Epidemiological changes on the Isle of Wight after the launch of the NHS Test and Trace programme: a preliminary analysis

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Summary

Background In May 2020, the UK National Health Service (NHS) Test and Trace programme was launched in England in response to the COVID-19 pandemic. The programme was first rolled out on the Isle of Wight and included version 1 of the NHS contact tracing app. The aim of the study was to make a preliminary assessment of the epidemiological impact of the Test and Trace programme using publicly available data.

Methods We used COVID-19 daily case data from Public Health England to infer incidence of new infections and estimate the reproduction number (R) for each of the 150 Upper-Tier Local Authorities (UTLAs) in England and nationally, before and after the launch of the Test and Trace programme on the Isle of Wight. We used Bayesian and maximum-likelihood methods to estimate R and compared the Isle of Wight with other UTLAs using a synthetic control method.

Findings We observed significant decreases in incidence and R on the Isle of Wight immediately after the launch of the Test and Trace programme. The Isle of Wight had a marked reduction in R, from 1·3 before the Test and Trace programme to 0·5 after by one of our measures, and went from having the third highest R before the Test and Trace programme, to the twelfth lowest afterwards compared with other UTLAs.

Interpretation Our results show that the epidemic on the Isle of Wight was controlled quickly and effectively after the launch of Test and Trace. Our findings highlight the need for further research to determine the causes of the reduction in the spread of the disease, as these could be translated into local and national non-pharmaceutical intervention strategies in the period before a treatment or vaccination for COVID-19 becomes available.

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Introduction

As part of efforts to control the spread of COVID-19 using non-pharmaceutical interventions, many countries are prioritising community testing, case isolation, and contact tracing.[1] Contact tracing has historically required individual questioning of infected individuals, relying on their memory of past close-proximity contact events.[2] Digital contact tracing approaches have been introduced to keep records of contact events using combinations of QR codes, global positioning system, and low-energy Bluetooth exchanges.[3–5] Traditional and digital approaches are complementary. The traditional approach relies on noticing and remembering contacts and an efficient infrastructure of trained public health officials, and the digital approach relies on establishing well-calibrated new technology and appreciable population uptake and adherence. The former approach is a more familiar intervention and a phone call might be more effective once received, but the speed of notification of the latter approach might be critical given the speed of COVID-19 transmission.[4]

In May 2020, a widely-publicised testing and tracing intervention was launched on the Isle of Wight, an island to the south of mainland England, and later rolled out nationwide as the UK National Health Service (NHS) Test and Trace programme (figure 1). The Isle of Wight programme included version 1 of the NHS contact tracing app. The app used Bluetooth to detect close proximity contacts, and was configured for people to report two characteristic symptoms of COVID-19 (cough and fever) and provided links to generic health advice and details about testing. Shortly after reporting symptoms, the app anonymously notified other app users who had been in recent contact with the individual and provided guidance on how to reduce the risk of transmission to others (although no instructions to self-isolate or quarantine were given).

The Isle of Wight has 141 536 inhabitants, of whom 34 000 (24%) are older than 65 years.[6] The Isle of Wight Test and Trace programme was launched on May 5, 2020 (figure 1). The app was available for download by the general public from May 7, and was downloaded by more than 54 000 (38%) people on the island during the trial period.[7] On May 18, community testing was introduced nationwide, initially for all people over the age of 5 years, and for everyone on May 28, when the national

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Research in context

Evidence before this study

Contact tracing programmes are an established public health tool to contain outbreaks of infectious diseases. Thorough contact tracing has been credited with containing the severe acute respiratory syndrome epidemic in 2003. Countries that successfully contained a surge in initial cases during the COVID-19 epidemic in early 2020 were characterised by effective programmes to trace and isolate contacts of infected individuals. These countries differ in various aspects, including individual distancing behaviour and health-care systems, and it is difficult to isolate the effect of contact tracing on the epidemic. To our knowledge, there has been no epidemiological evaluation to date of contact tracing programmes for COVID-19 using a within-country control area, which would hold constant country-specific differences. We searched PubMed and the medRxiv and bioRxiv preprint servers for epidemiological studies up to July 10, 2020, using the terms "contact tracing" or "test trace isolate" and "United Kingdom" and "COVID-19" or "SARS-CoV-2", without date or language restrictions. Based on this search, no epidemiological assessment of the Test and Trace programme in the UK has yet been published.

Added value of this study

Our analysis compared the epidemic on the Isle of Wight with the rest of England and the UK, thereby providing a within-country comparison of test and trace programmes launched at different times, albeit between an island and the mainland. We studied the combined effect of a programme that includes traditional contact tracing and a mobile phone contact tracing app. We developed and used an improved method to estimate R from data sources with varying lag times.

Implications of all the available evidence

We observed significant decreases in incidence and R on the Isle of Wight immediately after the launch of the Test and Trace programme. Our results support that Test and Trace programmes could be effective in suppressing the COVID-19 epidemic and future studies to assess the combined and individual effects of each aspect of test and trace interventions are needed. We have made our new methods available in the web application *LocalCovidTracker*, which provides approximate localised COVID-19 surveillance and nowcasting for England and Wales using publicly available data. Determining the exact causes of successful suppression of local epidemics will be crucial for informing national non-pharmaceutical intervention strategies.

contact tracing service reintroduced traditional contact tracing. There was no nationwide contact tracing app during the period of study.

