

Most staff participated in the study (81.7%, 407/498; range 50.6% to 100% by care home). 8.6% of staff took more than 9 tests (75% protocol adherence), 25.3% took 6 or more (≥50% adherence), and the majority (62.9%) performed 4 tests or less (≤25% adherence). The proportion of staff achieving a minimum of 50% (0-80.0%) and 75% (0-36.7%) protocol adherence varied considerably between homes. There was no apparent trend between testing protocol adherence and outbreak status. The testing protocol adherence of the five Covid-19 positive individuals are displayed in Figure 16.

Eight out of the eleven study care homes participated in visitor testing. During the pilot 113 potential care home visitors attended the central testing site. The LFTs identified nine Covid-19 positive individuals, two of which were PCR negative (these could have been LFT false positives or PCR false negatives). The remaining 104 individuals were eligible to go to a care home where the second test would be administered. Of these, one individual was identified as a false negative by PCR prior to arriving at a care home; they were informed before arriving at a care home. In total, 101 individuals arrived at their respective care homes and all tested negative on arrival with LFDs.

Many staff members in care homes did not participate at all, and the majority had less than 25% adherence to the study protocol. Additionally, no voided/unreadable LFTs were recorded. In PHE Phase 4 validation studies, the proportion of unreadable ranged from 0.7% to 16.8% (mean 5.4%). Thus, in the pilot care homes we would have expected to see between 11and 275 voided results. The lack of voided LFD tests is surprising, and the reasons are unknown, but we could hypothesise that voided results were not uploaded onto the testing system or incorrectly uploaded as negative results, and/or that the swabbing and testing procedures were not followed correctly. AI reading of LFD ID and result from an uploaded photograph could improve the provenance and validity of such results.

Figure 16: Adherence of a testing protocol for the five Covid-19 LFT positive staff members in a care home testing pilot scheme



- *Conclusions*

Care homes need better testing regimes to assure Covid safety and to restart the visiting that is important for residents' wellbeing.

We found that human factors not technology were the main barrier to successful implementation of enhanced testing of staff, specifically staff workload, morale and conflicting communications over protocols for testing in care homes. As testing adherence was poor, unsurprisingly the care homes taking part in the pilot still experienced outbreaks as the Kent variant surged in December 2020.

For visitor testing, staff workload was a key barrier as the additional infection prevention and control measures consume 2-3 hours of person time for each visit. Further work is needed to evaluate serial LFT visiting protocols in the post-vaccination context, including consideration of the resources care homes need to support visits while Covid safety measures are still needed.

Workplaces: SMART-release (daily contact testing)

Aim

The aim was to pilot daily testing of contacts of cases as an alternative to quarantine, particularly for emergency services and other key workers where loss of teams such as a fire crew posed serious threats to civic resilience.

Sources and methods

The following SMART-release protocol was developed by the Liverpool Covid-SMART team in response to demand from emergency services:

1. Key worker is notified that they are a non-household contact of a confirmed case.
2. Key worker invited into SMART-release by organisation's pilot coordinator.
3. Key worker quarantines until they can access an LFT (at ATS, workplace or home).
4. If identified on day of exposure (day 0), negative LFT releases them from quarantine for 24h, then they start usual daily LFT from the next day (day 1).
5. Key worker takes daily LFTs from day 1 post exposure, or, the day identified as a contact, up to day 7 post exposure.
   - ➔ If the LFT result is negative, the key worker is released daily from quarantine for 24 hours.
   - ➔ If the LFT result is positive, the key worker must isolate according to national guidance, and get a confirmatory PCR test.
     - i. If the confirmatory PCR is positive, the key worker continues to isolate.
     - ii. If the confirmatory PCR is negative, the key worker resumes serial LFTs up to day 7 post exposure. The key worker must commit to daily serial tests, and is removed from pilot if unable to comply, and must quarantine according to national guidance.
6. The final serial daily LFT is done on day 7 post exposure and if negative, the key worker is again released from quarantine and no further LFTs are required.
7. At the end of testing, the key worker takes a PCR (booked through national system on day 6/7 post exposure) for evaluation of the pilot. Director of Public Health is notified if PCR is positive.
8. Throughout, the key worker must assume an infection risk and comply with usual PPE, social distancing and hand washing requirements.
9. Workplace co-ordinator contacts participants daily, capturing data and ensuring adherence.
10. Workplace coordinator submits a weekly report to the SMART team.

Findings

- *Main outcomes*

Daily contact testing proved useful in sustaining key services. A total of 17 cases were identified promptly among 768 participants from Merseyside Police (689), Mersey Fire (45), Alder Hey Hospital (18), small private care providers (16).

In the largest cohort – police – around two thirds of those invited to participate accepted. The main reasons for not participating were: 1) travel to ATS as home testing was not available at the time; 2) taking the home working option.

There was strong partnership working between the emergency services, SMART pilot team and participants. A local implementation pack helped defog an otherwise complex national landscape described as “too much guidance”. The SMART-release team and workplace coordinators ran drop in Q&A sessions and the support resources for participants and employers improved with feedback.

Adherence to daily testing was high (3563/3390 tests = 95%). The feasible proportion is likely higher after allowing for end-of-day notifications of contacts when it was too late to get tested that day.

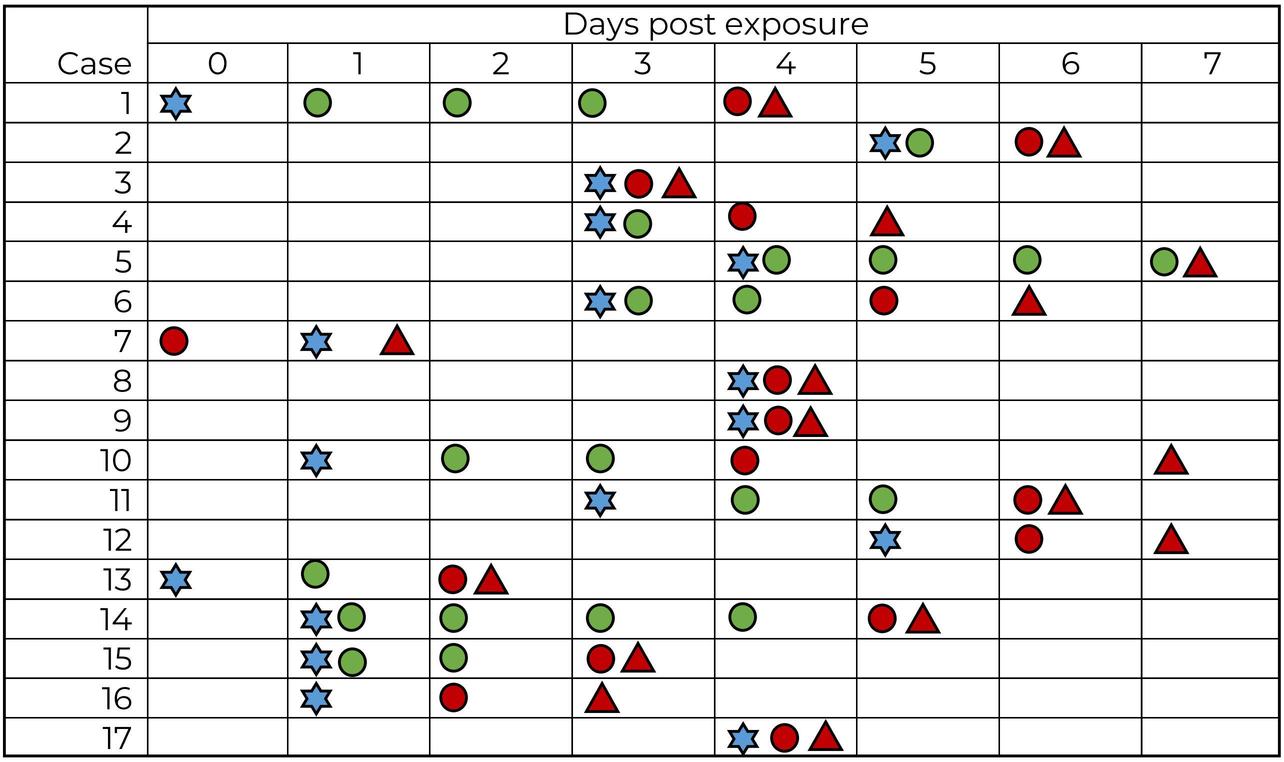
The median time from exposure to identification was 2 days (IQR 1-4; range 0-7).

Seventeen individuals tested positive with PCR during the pilot. Sixteen of these were identified by LFT. Table 2 shows when each of these 17 individuals was identified and their testing history.

- *Key barriers*
    - There was anxiety over whether the protocol complied with NHS Test and Trace, despite it being approved by DHSC.
    - There was some confusion with whether contacts of contacts could return to work as normal. Staff isolating because of this confusion impacted services and participation.
    - Different presentations of the protocol via different channels caused some confusion.
    - Strict implementation of the 24-hour gap between tests was difficult for shift workers.
    - Travel to ATS was difficult for some.
    - High management resource overhead for employers and SMART team (at least in pilot phase).
    - There were 41 missing PCR results due to laboratory issues.

