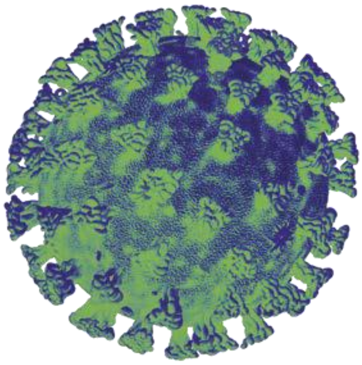
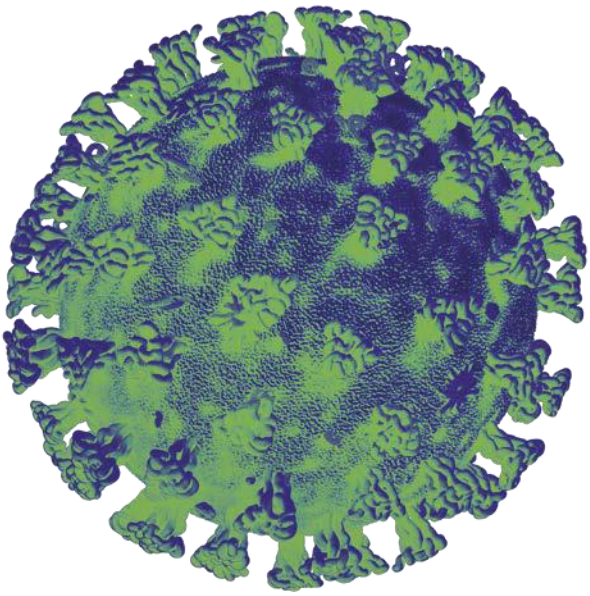
Llywodraeth Cymru
Welsh Government

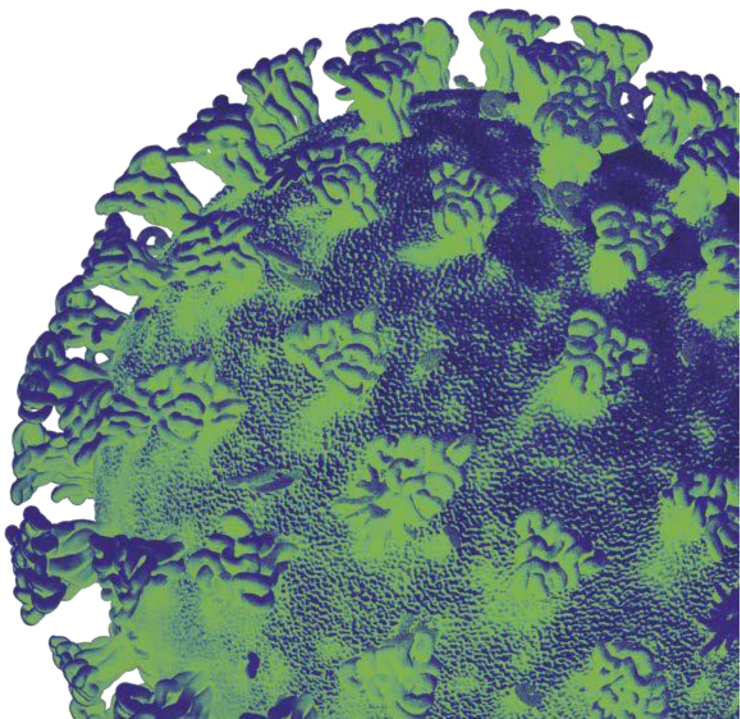
Technical Advisory Cell

Modelling Update

26th May 2020







Authors of this report

This report has been developed by Dr Brendan Collins and Craiger Solomons, who lead the TAC Modelling sub-cell. This work has been carried out in partnership with colleagues in Public Health Wales.

Future Publications

This publication includes short term forecasts for the first time. In our next publication we are hoping to include further data, including data from the COVID-19 Symptom Tracker application.

Definitions and terms used in this publication

Incubation / pre-symptomatic period	The period between becoming infected with the virus and showing symptoms. *For Covid-19 this is 5-6 days on average, but can be as long as 14 days*
R_0	The initial reproduction number. The average number of people an infected person transmitted the disease to at the start of the epidemic, before anyone has immunity to it. *This has been estimated to be 2.8 for Covid-19 in Wales*
R_t	The reproduction number at a point in time; the average number of people an infected person transmitted the disease to at some point in the epidemic. *This is currently estimated to be 0.7 – 1.0 (but still below one) for Covid 19 in Wales*
Susceptible person / population	An individual or group at risk of becoming infected by a disease
Nosocomial Transmission	The infections that develop as a result of a stay in hospital or are produced by microorganisms and viruses acquired during hospitalization.[1]

[1] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC88988/

COVID-19 characteristics

COVID-19 is the name given to the disease caused by the SARS-CoV-2 virus. The main steps in infection are exposure (where someone comes into contact with virus due to direct or indirect contact); incubation period, when the virus is replicating in the patient; then development of symptoms, immune response, and recovery or other outcome.

