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Editorial

Beyond the pandemic: building forward better?

There comes a point in every disaster when the question arises as to what affected societies want to achieve from their recovery efforts. Do they return to the predisaster a priori situation? Alternatively, do they seek a different objective?

The pandemic has revealed and exacerbated the stark inequalities present within our societies. The poorest and most vulnerable members of our societies have been worst affected—those in low-paid insecure employment such as day labourers, those with disabilities, ethnic minorities, the homeless, migrants and refugees and many other inclusion health groups.[1] Indeed, the risks of infection and disease burden are increased in these socio-economically disadvantaged groups.[2] Some of this population vulnerability is explained by the prevalence of long-term health conditions and higher levels of overcrowded housing. In the UK, for example, areas with pre-existing higher levels of socio-economic deprivation have seen transmission of COVID-19 at higher rates than regions that are more affluent.[3]

Many of these determinants of population susceptibility to infection predate the pandemic such as poorer access to health care, lower levels of literacy, lack of health insurance, poor housing including multiple occupancy housing, riskier work environments and practices and the consequences of structural racism. Restoring societies to their prepandemic state may simply mean recreating the conditions that allowed the pandemic to flourish in the first place.

It may seem intuitive that affected societies would want to 'build back better', but is that what affected societies really want? What are the alternatives? Moreover, what compromises are they willing to make to achieve this? Paradoxically, affected communities may be unprepared to change behaviours and may wish to return to the familiar ways of living. Here is where greater dialogue between policymakers, public health and the public is required to try to establish a vision as to where society could and should go.

Much of the current discourse on building back better has been on recovering from the effects of the pandemic and restoring society back to a less vulnerable state. However, there is scope to consider a more ambitious goal to 'build forward better' and tackle a much broader remit. The UN has described pandemic recovery as 'an opportunity to address inequality, exclusion, gaps in social protection systems, the climate crisis and the many other fragilities and injustices that have been exposed'.[4] Others have called for the strengthening of public institutions that promote the rule of law, protection of human rights and the environment, as well as the pursuit of a more inclusive, greener and resilient future through domestic and global partnerships focused on sustainable development.[5,6] Such aspiration will require greater efforts to eradicate the socio-economic inequalities and wider determinants of health that exist in our societies, beyond just addressing health equity issues.

However, change comes at a cost and it is uncertain if governments and the public are prepared for what is required to be more pandemic resilient. In libertarian societies such as the US, Australia and UK, for example, there has been resistance to some of the more stringent public health measures such as vaccine certification or face covering mandates. In the UK, the government has adopted a policy position of leaving it up to individual choice as to whether public health measures were followed.[7] Unsurprisingly, adherence to the measures has plummeted in recent months which has coincided with a surge in case rates fuelled by the more infectious Delta variant.[8]

Changing population behaviour and norms is not easy at the best of times, as public health practitioners well know from decades of trying to shift public attitudes towards smoking, alcohol, obesity and other public health illness. Nevertheless, change is possible. It has to be deliberate. It requires persistence and continued pressure. The case for change also has to be clearly articulated, covering both the benefits and costs of doing so. The 'new normal' needs to be defined, advocated for and supported with appropriate policy measures.

However, what does this 'new normal' look like? Is it a future where the use of face coverings and social distancing is ubiquitous? Does it entail significant changes in how education is delivered with greater use of digital home learning? Will work practices change to include more remote working and less emphasis on 'presenteeism' that are common in many settings? Will health controls at borders be made more stringent? Will COVID-19 vaccinations become mandatory requirements for certain occupations? Do building design regulations need to change to meet higher ventilation requirements?

Some of the positive changes in the way health care is delivered, such as the greater use of digital and telehealth modalities, are probably here to stay. The pandemic has also shown the value of civil society organisations for augmenting the response, supporting and engaging local communities and addressing service gaps and marginalized groups.[9] More challenging to address are the wider societal issues such as housing, low-wage local economies and racism. There may also be some in society who remain disadvantaged by the 'new normal'. For example, the elderly, those with learning disabilities, the poor and ethnic minorities may disproportionately be affected by digital exclusion.[10]

At some point, the world will need to 'live with the virus'. At that point in time, the virus will be endemic, probably like its cousins, the other human coronaviruses, and manifest itself through seasonal epidemics. Population immunity, from either past infection or vaccination, will hopefully keep the health consequences, including mortality, down. However, we are not there yet and the pandemic has at least another year to run. Recovery may take years.

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Until then, as societies transition towards this endpoint, there is a window of opportunity to determine the destination and for governments to steer towards. Urgent dialogue is needed now.

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Short Communication

Breakthrough infections with the SARS-CoV-2 Delta variant: vaccinations halved transmission risk

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ABSTRACT

Objectives: The SARS-CoV-2 Delta variant (B.1.617.2) is associated with increased infectivity. Data on breakthrough SARS-CoV-2 Delta variant infections in vaccinated individuals and transmission risk are limited. The aim of this study was to provide estimates of transmission risk in Delta variant breakthrough infections.
Study design: A matched case-control study was performed.
Methods: To analyse onward transmission of fully vaccinated individuals infected with B.1.617.2, we compared 85 patients (vaccination group [VG]) with an age- and sex-matched unvaccinated control group (CG; $n = 85$).
Results: Transmission of B.1.617.2 was significantly reduced (halved) in the VG. The number of infected contacts to total number of contacts per infected person was 0.26 ± 0.40 in the VG vs 0.56 ± 0.45 in the CG ($P = .001$). Similarly, fully vaccinated contacts were less likely to be infected by fully vaccinated infected persons (IPs) than by unvaccinated IPs (20.0% vs 37.5%), although this association was not significant.
Conclusions: Fully vaccinated contacts had 50% less transmissions than unvaccinated individuals. These findings must be verified in larger sample populations, and it is especially important to investigate the role of vaccination status of close contacts.

Introduction

The SARS-CoV-2 Delta (B.1.617.2) variant of concern (VoC) has rapidly become the dominant variant in numerous countries and now accounts for more than 95% of cases in Germany.[1] It was first reported in India in early October 2020 and increasingly displaced other SARS-CoV-2 variants, such as Alpha (B.1.1.7), Beta (B.1.351) and Gamma (P.1). In addition to other authors, Liu et al.[2] identified the spike mutation P681R as a significant determinant for enhanced viral replication fitness of the Delta variant compared with the Alpha variant. Thus, the R0 (the initial reproduction number in an immune-naïve population) of the ancestral COVID-19 strain (wild type), the Alpha variant and the Delta variant were reported as 2.4–2.6, 4–5 and 5–8, respectively.[3]

Initial data show that (full) vaccination protects against infection with the Delta variant, but vaccine effectiveness seems to be reduced.[4] However, it is unclear whether complete vaccination influences onward transmission in the case of so-called breakthrough infections. Preliminary results found no difference in viral load between unvaccinated and vaccinated individuals with breakthrough infections.[5] In contrast, Chia et al. demonstrated that the viral load of B.1.617.2 decreased more rapidly in vaccinated than in unvaccinated infected individuals (preliminary data).[6] In terms of breakthrough B.1.617.2 infections after AstraZeneca vaccination, Chau et al. described asymptomatic or mild diseases, which were associated with higher cycle threshold (Ct) values, prolonged polymerase chain reaction (PCR) positivity and low levels of vaccine-induced neutralising antibodies.[7] However, the effect of vaccination

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is not only via neutralising antibodies but also cellular immunity. Thus, a robust T-cell response also correlates with clinical protection and is probably involved in immunity to COVID-19 even with a reduction in antibodies.[8]

Accurate assessment of breakthrough infections and the risk of ongoing transmission from vaccinated infected individuals to other (vaccinated) persons is essential in successfully fighting this pandemic. So far, however, no corresponding studies on vaccine-induced protection in terms of the Delta variant are available. To date, methods analysing onward transmissions or transmission risks have been highly respectively. Ct values are frequently used as a marker of infectivity, resp. viral load. Other possibilities are monitoring, cohort studies or the tracking of close contacts according to the legal regulations for the control of infectious diseases, as has been done by the German Public Health Departments on the basis of the Infection Protection Act. Close contact individuals in Germany are defined as those who had contact with an infected person (IP) for >10 min at <1.5 m, without face masks or direct physical contact, within a timeframe ranging from 2 days before symptom onset in the IP to 10–14 days after symptom onset.[9]

To analyse vaccine-induced protection in terms of Delta variant breakthrough infections, real-world data from the largest German public health department, which is based in Cologne, were used. Data for the transmission of B.1.617.2 infection to close contacts were compared between fully vaccinated IPs in the vaccination group (VG) and IPs in the unvaccinated control group (CG).