- *Recommendations*
    - National and local messaging about daily contact testing schemes needs to be seamless. Local implementation packs supported by local public health teams are advisable.
    - Data-capture needs to be automated and linked to home-based testing through national systems feeding into local coordination.
    - Bring employers together in a local peer support network.
    - Localise guidance and support for specific staff cohorts such as shift workers.
    - Pursue further research into secondary attack rates.

Table 2: **Testing history of 17 contacts in SMART-release daily contact testing who became cases, with symbols: blue star = date identified as contact, green circle = negative LFT, red circle = positive LFT, and red triangle = positive PCR**



PUBLIC HEALTH

Aim

We aimed to answer the following research questions:

1. To what extent did community testing uptake vary by gender, age, ethnicity, deprivation, access to testing centres and digital inclusion?
2. To what extent has community testing led to increased detection of SARS-CoV-2 infections?
3. What has the impact of community testing been on:
   a. SARS-CoV-2 transmission?
   b. hospital admissions for Covid-19?

Key findings

1. Between 6 November 2020 and 30 April 2021, 57% (n = 283 338) of residents aged over 5 years in Liverpool took 739 553 LFTs through community testing, identifying 6300 positive tests (0.9%) (Table 4). 47% (n = 132 375; 26.6% of residents) of people who got tested had more than one test.
2. Spatial regression models demonstrated that uptake and repeat testing were lower in areas of higher deprivation, amongst people from Black, Asian and Minority Ethnic (BAME) groups, areas located further from test sites and areas containing populations less confident in the using Internet technologies. Uptake was lower is places with higher prevalence of infection.

3. A relative increase in the case detection rate of 17.5% (RR = 1.175, 95% CI 1.07 to 1.29) associated with SMART was identified using Poisson regression modelling.
4. Simulation modelling estimates indicate that the additional cases detected through community testing and their subsequent isolation could have prevented between 850 infections (95% CI 500 to 1350) and 6600 infections (95%CI 4840 to 9070) infections by breaking chains of transmission. The wide range of these estimates depends on the assumed levels of isolation and the transmissibility of asymptomatic infections.
5. Synthetic control analysis found that between the introduction of community testing and the relaxation of restrictions to Tier 2, case rates in Liverpool were 21% lower than expected without community testing (95% CI 27% lower to 12% lower). No statistically significant difference in case rates (compared with the synthetic control group) is found after this time when the Kent variant surged through England and a national lockdown was implemented.
6. A slight reduction in hospital admissions in Liverpool compared to the counterfactual areas was observed using Bayesian structural times series modelling, although the results were not statistically significant.

Sources and methods

Background

From 6 November 2020 the UK Government and Liverpool public health authorities piloted free rapid lateral flow SARS-CoV-2 antigen testing (LFT) for people living or working in the City of Liverpool, UK.[16] Liverpool had the highest (out of English local authority areas) prevalence of Covid-19 at the time of planning in early November 2020. The pilot was deployed rapidly with the assistance of the British Army and was widely advertised across different media. The pilot was extended by request of Liverpool's public health teams, moving from a 'mass' (i.e., trying to test whole populations) to a SMART approach, through testing targeted to neighbourhoods, workplaces and or specific groups at higher risk of infection or of more severe Covid-19 consequences.[17] The objective was to identify cases early and break potential chains of transmission. We analyse the impact of community testing on case detection, infection rates and hospitalisations from 6 November 2020 to the end of April. For research question 1 data was available to the 30 April 2021, whilst for research questions 2-4 the analysis extends to 22 April, the latest national data available for analysis.

Data

To investigate differences in testing uptake we used person-level pseudonymised records from the CIPHA (www.cipha.nhs.uk) data resource. CIPHA records included age, sex and ethnic group. Missing data were low other than for ethnic group. Following data linkage and selecting ethnicity from repeated tests, 9.8% of individuals had missing ethnicity records. Where ethnicity was missing, ethnic group was imputed by polytomous regression using an individual's age and the ethnicity profile of their neighbourhood of residence. Addresses of individuals were matched to Lower Super Output Areas (LSOAs) to provide geographical location. Records were aggregated to LSOAs (n=298) to allow for analysis of geographical patterns.

To enable comparisons in case detection, transmission and hospitalisation, between Liverpool and places not implementing community testing during this time, we utilised publicly available data from the UK government Covid-19 dashboard at the lower tier local authority (LTLA) level on daily confirmed Covid-19 cases and deaths along with the weekly number of people with at least one positive Covid-19 test result within each Middle Layer Super Output Areas (MSOAs).[18] In this MSOA data where there were fewer than 3 cases in any given week the number of cases was supressed. In these situations, we imputed the number of cases, using complete data available at a higher geographical level (LTLA), so that the sum of cases across MSOAs within a LTLA was equal to the total number of cases reported for that LTLA in that week. In total, 18% of the MSOA outcome data was imputed in this way. Hospital admissions data was only available at the level of the NHS Trust. We therefore mapped Covid-19 admissions to LTLAs based on their historic catchment populations. In other words, the share of Covid-19 admissions from each Trust living in each LTLA population was assumed to be the same as the share of all admissions over the past 5 years.

Statistical analyses

Analysis of uptake

To provide context for geographical patterns, we matched LSOAs to their most recently available external data on key population, social and spatial determinants of testing uptake. Official mid-year (2019) population estimates by age were used to provide denominators for uptake and account for age profiles of areas.[19] Index of Multiple Deprivation (IMD) 2019 was used to measure level of neighbourhood deprivation to identify social inequalities in uptake patterns.[20] We used deprivation score for analytical models, and present summary statistics by Liverpool quintiles (to measure city-based inequalities) and national quintiles (to allow for wider comparisons as Liverpool is a highly deprived city). The proportion of university students in an area, using data from the 2011 Census, was included to account for targeted testing across Liverpool's universities. Whether a LSOA contained a care home or not was included, using data from the Care Quality Commission (CQC), to account for targeted testing in care homes. The Internet User Classification (IUC) 2018 was selected as a proxy for confidence in using the Internet and related digital inequalities.[21] This multidimensional measure classifies areas based on their access to Internet-related infrastructure, frequency of use, and online behaviours. This was due to the reliance on Internet enabled technologies for advertising the pilot, registering for tests (walk-in tests were also accepted) and receiving test results. Finally, we estimated the street network walking distance (km) for each postcode to the nearest test site and calculated the average distance for each LSOA to account for accessibility issues that may have affected uptake. This distance was calculated at the mid time point of each of the three periods of the pilot, as the test sites that were available varied across the study period.

We use a spatial regression framework to explore how uptake varied with the area-based factors outlined above, whilst adjusting for age, sex and ethnicity of test recipients.[22] For each spatial model, we used an indirect standardisation approach to adjust for the age, sex and ethnic profile of the test recipients. First, we estimate the expected numbers tested in each LSOA, by applying the Liverpool-wide age, sex and ethnic group specific rates to the population estimates for each age, sex and ethnic group within each LSOA. We then included the log of these expected counts as an offset in the regression model, with the observed number of people who had a test in each LSOA as the outcome. Our area-based measures outlined above were independent variables to estimate how the relative probability of uptake varied across these measures adjusting for age, sex and ethnicity. We also plot the predicted relative uptake rate (observed/expected) estimated for each LSOA from our models.[23] For comparison we also plot predicted positivity rates using a similar modelling approach.

To analyse how patterns of uptake varied over time we divided our analysis into four distinct periods reflecting the evolution of the pilot: (i) Initial 'mass testing' pilot period with military support (6 November to 2 December 2020) with testing marketed as "let's all get tested";

(ii) Christmas period (3 December 2020 to 5 January 2021), when Liverpool was one of two regions placed in Tier 2, with fewer restrictions on movement and economic activities than the rest of the country, with testing marketed as "test before you go"; (iii) return to national lockdown (6 January to 30 April) with testing marketed as "testing our front line"; (iv) the whole period (6 November 2020 to 30 April 2021). We did not consider later periods to allow for comparisons of time periods of similar lengths and avoid the Schools testing period. Full details of the analysis have been published elsewhere along with analytical code.[24,25]

Analysis of impact on case detection

To empirically estimate the impact of community testing on the case detection rate in Liverpool, compared to other places that had not implemented community testing, we compared the trend in 7-day moving average of cases of Covid-19 detected through testing to estimated trends in infections derived from subsequent hospitalisation data. We assume that the Infection Hospitalisation Rate (IHR) remains approximately constant over the time of the community testing pilot, and therefore the true trend in infections within each LTLA will be proportional to the trend in subsequent Covid-19 admissions. We can therefore model the relative change in case detection rates before and after the introduction of community testing in Liverpool compared to the change in case detection rates in a similar group of LTLAs over the same time periods as a log linear Poisson regression model with the 7-day moving average of confirmed cases as the outcome and the log of the 7-day moving average of Covid-19 admissions, 8 days later, as an offset. We used an 8-day lag between cases and admissions as this provided the best model fit based on Akaike Information Criterion (AIC). We selected a comparison group of 20 local authorities in this analysis, that were like Liverpool in terms of deprivation, age (% over 70), ethnicity (% from BAME background), prevalence of chronic illness (Diabetes, cardiovascular disease, chronic respiratory disease, diabetes or chronic kidney disease), population density and trends in Covid-19 cases in the month prior to the start of community testing. Selection of comparison areas was based on Mahalanobis distance.[26] To avoid spill-over effects into neighbouring areas and the effect of other areas with asymptomatic testing programmes we excluded other LTLAs in the Liverpool City Region (LCR) and areas that had an average LFT testing rate of more than 1 test per 100 population per week. We then used Poisson regression to compare the relative change in the case detection rate in Liverpool, to the change in the matched comparison population 4 weeks before the introduction of community testing and after this point up to the end of April. Applying this estimate of the relative increase in the case detection rate to the number of cases detected gives an estimate of the number of additional infections that were detected through community testing than would have been the case without community testing.