The **incubation period** for COVID-19, which is the time between exposure to the virus (becoming infected) and symptom onset, is on average 5-6 days, however can be up to 14 days.

Patients with COVID-19 will either show symptoms (symptomatic) or not show symptoms (asymptomatic). International evidence suggests that approximately a third of people with COVID-19 will not show symptoms.[2] Unpublished modelling by academic groups currently uses an assumption that 33% of cases are asymptomatic but evidence is evolving over time and this figure may be lower.[3]

Why the 'R' number matters

The importance of R in describing an outbreak such as COVID, where person-to-person transmission is the driver, is in the impact on increasing or decreasing case numbers.

Put simply, if R is below 1, each case will give rise to fewer than one additional case, so over time case numbers will dwindle to zero. However, if R is above 1, case numbers will increase exponentially. The higher the R, the faster this increase will occur.

For a completely uncontrolled infection with $R_0>1$, infections rise exponentially until most of the population has been infected, then R_t falls below 1 and new cases decrease back to baseline. The reason for this fall in R_t and case numbers is that those infected are no longer susceptible to repeat infection, for a short or longer period, so the number of people left to infect is not sufficient to maintain transmission. In a population where everyone is infected or has just recovered (and so are not susceptible), one infection will not give rise to any more cases as there is no-one left to infect.

Measles is one of the most infectious common diseases with an R_0 value of 12-18. R_0 for COVID-19 has been estimated at around 2.8. This means that in the absence of immunity or mitigation measures, each case would pass on the virus to a further 2.8 people on average.[4] This R_0 value also means that around 64% $(1-\frac{1}{2.8})$ of people need to have antibodies for the virus to see herd protection effects. It is unlikely that

[2] https://www.cebm.net/covid-19/covid-19-what-proportion-are-asymptomatic/
[3] SAGE reasonable worst case (RWC) planning assumptions – 29 March 2020
[4] SPI M O consensus 25th March 2020. Published at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/882723/26-spi-m-o-working-group-scenario-planning-consensus-view-25032020.pdf

more than 10% of people in Wales have had the virus yet so we are a long way off seeing these kind of herd protection effects.

For this publication, R_t has been measured by the Welsh Government, Public Health Wales and leading academics across the UK (e.g. Imperial[5], London School of Hygiene and Tropical Medicine (LSHTM)[6], Bristol[7] and others). All contributors use a different methodology for modelling R_t and their results are brought together for a consensus view. The models use new hospital admissions where the patient has tested positive for COVID-19, new confirmed cases (where a patient has been tested positive for COVID-19), and deaths where the deceased has been tested positive for COVID-19. We also consider that – due the incubation period – there will always be a time lag in reporting R_t and therefore caution is needed in interpreting the current position.

Each of the methods used has its own strengths and weaknesses, and as with any modelling, this means that care should be taken in interpretation of the results.

The **number of cases** (tested positive for COVID) will present the most rapid estimate of R_t. It is very likely that the estimate is an undercount. However, we can follow the data over time to show the relative change in this measure. Notably, whether the number of cases is increasing or decreasing, and therefore how quickly the virus is spreading. As the number of people tested for the virus increases, we expect these estimates to improve. One weakness of this method is that if the volume of testing increases rapidly, it can make the estimated Rt value increase while the true number of cases is actually falling.

The **number of hospital admissions** (tested positive for COVID) is a less timely measure but more robust. This measure only includes people who have developed symptoms requiring hospital treatment which should be a reasonably constant proportion of the total number of cases. This value also depends on the number of tests carried out. However, we can follow the data over time to show the relative change in this measure.

The **number of deaths** (tested positive for COVID) is the least timely estimate of R_t. The accuracy of this figure is dependent on the source of the data. Using hospital deaths provides a quicker estimate, however ONS statistics will provide records for the whole population of Wales.