Methods

A total of 679 B.1.617.2 infections were reported to the public health department in Cologne between 19 April (occurrence of the first B.1.617.2 case) and 24 July 2021; 116 of these infections were in fully vaccinated individuals, defined as ≥14 days after receipt of all recommended COVID-19 vaccine doses.

Of the 116 fully vaccinated individuals, 47 had been vaccinated with Pfizer BNT162b2 (55.3%), three had been vaccinated with Moderna mRNA-1273 (3.5%), six had been vaccinated with Astra Zeneca AZD1222 (7.1%), 24 had been vaccinated with Johnson & Johnson Ad26.COV2.S (28.2%) and 5 had been vaccinated with a combination vaccine (5.9%). The last vaccination took place on average 56.8 ± 40.2 days before infection, with a range of 16–176 days.

From the 116 fully vaccinated individuals, only patients for whom complete contact tracing was possible were included ($n = 85$ [VG]). Individuals for whom complete contact tracing was not possible or who were incompletely vaccinated were excluded.

We selected a control population (CG) from the Cologne Health Department's registry. The CG included patients with PCR-confirmed COVID-19 during the same observation period who had not yet received any vaccination. Each patient in the VG was randomly matched 1:1 with a B.1.617.2-positive patient without vaccination (CG). Age and sex were chosen as matching criteria, as they may influence immune response on vaccination and transmissibility.

Data analyses

We considered the total number of contacts per IP and the total number of infected contacts per IP to determine the infected contacts relative to the total number of contacts per IP. In addition to descriptive statistics (age and sex), differences between VG and CG were assessed using an unpaired *t*-test or a chi-squared test. Linear regression (backwards elimination) was used to examine the influence of vaccination (yes = 0, no = 1), age (in years), sex (male = 1, female = 2), symptoms (present = 1, not present = 2) and vaccination interval (in days) on the number of infected contacts relative to the total number of contacts per IP. A *P* value below 0.05 was considered significant. All calculations were performed with SPSS version 27.0.

Results

In both the VG and CG, 45.9% were female. On average, vaccinated individuals were aged 35.8 ± 17.7 years; this did not differ from the CG (age: 34.8 ± 16.0 years). In the VG group, 138 close contacts (range per IP 0–9) were identified, compared with 95 close contacts in the CG (range per IP 0–7). The number of total and infected contacts, as well as the number of infected contacts in relation to the total number of contacts per IP, are shown in Table 1. There was a trend towards a higher number of total contacts per IP in the VG, but these contacts were significantly less infected. The total number of infected contacts per IP and the number of infected contacts in relation to the total number of contacts per IP were higher in the unvaccinated CG. The number of infected contacts in relation to the total number of contacts per IP increased in the unvaccinated group ($\beta = 0.350$; $P < .001$) and with age ($\beta = 0.454$; $P < .001$). This model was able to explain 30.8% (corr. R^2) of the variance. Sex, symptoms and vaccination interval (in days) were excluded in the final model (see table S1 in the supplementary material).

Of the 138 close contacts in the VC, 80 (58.0%) were fully vaccinated, whereas only 23 (24.2%) of 95 close contacts in the CG were fully vaccinated ($P < .001$; see Table 1). Fully vaccinated

Table 1
Total contacts, total infected contacts and relation to the total number per infected persons (IPs); total fully vaccinated contacts and infected fully vaccinated contacts in total and in relation to total number in vaccination group (VG) vs control group (CG).

Variable	Group (*n*)	Mean	Standard deviation	*P*-value[a]
Number of contacts per IP[b]	VG (85)	1.62	1.85	0.056
	CG (85)	1.12	1.57	
Number of infected contacts per IP[c]	VG (57)	0.47	0.76	0.001
	CG (42)	1.17	1.23	
Number of infected contacts to total number of contacts per IP[c]	VG (57)	0.26	0.40	0.001
	CG (42)	0.56	0.45	
Number of fully vaccinated contacts per IP	VG (57)	1.40	1.32	<0.001
	CG (42)	0.55	0.92	
Number of infected, fully vaccinated contacts per IP	VG (42)	0.38	0.62	0.270
	CG (15)	0.60	0.74	
Number of infected, fully vaccinated contacts in relation to total number of fully vaccinated contacts per IP	VG (38)	0.29	0.43	0.360
	CG (13)	0.41	0.48	

[a] Calculated with unpaired *t*-test.
[b] Persons who did not indicate close contacts were also integrated in order not to distort the number.
[c] Only taken into account if close contacts were indicated.

contacts in the VG had an infection rate of 20.0% ($n = 16$) compared with 37.5% ($n = 9$) in the CG. The total number of fully vaccinated contacts infected, and the total number of fully vaccinated contacts infected in relation to the total number of vaccinated contacts per IP did not differ significantly.

Discussion

Based on real-world studies, SARS-CoV-2 vaccines have reassuring safety and can effectively reduce fatal outcomes, severe cases, symptomatic cases and infections.[10] In addition, a follow-up of 6 months after the application of BNT162b2 showed a favourable safety profile, but with a gradual decline in efficacy.[11] However, few and inconsistent data exist regarding the transmission of the SARS-CoV-2 Delta variant between fully vaccinated individuals. Such knowledge is essential for the implementation of effective infection control measures. Most studies are currently looking at the occurrence of breakthrough infections and the clinical course. However, the results are very heterogeneous. Two studies reported substantially lower viral loads in BNT162b2-infected patients who were vaccinated compared with those who were not vaccinated.[12,13] In contrast, Ioannou et al. showed comparable viral loads among vaccinated and non-vaccinated healthcare workers infected with variant B.1.1.7, suggesting suboptimal protection of SARS-CoV-2 vaccines against new variants compared with wild-type SARS-CoV-2.[14]

Most studies focus on the risk of infection or infectivity, and little is known about the transmission risk of close contacts in terms of the SARS-CoV-2 Delta variant. Therefore, to our knowledge, this is the first study based on epidemiological data to investigate the ongoing transmission of B.1.617.2 from fully vaccinated IPs to close (vaccinated) contacts. The results of the present study show a significant reduction in transmission of more than 50% in vaccinated compared with unvaccinated IPs.

Similarly, fully vaccinated contacts were less likely to be infected by fully vaccinated IPs than by unvaccinated IPs (20.0% vs 37.5%), although this association was not significant.

Strength and limitations

A strength of this study is the systematic and complete recording of the data by the Cologne Public Health Department. IPs were digitally recorded and interviewed via telephone to determine the route of infection, symptoms and medical history, including vaccination. In each case, VoC analysis was carried out via PCR, provided that sufficient sample material was available. Accordingly, the proportion of B.1.617.2 infections was complete compared with other surveys, which often assume estimated values. In addition, all close contacts in Cologne were also tracked during quarantine, both digitally and by telephone. PCR testing was carried out when symptoms occur.

This study is limited by its small number of IPs and fully vaccinated close contacts. In addition, deviations in PCR tests and sequencing in various Cologne laboratories are possible because a unified method is not present. Although the ct values were recorded, they were only available at one test time in IPs; therefore, ct values were not taken into account in the context of this analysis and among new variants.

Conclusions

In conclusion, fully vaccinated individuals who are infected with B.1.617.2 can transmit the infection to close contacts; however, they had a >50% reduced transmission rate compared with the unvaccinated CG. These findings must now be verified in larger sample populations. It will be especially important to investigate the role of vaccination status of close contacts and to also consider the decreased efficacy of the vaccine over time.