We compare this estimate of the additional infections identified through community testing as outlined above, to the actual number of true positive asymptomatic cases identified by LFT in Liverpool during the pilot. To derive this number, we started with the number of people having a positive LFT and exclude anyone who reported that they had symptoms. Secondly, we identified all of the LFT positives that had a confirmatory PCR test result within 7 days (classified as true positives). Thirdly for people who did not have a confirmatory PCR test, we apply the positive predictive value of 91% estimated from those that did have a confirmatory PCR. This gave the total number of true positives identified by LFT in Liverpool during the pilot.

Comparing total number of true positives identified by LFT in Liverpool during the pilot to the estimated additional infections that were detected through community testing gives an estimate of the deadweight loss of the testing programme, i.e., the proportion of infections identified through the programme that that would have been picked up through symptomatic testing anyway in the absence of community testing. This could be for example because some people had symptoms at the time of LFT testing but did not report them or developed symptoms shortly after testing.

Simulation of plausible impact on transmission

The identification of these additional cases and subsequent notification to self-isolate could have prevented multiple further generations of infections, by breaking the chain of transmission. We therefore simulated the potential number of infections that would have been prevented under different assumptions, applying a similar approach to that used in the evaluation of the testing programme in Merthyr Tydfil.[27] The number of subsequent cases prevented due to community testing depends on the following factors:

1. The deadweight loss as estimated above.
2. The proportion of asymptomatic positive cases that self-isolate preventing onward transmission. In a survey run in Liverpool by ONS between 16 – 22 November 2020, 86% reported that they were compliant with self-isolation following a positive LFT result. It is however not possible to validate this self-reported behaviour. A national survey in May 2020 reported only 20% compliance with self-isolation guidance, however this was before a legal duty to self-isolate was introduced on September 2020.[28] In the national COVID Test and Trace Cases Insights Survey in February 2021 86% of respondents reported fully adhering to the self-isolation requirements throughout their self-isolation period.[29]
3. The average number of first-generation cases that would have arisen from asymptomatic cases identified and self-isolating because of community testing. This will depend on the level of transmission in Liverpool at any given period and the relative reduction in transmissibility of asymptomatic cases compared to symptomatic cases. In other words, how much lower Rt is for asymptomatic cases relative to symptomatic cases. Estimates of Rt during this period with upper and lower confidence intervals have been calculated at the local authority level.[30] Estimates of the extent of reduced transmissibility of asymptomatic cases vary – with one metanalysis estimating this to be 0.58, however confidence intervals on this measure were wide (0.33 to 0.99).[31]
4. The time point during the infectious period that an asymptomatic case received their initial positive test. Some transmission may have occurred before people were tested and therefore the first generation of cases prevented will only be those that would have been infected after a person tested positive and isolated.
5. The average number of people that would have been infected by the first generation of cases, and subsequent generations of cases that were prevented through isolation of the initial cases. This can be assumed to reflect Rt at any given time.

To estimate the potential impact of community testing on infections we simulate impact based on two sets of assumptions – an optimistic scenario with the factors above set to upper plausible levels that would lead to higher impact and a pessimistic scenario, with these factors set to lower plausible that would lead to lower simulated impact of community testing. The assumed parameters in each of the two scenarios are given overleaf:

Table 3: Parameters varied between pessimistic and optimistic scenarios of community testing simulated impacts on virus transmission

Parameter	Pessimistic scenario	Optimistic scenario
The proportion of true LFT positive cases, that would have been identified the absence of community testing.	25%	5%
The proportion of asymptomatic positive cases identified that self-isolate.	60%	90%
The number of additional first-generation cases that would have arisen from these cases if they had not isolated.	The total number of subsequent infections from an asymptomatic case is estimated as the Rt[30] on that day, multiplied by a factor reflecting the reduced transmissibility of asymptomatic infections – assumed to be 0.33.[31] Subsequent infections are assumed to be uniformly distributed across the infectious period for each individual, which is assumed to have be a mean of 6 days (gamma distribution – shape=3, beta=2).[32] The test date was randomly assigned across the infectious period for each individual and only those infections that would have occurred after the test date counted as prevented.	Same as in the pessimistic scenario except asymptomatic cases assumed to have the same transmissibility as symptomatic cases.
The number of subsequent generation cases that would have arisen from each first-generation case.	Estimated as the Rt[30] on that day, distributed uniformly over the infectious period as defined above starting mean of 5 days after infection (log normal distribution, mean= 1.6, sd=0.4).[33]	Same as in pessimistic scenario.

This simulation makes several other assumptions. Firstly, that all positive LFTs with confirmatory positive PCR tests are true positives and that this estimate of the positive predictive value also applies to LFT positives without confirmatory PCR. Secondly that the proportion of true LFT positive cases, that would have been identified the absence of community testing, and the proportion that self-isolate remained constant over time. And thirdly that all infected persons are equality infectious irrespective of age, gender, demographic variables, etc.

Analysis of impact on transmission

To investigate the impact of community testing on SARS-CoV-2 transmission we use weekly data on Covid-19 cases for each MSOA in England. As trends in reported cases will be affected by changes in testing practice, we adjusted the weekly count of cases reported for each MSOA by dividing it by a weekly estimate of the case detection rate as outlined above in each LTLA area. We assume that the minimum plausible period from the start of the testing programme to the time when we might expect an impact on transmission would be 1 week and therefore analyse the change in cases in Liverpool, five weeks before the 13 November 2020 and from that time point to the end of April compared to a synthetic control group.

We apply the synthetic control method for microdata developed by Robbins et al to estimate the intervention effect.[34,35] To construct the synthetic control group, we derive calibration weights to match the MSOAs outside Liverpool to those within Liverpool across the five-week period prior to the intervention in terms of deprivation, ethnicity, population density, age profile, prevalence of chronic conditions and prior trend in cases.[36] We exclude other areas within LCR, those implementing with high levels of LFT testing as above. The effect of community testing is estimated as the difference in cumulative number of cases in Liverpool in the period after 13 November 2020 to the end of April 2021 compared to the (weighted) number of cases in the synthetic control group. To estimate the 95% confidence intervals and p-values we apply a permutation procedure, through repeating the analysis through 250 placebo permutations randomly allocating non-Liverpool MSOAs to the intervention group, to estimate the sampling distribution of the treatment effect and calculating permuted p-values and confidence intervals.[35]

Liverpool entered less stringent Tier 2 restrictions on 3 December 2020, whilst most similar areas entered Tier 3 restrictions, we know that this had a relatively large impact on transmission.[36] We therefore adjust our analysis to remove the effect of the Tier 3 restrictions relative to Tier 2 restrictions, in the synthetic control group. Extending our previous analysis[36] we find that Tier 3 restrictions reduced case rates by 24% (95% CI 20%-28%) relative to Tier 2 restrictions and that these effects started around the 17 December 2020 (week 51) and extended to the 11 February 2021 (week 6). We therefore adjust 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 similar transmission conditions as experienced in Liverpool.

This adjustment assumes the effect of Tier 2 restrictions on transmission in Liverpool was the same as the average effect across Tier 2 areas in England. The effect could have, however, been greater in Liverpool, because unlike other Tier 2 areas, most of the areas surrounding Liverpool were in Tier 3. We therefore conducted additional analysis investigating the differences between case rates in Liverpool and the synthetic control group, before the Tier 2 restrictions take effect (i.e., before the 17 December 2020) and after the time we no longer observe an effect of the Tiered restrictions (i.e., after 11 February 2021). All analysis was performed using R version 4.0.3 and the Microsynth package.[34]

Analysis of impact on hospitalisation

A Bayesian structural time-series model was used to estimate how hospital admission changed in Liverpool after the introduction of community testing compared to a counterfactual predicted based on a trends in admissions in a group of 10 comparison LTLAs that did not undergo similar testing but that had similar trends in Covid-19 admissions and cases prior to the introduction of the pilot. To derive the comparison group, we applied the same exclusion criteria as above. We then identified 10 LTLAs based on Mahalanobis distance to select those with the most similar levels and trends in Covid-19 cases and admission prior to the start of community testing. We did not use other area characteristics in this matching (e.g., ethnicity, population density and IMD), because there were only a limited number of LTLAs with similar trends in admissions prior to the start of SMART and inclusion of other matching variables led to the inclusion of LTLAs with very divergent trends in admissions that would likely bias the results. We assume that the minimum plausible period from the start of the testing programme to the time when we might expect an impact on hospitalisation would be 2 weeks and therefore analyse the trend in admissions in Liverpool, five weeks before the 20 November 2020 and from that period to the end of April compared to the predicted counterfactual. As above we initially estimated the impact of Tier 3 restrictions on case rates and adjusted these upwards in Tier 3 areas to account for the decreased level of transmission in comparison areas that was due to stricter versions of Tier 3 restrictions introduced in December 2020.