Estimating R in different settings

In Wales, Public Health Wales (PHW) are estimating R_t using new admissions to hospital with confirmed COVID-19 infection. Infections likely acquired in hospital, and those tests not done in hospital (for example key worker testing) are excluded, leaving only those cases who have probably contracted infection in the community, deteriorated, and required hospital admission. This is likely to represent around 4%

[5] https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/
[6] https://www.lshtm.ac.uk/research/research-action/covid-19
[7] Challen et al. (2020) Estimates of regional infectivity of COVID-19 in the United Kingdom following imposition of social distancing measures. https://www.medrxiv.org/content/10.1101/2020.04.13.20062760v2

of community symptomatic cases (Source: PHW analysis). As the probability of hospitalisation for a case should remain constant (as long as the virus has similar characteristics, and criteria for hospitalisation do not change), this is a stable sample of all community-onset COVID-19 cases and so estimates community transmission rates.

What is the impact of R on healthcare demand?

Case numbers in the community give rise to hospital admissions, and also to requirement for ventilation and ICU admission for severe cases. For each outcome, there is a distribution of lengths of stay leading to an accumulation of new cases in various levels of care. This means that there is a lag between increases in community cases and hospitalisations, and also a lag while admitted cases accumulate in hospital and recover- so bed occupancy can rise even while community transmission is falling.

Interpretation of the impact of lockdown measures on R_t

Decisions will need to be made on which lockdown measures to relax and when. Most models are developed based on previous events. As these measures have been introduced for the first time, it is not yet clear what will happen to R_t if interventions are switched on or off. Most studies suggest that lifting lockdown may lead to a rapid increase in R_t. This can be partially offset by other interventions like track and trace.

Analyses for Wales

Reproduction Ratio

R_t = 0.7-1.0 (but still below 1), this means the number of cases is most likely to be **decreasing** in Wales. The value of 0.7-1.0 was agreed as the consensus value on 11th May 2020.

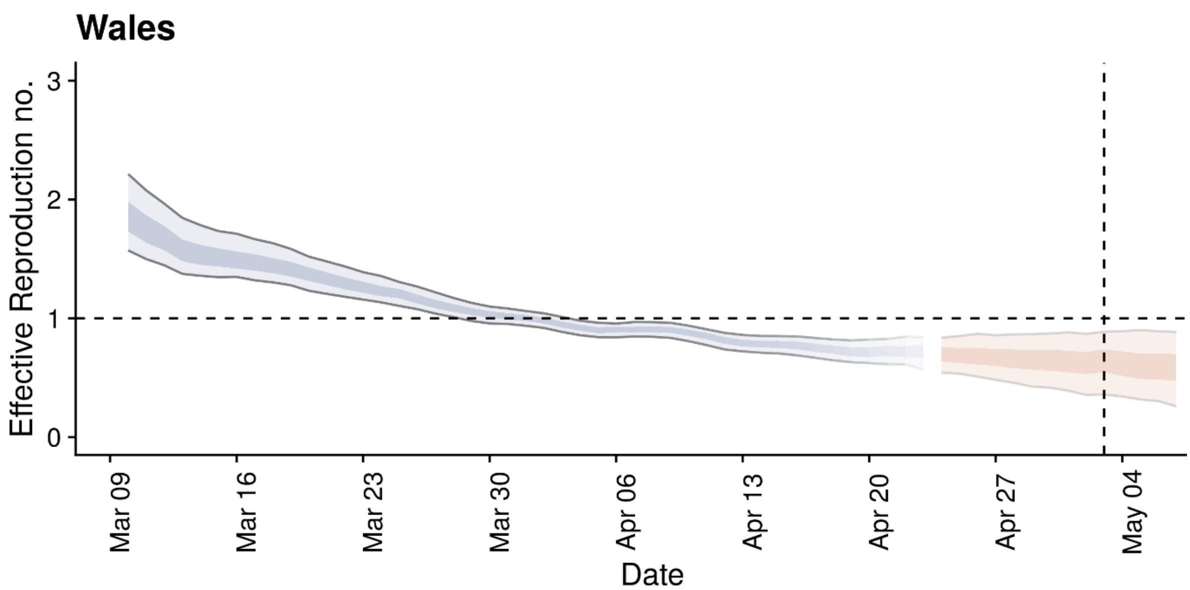
Estimates from LSHTM as of 14th May (which use data up to 24th April 2020) suggests that R_t = 0.7 for Wales, with 90% credible intervals of 0.6 to 0.8. This means for every ten people that are infected, seven further people are infected. These same estimates put Rt as 1.1 for the UK, however at the moment in many places testing is being ramped up which can lead to a transient estimate of R>1 because notified case numbers are increasing even if infections are actually in decline.