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Appendix A. Supplementary data

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Original Research

College reopening and community spread of COVID-19 in the United States

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ABSTRACT

Objective: After months of lockdown due to the COVID-19 outbreak, the US postsecondary institutions implemented different instruction approaches to bring their students back for the Fall 2020 semester. Given public health concerns with reopening campuses, the study evaluated the impact of Fall 2020 college reopenings on COVID-19 transmission within the 632 US university counties.
Study design: This was a retrospective and observational study.
Methods: Bayesian Structural Time Series (BSTS) models were conducted to investigate the county-level COVID-19 case increases during the first 21 days of Fall 2020. The case increase for each county was estimated by comparing the observed time series (actual daily cases after school reopening) to the BSTS counterfactual time series (predictive daily cases if not reopening during the same time frame). We then used multilevel models to examine the associations between opening approaches (in-person, online, and hybrid) and county-level COVID-19 case increases within 21 and 42 days after classes began. The multigroup comparison between mask and non-mask-required states for these associations were also performed, given that the statewide guidelines might moderate the effects of college opening approaches.
Results: More than 80% of our university county sample did not experience a significant case increase in Fall 2020. There were no significant relationships between opening approaches and community transmission in both mask-required and non-mask-required states. Only small metropolitan counties and counties with a non-community college or a higher percentage of student population showed significantly positive associations with the case number increase within the first 21-day period of Fall 2020. For the longer 42-day period, the counties with a higher percentage of the student population showed a significant case increase.
Conclusion: The overall findings underscored the outcomes of US higher education reopening efforts when the vaccines were still under development in Fall 2020. For individual county results, we invite the college- and county-level decision-makers to interpret their results using our web application.
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Introduction

The COVID-19 pandemic has severely disrupted the functioning of global postsecondary institutions since 2020. In late March 2020, more than 1300 colleges and universities in the United States suspended in-person classes and closed campuses,[1] resulting in many students moving back to their hometowns to complete their coursework remotely. After months of lockdown, institutions started implementing different instruction approaches (in-person, online, and hybrid) to bring their students back for the Fall 2020 semester. At the same time, it also concerns that college campuses could potentially become COVID-19 spreaders for the community.[2] The present study aimed to evaluate the causal effect of college reopening on county-level COVID-19 cases for Fall 2020. This study provides one of the first national evidence on whether and to what extent the US higher education reopening efforts could prevent disease spread and the occurrence of an outbreak without any vaccine.

The US Centers for Disease Control and Prevention (CDC) found the links between large institution openings and COVID-19 community incidence.[3] Their research findings through a Difference-in-Difference (DD) analysis indicated that in comparison with the 21-day periods before and after the Fall 2020 semester started,

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counties with large universities with online instruction (n = 22) experienced a decrease in COVID-19 incidence, whereas those with in-person instruction (n = 79) experienced an increase in confirmed cases. However, little attention has been paid to the investigations on hybrid instruction and other sized institutions. In addition, studies have shown days from symptom onset to diagnosis could be up to 42 days.[4,5] It is also necessary to investigate the college opening impacts within a 42-day time frame.[6]

Building on the US CDC research, this study used Bayesian Structural Time Series (BSTS) models to evaluate the causal effects of Fall 2020 college reopenings on the county-level COVID-19 cases in 632 US counties (approximately 20% of the US counties) and examined the associations between opening approaches (in-person, online, and hybrid) and county-level incidence within the first 21- and 42-day period after the Fall 2020 classes began. Importantly, compared with the classical DD designs testing the difference before and after the intervention, BSTS is a machine learning approach to investigating a causal effect evolving over time.[7] This approach has started being applied in analyzing the casual impact of lockdown during the COVID-19 outbreak around the world.[8]

Methods

Data

The data for this study include the US county-level daily COVID-19 confirm cases (data version: January 29, 2021),[9] university's Fall 2020 reopening date (collected from each university website in December 2020 and January 2021), university's Fall 2020 opening approach (Data version: November 10, 2020),[1,10] university types,[1,10,11] university's enrollment in 2018 (most recent data),[12] county urban–rural classification,[13] and state-level mask requirements (August to September 2020).[14]

Study population

The population of this study is US counties that have higher education institutions. Among 3006 US counties,[15] only 1265 counties have at least one university or college.[1,10] Our study sample was selected from these 1265 counties based on the following steps. First, to avoid the interference of multiple college opening approaches (e.g. different instruction types and different first days of classes) within a county in examining a college opening effect, we only selected the counties with only one college or university (n = 733). Second, among these 733 institutions, we only included those institutions (n = 693) whose opening approach in Fall 2020 was clearly specified as in-person, online, or hybrid.[1,10] Third, if the effects estimated through BSTS models are identified as extreme values in a stem-and-leaf plot, these outliers will be excluded from the study sample. The final analytic sample ended up with 632 US counties.

Estimating a college opening effect

A BSTS model was performed in each county to investigate the causal effect of college reopening by comparing the observed time series (i.e. daily COVID-19 cases within 21 days after classes began) to the counterfactual time series (daily COVID-19 cases during the same period under the scenario of "if the college or university did not reopen"). The novel part is the simulation of the counterfactual time series using a large set of potential predictors (i.e. spike-and-slab prior). These predictors consisted of a set of time series of daily confirmed cases since January 22, 2020, from the other non-university counties in each state. As demonstrated in Fig. 1, the simulated predictions fit the actual cases before the Fall 2020 classes started. Within 21 days after classes began, the discrepancy between observed data and counterfactual predictions is an estimated college opening effect in the county. The college opening effect can be quantified by the average relative effect: (21-day cumulative actual cases − 21-day cumulative predictive cases)/|21-day cumulative predictive cases|. This value suggests the actual percentage increase of county-level cases when opening a college in a given county compared with a counterfactual scenario (i.e. no college opening in the same county). A positive effect implies a case increase within the county during the first 21-day school reopening, whereas a negative effect stands for a case decrease. Ninety-five percent Bayesian posterior probability intervals would help identify the significance of the school opening effect. A web application was developed to display each of the county results. The web application, quick start guide, and our county sample may be accessed on https://sites.google.com/view/collegereopening.

Analytic strategies

A total of 632 BSTS models for 632 US counties were conducted. Each model was estimated using 10,000 Markov chain Monte Carlo samples in *R*.[16] The descriptive results for college opening effects in the first 21 days of Fall 2020 are plotted in Fig. 2 and presented in Table 1. Given the nested data structure (counties clustered within states), we used multilevel models to examine the associations between opening approaches (in-person, hybrid, and online) and county-level COVID-19 case increases (i.e. the college opening effect estimated from the BSTS models) within 21 and 42 days after classes began, controlling for the covariates including statewide public mask requirements in August and September 2020 (mask-required states/non-mask-required states), university sector (private/public), community college, college enrollment, percentage of college student population in a county, and county-rural classification.[3] Additional multigroup chi-square difference tests between mask and non-mask-required states for these associations were also performed, given that the statewide guidelines might moderate the effects of college opening approaches.

Results

County-level COVID-19 infection during the first 21 days of Fall 2020

Fig. 2 shows the college opening effect within the first 21 days of the Fall 2020 semester in each county. Each of these effects was estimated through a BSTS model, indicating the actual percentage increase of county-level cases when opening a college in a county, compared with a counterfactual scenario (i.e. no college opening in the same county). Counties filled in red indicate that the college openings in these counties might bring more COVID-19 confirmed cases, whereas counties in green show that the COVID-19 cases might be less than expected. Blue county means that the county's case number did not show a significant change. Overall, as shown in Table 1, 18% of counties (114/632) showed an 85.3% case increase within the first 21 days, whereas 21% of counties (133/632) showed a 50.3% case decrease during the first 21 days of Fall 2020. No significant case changes were found in the remaining 61% of counties (385/632).

Table 1 also reveals the descriptive results for college opening effects by statewide public mask requirements, opening approaches, university sector, community college, college enrollment, percentage of the college student population within a county, and urban–rural classification. On average, counties in non-mask-required states showed a 12.7% increase in the case number, which was higher than the counties in mask-required states (1.6%). Counties with in-person college opening approaches showed a 10.2% increase in the case number, which was higher than the online (2.2%) and hybrid (−0.9%) approaches. Counties with private and public institutions showed

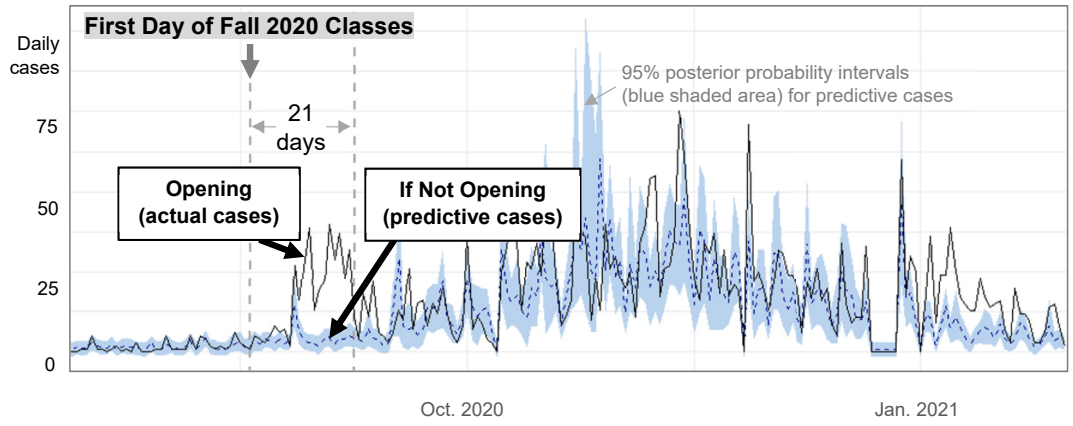

Fig. 1. Causal effect of a college reopening on COVID-19 case increase in an example county.

