Office for National Statistics

Article

Coronavirus (COVID-19) Infection Survey Technical Article: Impact of vaccination on testing positive in the UK: October 2021

The reduction in risk of testing positive for COVID-19 associated with vaccination overall and by different vaccine types using data from the Coronavirus (COVID-19) Infection Survey. Two time periods were analysed; when the Alpha variant was dominant in the UK (1 December 2020 to 16 May 2021), and when the Delta variant was dominant (17 May to 14 August 2021).

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1 . Main points

- Vaccination significantly reduced the risk of people testing positive during both the Alpha-dominant period and the Delta-dominant period.
- Vaccine effectiveness was reduced in the Delta-dominant period compared with the Alpha-dominant period, particularly in preventing infections with symptoms.
- Two doses of either Pfizer-BioNTech or Oxford-AstraZeneca vaccines provided a similar level of protection to prior natural infection when the Delta variant was dominant.
- Two doses of either vaccine provided significantly greater protection than one dose across all analyses.

2 . Overview

This analysis uses results from the Coronavirus (COVID-19) Infection Survey (CIS) and pillars 1 and 2 of NHS Test and Trace to estimate the reduction in risk of testing positive for COVID-19 associated with vaccination overall and by different vaccine types. Two time periods were analysed: when the Alpha variant was dominant in the UK (1 December 2020 to 16 May 2021), and when the Delta variant was dominant (17 May to 14 August 2021). This allowed the study to assess vaccine effectiveness against these different strains.

Primary analysis included all new positive infection episodes. Secondary analyses considered the impact of vaccine type (Pfizer-BioNTech or Oxford-AstraZeneca) on positivity. Finally, the analysis considered the impact of vaccination on new positives with self-reported symptoms (any reported symptoms or no reported symptoms).

This analysis builds on academic research conducted by our survey partners from Oxford University led by Professor Sarah Walker. You can see the article for this research. In this updated analysis, Poisson regression was used rather than logistic regression. This allowed the inclusion of additional positive tests from the NHS Test and Trace programme for participants from England, improving the accuracy of the date of the first positive test in new infection episodes and including extra positive tests which are not present in CIS. This increases statistical power to detect effects of vaccination. This updated analysis also includes an additional two weeks of data from the Delta-dominant period, increasing statistical power.

For an explanation of what the COVID-19 Infection Survey can tell us about vaccine effectiveness and how this analysis builds on previous research, read our blog.

3 . About the data

This analysis uses SARS-CoV-2 real-time reverse transcriptase polymerase chain reaction test (RT-PCR) results from nose and throat swabs of participants from the Office for National Statistics (ONS) COVID-19 Infection Survey (CIS), a large survey monitoring current COVID-19 infections among the population living in private households, excluding people living in hospitals, care homes and/or other communal establishments.

Irrespective of whether they tested positive for COVID-19, individuals taking part in the survey were asked at each visit whether they had experienced a range of possible symptoms in the seven days before they were tested.

Participants were also asked about their vaccination status, including type, number of doses and date(s). Where possible, data from participants were linked to administrative records from the National Immunisation Management Service (NIMS). However, as NIMS does not contain information about vaccinations received abroad or in Northern Ireland, Scotland, and Wales, and linkage is periodic, not all participants could be linked. In these cases, survey responses were used.

From a random 10% to 20% of households participating in the COVID-19 Infection Survey (CIS), those 16 years or older were invited to provide blood on a monthly basis for antibody testing. Blood samples were tested for the SARS-CoV-2 antibody using an ELISA detecting anti-trimeric spike IgG.

Our methodology article provides further information about the survey design, how we process data and how data are analysed. This analysis also includes NHS Test and Trace positive test results for study participants in England to increase power and improve estimates. Data, quality and methodology is available in the NHS Test and Trace methodology paper.

4 . About the analysis

Multiple polymerase chain reaction (PCR) test-positive results may be obtained after infection, so positive tests are grouped into "episodes". The start of a new "infection episode" was defined as the date of either:

- the first positive test in the study
- a positive test after four consecutive Coronavirus Infection Survey (CIS) negative tests
- a positive test at least 120 days after the start of a previous infection episode with one or more CIS negative tests preceding it

For more information on the definition of reinfection, read our technical article.