Current estimates of R_t reflect cases from around two weeks ago. There is a delay in estimating R_t due to the ‘incubation period’ and the time it takes to be tested for the virus.

Because R_t is below 1, it is expected that the number of new cases of COVID-19 are decreasing. When excluding hospital-acquired cases, the community Rt is lower.

Figure 1 below shows the time-varying estimate of the effective reproduction number (light ribbon = 90% credible interval; dark ribbon = the 50% credible interval) in all regions. Estimates from existing data are shown up to the 24th April 2020 from when forecasts are shown. These should be considered indicative only. Confidence in the estimated values is indicated by translucency with increased translucency corresponding to reduced confidence. The horizontal dotted line indicates the target value of 1 for the effective reproduction no. required for control. The vertical dashed line indicates the date of report generation.

Figure 1: Rt in Wales



Source and further information: National and Subnational estimates for the United Kingdom https://epiforecasts.io/covid/posts/national/united-kingdom/

R_t has decreased in Wales since social distancing and lockdown measures were introduced. These R_t estimates are for the whole population, however may be slightly higher due to health care workers having had proportionately more tests. Hospital admissions from 24th March to 27th April also gave an estimated R_t value of around 0.9. Trend analysis of this hospital admissions data suggested the previous R_t value for admissions had hovered around 1 since lockdown.

We are likely to be seeing three different outbreaks at the moment:

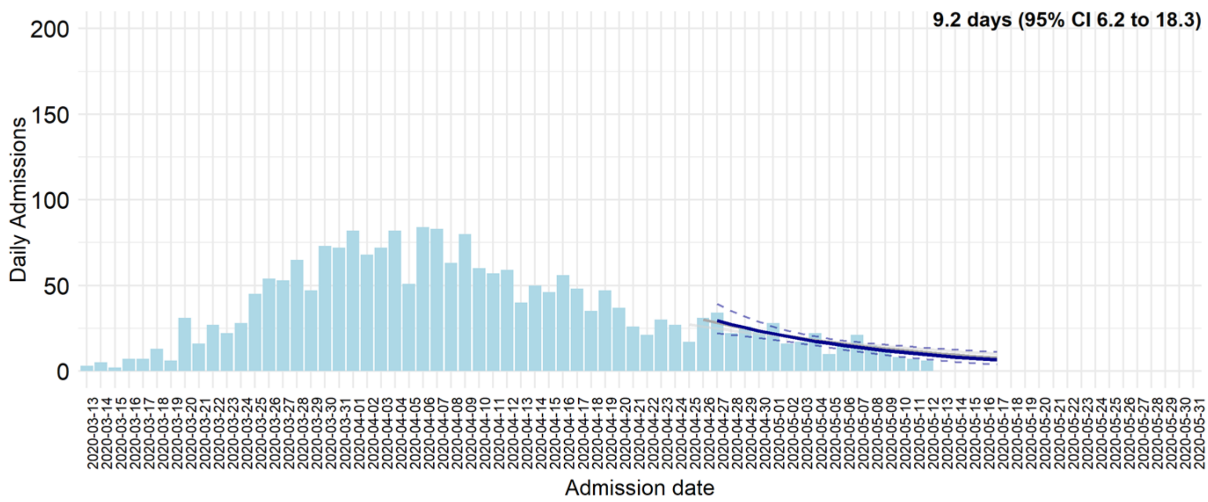
1. Community where R_t is falling and is likely to be below 1
2. Hospital/healthcare setting where R_t may be between 0.1 and 0. 5. The R_t value varies with some hospitals having larger outbreaks.
3. Care homes where infection can spread rapidly.

Infections in health and social care workers may contribute as well. The dynamics between these outbreaks can be unpredictable with cases in one setting 'seeding' cases elsewhere.

Halving times (in Wales)
About 9.2 days: Good

The number of new hospitalisations for COVID-19 in Wales has passed the first peak and is estimated to be falling. So, instead of talking about 'doubling times', we now talking about 'halving times' – the time it takes for the number of cases to halve. From 22 March to 10th April, the estimated doubling times increased from 7.6 to 92.1 days. This was based on community-acquired hospital admissions (it excluded possible hospital-acquired cases). Halving time estimates as at 13th May (based on admissions from 27th April to 10th May) suggest the time taken for the number of new cases to halve is approximately 9.2 days. This indicates that the rate of hospital admissions has slowed down further since last week when the halving time was 18.1 days.