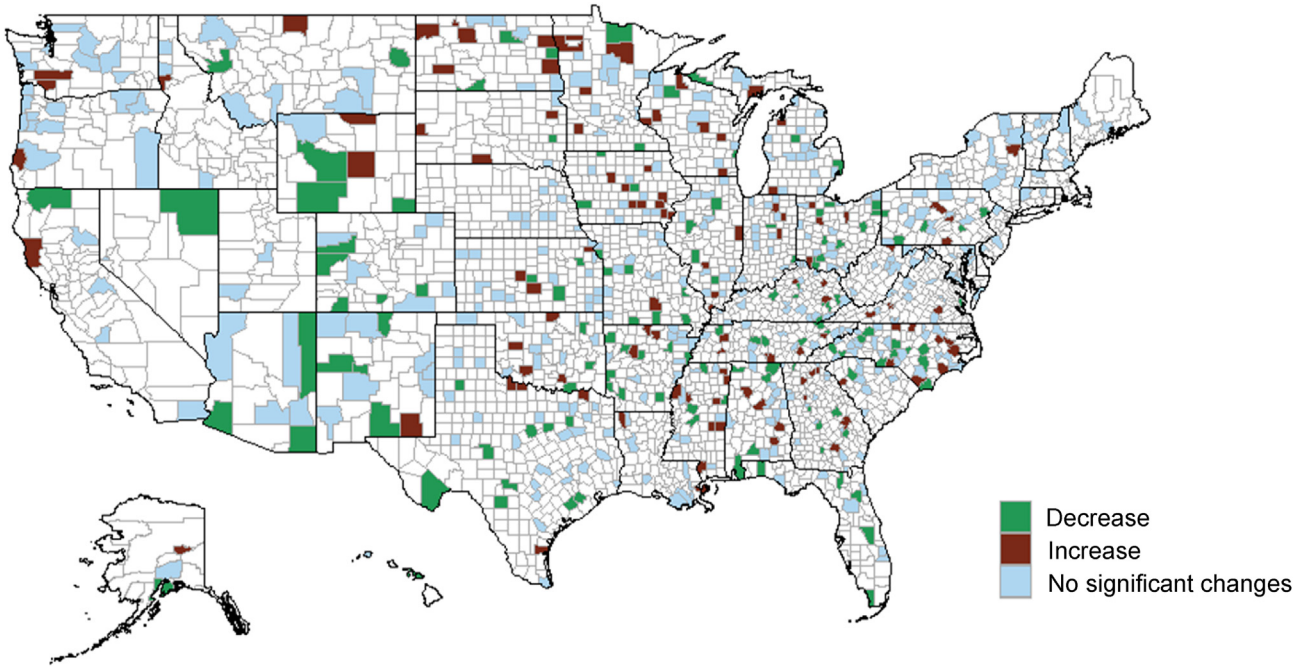

Fig. 2. County-level COVID-19 infection during the first 21 days of Fall 2020 semester. *Note.* Blank counties were excluded from our study, given the criteria of sample selection.

4.1% and 5.0% increases in the case number, respectively. Counties with community colleges showed a 1.5% decrease; however, the remaining counties with non-community colleges showed a 10.4% case increase. Counties with a larger college (enrollment ≥5000) showed a 9.8% case increase, and counties with a small-size institution (enrollment <5000) showed a 3.2% case increase. Similarly, for counties with a larger student population (>10% of total county population), the total confirmed cases increased about 12.1%, which was higher than the remaining counties' 2.1% case increase. The results also showed COVID-19 cases decreased in large metropolitan counties (−7.5% to −16.6%), but cases increased in medium metropolitan counties (2.9%), small metropolitan counties (15.4%), micropolitan counties (8.2%), and non-core counties (1.1%).

Associations between college opening approaches and county-level case increases

Multilevel analyses (Table 2) indicated weak associations between the college opening approaches and county-level case increases in the first 21 and 42 days of the Fall 2021 semester. The outcome, county-level case increase (i.e. college opening effect estimated through BSTS), was the actual percentage increase of county-level cases when opening a college in a county, compared with a counterfactual scenario (i.e. no college opening in the same county). For the first 21-day period, model 1 revealed that the in-person opening approach showed a marginally significant tendency ($P = .085$) toward a higher COVID-19 case increase than the online opening approach. After controlling for the state-level mask requirements and other county-level covariates, the in-person instruction mode was still not significant in Model 2. Instead, we found that small metropolitan counties and counties with a non-community college or a higher percentage of student population showed a significant case number increase. All the county-level variables could account for 4.6% (small effect) of the variance in county-level case number increase. There were no significant differences between hybrid and online opening approaches in models 1 and 2. For a longer term 42 days, there were also no significant differences between in-person, hybrid, and online approaches in models 3 and 4. The results showed that the county-level case increase within the 42 days was significantly found in those counties

Table 1
County-level COVID-19 infection within the first 21 days of Fall 2020 semester.

County characteristics	N (%)	Average effect
All counties	632 (100%)	4.7%
Case decrease	133 (21%)	−50.3%
Case increase	114 (18%)	85.3%
No significant changes	385 (61%)	−0.1%
Statewide public mask requirements		
Required	453 (72%)	1.6%
Not required	179 (28%)	12.7%
Opening approaches		
In person	257 (41%)	10.2%
Hybrid	148 (23%)	−0.9%
Online	227 (36%)	2.2%
Sector		
Private	165 (26%)	4.1%
Public	467 (74%)	5.0%
Community college		
Community	301 (48%)	−1.5%
Non-comm.	331 (52%)	10.4%
Enrollment		
<5000	486 (77%)	3.2%
≥5000	146 (23%)	9.8%
Percentage of student population		
<10%	468 (74%)	2.1%
≥10%	164 (26%)	12.1%
Urban–rural classification		
Large central metro	2 (0%)	−16.6%
Large fringe metro	90 (14%)	−7.5%
Medium metro	63 (10%)	2.9%
Small metro	92 (15%)	15.4%
Micropolitan	236 (37%)	8.2%
Noncore	149 (24%)	1.1%

Note. N = number of counties. % = the percentage of counties in 632 counties. No significant changes = the 95% posterior probability interval of the college opening effect includes zero. Non-comm. = non-community college.

with a higher percentage of student population, which could explain 2.9% (small effect) of variance.

Table 3 further indicated the association between college opening approaches and county-level case increase by statewide public mask requirements. There were no significant associations ($P < .05$) between college opening approaches and COVID-19 case increase within the communities in both mask and non-mask-required states. The percentage of student population in non-mask-required state counties might positively predict the county-level case increase within the first 21 days. The multigroup comparison tests summarized no significant differences between mask and non-mask-required states in their group-specific parameter estimates within the first 21 and 42 days of the Fall 2021 semester. In other words, the estimated effects shown in Table 3 did not significantly vary by the statewide public mask requirements.

Discussion

The public health concerns about school closures and reopenings during the pandemic are continually discussed.[2,3,17–19] The present study evaluated the impact of college reopenings in Fall 2020 on COVID-19 transmission within the 632 university counties in the United States. We found that 18% of these counties had a significant case increase during the first 21 days of the Fall 2020 semester. These counties showed an 85% case increase on average, compared with the counterfactual scenario if not reopening the campus in these counties. We discovered some case increase patterns in non-mask-required states, small metropolitan counties, micropolitan counties, counties with an in-person college reopening, a non-community college, a large enrollment size institution, or a higher percentage of the student

Table 2
Associations between college opening approaches and county-level COVID-19 case increase.