NHS Test and Trace positives are used to define the start of an infection episode if they occur before a CIS positive in an infection episode, or if they occur independently of any CIS positive using the definition above. Positive episodes were used to classify exposure groups and outcomes.

Analysis from the latest of 1 December 2020 or the first study test to 14 August 2021 used the first positive test in each infection episode as the outcome and “days at risk” as the risk exposure (offset) using a Poisson model. Participants contributed days at risk following each negative CIS test up until their next test or for a maximum of 42 days. Following a first positive test in an infection episode, each participant contributed days at risk again only from the first subsequent test where they could have been classified as having had a new infection episode had they tested positive. This helps to avoid immortal time bias. Participant days at risk and immortal time bias are defined in the glossary.

On each day at risk, a participant was classified into one of seven exposure groups based on vaccination status, and antibody and PCR tests. These were as follows:

- 21 days or more before first vaccination, including those currently with no vaccination date, with no prior PCR/antibody-positive ("Not vaccinated, not positive previously, 21 days or more before vaccination") (reference group)
- less than 21 days before first vaccination with no prior PCR/antibody positive ("Not vaccinated, not positive previously, less than 21 days before first vaccination")
- 0 to 20 days following a first vaccination ("Vaccinated first dose 0-20 days previously")
- 21 days or more following a first vaccination ("Vaccinated first dose 21 days or more previously")
- 0 to 13 days following a second vaccination ("Vaccinated second dose 0-13 days previously")
- 14 days or more after second vaccination ("Vaccinated second dose 14 days or more previously")
- previously PCR/antibody-positive and not (yet) vaccinated ("Not vaccinated, previously positive")

As antibody status before vaccination is not available for all participants, we defined prior positivity by having either a prior PCR-positive episode or a positive S-antibody measurement more than 90 days previously, or two consecutive positive N-antibody measurements more than 42 days previously. For more information on antibody measurements, read our methodology article. The choice of 90 days was to exclude ongoing infections acquired previously being misattributed to current days at risk. Days at risk from vaccinated individuals were defined irrespective of previous positivity. Days at risk from the same participant were classified in different groups depending on their status at each timepoint.

Primary analysis included all new positive infection episodes. Secondary analyses considered the impact of vaccine type (Pfizer-BioNTech or Oxford-AstraZeneca) on positivity. Finally, the analysis considered the impact of vaccination on new positives with self-reported symptoms (any reported symptoms or no reported symptoms).

To allow pre-symptomatic positives to be identified, self-reported symptoms at any CIS visit within 0 to 35 days after the first positive in each infection episode were included, as were any symptoms reported with any NHS Test and Trace positive in the same time period. This means that if an individual did not have symptoms at the time of their first positive test but developed symptoms within the next 35 days, their infection would be categorised as symptomatic.

Because of the small volume of data currently available for the Moderna vaccine, the impact of this vaccine type on positivity could not be analysed robustly.

Statistical modelling

The analysis uses Poisson regression modelling adjusting for:

- region and age
- sex
- ethnicity
- Index of Multiple Deprivation
- working in a care home
- having a patient-facing role
- long-term health conditions
- household size
- whether the household is multigenerational
- rural-urban classification
- direct or indirect contact with a hospital or care home
- smoking status

This modelling helps to improve understanding of the relationship between vaccination and testing positive when adjusting for these factors.

Robust standard errors were used to account for multiple visits per participant. Pairwise comparisons (see glossary) were performed using Tukey adjustments.

Interpreting the charts

Results are presented as risk ratios (see glossary), which give the risk of infection in a specified group compared with the risk of infection in a reference group. When a group (for example, vaccinated participants) has a risk ratio lower than one, this means that there is a decreased risk of infection compared with the reference group (for example, unvaccinated participants).

5 . Risk of testing positive for COVID-19 by vaccination status

Alpha-dominant period (1 December 2020 to 16 May 2021)

This analysis uses data from 1 December 2020 to 16 May 2021, when the Alpha variant was dominant in the UK. There were 18,676 positive test results that were the first positive in a new infection episode from participants across the UK. The number of positives in each of the vaccine status exposure groups can be found in the accompanying dataset.

Throughout the analysis, the risk ratios presented are relative to the reference group: those not yet vaccinated or 21 days or more before their first vaccination without evidence of prior infection.