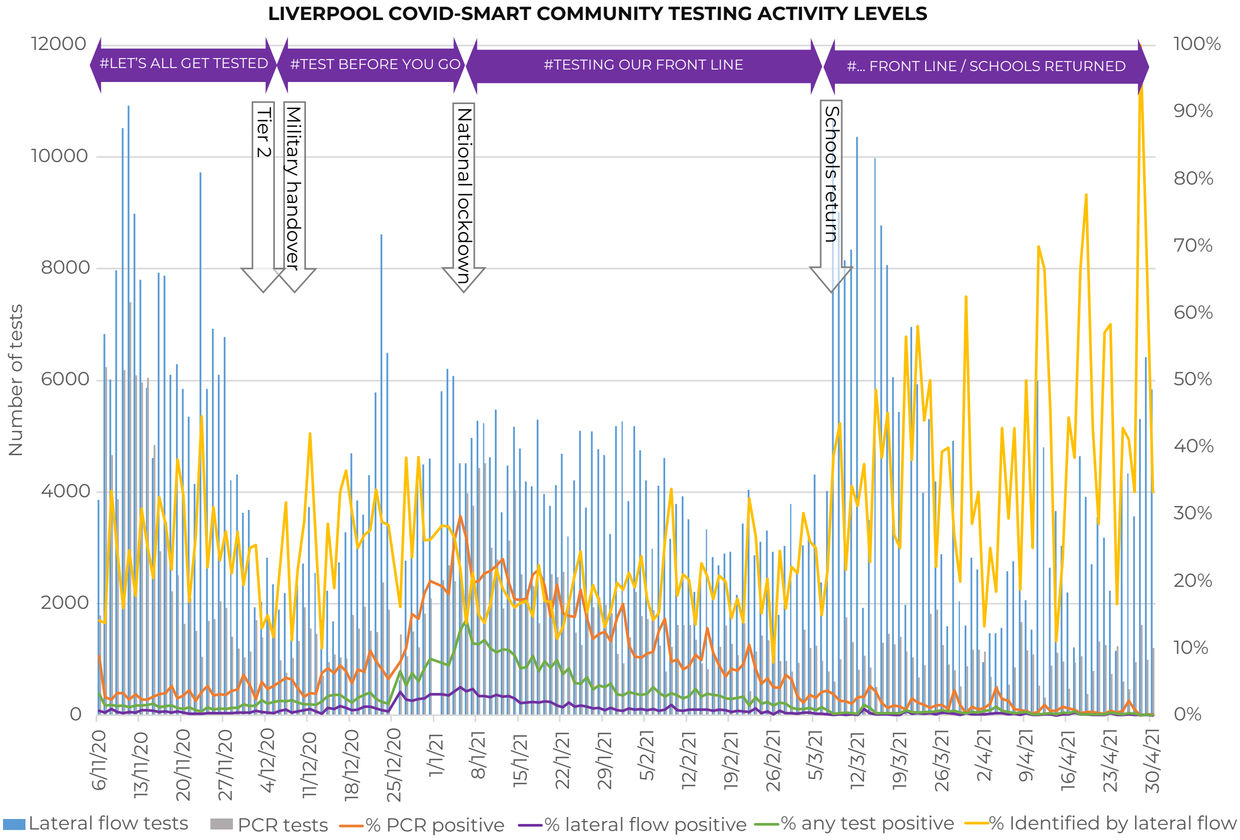
Findings

Uptake

Between 6 November 2020 and 30 April 2021, 57% (n = 283 338) of residents aged over 5 in Liverpool took 739 553 LFTs through SMART identifying 6300 positive tests (0.9%) (Table 4). 47% (n = 132 375; 26.6% of residents) of people who got tested had more than one test. More females (60%) than males (53%) accessed testing over the study period. Working age adults were more likely to have been tested (including 65% of residents aged 15-34), although the age group 15-34 were over-represented by university students due to targeted testing during the pilot. There was lower test uptake among BAME groups, especially among Mixed (42%) and Other (45%) ethnic groups. Inequalities were observed by neighbourhood deprivation, with residents of the most deprived areas having lower uptake (45% for most deprived vs 65% least deprived Liverpool quintiles). This social gradient was present across all the periods but was less pronounced from the January national lockdown onwards.

Trends in the number of tests over time (Figure 17) reflect initial high uptake during the initial push, declining following planned withdrawal of military assistance shortly after Liverpool's move into less stringent (Tier 2) local restrictions (announced 26 November 2020, enacted 2 December 2020). Uptake remained initially low in December, before a sharp increase in the week before Christmas as individuals may have sought tests before mixing among Christmas bubbles. High demand was sustained after Christmas and into the national lockdown (starting 6 January 2021). A large increase in testing was observed when schools and colleges re-opened (8 March 2021), before declining during the Easter holidays. Trends in testing did not increase when they re-opened following the end of the holidays. A small increase was observed at the end of April reflecting the Events Research Programme testing.

Figure 17: Trends in the number of Pillar 2 lateral flow and PCR tests per day, the percentage of tests that were positive and the percentage of cases detected by lateral flow over four phases of testing and restrictions, with 7-day moving averages below



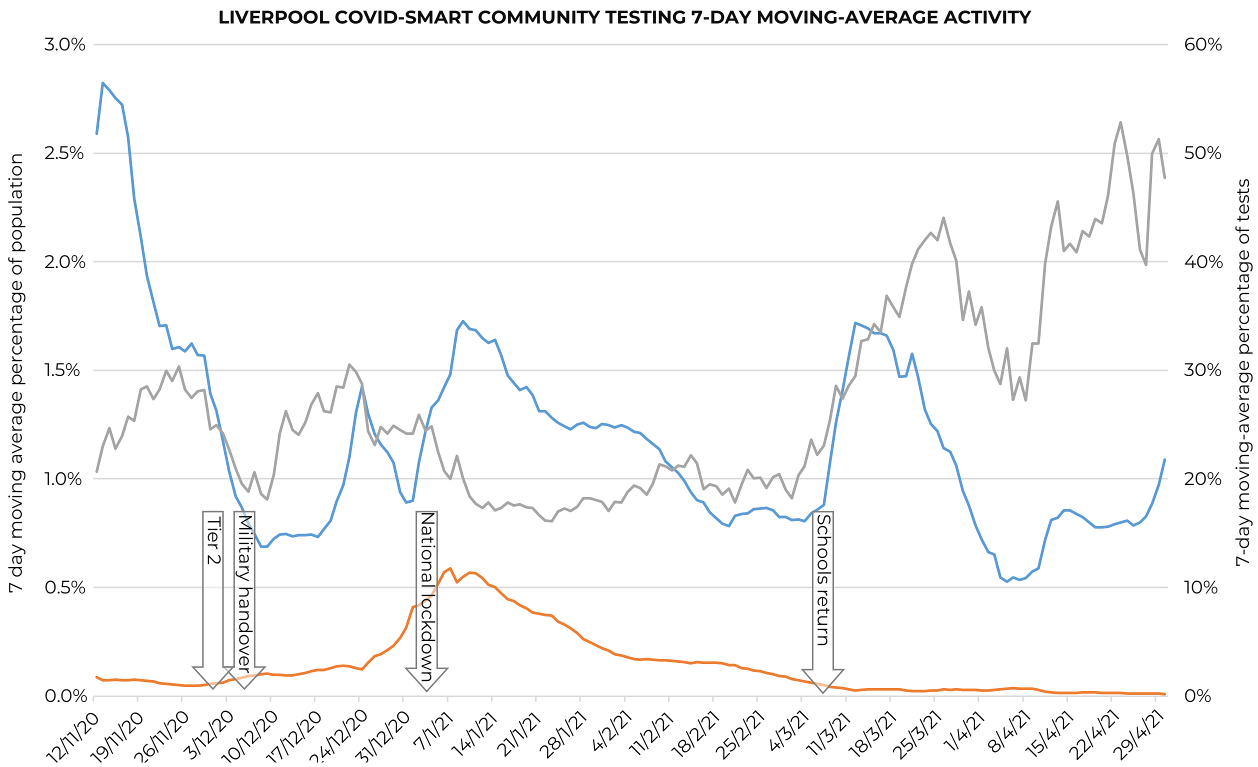
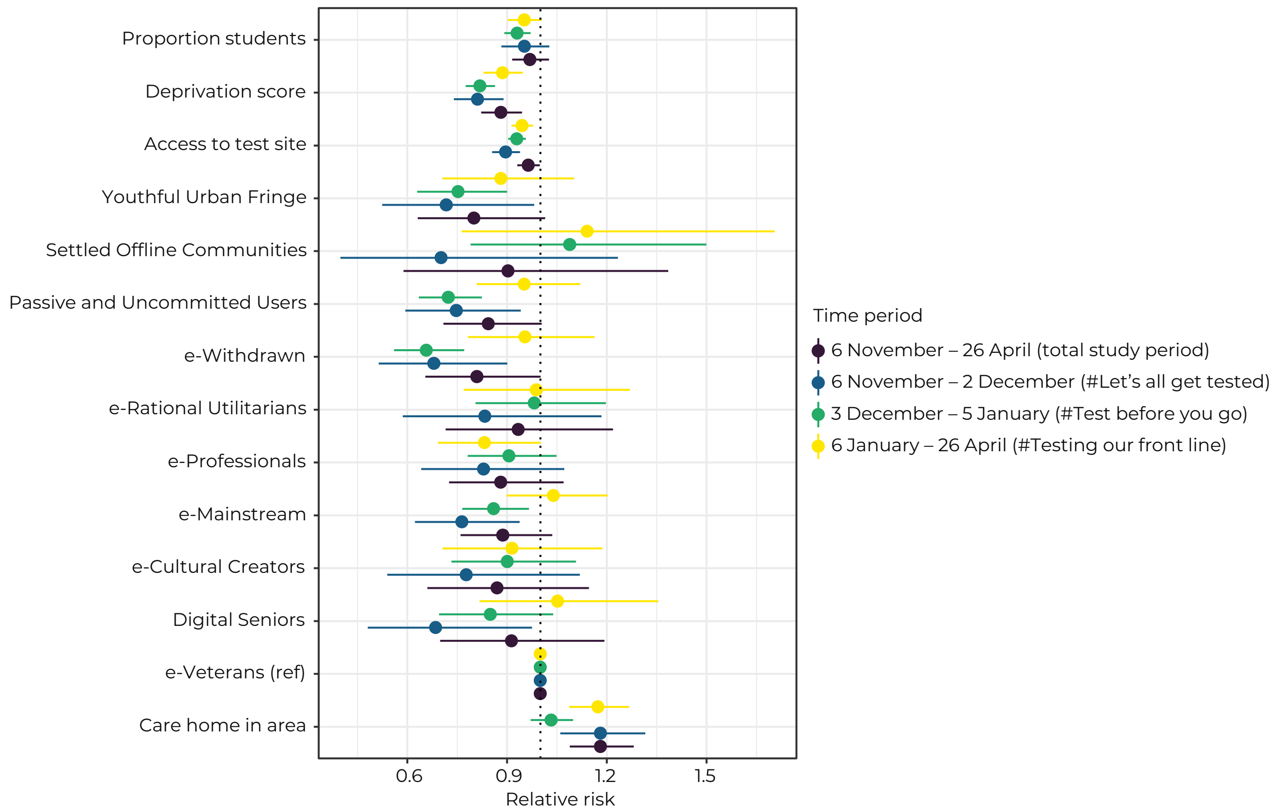