Independent variable	21 days after classes began		42 days after classes began	
	Model 1	Model 2	Model 3	Model 4
Fixed effects				
State level				
Mask required[a]		−.09 (.06)		.004 (.06)
County level				
Opening approaches[b]				
In person	.09 (.05) †	.08 (.05)	.09 (.06)	.08 (.06)
Hybrid	−.02 (.06)	−.03 (.06)	.01 (.07)	.01 (.07)
Covariates				
Private[c]		−.05 (.06)		−.01 (.08)
Community college[d]		−.12 (.05) *		−.07 (.06)
Enrollment (per 1000)[e]		−.001 (.01)		.003 (.01)
Percentage of student population[e]		.76 (.26) **		.78 (.33) *
Urban–rural level[f]				
Large metro[g]		−.02 (.08)		−.12 (.09)
Medium metro		.07 (.08)		−.03 (.10)
Small metro		.17 (.08) *		.05 (.09)
Micropolitan		.10 (.06) †		−.03 (.07)
Intercept	.02 (.04)	.03 (.09)	.07 (.04)	.058 (.088)
R^2 (county level)	0.7% (.007)	5.3% (.018) **	0.4% (.005)	3.3% (.014) *
R^2 change (county level)		4.6%		2.9%
Random variance components				
Intercept (τ_{00})	.01 (.01)	.01 (.01)	.003 (.01)	.004 (.01)
σ^2	.29 (.02) ***	28 (.02) ***	.42 (.03) ***	.41 (.02) ***

Note. Model 1 and Model 3 included the opening approach variables. The state-level mask requirement and county-level covariates were added further in Model 2 and Model 4. Values are unstandardized estimates and standard errors (in parentheses).
†$P < .10$,*$P < .05$, **$P < .01$,***$P < .001$.
[a] Reference group: not required.
[b] Reference group: online.
[c] Reference group: public.
[d] Reference group: non-community college.
[e] Continuous variable.
[f] Reference group: non-core.
[g] This category includes large central metros and large fringe metros because only two counties are large central metros.

Table 3
Associations between college opening approaches and county-level COVID-19 case increase by statewide public mask requirements.

Independent variable	21 days after classes began		42 days after classes began	
	Mask-required states	Non-mask-required states	Mask-required states	Non-mask-required states
Fixed effects				
County level				
Opening approaches[a]				
In person	.03 (.06)	.20 (.11) †	.04 (.08)	.16 (.12)
Hybrid	−.01 (.07)	−.04 (.12)	.05 (.08)	−.07 (.14)
Covariates				
Private[b]	−.11 (.08)	.10 (.13)	−.04 (.09)	.03 (.11)
Community college[c]	−.11 (.07) †	−.12 (.11)	−.03 (.07)	−.18 (.11)
Enrollment (per 1000)[d]	−.002 (.01)	.01 (.01)	.01 (.01)	−.01 (.01)
Percentage of student population[d]	.59 (.32) †	.99 (.44) *	.62 (.38)	1.03 (.62)
Urban–rural level[e]				
Large metro[f]	.02 (.09)	−.11 (.16)	−.16 (.11)	.03 (.18)
Medium metro	.11 (.10)	−.09 (.17)	−.002 (.11)	−.16 (.20)
Small metro	.14 (.09)	.21 (.14)	.05 (.11)	.08 (.17)
Micropolitan	.12 (.07) †	.07 (.11)	−.08 (.08)	.11 (.13)
Intercept	−.03 (.08)	−.11 (.17)	.07 (.10)	.02 (.20)
R-square (county level)	3.3% (.02) †	15.3% (.05) **	3.3% (.02) *	9.9% (.04) *
Random variance components				
Intercept (τ_{00})	.01 (.01)	.01 (.02)	.004 (.01)	.001 (.03)
σ^2	.27 (.02) ***	.29 (.03) ***	.41 (.03) ***	.37 (.04) ***
Multigroup comparison[g]				
Chi-squared (*df*)	12.55 (10)		12.37 (10)	

Note. Values are unstandardized estimates and standard errors (in parentheses).
†$P < .10$,*$P < .05$,**$P < .01$,***$P < .001$.
[a] Reference group: online.
[b] Reference group: public.
[c] Reference group: non-community college.
[d] Continuous variable.
[e] Reference group: non-core.
[f] This category includes large central metros and large fringe metros.
[g] Difference test between mask and non-mask-required states.

population. The multilevel models revealed that only small metropolitan counties and counties with a non-community college or a higher percentage of student population showed significantly positive associations with the case number increase within the first 21-day period. For the longer 42 days after Fall 2020 began, we only found the link between the counties with a higher percentage of the student population and the county-level case increase.

Although recent studies indicated in-person opening approach increased the risk of COVID-19 spread within communities for some of the large-size universities,[2,3] our study did not find a significant association between the instruction type and case increase in the 632 diverse US university counties, even controlling for other county-level covariates and state-level public mask requirements. The multigroup comparison results indicated our findings were consistent in both mask and non-mask-required states. As higher education institutions developed campus reopening plans (e.g. COVID-19 testing, mask mandates, social distancing, etc.) based on the CDC and local government guideline,[20,21] it is not a surprise to see there were no significant differences among in-person, hybrid, and online approaches in community transmission. Especially, 82% of the 632 university counties did not show a significant community spread of COVID-19. These findings underscored the reopening efforts and outcomes of US higher education institutions when the vaccines were still under development in Fall 2020.

As expected, given a large number of college students moving back from their hometowns in Fall 2020, the potential virus spread was more likely to happen in small metropolitans and counties with a higher percentage of the student population or a non-community college. Although we found these significant associations, these factors only showed small effects on the county-level COVID-19 case increase. There might be other factors and different contexts in each county that could potentially boost the case number during the campus opening. We invite the US college-level and county-level decision-makers to interpret their college opening effects and outcomes using our web application (https://sites.google.com/view/collegereopening). This web application includes all the 1265 US counties with at least one university or college. One can select their state and county, college opening date in Fall 2020, and the days after the semester started to run a BSTS model and test if the actual case number is higher than the counterfactual predictive case number within the selected period.

There are some limitations to our study. First, our study relied on the public use data. Some covariates (e.g. the testing rate in each county before the semester started) that were not publicly accessible might be omitted. Although we could not include all possible covariates in the models, we still did not find a significant linkage between college opening approaches (in-person, hybrid, and online) and community transmissions. Second, our study sample was the 632 US counties with only one higher education institution. The findings might not be able to generalize to the US counties with multiple colleges. Third, this study provides macro trends and insights based on the evidence collected from these 632 counties, but we could not interpret individual county results. Only the county-level and college-level decision-makers with contextual data (e.g. county-level public health policy, local/residential case outbreak, college reopening plan implementation, etc.) could explain their BSTS results. Future studies could investigate the best practice of college openings during the pandemic by qualitatively and quantitatively linking the prevention plan and community transmission.

Despite these limitations, this study makes several methodological and practical contributions to public health, higher education, and crisis response literature. At the methodological level, this study is one of the first to analyze the linkage between college

openings and county-level COVID-19 confirmed cases with a large-scale US county sample. Our findings have greater generalizability than the prior studies with smaller sample sizes.[2,3] More importantly, compared with CDC's DD design,[3] our study using the BSTS models demonstrated methodological advantages in examining the evolution of a causal effect over time.[7] At the practical level, our empirical evidence showed only 18% of 632 US counties experienced a COVID-19 case increase during the first 21 days of Fall 2020. There was also no significant association between the in-person opening approach and the community spread of COVID-19 in both mask and non-mask-required states. These findings highlight the college reopening efforts in Fall 2020, which could potentially reduce the risk of disease spread without any vaccine.

Conclusion

This study found that 82% of US university counties did not experience a significant increase in county-level COVID-19 cases during the first 21 days of Fall 2020. Although the virus was more likely to spread within the small metropolitan counties and the counties with a higher percentage of student population or a non-community college, there were no significant relationships between opening approaches (in-person, online, and hybrid) and community transmission in both mask and non-mask-required states. The findings showed the outcomes of US higher education reopening efforts when the vaccines were still under development in Fall 2020.

Author statements

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Ethical approval

This study is an analysis of secondary data and therefore does not require ethical approval.

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Competing interests

None declared.