Figure 1 shows the risk ratios for testing positive by vaccine exposure group during the Alpha-dominant period, irrespective of vaccine type:

- two vaccine doses (14 days or more previously) reduced the risk of testing positive by 79% (95% confidence interval: 73% to 84%). This was the greatest reduction in risk compared with the other groups
- one dose (21 days or more previously) reduced the risk by 62% (95% confidence interval: 58% to 66%)
- for those not vaccinated but previously positive, their risk was reduced by 65% (95% confidence interval: 58% to 71%)

Figure 1: Vaccination reduced the risk of testing positive during the Alpha-dominant period

Modelled risk ratios of testing positive for COVID-19 by COVID-19 vaccine exposure, when the Alpha variant was dominant, UK, 1 December 2020 to 16 May 2021

Notes

1. Risk ratios are relative to the reference group: those not yet vaccinated or 21 days or more before vaccination without evidence of prior infection. The relative risk reduction is 1 - risk ratio.

Download the data

Figure 2 shows the risk ratios for testing positive by vaccine exposure group during the Alpha-dominant period, split by vaccine type:

- two doses of Pfizer-BioNTech reduced the risk of testing positive by 80% (95% confidence interval: 74% to 85%)
- two doses of Oxford-AstraZeneca reduced the risk of testing positive by 76% (95% confidence interval: 61% to 85%)
- there was no evidence of difference in the risk reduction associated with two doses (14 days or more previously) between the vaccine types

Figure 2: Pfizer-BioNTech and Oxford-AstraZeneca vaccines provided similar levels of protection during the Alpha-dominant period

Modelled risk ratios of testing positive for COVID-19 by COVID-19 vaccine exposure and vaccine type, when the Alpha variant was dominant, UK, 1 December 2020 to 16 May 2021

Notes

1. Risk ratios are relative to the reference group: those not yet vaccinated or 21 days or more before vaccination without evidence of prior infection. The relative risk reduction is 1 - risk ratio.
2. “PF” indicates the Pfizer-BioNTech vaccine and “AZ” indicates the Oxford-AstraZeneca vaccine.

Download the data

Figure 3 presents the risk ratios for testing positive by vaccine exposure group (irrespective of vaccine type) during the Alpha-dominant period, split by whether symptoms were reported:

- two doses reduced the risk of symptomatic infection by 95% (95% confidence interval: 91% to 98%)
- two doses reduced the risk of symptomatic infection by more than one dose (21 days or more previously)
- the reduction in risk for symptomatic infection was greater in those with two vaccine doses than those not vaccinated but previously positive (75% risk reduction, 95% confidence interval: 64% to 83%)

Figure 3: Two vaccination doses were more effective than one dose at preventing symptomatic infection during the Alpha-dominant period

Modelled risk ratios of testing positive for COVID-19 by reported symptoms and COVID-19 vaccine exposure, when the Alpha variant was dominant, UK, 1 December 2020 to 16 May 2021

Notes

1. Risk ratios are relative to the reference group: those not yet vaccinated or 21 days or more before vaccination without evidence of prior infection. The relative risk reduction is 1 - risk ratio.
2. Symptoms are self-reported and were not professionally diagnosed.
3. Because of small sample sizes, for symptomatic infection, risk ratios are reported for all those who have received a second dose of a vaccine, regardless of how many days previously.

Download the data

Figure 4 shows the risk ratios for testing positive by vaccine exposure group, split by vaccine type and by whether symptoms were reported during the Alpha-dominant period:

- two doses of Pfizer-BioNTech reduced the risk of symptomatic infection by 96% (95% confidence interval: 91% to 98%)
- two doses of Oxford-AstraZeneca reduced the risk of symptomatic infection by 90% (95% confidence interval: 70% to 96%)
- there was no evidence of difference in the effectiveness of two doses (14 days or more previously) of Pfizer-BioNTech and Oxford-AstraZeneca vaccines in preventing symptomatic infection

Figure 4: Pfizer-BioNTech and Oxford-AstraZeneca provided similar levels of protection against symptomatic infection during the Alpha-dominant period

Modelled risk ratios of testing positive for COVID-19 by reported symptoms, COVID-19 vaccine exposure and vaccine type, when the Alpha variant was dominant, UK, 1 December 2020 to 16 May 2021

Notes

1. Risk ratios are relative to the reference group: those not yet vaccinated or 21 days or more before vaccination without evidence of prior infection. The relative risk reduction is 1 - risk ratio.
2. Symptoms are self-reported and were not professionally diagnosed.
3. "PF" indicates the Pfizer-BioNTech vaccine and "AZ" indicates the Oxford-AstraZeneca vaccine.