Figure 2: Estimated halving time for new hospital admissions for community acquired COVID



Footnotes:
Community acquired cases are assumed to be those where the time between admission and COVID-19 sample date is less than four days. This subset of data has been used for the purposes of estimating changes in transmission in the community and the number of new COVID diagnoses in patients in hospital will be higher than presented in this chart.

Doubling/halving time estimates are sensitive to the time period chosen. For the purpose of this analysis 14 days' worth of data has been used. Halving time estimates as at 13/05/2020 and are based on admissions from 27/04/2020 to 10/05/2020. 95% confidence intervals are indicated by dashed lines on Figure 2. These data exclude patients where the hospital admission date is more than 14 days after the specimen date. These are assumed to be non-COVID related admissions because it is likely that most people will either recover from COVID or deteriorate and require hospital before 14 days. After 14 days the COVID test result is likely to be incidental to the subsequent hospital admission. .

Estimates from 12/05/20: 10.9 days (95% CI 7.1 to 23.1) and 11/05/20: 15.4 days (95% CI 8.1 to 153.1) are also shown (dark grey and light grey lines).

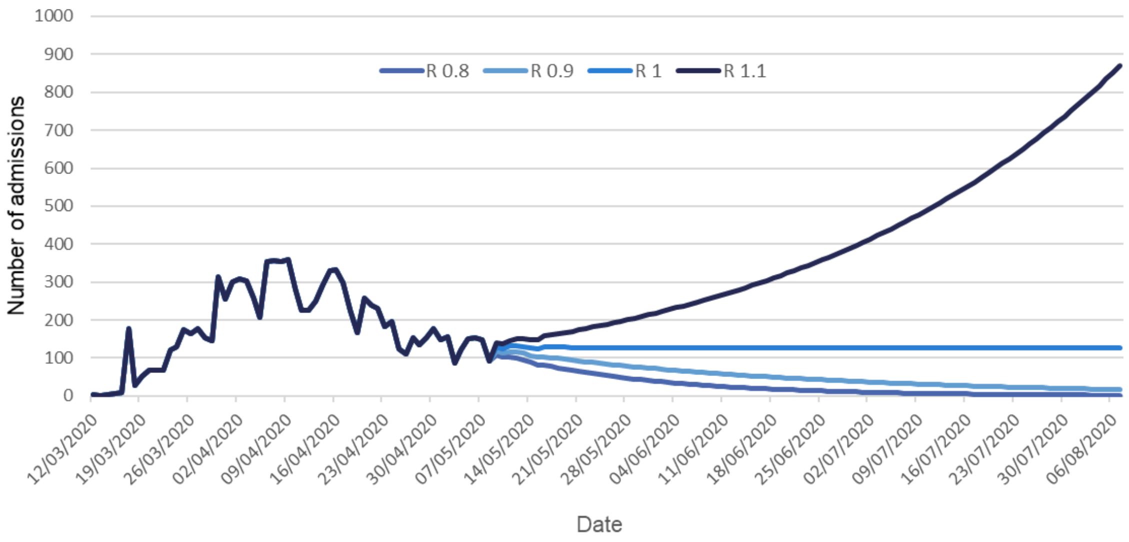
Source: All Wales Hospital Case Management System, Public Health Wales – as at 14/05/2020.

Hospital capacity
Demand and capacity in hospitals: Falling but could increase if restrictions are lifted.

A small increase in R_t above 1, maintained for 3 months, can have a huge impact on hospital demand. It can greatly increase the number of hospital admissions and deaths.

The assumptions used to calculate R_t in figure 3 have been updated. The daily cases, admissions data and death data has been updated to 8th May. We have also refined our estimate of the serial interval (also known as generation time), which is the time between cases, changing this from 6 days to 4.7 days. This slightly lowers the impact of Rt 1.1 from 8th May compared to the previous estimate of 7,200 deaths. The following results are produced.

Figure 3: Estimated hospital admissions per day in Wales from COVID-19 under different scenarios of Rt, up to 7th August 2020.



	Cumulative for the time period 8th May – 7th August		
R_t scenario	**Confirmed cases**	**Hospital admissions**	**Deaths**
0.8	2,800	2,500	500
0.9	5,300	4,800	900
1.0	12,800	11,700	2,300
1.1	39,400	36,200	7,000
Source: Welsh Government, TAC			

Short Term Forecasts

Data presented below include historical values (indicated in the past) and forecasts that predict an estimated number going forward. The forecasts are produced by academics who are working as part of SPI-M, a sub group of SAGE. The data below are **combined values** from at least two academic groups.