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Short Communication

Decreased risk of COVID-19 pneumonia in children and adolescents during the Delta variant emergence

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ABSTRACT

Objectives: This study aimed to evaluate factors associated with the risk of COVID-19 pneumonia in children (aged <10 years) and adolescents (aged 10–19 years) before (March 2020–April 2021) and during (May–July 2021) the Delta (B.1.617.2) variant emergence.
Study design: A retrospective and nationwide cohort study was conducted in Mexico.
Methods: Data from 26,961 laboratory-confirmed cases of COVID-19 were analyzed. Risk ratios (RRs) and 95% confidence intervals (CIs) were used to evaluate the association of the evaluated exposures with the risk of COVID-19 pneumonia.
Results: The overall incidence rate of pneumonia was 23.0 per 10,000 person-days, and it was lower during the Delta variant emergence (30.3 vs. 9.4 person-days, $p < 0.001$). In multiple analysis, a decreased risk of pneumonia was observed among those cases occurring in May 2021 or later (vs. March 2020–April 2021, RR = 0.98, 95% CI 0.97–0.99) and among older patients ($RR_{per\ year} = 0.998$, 95% CI 0.996–0.998). Other comorbidities (namely, obesity, chronic kidney disease, diabetes mellitus, immunosuppression, or malignant tumors) were associated with an increased risk of severe COVID-19 manifestations.
Conclusions: Our findings suggest that during the Delta variant emergence, children and adolescent patients were at reduced risk of COVID-19 pneumonia in Mexico. Further research is needed to identify factors determining the observed scenario.

Background

The severe acute respiratory syndrome coronavirus-2 (SARS-COV-2) Delta variant (B.1.617.2), given its accelerated spread and reduced sensitivity to antibody neutralization, has become the dominant strain in many regions of the world including North America.[1,2] In Mexico, the Delta variant was first isolated in April 2021. Shortly after, persistently increasing trends symptomatic infections have been observed across the country.

The COVID-19 vaccination in Mexican younger adults (aged 18–29 years) started in the second half of July 2021, and by September 2021, the vaccine is not being offered for persons aged < 18 years. Therefore, concerns over rising coronavirus disease 2019 (COVID-19) cases related to the Delta variant in children and

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adolescent patients have emerged. This study aimed to evaluate factors associated with the risk of COVID-19 pneumonia in children and adolescents before and during the Delta variant emergence.

Methods

We performed a nationwide cohort study in Mexico, and a broader description of research methods was previously published.[3] Children (aged <10 years) and adolescents (aged 10–19 years) with laboratory-positive (reverse transcription-polymerase chain reaction or rapid antigen-based test) COVID-19, from March 2020 to July 2021, were eligible. Asymptomatic cases were excluded. The medical units where the patients received care are public facilities and belong to the Mexican Institute of Social Security (IMSS, the Spanish acronym).

Pneumonia was the main binary outcome, and it was defined by clinical (fever or chills, cough, shortness of breath, and tachypnea) and radiographic findings (ground glass patterns in X-ray or computed tomography scanning)[4] that required hospital admission. Clinical and epidemiological data of interest were collected from clinical files and death certificates, if applicable. Enrolled patients were classified according to the date of symptoms onset since those occurring during May 2021 or later were more likely to be related to the Delta strain.

We used risk ratios (RRs) and 95% confidence intervals (CIs), computed through generalized linear regression models, to evaluate the association of the evaluated expositions with the risk of COVID-19 pneumonia in children and adolescents. This study was approved by the Local Health Research Committee of the IMSS (approval R-601-2020-015).

Results

Data from 26,961 COVID-19 patients were analyzed for a total follow-up of 297,099 person-days. The overall incidence rate of pneumonia was 23.0 per 10,000 person-days, and it was lower during the Delta variant emergence (30.3 vs. 9.4 per 10,000 person-days, $p < 0.001$). The number of analyzed cases according to the date of symptoms onset and the proportion of pneumonia cases are presented as Supplementary data 1. None of the enrolled subjects had received any dose of any COVID-19 vaccine.

The characteristics of analyzed patients for selected variables are presented as Supplementary data 2. Children and adolescents with pneumonia, and when compared with those with non-severe manifestations, were younger and were more likely to have occurred before May 2021 and to present any comorbidity (namely obesity, diabetes mellitus, arterial hypertension, immunosuppression (due to any cause excepting diabetes), chronic kidney diseases, and malignant tumors at any site).

In multiple regression analysis (Table 1), we observed a decreased risk of pneumonia among older patients (reference: <1 year old; 1–4, RR = 0.95, 95% CI 0.94–0.97; 5–9 years old, RR = 0.94, 95% CI 0.93–0.95; 10–19 years old, RR = 0.93, 95% CI 0.92–0.94), in patients with symptoms onset from May to July 2021 (RR = 0.98, 95% CI 0.97–0.99) and among patients with personal history of arterial hypertension (RR = 0.97, 95% CI 0.94–0.99).

Table 1
Predictors of COVID-19 pneumonia in children and teenagers, Mexico 2020–2021.

Characteristic	RR (95% CI), *p*					
	Bivariate analysis			Multiple analysis		
Gender						
Female	1.00			1.00		
Male	1.01	(0.99–1.02)	0.213	1.01	(0.99–1.02)	0.369
Age (years)						
<1	1.00			1.00		
1–4	0.95	(0.94–0.96)	<0.001	0.95	(0.94–0.97)	<0.001
5–9	0.95	(0.94–0.96)	<0.001	0.94	(0.93–0.95)	<0.001
10–19	0.93	(0.92–0.94)	<0.001	0.93	(0.92–0.94)	<0.001
Date of symptoms onset						
March 2020 to April 2021	1.00			1.00		
May 2021 to July 2021	0.98	(0.97–0.98)	<0.001	0.98	(0.97–0.99)	<0.001
Personal history of:						
Obesity						
No	1.00			1.00		
Yes	1.03	(1.02–1.04)	<0.001	1.03	(1.02–1.04)	<0.001
Diabetes mellitus						
No	1.00			1.00		
Yes	1.10	(1.06–1.14)	<0.001	1.09	(1.06–1.13)	<0.001
Arterial hypertension						
No	1.00			1.00		
Yes	1.03	(1.01–1.06)	0.033	0.97	(0.94–0.99)	0.027
Immunosuppression						
No	1.00			1.00		
Yes	1.22	(1.17–1.26)	<0.001	1.16	(1.12–1.21)	<0.001
CKD						
No	1.00			1.00		
Yes	1.27	(1.23–1.31)	<0.001	1.27	(1.23–1.31)	<0.001
Asthma						
No	1.00			1.00		
Yes	1.02	(0.99–1.04)	0.060	1.01	(0.99–1.03)	0.114
Malignant tumor						
No	1.00			1.00		
Yes	1.13	(1.09–1.17)	<0.001	1.07	(1.03–1.11)	<0.001

RR, risk ratio; CI, confidence interval; CKD, chronic kidney disease.
Notes: (1) Generalized linear regression models were used to obtain RR and 95% CI; (2) Multiple regression coefficients were adjusted by variables listed in the table; (3) Immunosuppression referred to any cause of the related deficiency except for diabetes mellitus or renal impairment; (4) Malignant tumor referred to any cancer at any site.

The COVID-19 patients with a previous diagnosis of chronic kidney disease had a 27% increase in the risk of pneumonia (RR = 1.27, 95% CI 1.23–1.31). Other factors associated with a slightly increased risk of severe disease were obesity, diabetes mellitus, immunosuppression, and malignant tumors.

Discussion

Our study characterized factors associated with the risk of COVID-19 pneumonia in children and adolescents before and during the Delta variant emergence in Mexico, where the related economic and social burden of the disease has been high. The presented results suggest that even when an increased incidence of symptomatic infections was observed during the Delta emergence, the COVID-19 cases in children and teenagers were more likely to be non-severe, and a reduced risk of pneumonia was documented.

We also observed a reduced risk of pneumonia in older patients ($RR_{per\ year} = 0.998$, 95% CI 0.996–0.998), and infants (aged <1 year) were at higher risk of developing severe manifestations. Similar findings had been previously published.[5] Despite this later, no significant differences ($p = 0.563$) were observed in our study in the age-stratified risk of a fatal outcome among patients with COVID-19 pneumonia (<1 year, 20.6%; 1–4 years, 23.3%; 5–9 years, 14.9%; and 10–19 years, 19.0%).