Download the data

Delta-dominant period (17 May to 14 August 2021)

During the Delta-dominant period from 17 May to 14 August 2021, there were 8,306 polymerase chain reaction-(PCR-) positive test results that were the first positive in a new infection episode. The number of positives in each of the vaccine status exposure groups can be found in the accompanying dataset.

Figure 5 shows the risk ratios for testing positive by vaccine exposure group during the Delta-dominant period, irrespective of vaccine type:

- two vaccine doses (14 days or more previously) reduced the risk of testing positive by 67% (95% confidence interval: 64% to 70%) during the Delta period. During the Alpha period this figure was 79% (95% confidence interval: 73% to 84%)

- there was no evidence that the reduction in risk of infection from two vaccine doses (14 days or more previously) differed from that of previous natural infection (71% risk reduction, 95% confidence interval: 65% to 77%)

- two doses (14 days or more previously) provided a greater reduction in risk than one dose (21 days or more previously), which reduced the risk of testing positive by 49% (95% confidence interval: 44% to 53%)

Figure 5: Two vaccination doses provided a similar level of protection to previous natural infection during the Delta-dominant period

Modelled risk ratios of testing positive for COVID-19 by COVID-19 vaccine exposure, when the Delta variant was dominant, UK, 17 May to 14 August 2021

Notes

1. Risk ratios are relative to the reference group: those not yet vaccinated or 21 days or more before vaccination without evidence of prior infection. The relative risk reduction is 1 - risk ratio.

Download the data

Figure 6 shows the risk ratios for testing positive by vaccine exposure group during the Delta-dominant period, split by vaccine type:

- two doses (14 days or more previously) of Pfizer-BioNTech reduced the risk of testing positive by 73% (95% confidence interval: 70% to 76%) in the Delta period, compared with 80% (95% confidence interval: 74% to 85%) in the Alpha period

- two doses (14 days or more previously) of Oxford-AstraZeneca reduced the risk of testing positive by 62% (95% confidence interval: 58% to 66%) in the Delta period, compared with 76% (95% confidence interval: 62% to 85%) in the Alpha period

- the reduction in risk 14 days or more after second dose was significantly higher with Pfizer-BioNTech compared with Oxford-AstraZeneca

This analysis does not account for the time since the second vaccination. Because of the relationship between vaccine type and the timing of vaccine roll-out, care must be taken when comparing the effectiveness of Pfizer-BioNTech and Oxford-AstraZeneca vaccines. They differ in the amount of follow-up time post-second vaccination. There are also differences in the age profile of individuals offered each vaccine type.

- there was no evidence that the reduction in risk of infection from two doses of either vaccine differed from that of previous natural infection

- the risk reduction from two doses of either vaccine was greater than from one dose (21 days or more previously)

Figure 6: Two doses of either Pfizer-BioNTech or Oxford-AstraZeneca provided a similar level of protection to previous natural infection during the Delta-dominant period

Modelled risk ratios of testing positive for COVID-19 by COVID-19 vaccine exposure and vaccine type, when the Delta variant was dominant, UK, 17 May to 14 August 2021

Notes

1. Risk ratios are relative to the reference group: those not yet vaccinated or 21 days or more before vaccination without evidence of prior infection. The relative risk reduction is 1 - risk ratio.

2. "PF" indicates the Pfizer-BioNTech vaccine and "AZ" indicates the Oxford-AstraZeneca vaccine.