The forecasts outlined below have been produced by the Scientific Pandemic Influenza Group on Modelling (SPI-M). SPI-M is a sub group of SAGE and provides expert advice on scientific matters relating to the UK's response to an influenza pandemic (or other emerging human infectious disease threats). SPI-M's advice is based on infectious disease modelling and epidemiology.

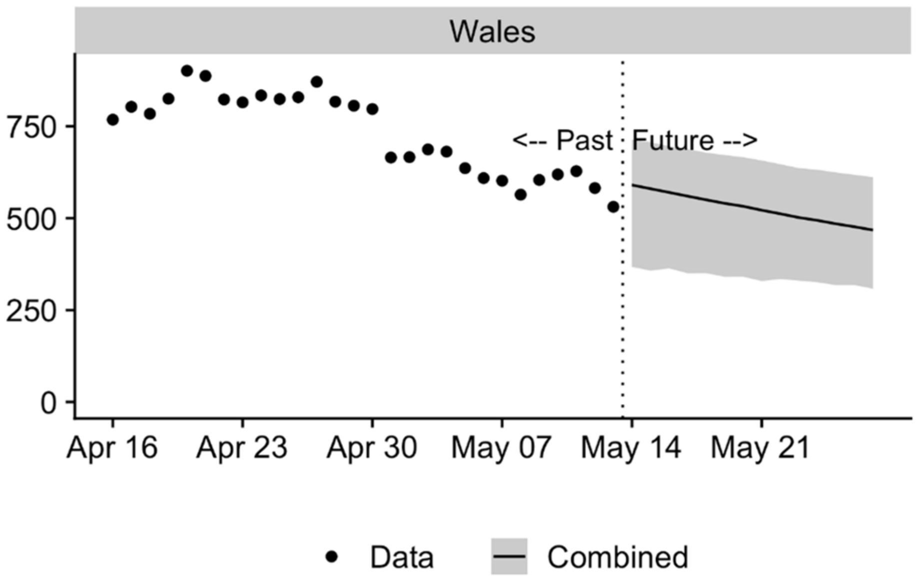
Separate forecasts are produced using different models and approaches by the modelling groups represented at SPI-M. These individual forecasts are then combined to form a consensus forecast. Forecasts come from transmission models of the epidemic process, and are fitted to hospital data. Where data series are inconsistent (for example if ICU occupancy drops much more quickly than general bed occupancy), the models may not always fit well to data. Note that the models used for these short term forecasts are different to those used for longer term forecasts, such as those evaluating the possible impact of changes to social distancing measures.

Each group fits their model to the trends in the historical data. As a result, these forecasts do not include impact of the changes to social distancing measures which have been announced by the Welsh Government and other UK administrations but which had not resulted in changes to hospital or death data by the time the forecasts were made.

The forecasts have wider confidence intervals because of the relatively small number of ICU patients and deaths in Wales compared to other UK nations.

Data presented below include historical values (indicated in the past) and forecasts which cover the next 2 weeks. The data below are **combined values** from at least two academic groups.

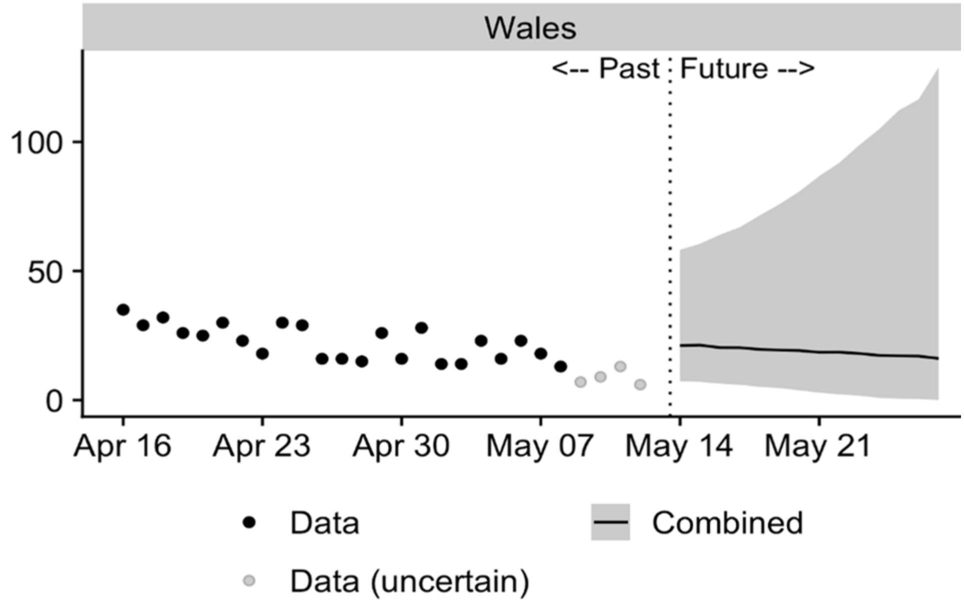
Figure 4: Total number of hospital beds (including ICU) occupied by COVID positive patients