Between May 6, and May 28, 2020, 160 COVID-19 cases on the Isle of Wight were reported to traditional contact tracing, resulting in 163 individuals receiving a notification and request to self-isolate. During the same period, 1524 people reported symptoms to the app, resulting in 1188 people receiving an exposure notification. These occurrences were in the context of lockdown and social distancing policies, which reduced the average numbers of close-proximity contacts from pre-lockdown levels.

We analysed the epidemic trajectory on the Isle of Wight before and after the Test and Trace programme launch and compared this with the epidemic trajectory in other areas of England. We focused on estimated per-capita incidence and the reproduction number (R). The data required to evaluate the function and effects of the separate elements of the Test and Trace programme were not available. We explored whether the timings of interventions were associated with improvements in epidemic trajectories.

There are some key interpretational challenges regarding R. This measure captures both the inherent transmissibility of the virus and the properties of the network in which it is spreading. We assume that the transmissibility of the virus was close to constant throughout the study period, but the network in which the virus is spreading is affected by non-pharmaceutical interventions. The threshold R=1 is important for epidemic control and it is broadly true that where R is less than 1 interventions are successfully reducing transmission towards a state of eradication. However, when case numbers are low it is hard to accurately estimate R given the wide credibility intervals and, in a Bayesian framework, the result is sensitive to the prior. Moreover, an area with vast but declining numbers of daily new infections would have an R value less than 1, whereas an area with a single new infection roughly every 5 days would have an R of almost exactly 1, despite being much closer to eradication in a practical sense. Therefore, we introduced a nowcasting measure, which combines incidence and R for a more complete daily assessment of local epidemics.

Finally, we introduce some context for the reductions in R we might expect to find. Blanket lockdown measures can reduce R rapidly but carry health, social, and economic costs. Ideally, contact tracing will help quarantine those who are most likely to be infected, while allowing others more normal levels of freedom. If everyone perfectly self-isolated at symptom onset and all their recent close contacts were instantly quarantined, this could reduce R for COVID-19 by around 80%.[4] In a more realistic setting, for example with a 24-h delay and 50% of contacts traced (traditionally and digitally), we could expect a reduction in R of around 44%.[4,8] When we
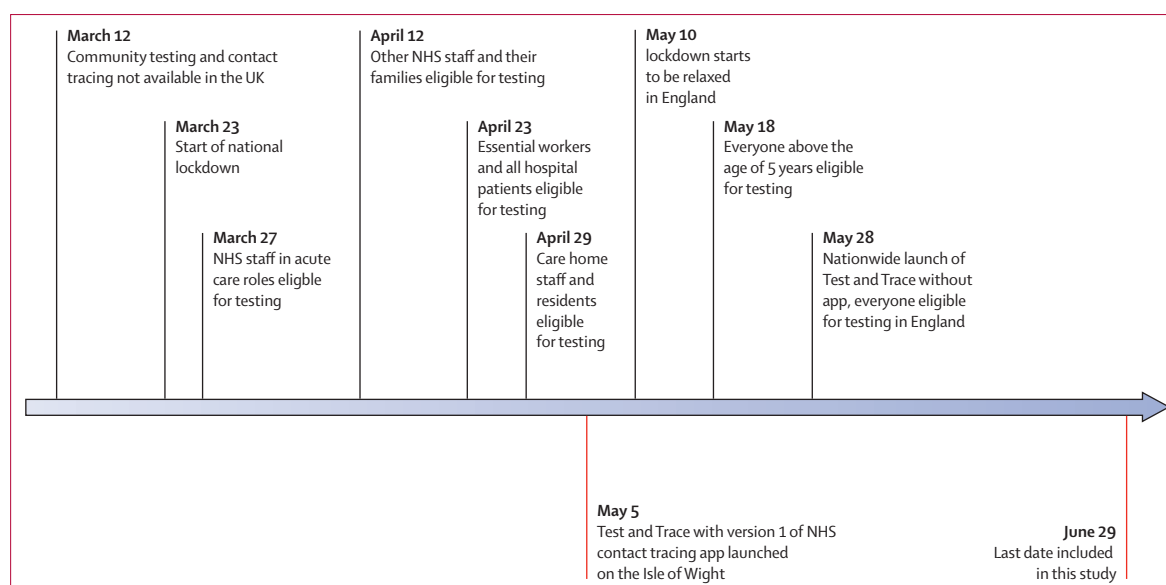
March 12
Community testing and contact tracing not available in the UK

March 23
Start of national lockdown

March 27
NHS staff in acute care roles eligble for testing

April 12
Other NHS staff and their families eligible for testing

April 23
Essential workers and all hospital patients eligible for testing

April 29
Care home staff and residents eligible for testing

May 10
lockdown starts to be relaxed in England

May 18
Everyone above the age of 5 years eligible for testing

May 28
Nationwide launch of Test and Trace without app, everyone eligible for testing in England

May 5
Test and Trace with version 1 of NHS contact tracing app launched on the Isle of Wight

June 29
Last date included in this study

Figure 1: Timeline of policy changes related to contact tracing and testing in England (black) and the Isle of Wight (red)

see a reduction in R, it is important to bear in mind how much of this can reasonably be attributed to contact tracing and not to overlook the effects of social distancing and mask wearing, and the influences of test availability, community engagement, and awareness.