Download the data

Figure 7 presents the risk ratios for testing positive by vaccine exposure group (irrespective of vaccine type) during the Delta-dominant period, split by whether symptoms were reported:

- two doses (14 days or more previously) reduced the risk of symptomatic infection by 75% (95% confidence interval: 71% to 78%) in the Delta period, compared with 95% (95% confidence interval: 91% to 98%) after two doses in the Alpha period
- two doses reduced the risk of symptomatic infection more than one dose (21 days or more previously)
- there was no evidence that the reduction in risk of symptomatic infection from two doses (14 days or more previously) differed from that of previous natural infection

Figure 7: Two vaccination doses were more effective than one dose at preventing symptomatic infection during the Delta-dominant period

Modelled risk ratios of testing positive for COVID-19 by reported symptoms and COVID-19 vaccine exposure, when the Delta variant was dominant, UK, 17 May to 14 August 2021

Notes

1. Risk ratios are relative to the reference group: those not yet vaccinated or 21 days or more before vaccination without evidence of prior infection. The relative risk reduction is 1 - risk ratio.

2. Symptoms are self-reported and were not professionally diagnosed.

Download the data

Figure 8 shows the risk ratios for testing positive by vaccine exposure group, split by vaccine type and by whether symptoms were reported during the Delta-dominant period:

- two doses (14 days or more previously) of Pfizer-BioNTech reduced the risk of symptomatic infection by 83% (95% confidence interval: 79% to 86%), a greater risk reduction than two doses (14 days or more previously) of Oxford-AstraZeneca, which reduced the risk by 69% (95% confidence interval: 64% to 74%)

This analysis does not account for the time since the second vaccination. Because of the relationship between vaccine type and the timing of vaccine roll-out, care must be taken when comparing the effectiveness of Pfizer-BioNTech and Oxford-AstraZeneca vaccines because they differ in the amount of follow-up time post second vaccination. There are also differences in the age profile of individuals offered each vaccine type.

- two doses (14 days or more previously) of either vaccine provided a greater risk reduction than one dose (21 days or more previously)
- the protection afforded by two doses (14 days or more previously) of either vaccine against symptomatic infection did not differ from the protection afforded by previous natural infection

Figure 8: Pfizer-BioNTech and Oxford-AstraZeneca vaccines both provided a similar level of protection to previous natural infection against symptomatic infection during the Delta-dominant period

Modelled risk ratios of testing positive for COVID-19 by reported symptoms, COVID-19 vaccine exposure and vaccine type, when the Delta variant was dominant, UK, 17 May to 14 August 2021

Notes

1. Risk ratios are relative to the reference group: those not yet vaccinated or 21 days or more before vaccination without evidence of prior infection. The relative risk reduction is 1 - risk ratio.

2. Symptoms are self-reported and were not professionally diagnosed.

3. "PF" indicates the Pfizer-BioNTech vaccine and "AZ" indicates the Oxford-AstraZeneca vaccine.

Download the data

6 . Coronavirus (COVID-19) Infection Survey technical data

Impact of vaccination on testing positive in the UK
Dataset | Released 18 October 2021
Impact of vaccination on testing positive for the coronavirus (COVID-19) in the UK taken from the COVID-19 Infection Survey.

7 . Collaboration

The Coronavirus (COVID-19) Infection Survey analysis was produced by the Office for National Statistics (ONS) in partnership with the University of Oxford, the University of Manchester, Public Health England and Wellcome Trust. Of particular note are:

- Sarah Walker - University of Oxford, Nuffield Department for Medicine: Professor of Medical Statistics and Epidemiology and Study Chief Investigator
- the ONS COVID-19 Infection Survey analysis team - Heledd Thomas, Petya Kozhuharova, Emma Nash and Joy Preece
- the ONS COVID-19 Infection Survey dissemination team - Emma Bubb, Isabella Kisielowska, Eleanor Fordham and Jonathan Laszlo

8 . Glossary

Confidence interval

A confidence interval gives an indication of the degree of uncertainty of an estimate, showing the precision of a sample estimate. The 95% confidence intervals are calculated so that if we repeated the study many times, 95% of the time the true unknown value would lie between the lower and upper confidence limits. A wider interval indicates more uncertainty in the estimate. Overlapping confidence intervals indicate that there may not be a true difference between two estimates.

For more information, see our methodology page on statistical uncertainty.

Immortal time bias

"Immortal time" is a period of time where participants in the exposed group cannot experience the outcome. When immortal time is misclassified or not controlled for during analysis, immortal time bias leads to a biased association.