Children and teenagers with a personal history of arterial hypertension seemed to have a reduced risk of pneumonia (RR = 0.97, 95% CI 0.94–0.99). Unfortunately, we were unable to determine if they were receiving any specific antihypertensive drugs such as calcium channel blockers that have been associated with a reduction of fatal outcomes among COVID-19 patients.[6]

Renal impairment was related to the highest increase in the risk of severe manifestations in the study sample. Pediatric patients with chronic kidney disease also had a 2-fold increase in the risk of dying (9.2% vs. 4.6%, $p = 0.079$).

Children and teenagers with obesity also were at greater risk of pneumonia. This was observed despite the low prevalence of obesity in the study sample (4.7%) when compared with the national mean (35.6%).[6] According to normative standards of Mexico, the World Health Organization body mass index-for-age charts must be used in pediatric patients to assess their nutritional status. However, the obesity variable was collected as a binary exposure (yes/no), and we were unable to verify if the standards were strictly followed.

The limitation of our study must be discussed. First, the observed reduced risk of COVID-19 pneumonia in the analyzed children and adolescents may not be fully attributed to the prevalent Delta variant, and other determinants may be involved. However, all the analyzed subjects were unvaccinated for COVID-19, and no major changes in the available treatments were observed during the study period. Besides and in a real-world scenario, none of the available treatments for COVID-19 pneumonia has shown to be effective in reducing the all-cause mortality in Mexico.[7]

Second, the prevalence of arterial hypertension in the study sample was low (0.4%), and, even when a reduced risk of pneumonia was documented among them, we are unable to conclude that these patients were at reduced risk of severe COVID-19 because of its cardiovascular condition. Third, data regarding the comorbidities of the participants were collected from medical records as dichotomous variables (yes/no). Additional information such as elapsed time since diagnosis and current treatment would have enriched our study. And fourth, we did not analyze other relevant outcomes (i.e. pediatric inflammatory multisystem syndrome temporally associated with COVID-19 or PIMS-TS)[8] that might have occurred in the participants.

Conclusions

Our findings suggest that during the Delta variant emergence in Mexico, children and adolescents were at reduced risk of COVID-19 pneumonia. However, non-adult patients play a major role in the spread of respiratory pathogens, and efforts focusing on the prevention of infections in these patients may have a favorable impact on other age groups.

Author statements

Ethical approval

This study was approved by the Local Health Research Committee 601 of the Mexican Institute of Social Security (approval R-601-2020-015).

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Competing interests

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2021.12.017.

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Original Research

Depression and anxiety symptoms remained elevated after 10 months of the COVID-19 pandemic in southern Brazil: findings from the PAMPA cohort

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ABSTRACT

Objectives: This study aimed to examine the changes in depression and anxiety symptoms among Brazilian adults over 10 months of the COVID-19 pandemic.

Study design/Methods: The present study used data from wave 1 (June/July 2020) and wave 2 (December 2020/January 2021) of the Prospective Study About Mental and Physical Health (PAMPA) Cohort, a state-level, ambispective longitudinal study with adults from southern Brazil. The frequency of anxiety and depressive symptoms was assessed using the Hospital Anxiety and Depression Scale. Anxiety and depressive symptoms before social distancing were retrospectively assessed during wave 1.

Results: Most of the 674 participants were classified as non-symptomatic for depressive (85.0%) and anxiety symptoms (73.2%) before the COVID-19 pandemic. At wave 1, there were increases in symptoms of depression (7.6% [95% confidence interval [CI]: 7.2%, 8.1%]) and anxiety (9.1% [95% CI: 8.6%, 9.5%]). These decreased at wave 2 (depression: 6.9% [95% CI: 6.5%, 7.2%]; anxiety: 7.4% [95% CI: 7.1%, 7.8%]) although they were still elevated compared with pre-COVID (depression: 4.5% [95% CI: 4.2%, 4.8%]; anxiety: 5.8% [95% CI: 5.5%, 6.1%]). Adults living alone (b = 0.44 [95% CI: 0.07, 0.82]) had a faster trajectory in anxiety symptoms than their counterparts. Cohort members who were living alone (b = 0.24 [95% CI: 0.06, 0.42]) and with diagnosed chronic disease (0.32 [95% CI: 0.18, 0.46]) had a faster increase in depressive symptoms than their respective counterparts. Participants aged ≥60 years showed a slower trajectory of depressive (b = −0.46 [95% CI: −0.73, −0.18]) and anxiety (b = −0.61 [95% CI: −1.20, −0.02) symptoms.

Conclusions: During 10 months of COVID-19, anxiety and depression symptoms improved but were still higher than before COVID-19.

Introduction

The new COVID-19 had the first case reported in late December 2019 in China. Since then, more than 154 million cases had been recorded worldwide, with the United States and Brazil accounting for roughly one-third of the number of people diagnosed with COVID-19.[1] Also, millions of people had lost their lives due to this disease in the world. Furthermore, robust healthcare systems have

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been disrupted due to the sharp and rapid increase in hospitalizations due to COVID-19.[2]

As disease-modifying treatments have not been developed before 2021, non-pharmacological strategies to mitigate virus transmission such as social distancing have been used.[3] Social distancing has been proven to be an efficient approach at the population level to lessen the number of cases, deaths, and hospitalizations attributed to COVID-19.[4] However, it also has been associated with other effects such as aggravated symptoms of anxiety and depression.[5,6] To identify the effects of social distancing on mental and physical health in adults from southern Brazil, the PAMPA (**P**rospective Study **A**bout **M**ental and **P**hysical He**a**lth) Cohort was created.[7] Using data from wave 1 carried out between June and July 2020, we observed that cases of moderate-to-severe anxiety and depressive symptoms had increased by 7.4- and 6.6-fold, respectively.[8] These increases were even higher than those observed in countries where more restrictive strategies (e.g. lockdown) were adopted.[9–11]

Sociodemographic and health-related factors, including female sex, age (≤45 years), presence of a chronic disease, and physical inactivity, have been identified as risk factors for higher levels of depressive and anxiety symptoms during the pandemic.[5,6,9,10,12,13] However, individual repeated-measures data to quantify the longitudinal changes on anxiety and depressive symptoms since the beginning of social distancing are scarce.[14] This gap limits our knowledge as to whether these symptoms are still elevated, have increased even more, or have diminished after several months into the COVID-19 pandemic. For example, data from the United Kingdom[15] and Germany[16] showed that the rapid increase in depressive and anxiety symptoms observed in March 2020 was followed by a decline up to 5 months later. Thus, we aimed to examine the changes in depression and anxiety symptoms among Brazilian adults over 10 months of the COVID-19 pandemic. Based on previous longitudinal studies with shorter follow-up,[15,16] we hypothesized that the frequency of anxiety and depressive symptoms would remain elevated although stable in our cohort in the second half of 2020.

Methods

The present study used data from the first two waves of the PAMPA Cohort, a state-level, ambispective longitudinal study with adults from southern Brazil. A full description of the PAMPA cohort can be found elsewhere.[7] The study protocol was approved by the institutional research ethics board of the Superior School of Physical Education of the Federal University of Pelotas, Brazil (protocol: 4.093.170).

Recruitment phase

Adults living in the Rio Grande do Sul state were recruited via personal networks and social and local media.[7,17] Data were collected using an online-based, self-reported questionnaire. In wave 1, recruitment lasted 4 weeks (June 22, 2020, to July 23, 2020), whereas in wave 2, it was over 7 weeks because it included the holiday period (December 1, 2020, to January 15, 2021). Both sets of data collection were performed exclusively online.

The Rio Grande do Sul state is divided into regions by the government, and each region is weekly classified into one of the four flag colors (i.e. yellow, orange, red, and black) based on the current number of COVID-19 cases and the rate of contamination as well as the capacity of the health system to attend to the population of the region. The yellow flag indicates a region that has low risk of transmission and hospital occupancy rate and a high availability of intensive care units (ICU), whereas the black flag indicates a region with high risk of transmission and hospital occupancy rate and a low ICU availability. Regions rated with a black flag have the most restrictive measures to limit virus spread. Up to 73.5% and 95.2% of the state's population were rated with red flag during waves 1 and 2, respectively, as defined by the State government's social distancing policies. During this level of restrictions, social clubs, gyms, theaters, religious temples, commercial activities, and malls were allowed to open, but with maximal capacity reduced by up to 75% to prevent gatherings.