Table 4: Summary statistics of the three outcome measures between 6 November 2020 to 30 April 2021. Note: Multiple tests percentage refers to percentage of people tested. Ethnicity estimates are following imputation.

Measure		Uptake (persons)		Multiple tests (persons)		Positivity (tests)	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
		283338	56.9%	132375	46.7%	6300	0.9%
Sex	Female	150573	60.4%	73731	49.0%	3179	0.8%
	Male	132765	53.4%	58644	44.2%	3121	1.0%
Age band	0-14	33353	40.5%	19183	57.5%	337	0.4%
	15-34	109179	64.8%	51190	46.9%	2793	1.0%
	35-69	118146	60.5%	53515	45.3%	2922	0.9%
	70+	22660	43.8%	8487	37.5%	248	0.5%
Ethnic group	Asian	11529	59.4%	5100	44.2%	215	0.8%
	Black	8196	66.6%	3703	45.2%	217	1.0%
	Mixed	4886	41.6%	2435	49.8%	93	0.7%
	Other	3732	45.1%	1475	39.5%	128	1.6%
	White	254995	61.5%	119662	46.9%	5647	0.8%
Deprivation (Liverpool quintiles)	Least deprived	63786	65.0%	32356	50.7%	1261	0.7%
	Quintile 2	69390	66.0%	33891	48.8%	1252	0.7%
	Quintile 3	58359	62.0%	26108	44.7%	1291	0.9%
	Quintile 4	46754	46.6%	20926	44.8%	1258	1.1%
	Most deprived	45049	44.9%	19094	42.4%	1238	1.1%
Deprivation (England quintiles)	Least deprived	4581	67.4%	2500	54.6%	66	0.5%
	Quintile 2	33369	69.0%	17493	52.4%	691	0.7%
	Quintile 3	32359	60.9%	15520	48.0%	639	0.7%
	Quintile 4	52007	64.6%	25057	48.2%	916	0.7%
	Most deprived	161022	52.1%	71805	44.6%	3988	1.0%

Figure 18 presents the results from the Bayesian Hierarchical Poisson model exploring the neighbourhood determinants of overall uptake patterns. Deprivation was negatively associated with uptake, suggesting that increasing levels of deprivation were related to lower uptake. For example, a one standard deviation increase in deprivation score (equivalent of going from Liverpool's third quintile to most deprived quintile) was associated to 14% fewer tests over the whole period (Relative Risk (RR) = 0.86, 95% Credible Intervals (CIs) = 0.80-0.91). The association was found for each period suggesting the importance of social inequalities in uptake. Distance from home to test site was also important, being negatively associated to uptake suggesting that uptake was lower among those living further from test sites (e.g., whole period RR = 0.95, 95% CIs = 0.91-0.98). Estimating the unstandardised effect size (standardised coefficient / standard deviation) to aid interpretation suggests that each 1km increase in distance to nearest test site was associated with 11% reduction in uptake. Estimated effect size was largest during the initial 'mass testing' period. While there were also a greater number of test sites during the pilot, the initial choice of sites had been driven by convenience for the Local Authority and military operators, and did not accommodate community perceptions of space, accessibility and risks. There was a negative association between the proportion of students in an area and uptake, with effect sizes largest for the two periods post-pilot reflecting that student populations were encouraged to return home in early December (e.g., 6 - 31 January RR = 0.91, 95% CIs = 0.87-0.94). Areas that contained a care home were positively associated with uptake, suggesting that testing was higher in areas with a care home present. For example, over the whole period, areas with care homes had 15% more tests (RR = 1.15, 95% CIs = 1.07-1.24).

Figure 18: Estimated relative risks (mean and 95% credible intervals) for the associations between independent variables and uptake of tests by period model. Transparent values represent estimates where credible intervals contain 1



We found the Internet-related characteristics of areas were associated with uptake, suggesting that digital exclusion was a legitimate concern. Populations less confident with using Internet technologies, as measured by the Internet User Classification, showed lower uptake. For example, areas classified as 'e-Withdrawn' (described as least engaged with the Internet) had 23% (RR = 0.77, 95% CIs = 0.63-0.94) lower uptake over the whole period than 'e-Veterans' (the group hypothesised to have the most confidence with using Internet technologies).

Figure 19 plots the geographical patterns of uptake estimated from our analytical models. There were distinct geographical inequalities in uptake (similar for both overall uptake and multiple tests), often following patterns of material deprivation with clustering of low uptake in densely populated deprived communities. Figure 20 shows similar maps for LFT positivity indicating that those places where uptake was lowest experienced the highest rates of positivity.

Figure 19: **Relative uptake (observed count / expected count) for overall lateral flow test uptake for lower layer super output areas. Note: red values are relative risks <1, blue colours are >1**