Pairwise comparisons

Pairwise comparisons are statistical tests used to determine whether there is evidence of differences between groups. This testing is a more robust method than comparing overlapping confidence intervals of the estimated probabilities.

Participant days at risk

An individual being classified as "at risk" reflects that it is possible for a test of theirs to be considered a new infection episode (as per our definition) if it turns out to be positive.

Risk ratio

A risk ratio, also called relative risk, compares the risk of a health event (for example, disease) among one group with the risk among another group. The groups of primary interest are labelled exposure groups, and the comparison group is labelled the reference group. When an exposure group has a risk ratio higher than one, this means that there is an increased risk compared with the reference group. When an exposure group has a risk ratio lower than one, this means that there is a decreased risk compared with the reference group. The relative risk reduction is 1 - risk ratio.

9 . Data sources and quality

In this article, we refer to the number of coronavirus (COVID-19) infections within the Coronavirus (COVID-19) Infection Survey (CIS). The survey includes individuals from the community population. Community in this instance refers to private residential households, and it excludes those in hospitals, care homes and/or other communal establishments in the UK.

More information on measuring the data and its strengths and limitations is available in the Coronavirus (COVID-19) Infection Survey statistical bulletin.

Our methodology article provides further information around the survey design, how we process data and how data are analysed.

Methods and technical information

This analysis builds on academic research conducted by our survey partners from Oxford University led by Professor Sarah Walker. You can see the article for this research. In this updated analysis, Poisson regression was used rather than logistic regression.

The logistic regression is based on CIS visits, the first visit in each new infection episode as the outcome and including swab-negative visits in the denominator (excluding visits after the first positive test in each new infection episode until a participant could be classified as having a new infection episode again). This means that any positives between monthly visits (with or without symptoms) cannot be included, meaning that power to detect effects of vaccination is lower because the models cannot exploit additional information on new infections from national testing programmes.

The updated analysis presented in this article uses Poisson modelling to address this limitation. The outcome is the first positive test in new infection episodes and the risk exposure is all days at risk from the latest 1 December 2020, or the first study test result, to 14 August 2021. Expanding from visits to days at risk allows us to use positive tests from the NHS Test and Trace programme for participants from England, improving the accuracy of the date of the first positive test in new infection episodes and including extra positive tests which are not present in CIS. This increases statistical power to detect effects of vaccination.

10 . Related links

Coronavirus (COVID-19) Infection Survey, UK
Bulletin | Updated weekly
Estimates for England, Wales, Northern Ireland and Scotland. This survey is being delivered in partnership with University of Oxford, University of Manchester, Public Health England and Wellcome Trust.

Coronavirus (COVID-19) Infection Survey: characteristics of people testing positive for COVID-19 in England
Bulletin | Updated fortnightly
Characteristics of people testing positive for COVID-19 from the Coronavirus (COVID-19) Infection Survey, including antibody data by UK country, and region and occupation for England. Antibodies data published before 3 February 2021 are available in this series.

Coronavirus (COVID-19) Infection Survey: antibody and vaccination data for the UK
Bulletin | Updated fortnightly
Antibody and vaccination data by UK country and English regions from the Coronavirus (COVID-19) Infection Survey. This survey is being delivered in partnership with the University of Oxford, University of Manchester, Public Health England and Wellcome Trust.

COVID-19 Infection Survey: methods and further information
Methodology article | Updated 24 August 2021
Information on the methods used to collect the data, process it, and calculate the statistics produced from the Coronavirus (COVID-19) Infection Survey.

Coronavirus (COVID-19) Infection Survey QMI
QMI | Released 16 July 2021
Quality and Methodology Information for the Coronavirus (COVID-19) Infection Survey (CIS), detailing the strengths and limitations of the data, methods used, and data and users.

Coronavirus (COVID-19) Infection Survey technical article: analysis of reinfections of COVID-19: June 2021
Technical article | Released 29 June 2021
Data about reinfections from the Coronavirus (COVID-19) Infection Survey. This analysis has been produced in partnership with the University of Oxford.

Coronavirus (COVID-19) Infection Survey technical article: analysis of positivity after vaccination
Technical article | Released 17 June 2021
Data about positivity after vaccination from the Coronavirus (COVID-19) Infection Survey. This analysis has been produced in partnership with the University of Oxford.