Methods

Data on daily new confirmed cases by area

There are two categories of COVID-19 case data as follows: pillar 1, from tests done in hospitals, for those with a clinical need, and health and care workers, and pillar 2, from tests in the wider population.[9] For the period of the study, pillar 1 cases were reported daily for each of England's 150 Upper-Tier Local Authorities (UTLAs), of which the Isle of Wight is one. Pillar 2 cases were reported nationally. A combined, de-duplicated pillars dataset was made available from July 2, 2020. Estimates of the total population size for each UTLA were obtained from the Office for National Statistics.[10] For further information see appendix (p 1).

Maximum-likelihood estimation of R

We undertook a maximum-likelihood estimation of the growth rate r and the corresponding value of R[11] on the Isle of Wight and nationally for fixed time periods after their respective Test and Trace programme launches using pillar 1, pillar 2, and combined pillars data. We also used pillar 1 data to compare R for each UTLA in time periods before and after introduction of Test and Trace programmes. This simple change-point analysis does not depend on the same modelling assumptions as our later analyses and therefore acted as a robustness check. For further information see appendix (pp 1–2).

Back calculation of infection times

We used a back-calculation approach to estimate the timings of new infections for pillar 1 cases, assuming that most pillar 1 tests are from patients in hospital. We used a log-normal distribution with mean 5·42 days and SD 2·7 days for the incubation period according to a meta-analysis,[12] and a gamma distribution with mean 5·14 days and SD 4·2 days for the time from symptom onset to hospitalisation.[13] Analyses were truncated at June 14, 2020, as calculations beyond this date would have been affected by missing data.[14] For further information see appendix (pp 2–3).

Renewal equation estimation for R

We used Bayesian estimation of the instantaneous reproduction number R[15] as implemented in the software package EpiEstim.[16,17] For the generation time we used a gamma distribution with mean 5·5 days and SD 2·14 days as obtained by Ferretti and colleagues[18] combining data from previous reports.[4,19–21] To reduce oversensitivity to the priors when the number of infections was low, we report the posterior mode rather than the posterior mean as the central estimate (appendix pp 3–4).

Nowcasting

We combined R with incidence per capita to provide a simple nowcast for each UTLA. For each day, we multiplied the estimated R value by the mean incidence per capita for the week beginning 3 days before and ending 3 days afterwards. For further information see appendix (p 4).

Synthetic controls for the 150 UTLAs in England

We used a synthetic control approach[22,23] to construct a comparison area for the Isle of Wight. This approach

See **Online** for appendix

created a weighted average of other areas in England that matched the Isle of Wight in the mean R before the Test and Trace programme launch, and in distributions of age and ethnicity. To choose the weights, we used cross-validation, splitting the pre-treatment period in half with a 19-day training period followed by a 19-day validation period. We set the start of the pre-treatment period for analyses in the paper to March 28, at the time when lockdown had consistently started to make an impact on all UTLAS. Significance was determined using a permutation test. For further information see appendix (pp 5–6).

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. All authors, including the corresponding author, had full access to all of the data in the study. The corresponding author had final responsibility for the decision to submit for publication.

Results

We recorded the daily numbers of new confirmed cases on the Isle of Wight and nationally by individual pillars (figure 2A, B) and using the combined, de-duplicated pillars data released on July 2, 2020 (figure 2C, D). By nationally, we refer to the following available data: England for pillar 1 and the combined pillars; and the UK except Wales for pillar 2. Although it is common to see pillar 1 and pillar 2 data displayed in stacked histograms, interpreting true incidence from these plots is non-trivial because of the different testing lag times between the two pillars. Nevertheless, there is a clear trend of declining incidence through May and June, 2020, even in the context of increasing test availability. The differences across figure 2 show the effect of the de-duplication procedure for the combined pillars dataset.