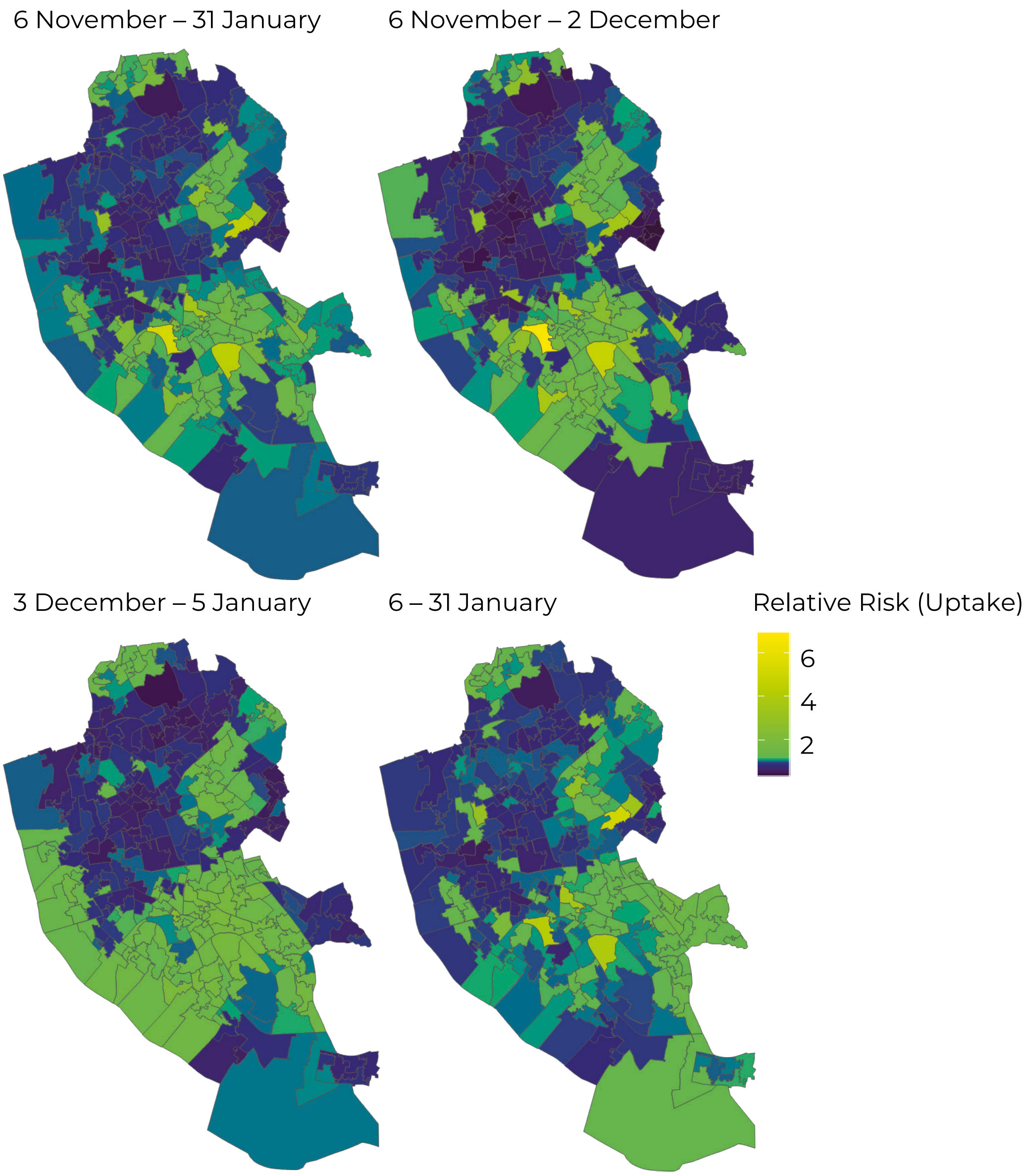
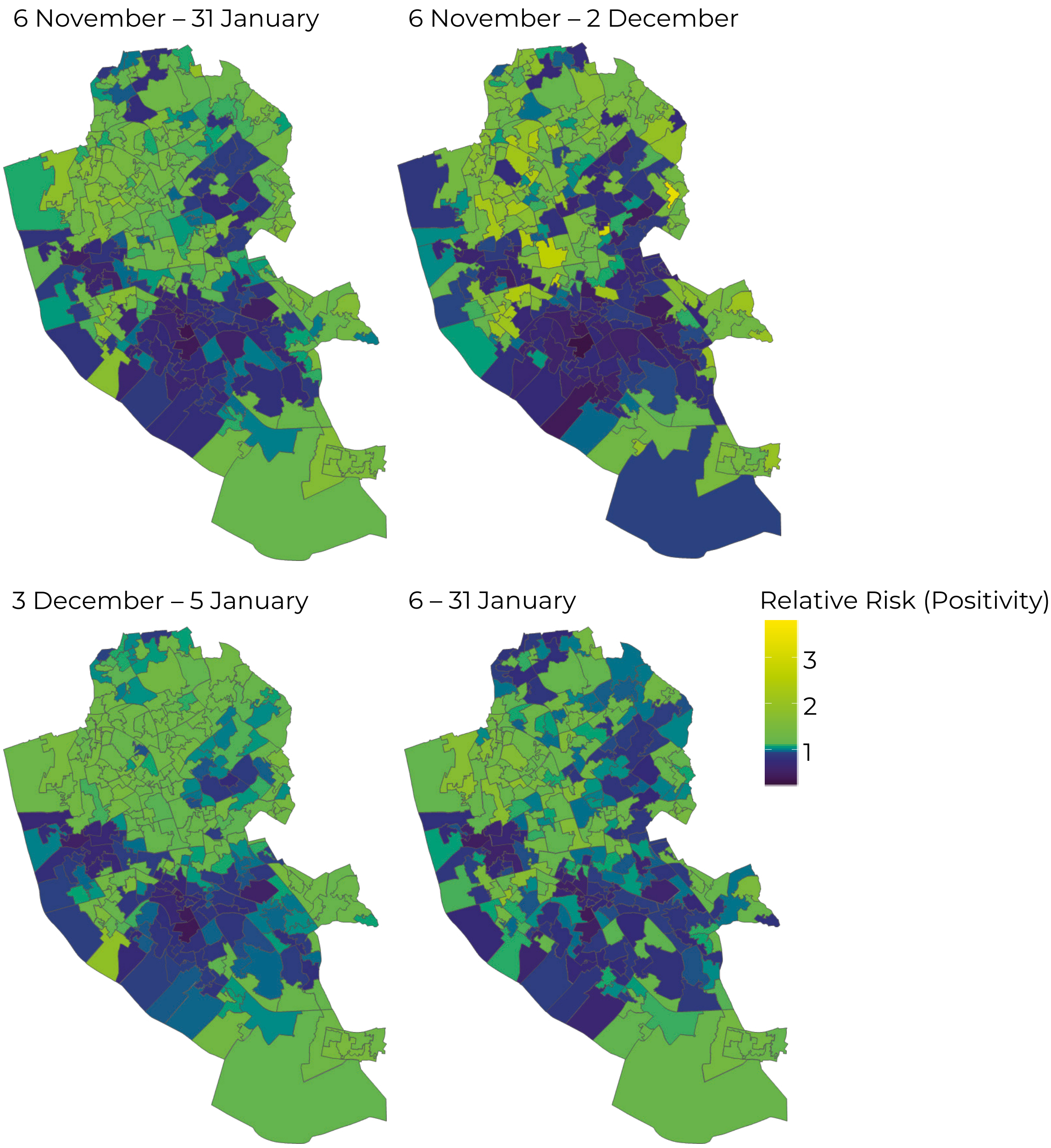


Figure 20: Relative lateral flow test prevalence rates (observed count / expected count) for lower super output areas. Note: red values are relative risks >1, blue colours are <1



Case detection

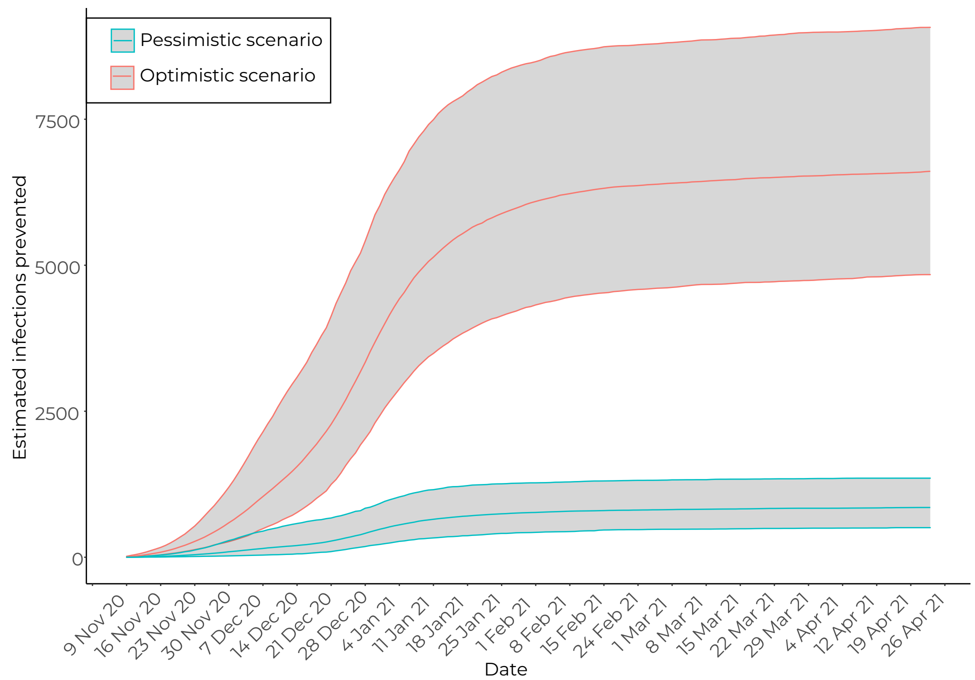
Based on the Poisson regression model comparing the change in case detection in Liverpool to that in a comparison group of areas without community testing, we estimated that community testing led to a relative increase in the case detection rate of 17.5% (RR = 1.175, 95% CI 1.07 to 1.29). This is equivalent to an additional 4766 cases (95% CI 1878 to 7940) of SARS-CoV-2 being identified between 6 November 2020 and 30 April 2021 than would have been identified without community testing.

This compares to an estimated 5429 true positive cases identified through LFT in Liverpool over the same period. This suggests that in most cases the asymptomatic LFT testing probably were identifying cases that would not have been identified in the absence of community testing. Based on these estimates, the level of deadweight loss, i.e., the proportion of these cases that that would have been picked up in the absence of community testing, would be 12% (5429-4766)/ 5429). This could be for example because some people had symptoms at the time of LFT testing but did not report them or developed symptoms shortly after testing, and in the absence of community testing they would have been identified through routine symptomatic testing.