Source: SAGE

SPI-M's combined forecast is for bed occupancy to continue to decline in Wales. The shaded area indicates 90% confidence interval around the estimates.

Figure 5: The number of deaths in hospitals and communities (by date of death)



Source: SAGE

This forecast may not represent all Covid-19 deaths in the community. The number of deaths are forecast to remain broadly flat in Wales.

The shaded area shows that the higher confidence interval (the top of the shaded area) shows that there is a small chance that this number may grow exponentially. This is likely due to small numbers used to calculate this value. Data are given by date of death. The grey data points are expected to be revised upwards in future.

The forecasts indicate that we can expect deaths in hospital and the community to remain broadly flat.

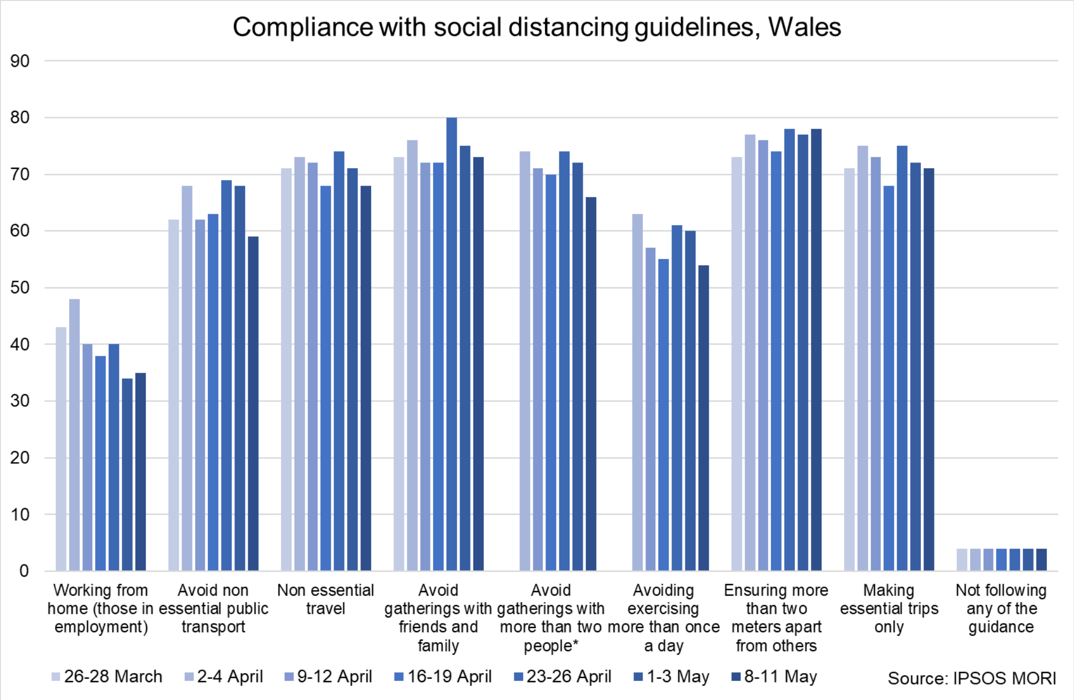
Social Distancing Adherence

Around 70%: Good

The assessment of this comes from survey data that asks if individuals in Wales are following the guidelines. Those who state they are following the guidelines is mostly around or over 70% with only 4% saying they are not following any of the guidance.

The most recent survey data for Wales shows continuing compliance. There has been a reduction in those saying they are working from home in Wales.

Figure 6: Adherence to social distancing guidelines, Wales



*Question was amended from the 8th of May to remove the word outside

Figure 6 represents data collected online by Ipsos Mori as part of a multi-country survey on the Global Advisor platform. Each of the past five waves have included c.600 respondents in Wales. The sample is broadly representative of the adult population aged 16-74. Data is weighted to reflect the age and gender profile of the Welsh population aged 16-74. All samples have a margin of error around them. For a sample of around 500, this is +/- 4.8 percentage points.