After introduction of the Test and Trace programme, maximum-likelihood estimates of R on the Isle of Wight were lower than the national rates. This result was consistent across pillar 1 ($p=6\times10^{-6}$; likelihood ratio test), pillar 2 ($p=5\times10^{-4}$), and combined pillars ($p=2\times10^{-11}$; figure 3). National estimates had narrow CIs (figure 3A), being informed and constrained by a larger dataset. We compared R across UTLAs before (figure 3B) and after (figure 3C) the Test and Trace launches using pillar 1 data. By this measure, the Isle of Wight had a marked reduction in R, from 1·3 before the Test and Trace programme, to 0·5 after. This reduction is particularly notable when compared with other UTLAs—the Isle of Wight went from having the third highest reproduction number
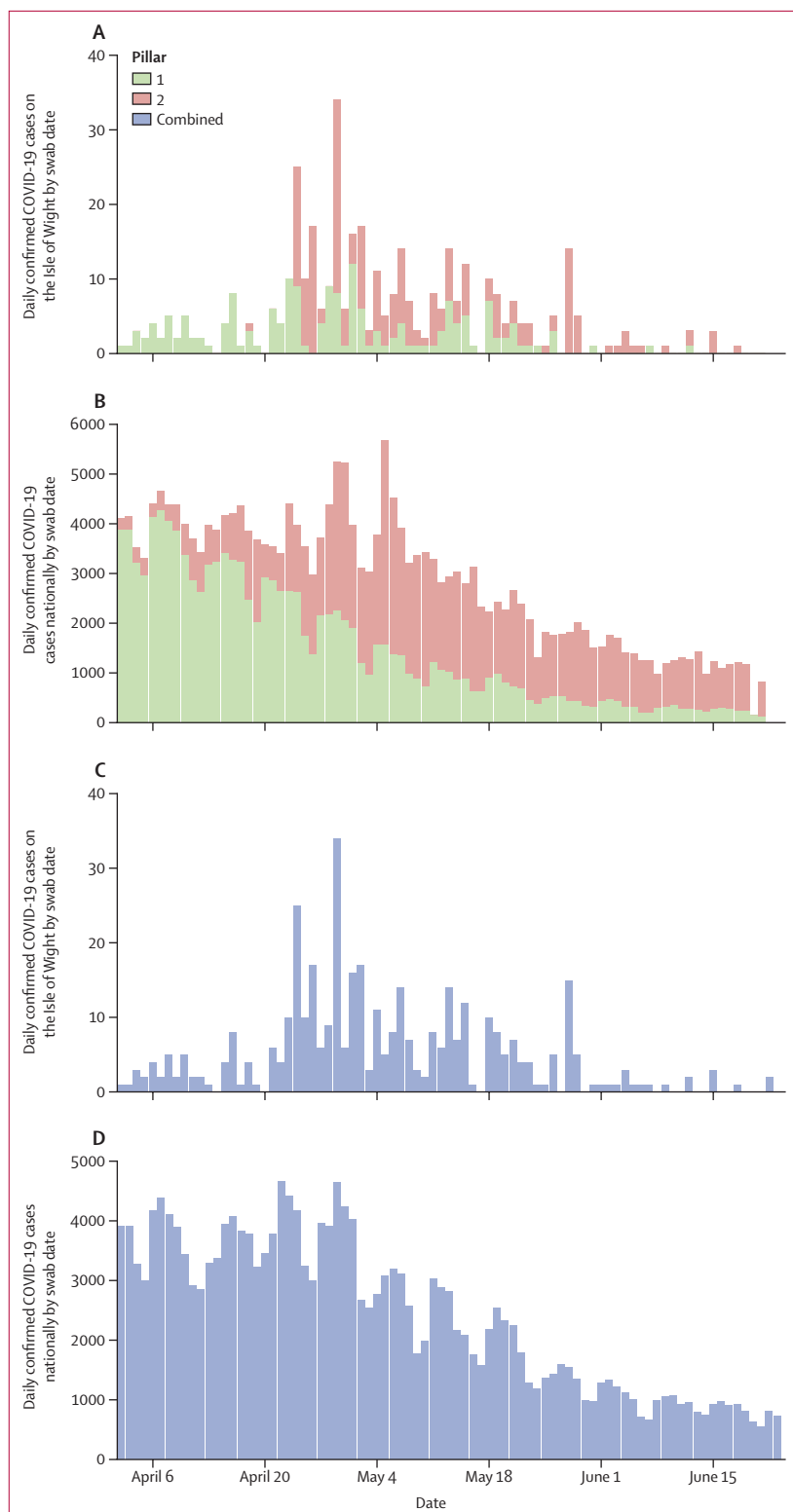
Figure 2: **Daily confirmed COVID-19 cases on the Isle of Wight (A) and nationally (B; England for pillar 1, UK except Wales for pillar 2), and using the combined pillars data (C and D)**
Each data presentation provides only a rough approximation of the true incidence because cases are recorded by the date the specimen was taken, not the time the individual became infected, and tests are expected to be done at different stages of infection between the two pillars.
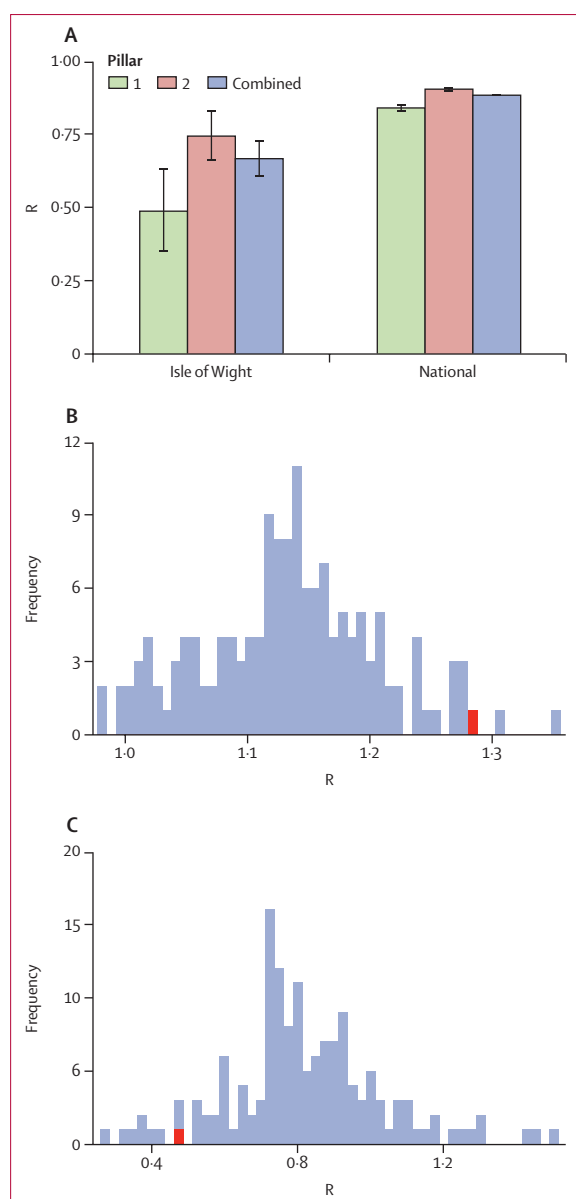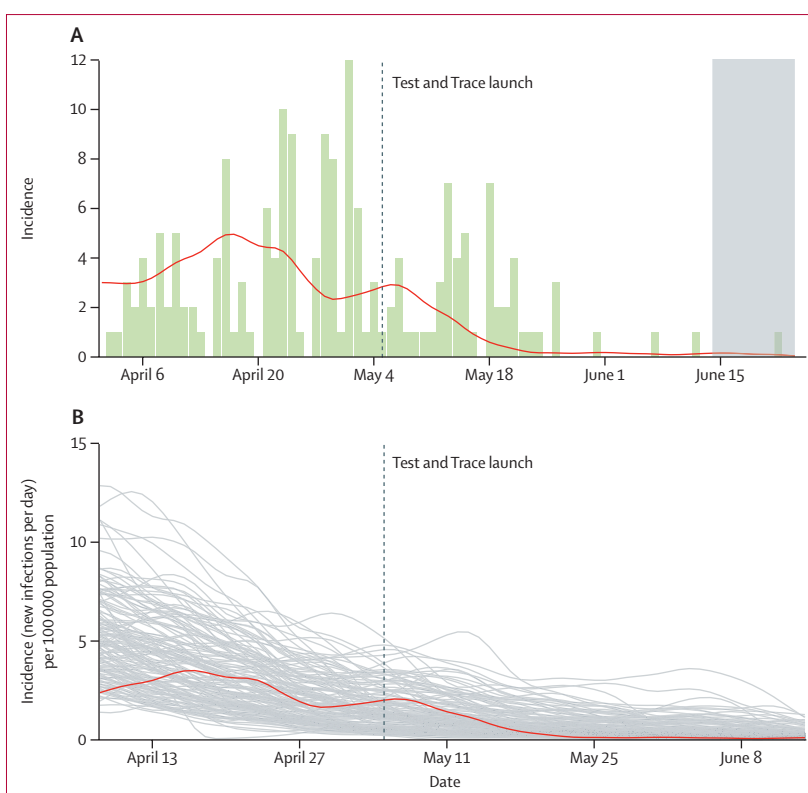
Figure 3: Maximum likelihood estimates of R
(A) On the Isle of Wight and nationally for each dataset. Error bars indicate the SE. (B) For each UTLA using pillar 1 data, with the Isle of Wight in red, before the Test and Trace intervention. For a list of the UTLAs see appendix (p 8). (C) For each UTLA using pillar 1 data , with the Isle of Wight in red, after the Test and Trace intervention. For a list of the UTLAs see appendix (p 9). UTLA=Upper-Tier Local Authorities.