Simulation of plausible impact on infections

Figure 21 shows the estimated cumulative number of infections prevented between the 6 November 2020 and the end of April 2021 under two simulated scenarios. A pessimistic scenario with - higher levels of deadweight loss (i.e., proportion of cases identified through community testing that would have been identified anyway), lower assumed transmissibility from asymptomatic cases, and lower assumed isolation rates, and a more optimistic scenario with lower assumed deadweight loss, higher assumed transmissibility from asymptomatic cases, and higher assumed solation rates (see section 2.2.3). Based on the two scenarios outlined above – in the pessimistic scenario 850 infections (95% CI 500 to 1350) would have prevented by the end of April 2021, whilst under more optimistic assumptions community testing could have prevented 6600 infections (95%CI 4840 to 9070).

Figure 21: Simulated number of infections prevented by community testing under "optimistic" and "pessimistic" assumptions



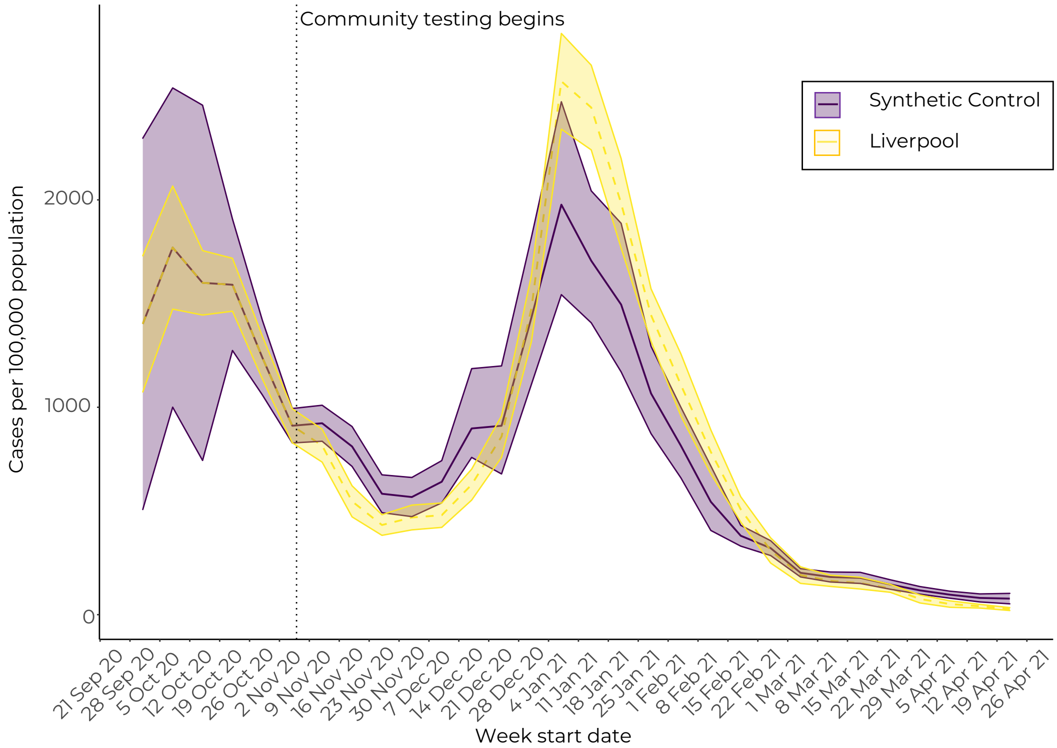
Impact on transmission

Figure 22 shows the trend in the average infection rates from the beginning of October to the end of April across MSOAs in Liverpool, and a synthetic control group constructed from the weighted average of MSOAs outside Liverpool adjusted for the effect of reduced transmission resulting from a stricter version of Tier 3 restrictions in December in these areas. Due to an exact match in calibration weights trends were identical in the synthetic control and intervention group in the pre-intervention period.

Over the entire observation period case rates in Liverpool were 9.5% higher compared to the synthetic control group (95%CI 5% lower to 27% higher). There is considerable uncertainty in relation to this estimate and the confidence intervals are wide. Part of the uncertainty relates to estimates of the effect of Liverpool entering Tier 2 as opposed to Tier 3 restrictions in December. This was followed by a larger increase in infections in Liverpool compared to similar areas that entered Tier 3. We have adjusted for this Tier 2 effect assuming the effect on transmission in Liverpool is the same as the average effect across Tier 2 areas in England. However, Tier 2 areas were quite different. The Tier 2 effect may have been greater in Liverpool, which would have led to an underestimate of the effect of community testing on reducing transmission in Liverpool. To investigate this further we estimated the difference between case rates in Liverpool compared to the synthetic control group – before the effect of the December tiered restrictions became evidence (before the 17 December 2020) and after we no longer see an effect of the December tiered restrictions (after the 11 February 2021).

From 6 November to 17 December 2020 case rates in Liverpool were 21% lower (95% CI -27% to -12%) compared to the synthetic control. It was these lower case-rates in Liverpool at the beginning of December that led to the city being allocated to Tier 2 rather than Tier 3 restrictions. After 11 February 2021 when the effect of the December tiered restrictions is no longer evident, we see fall below expected levels again – but not statistically significant: 7.5 % Lower (95% CI 19% lower to 5% higher).

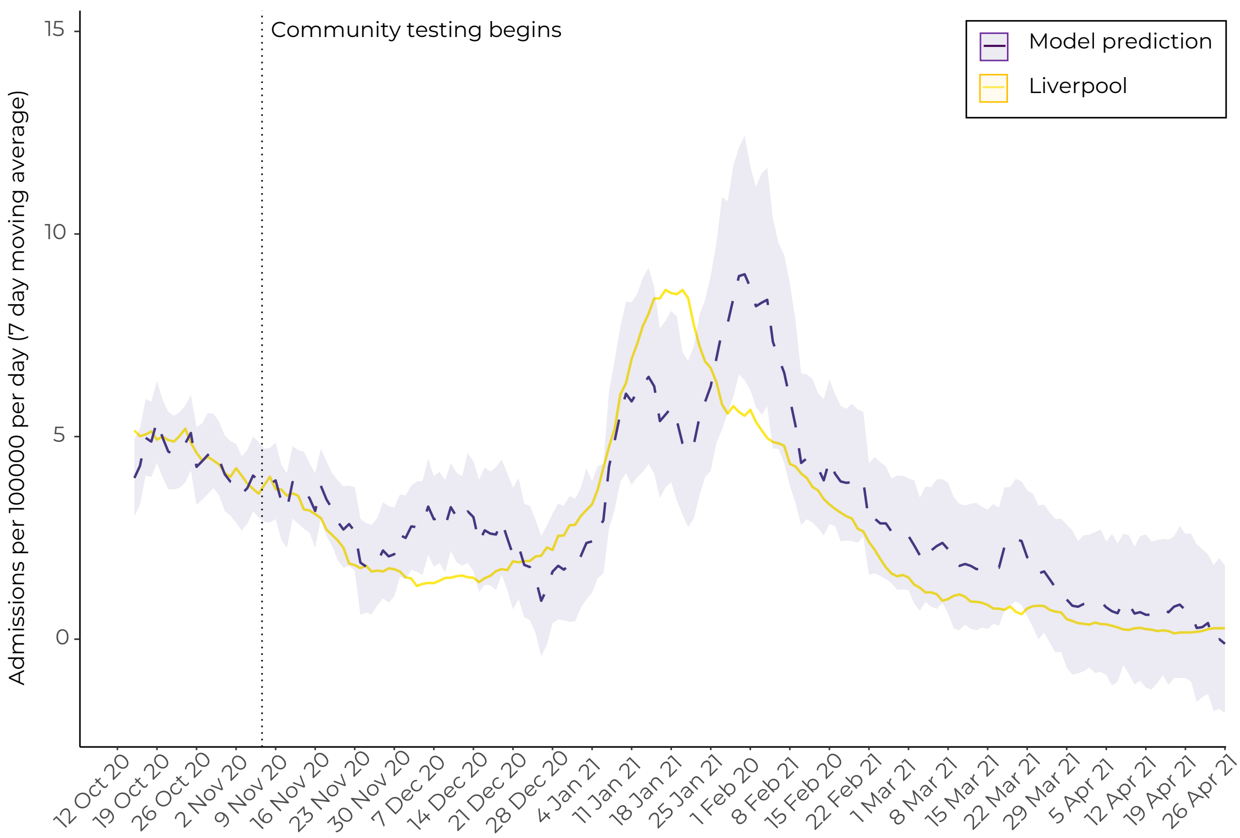
Figure 22: The trend in average case rates in MSOAs in Liverpool compared a synthetic control group constructed from the weighted average of MSOAs outside Liverpool without community testing



Impact on hospitalisation

Figure 23 shows this trend in terms of the Covid-19 hospital admission rate in Liverpool before and during community testing in comparison to the predicted counterfactual trend based on the Bayesian structural times series model after adjusting for the effect of stricter Tier 3 conditions introduced in some areas in December 2020. The estimated overall effect over that period is a 16% reduction in admissions, although the credible intervals of this estimate are large and cross zero (95% CI 53% reduction to 15% increase). This finding is broadly consistent with the estimated number of infections prevented during community testing.