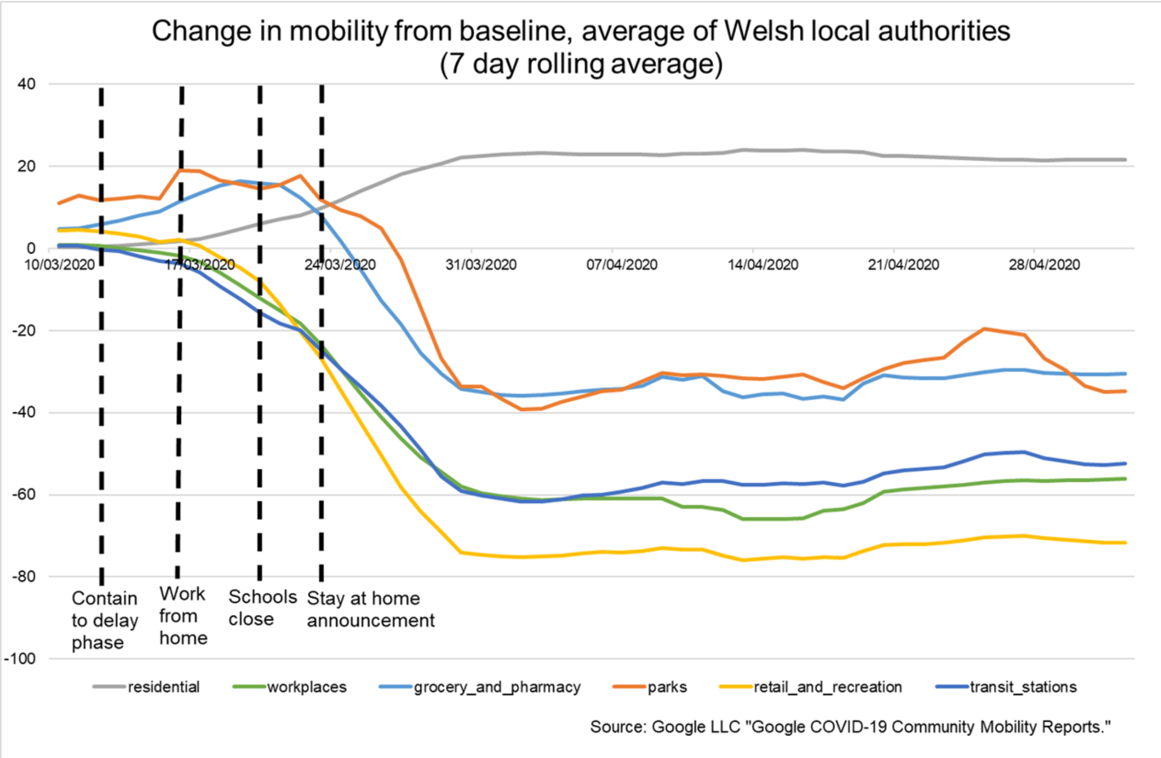
For further information on public views on COVID-19, please see: https://gov.wales/survey-public-views-coronavirus-covid-19

Alongside the survey data, a range of other mobility information is also used. Changes in the mobility data may not mean similar changes in compliance. For example recent opening of some shops (e.g. hardware and some food stores) may results in more trips/higher mobility or warmer weather may mean people are more likely to be outdoors than indoors. Further work is being developed to consider this.

The mobility data shows recent increases in movement. The Google mobility data for Wales shows increases in some categories in line with the rest of the UK and is consistent with increases in traffic (from monitoring points).

Figure 7 shows the change in mobility in Wales. The figures are based on the average of the local authorities that have data. The baseline is the median value, for the corresponding day of the week, during the 5-week period Jan 3–Feb 6, 2020.

Figure 7: Change in mobility.



This pattern is similar to that of the UK as a whole.

This shows large reductions in movement/travel in Wales since the middle of March. However, recent weeks have shown some increases in mobility. This may not mean that people are following the guidelines less.

Retail and recreation areas have seen the largest fall, followed by workplaces and then transit stations. Following a fall of around 40% in Wales, parks had increased, but have fallen again.

This data also shows large reductions in people using public transport and going to workplaces. Since 20th April there have been small increases in workplaces and transit stations (with a slight fall in residential).