Figure 4: Inferred incidence using pillar 1 data
(A) Back-calculated estimation of incidence of new infections (red line) from case data (green bars) on the Isle of Wight. Grey shading indicates the final 10 days. (B) Back-calculated incidence of new infections per capita for each Upper-Tier Local Authority (grey lines) and the Isle of Wight (red line). Dashed vertical lines indicate the date of the Test and Trace programme launch. Results are truncated on June 14.

before the Test and Trace programme, to the twelfth lowest afterwards.

Using pillar 1 data, we showed back-calculated the incidence of new infections from daily cases (figure 4A). Since the back-calculation relies on using around 10 days of future data, the inferred incidence over the final 10 days is increasingly prone to underestimation (figure 4A). The daily number of new infections on the Isle of Wight was generally decreasing from mid-April, although we do not

have the data to discern the extent to which this was the impact of non-pharmaceutical interventions versus the effect of insufficient test availability. We hypothesise that the apparent uptick in incidence in late April could be an artifact of increased test availability after the Test and Trace launch. We observed a decline in incidence straight after the introduction of the Test and Trace programme on May 5. Per capita incidence on the Isle of Wight was around average in mid-April but by late May was low, a trend which was not reflected by other UTLAs either on May 5 or after Test and Trace roll out between May 18 and May 28 (figure 4B).