Figure 23: Trend in daily Covid-19 hospital admission in Liverpool, compared to the trend predicted from the Bayesian structural time series model



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GLOSSARY

AIC	Akaike Information Criterion
ATS	Asymptomatic Testing Site
BAME	Black, Asian and Minority Ethnic groups
BEIS	Department for Business, Energy and Industrial Strategy
CI	Confidence Interval
CIPHA	Combined Intelligence for Population Health Action
CQC	Care Quality Commission
Ct	PCR Cycle threshold
DCMS	Department for Culture Media and Sport
DfE	Department for Education
DHSC	Department of Health and Social Care
IHR	Infection Hospitalisation Rate
IMD	Index of Multiple Deprivation
IUC	Internet User Classification
JBC	Joint Biosecurity Centre
LAMP	Loop-mediated isothermal AMPlification test for SARS-CoV-2 nucleic acid
LCC	Liverpool City Council
LCR	Liverpool City Region
LCVS	Liverpool Charity and Voluntary Services
LFC	Liverpool Football Club
LFT	Lateral Flow Test (the end-to-end rapid testing process for SARS-CoV-2 antigen)
LFD	Lateral Flow Device (the device used to test for SARS-CoV-2 antigen)
LRF	Merseyside Local Resilience Forum
LSOA	Lower Super Output Area
LSS	Liverpool Street Scene Ltd
LTLA	Lower Tier Local Authority
MACA	Military Aid to the Civil Authorities
MAST	Mass, Asymptomatic, Serial Testing
MHRA	Medicines and Healthcare Devices Regulatory Authority
MHCLG	Ministry of Housing Communities and Local Government
MSOA	Middle Layer Super Output Area
MTU	Mobile Testing Unit
ONS	Office for National Statistics
PCR	Reverse Transcriptase Polymerase Chain Reaction test for SARS-CoV-2 nucleic acid
PHE	Public Health England
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
SAGE	Scientific Advisory Group for Emergencies
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SMART	Systematic, Meaningful, Asymptomatic/Agile, Repeated Testing
SOP	Standard Operating Procedure
STAC	Scientific and Technical Advisory Cell

APPENDIX: PUBLICATIONS

Articles reporting emerging findings and clarifying external evidence as part of the Liverpool community testing pilot:

Crozier A, Rajan S, Buchan I, McKee M. Put to the test: use of rapid testing technologies for covid-19 BMJ 2021; 372 :n208 doi:10.1136/bmj.n208

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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 17 Feb 2021:S0140-6736(21)00425-6.

doi: 10.1016/S0140-6736(21)00425-6.

www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)00425-6/fulltext

Buchan IE, Semple MG, Peto TE. Can rapid tests help ease Covid-19 restrictions? Infectious Diseases campaign on www.globalcause.co.uk distributed with the New Scientist magazine 25 March 2021

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García-Fiñana M, Buchan IE. Rapid antigen testing in COVID-19 responses. Science 07 May 2021; 372 (6542):571-572. doi: 10.1126/science.abi6680

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García-Fiñana M, Hughes DM, Cheyne CP, Burnside G, Semple C, Buchan I. Performance of the Innova Lateral Flow SARS-CoV-2 antigen rapid lateral flow test in the Liverpool asymptomatic testing pilot. SSRN March, 2021. dx.doi.org/10.2139/ssrn.3798558

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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

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Fearon E, Buchan I, et al. SARS-CoV-2 antigen testing: weighing the false positives against the costs of failing to control transmission. Lancet Respiratory Medicine 14 June 2021. doi.org/10.1016/S2213-2600(21)00234-4.

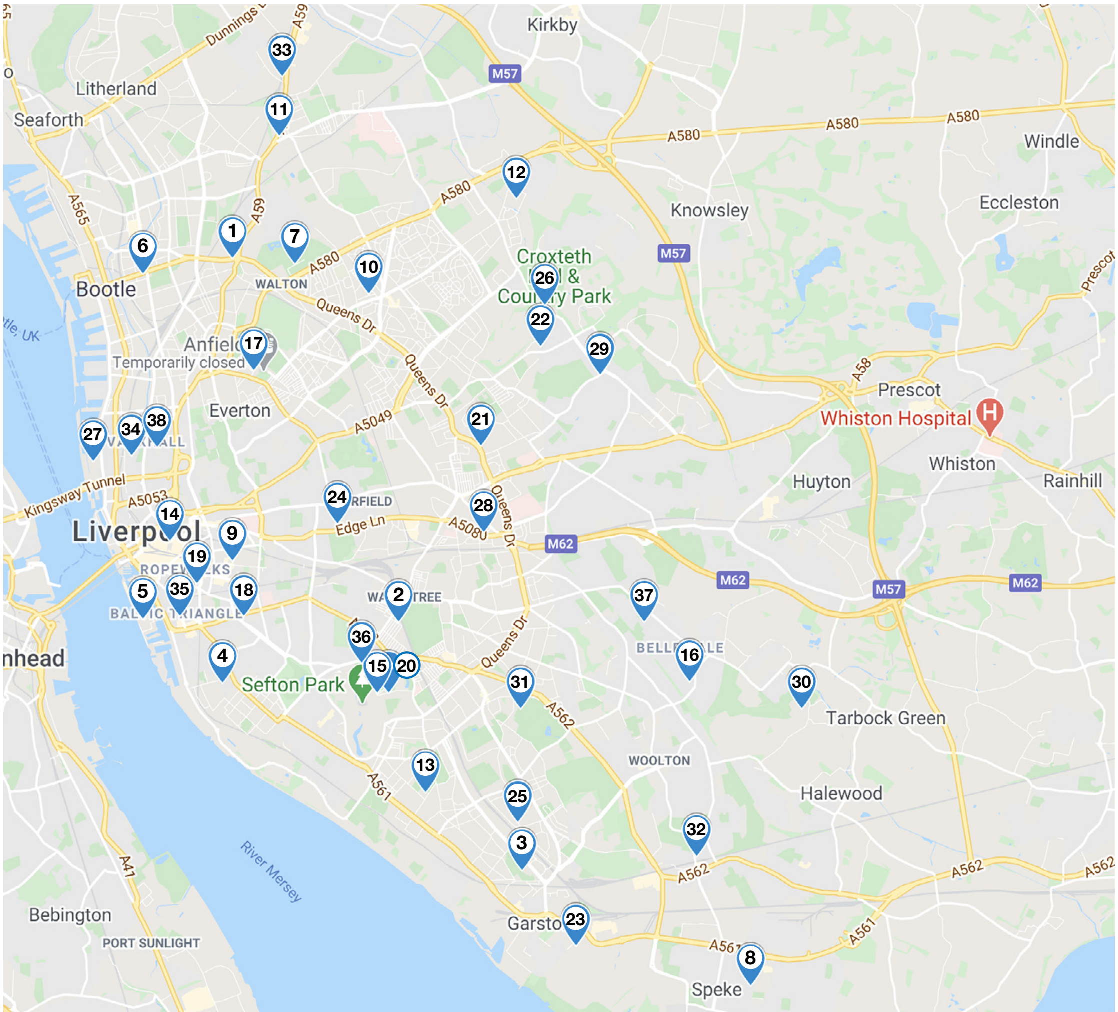
www.thelancet.com/journals/lanres/article/PIIS2213-2600(21)00234-4/fulltext

FURTHER INFORMATION

Liverpool community testing is being used to develop other Covid-19 responses, and so it is evolving; the findings of this report may be expanded.

Please contact buchan@liverpool.ac.uk for further information.

Liverpool Testing Centres on 21 November 2020



1. Lifestyles Alsop Fitness Centre
2. Liverpool Tennis Centre
3. Lifestyles Garston
4. Lifestyles Park Road
5. Exhibition Centre Liverpool
6. Lifestyles Ellergreen
7. Lifestyles Walton
8. Lifestyles Austin Rawlinson
9. Liverpool University Gym
10. Bridge Community Centre
11. Aintree Baptist Church
12. Croxteth Sports Centre
13. IM Marsh Sports
14. St John's Market
15. Greenbank University Village - STUDENTS ONLY
16. St Stephen's Parish Centre
17. Liverpool Football Club
18. Caribbean Community Centre
19. Liverpool Hope University Sports Centre
20. Greenbank Sports Academy
21. Alder Sports & Social Club
22. Deysbrook Village Community Centre
23. David Lloyd Liverpool Speke
24. Devonshire Hotel
25. Heath Hall
26. Croxteth Hall
27. Invisible Wind Factory
28. 15th Fairfield Scout Group
29. St Luke's Church, West Derby
30. Woodlands Community Centre
31. East Wavertree & Childwall Community Association
32. St Hilda's Parish Hall
33. Aintree Race Course
34. Eldonian Village Hall
35. Liverpool City College
36. Conference Centre LACE
37. Salvation Army Belle Vale
38. Lee Jones