On the Isle of Wight, R declined rapidly after the Test and Trace launch from a value of 1·0 on May 5, to 0·25 on May 23. The R value then fluctuated and gradually increased to 0·54 on June 14 (figure 5A). However, COVID-19 incidence was low towards the end of the study, with just one new case every 5–10 days (figure 4A), therefore, the credibility intervals on R are wide (figure 5A). A slight increase in R value is not a practical cause for concern in such a low-incidence setting; by this stage, incidence was sufficiently low on the Isle of Wight that R ceased to be a useful statistic. The decline in R from May 5 to May 23 was much more rapid for the Isle of Wight than
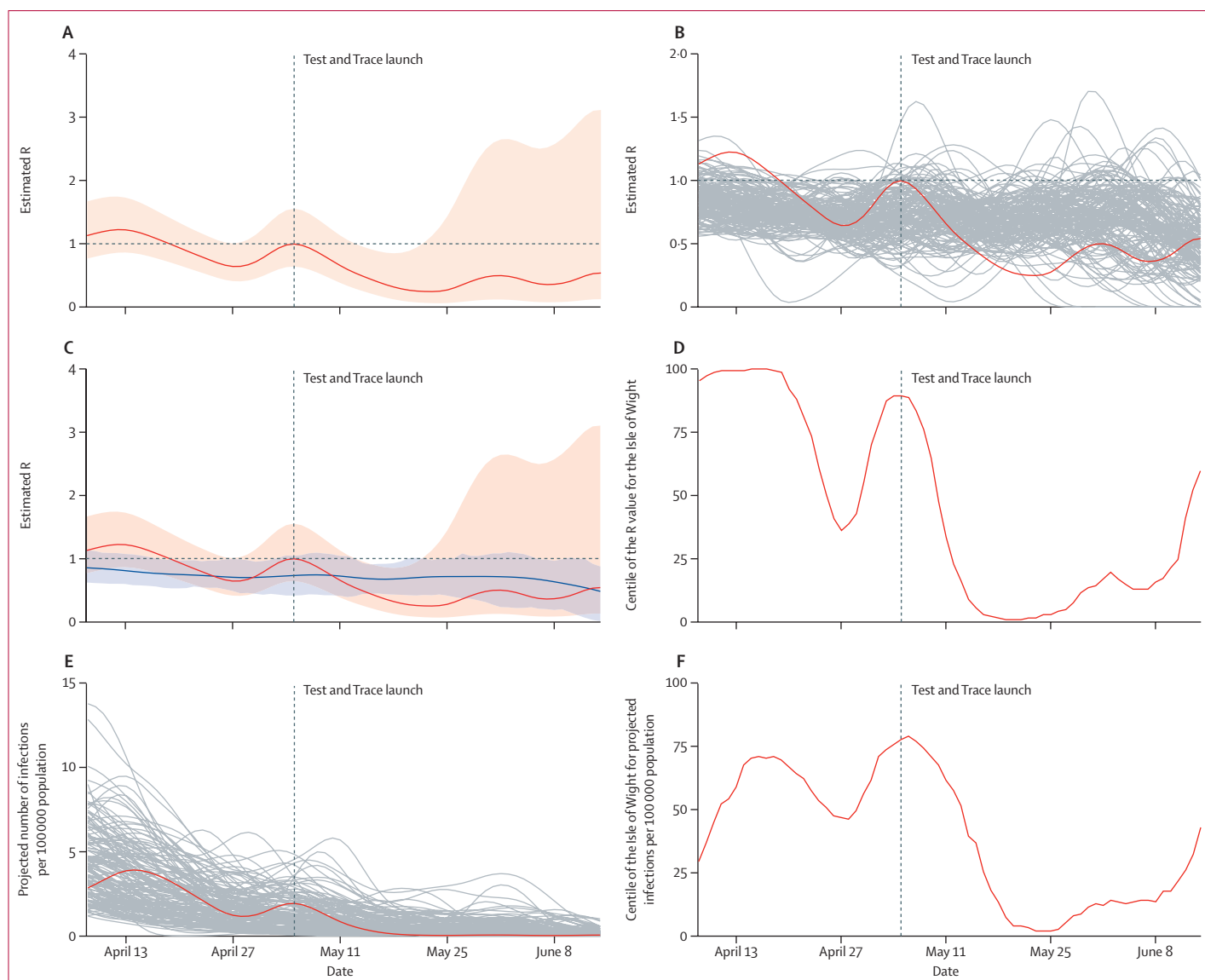
Figure 5: **Estimated R and nowcast using pillar 1 data**
(A) Estimated R on the Isle of Wight (red line), with credibility intervals shown in red. (B) Estimated R on the Isle of Wight (red line) and other UTLAs (grey lines). (C) Estimated R on the Isle of Wight (red line) with credibility intervals (red shading), and average R across other UTLAs (blue line) with 5%-95% range (blue shading). (D) Estimated R on the Isle of Wight as a centile of other UTLAs. (E) Nowcast for each UTLA, with the Isle of Wight line in red. (F) Centile of the Isle of Wight nowcast ranked against the other UTLAs. Dashed vertical lines indicate the date of the Test and Trace programme launch. Dashed horizontal lines indicate an R of 1. In all figure subparts, results are truncated on June 14. UTLA=Upper-Tier Local Authorities.

the average R of other UTLAs (figure 5B). On May 5, R on the Isle of Wight was high compared with the national average (figure 5C, D). By May 23, R was well below the 5% range (figure 5C) and ranked lowest of all UTLAs between May 19 and May 21 (figure 5D). Therefore, R decreased more rapidly on the Isle of Wight than in other areas of England.

The nowcast for each UTLA (figure 5E) shows that throughout April 2020, the epidemic on the Isle of Wight had a size and growth comparable with that of an average UTLA, between the 25th and 75th centiles (figure 5F). Following the Test and Trace programme launch, the

prospects for the Isle of Wight looked substantially better, reaching the second centile in late May 2020. For further context for the Isle of Wight centile rankings see the appendix (p 4).

In the final few weeks of the study, an increasing majority of cases were recorded as pillar 2 (figure 2B), while pillar 1 cases in all UTLAs decreased to almost zero (figures 4B, 5C). This led to stochasticity in our estimations of R and insufficient statistical power to compare epidemic trends. The magnitude of this shift from pillar 1 to pillar 2 case numbers was not consistent across UTLAs. Our results comparing incidence, R, and nowcasts using
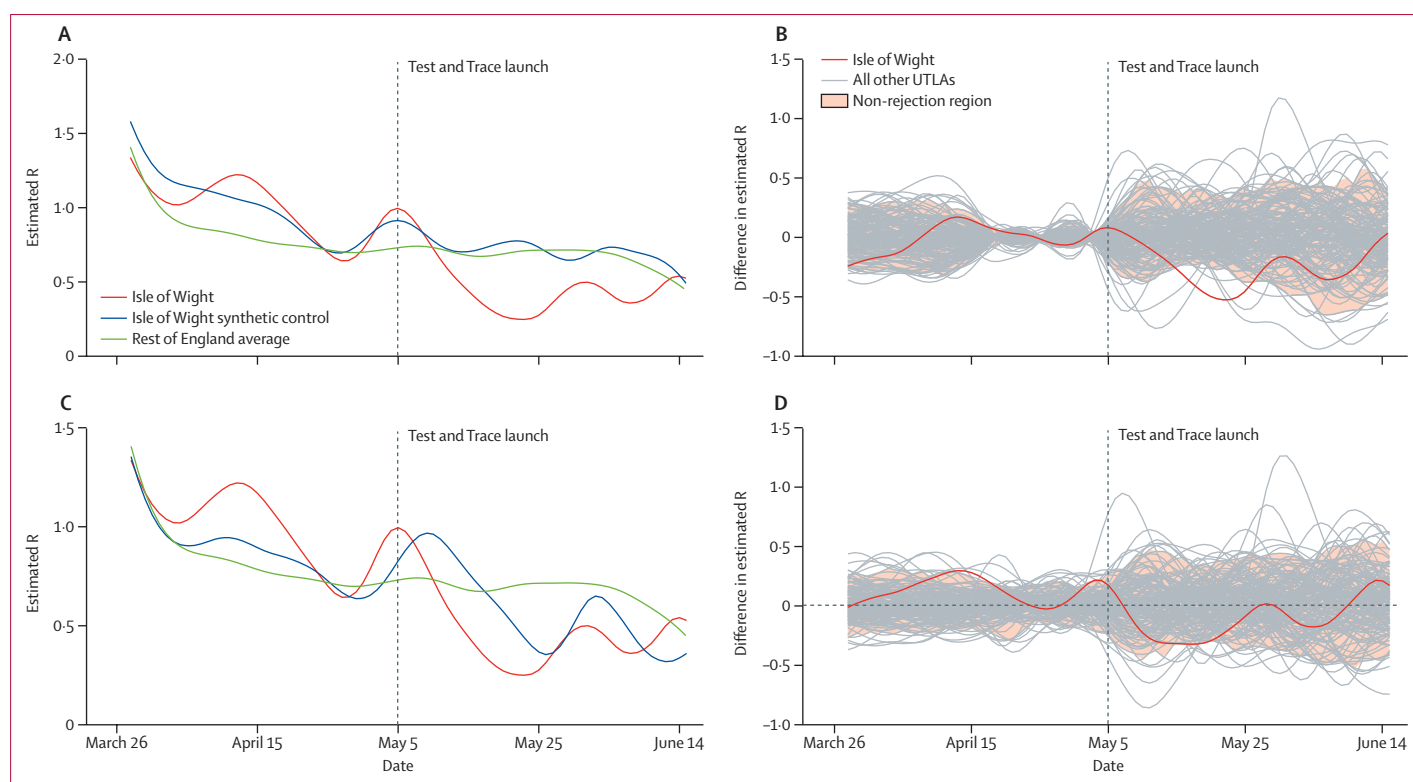
Figure 6: **Comparison between R on the Isle of Wight and other UTLAs in England using a synthetic control approach and pillar 1 data**
(A) Synthetic control using the mean R in each of the three weeks of the training or validation period as matching variables. This scenario gives 71% weight to the East Ridings of Yorkshire, 28% to Doncaster, and 1% to Sandwell in constructing the synthetic control. (B) Difference between each UTLA and its respective synthetic control (scenario 1). The non-rejection region (red shading) contains 95% of all UTLAs. A line outside the area is classified as significantly different from zero at the 5% level. (C) Synthetic control using the mean R in each of the 3-week periods and age and ethnicity variables (proportion of the population aged 0–19 years, 20–44 years, 45–64 years, 65–74 years, and ≥75 years, and the proportion of the population who were white, Asian, Black, and African Caribbean) as matching variables. This approach gives 64% weight to Dorset, 32% to North Somerset, 3% to the East Ridings of Yorkshire, and 1% to Kensington and Chelsea in constructing the synthetic control. (D) Difference between each UTLA and its respective synthetic control (scenario 2). The non-rejection region (red shading) contains 95% of all UTLAs. A line outside the area is classified as significantly different from zero at the 5% level. Dashed vertical lines indicate the date of the Test and Trace programme launch. In all figure subparts, results are truncated on June 14. UTLA=Upper-Tier Local Authorities.

pillar 1 data (figures 4B, 5B, 5E) are available in the *LocalCovidTracker* web application, where they can be explored in more detail. These results are provided alongside a daily extension of the analyses using the combined pillars dataset; these data provide a better estimate of the number of infections than do pillar 1 data alone, but present challenges for estimating timings and R. Our findings show that low incidence and R continued into July for the Isle of Wight, but for few other UTLAs.

Epidemic trajectories and demographics naturally vary across UTLAs, therefore we used a synthetic control approach[21] to create a more comparable control group for the Isle of Wight. We combined data from all other UTLAs and weighted their contributions to match the evolution of R on the Isle of Wight before the Test and Trace launch (figure 6A, C). The choice of matching variables is to some extent subjective and can influence the results—adding more matching variables does not automatically improve the analysis. Therefore, we considered two scenarios: first using weekly averages of the estimates of R alone, and second using additional demographic information. In both cases, we used a

cross-validation approach to guard against overfitting. Weights on the matching variables for the two scenarios are shown in the appendix (p 6). *LocalCovidTracker* includes further synthetic control analyses with different sets of matching variables to explore the robustness of the results.

Both synthetic control scenarios showed that R was lower for the Isle of Wight than for its synthetic control for most of the period after the Test and Trace launch. To establish the statistical significance of this result, we did a permutation test by constructing synthetic controls for all other UTLAs and computed the difference between each UTLA and its synthetic control (figure 6B, D). The difference for the Isle of Wight was statistically significant at the 5% level for part of May in both scenarios. In scenario 1, the difference was significant between May 15 and May 26, and in scenario 2 the difference was significant on May 15, May 16, May 19, and May 20. We also did a synthetic control analysis matching to nowcast values instead of R. The matching was poor because the Isle of Wight epidemic peaked later than most other epidemics, but the results supported the conclusion that

the Isle of Wight experienced an unusually rapid decrease in epidemic severity after the launch of Test and Trace.

Discussion

In this study, we analysed the course of the COVID-19 epidemic on the Isle of Wight before and after the launch of the Test and Trace programme and compared this with other areas of England and the UK. We focused on per-capita incidence and R, comparing these values using various approaches. We calculated the instantaneous reproduction number R considering variable lag times between infection and case counts; this method can be generalised to different distributions of lag times across data sources.

Our analyses produced consistent results. In mid-April, the Isle of Wight had moderate-to-high COVID-19 incidence per capita and a higher R than a typical UTLA. The launch of the Test and Trace programme on the Isle of Wight was followed by a short phase in which case numbers increased, as expected with increased testing. However, the inferred incidence of new infections and R declined markedly to below the national means and below predicted levels for a synthetic control immediately upon introduction of the Test and Trace programme.

Our results are correlative and rapid improvements in the epidemic on the Isle of Wight could be explained by multiple causes. The launch of the Test and Trace programme on the island included a large advertising campaign, community discussions, and national publicity. The attention surrounding the launch might have led to increased care and social distancing, although this is not apparent from Google mobility data (appendix p 7).[24] Positive community spirit and increased awareness might encourage a symptomatic person to self-isolate more meticulously, especially once they received a positive test result because of widespread test availability. Contact tracing could have contributed to the improvements in the epidemic via traditional or digital systems. All Isle of Wight inhabitants received a letter and an invitation to download the app, and contact tracers might have been highly motivated to make the first phase of the launch a success. A hospital-based app usability study concluded that the app had been embraced and adopted well during an initial trial period, while making recommendations for improvements for future versions.[25]

Alternatively, the success on the Isle of Wight might be attributable to reasons other than the Test and Trace programme launch. Our comparisons were statistically significant across various analyses, so chance fluctuations are unlikely to be the sole cause of the improvements. An epidemic could be easier to control on a small island and some of the effective strategies on the Isle of Wight might not fully translate to elsewhere. The national Test and Trace programme was launched on May 28, 2020, during a period of gradual relaxation of lockdown measures which began on May 10. This strategy might explain why we did not see similar improvements after the introduction of Test and Trace programmes elsewhere. Wider introduction of Test and Trace occurred from May 18 to May 28, towards the end of our study period, so there was little opportunity to observe more gradual improvements. We provide an ongoing analysis in our web application.

This study has several limitations. Data from the UK Contact Tracing and Advisory Service and time series of cases traced by the app are not yet publicly available. A strong indicator of the effectiveness of the Test and Trace programme would be the proportion of positive test results from individuals who were already quarantined at the point of diagnosis, but we have been unable to confirm whether these data are being collected. With the data available we cannot separately evaluate the effects of the individual aspects of the Test and Trace programme. We did not adjust for changes in testing practice and so probably overestimated R when widespread community testing became available. We hypothesise that this bias becomes less pronounced after a week. The Isle of Wight synthetic controls are not perfect matches, as is evident from several time periods that are distinctly different between the Isle of Wight and the synthetic control before the Test and Trace programme launch. However, this fact is unsurprising given the unusual epidemic trajectory and geography of the Isle of Wight. Our ongoing analysis could be more accurate if data were available separated by pillar or preferably with timing information, such as the date of symptom onset.

This study provides some quantitative support for the overall effect of a comprehensive policy of engagement of local policy makers and communities with a combination of enhanced testing and contact tracing approaches, which might serve as an example for approaches that could be used more widely in the UK. We encourage further analyses to compare local epidemics as the Test and Trace programme evolves, with focused data collection that allows evaluations of the separate Test and Trace components. Tracking the trajectories of local epidemics and identifying the key determinants of success will be crucial for informing local and national non-pharmaceutical intervention strategies.

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