Sample

The required sample size calculated before wave 1 was based on the prevalence of depression in the Rio Grande do Sul state in 2013 (13.2%; 95% confidence interval [CI]: 11.8%–15.0%]). Considering the state's population according to the latest census (10,693,929 inhabitants),[18] a 95% CI with 1.8 percentage points of margins of error, and a possible lost-to-follow-up of up to 30%, the required sample size was set at 1767 participants. Furthermore, the Rio Grande do Sul state is divided into seven macroregions of health, as follows (names are in Portuguese): *Serra, Norte, Nordeste, Centro-Oeste, Vales, Metropolitana, and Sul.* Using the latest national census, we divided the required sample size proportionally to the number of people living in each region. Participants aged ≥18 years, who provided contact information (e.g. phone number, social media), and were living in the Rio Grande do Sul State were included in wave 1. From this initial sample, participants who were still living in the State were contacted in wave 2, as shown in Fig. 1.

Outcome

The frequency of anxiety and depressive symptoms was assessed using the Hospital Anxiety and Depression Scale (HADS). This instrument was previously validated in both primary care and community settings.[19–22] The scale is composed by two domains (anxiety and depression), with seven items, each scoring from 0 to 3. Thus, each domain has a maximum score of 21 points, with higher scores indicating higher frequency of symptoms. Participants who scored seven or less were classified as non-symptomatic for that domain. Scores between 8 and 10 were considered as mild risk, scores between 11 and 14 were considered as moderate risk, and scores higher than 15 were considered as severe risk of anxiety or depression.[20]

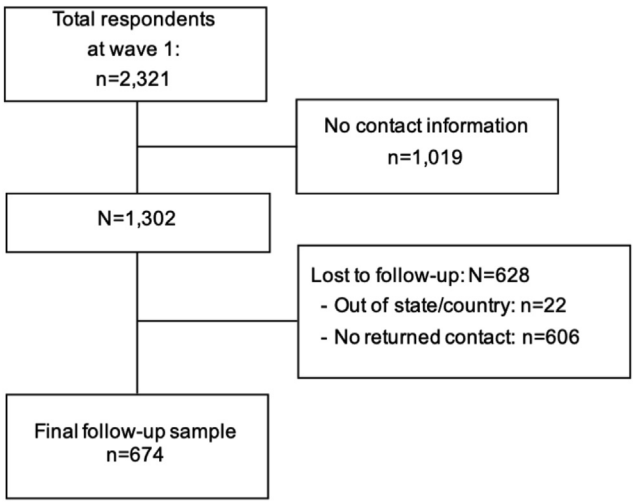

Fig. 1. Flow chart describing sampling process.

In wave 1, participants were asked to rate the frequency of depressive and anxiety symptoms twice. First, we explored depression and anxiety retrospectively by asking the participant to answer the HADS as if they were 2 months before (i.e. before the COVID-19 pandemic). Second, they responded to that same questionnaire but referred to the last 2 weeks. In wave 2, these symptoms were assessed using the HADS with the last two weeks as the reference period.

Exposures

Sociodemographic characteristics, including age, gender, skin color, conjugal situation, and educational level, were assessed in wave 1. We also asked participants in wave 1 how social distancing affected their monthly income (i.e. decreased, unchanged, increased). Self-reported weight and height were reported to calculate body mass index (BMI). BMI was further categorized into normal (BMI <25 kg/m^2), overweight (BMI ≥25 and <30 kg/m^2), and obese (BMI ≥30 kg/m^2). Chronic diseases diagnosed by a physician were also reported during wave 1 using the question previously used in the Brazilian Telephone-based Surveillance System for Noncommunicable Diseases.[23]

In wave 1, physical activity before social distancing and during the current week was determined. In wave 2, the reference period for physical activity was the current week. The following validated question was used:[24] "(*Before social distancing restrictions OR During the current week*), *were you engaged in physical activity regularly?*" If participants indicated a positive answer (i.e. "yes"), then the number of days and minutes were asked. Participants were further categorized according to the latest guidelines of physical activity provided by the World Health Organization.[25] Respondents with less than 150 min of physical activity per week were classified as inactive, and those with 150 min or more were considered physically active. We also asked participants about the use of online services to practice home-based physical activity during wave 2.

Data analyses

Due to the overrepresentation of respondents from one macroregion in the state (*Sul*, N = 436, 64.6%), all analyses were weighted by the respondents' proportion in each macroregion. Normality of data distribution and homoscedasticity were tested using Shapiro–Wilk and Bartlett tests, respectively. Continuous data were reported as mean and 95% CI, whereas categorical variables were shown as proportions and 95% CI. Differences between excluded and included participants were tested using the Chi-squared test. Two-way analysis of covariance with repeated measures was used to compare HADS scores among the three periods, with *P* values adjusted for multiple comparisons using the Bonferroni's post-hoc.

We further used structural equation modeling with maximum likelihood method to identify the velocity of change on depressive and anxiety symptoms over 10 months of the COVID-19 pandemic. The slope and intercept of the model for each domain (i.e. anxiety and depression) were integrated into multivariate linear regression models. A significant intercept indicates between-group differences before COVID-19 social distancing. Positive and negative slope coefficients indicated the trajectory of the symptoms was faster or slower, respectively, than the reference groups. All variables from univariate analyses were added in the multivariate model, and a *P* value ≤0.20 was set to determine whether variables were maintained in the model. We adopted a *P* value lower than 0.05 as the level of significance. All analyzes were performed using STATA/MP 14.2 (Stata Corp, College Station, TX).

Results

From the participants included in wave 1 (n = 2321), 1302 were available for wave 2, as shown in Fig. 1. A total of 674 (51.8% of the available sample) individuals participated in both waves and were included in this analysis. Eligible participants who were lost-to-follow-up in wave 2 were more likely to be older than 30 years ($P = 0.005$), as shown in Supplementary Table 1. Most of included participants were women (80.7%), aged between 31 and 59 years (52.4%), White (91.9%), and lived with a partner (57.0%). Also, participants were more likely to have a university degree (67.3%) and classified as overweight/obesity (53.9%) and have a medical diagnosis of some chronic disease (57.3%). Roughly half of the participants were active before social distancing, whereas 38.9% used online services to assist with home-based physical activity during wave 2. Most respondents were classified as non-symptomatic for depressive (85.0%) and anxiety (73.2%) symptoms before the COVID-19 pandemic.

Scores of both depressive and anxiety-specific domains increased in wave 1 and decreased in wave 2, as shown in Fig. 2. However, those values remained elevated compared with before COVID-19 period. Supplementary Table 2 illustrates the scores from the HADS depression-specific domain. Significant time × group interactions were observed based on age groups ($P < 0.001$), conjugal situation ($P = 0.003$), and depressive ($P < 0.001$) and anxiety ($P = 0.014$) symptoms before the pandemic. People aged <60 years reported an increased and sustained frequency of depressive symptoms over 10 months of the COVID-19 pandemic. On the other hand, no significant changes were observed among people aged ≥60 years and those with moderate-to-severe depressive symptoms. During social distancing, participants who lived with a partner showed a lower score on depressive symptoms than those who lived alone. Participants who were non-symptomatic for depressive symptoms before social distancing reported a higher score on the depression-specific HADS domain during wave 1 followed by a reduction in wave 2. However, scores in wave 2 remained elevated compared with before the pandemic. Participants with a mild risk of depression showed elevated scores in waves 1 and 2 with no significant difference between these two time points. No interaction effect was observed for other variables.

Changes on anxiety symptoms over 10 months of the COVID-19 pandemic are reported in Supplementary Table 3. Younger participants (i.e. aged <60 years) had higher scores of anxiety-specific

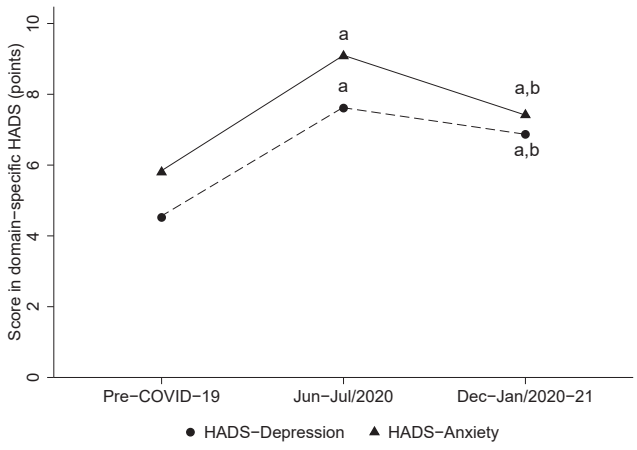

Fig. 2. Mean score at depression and anxiety domains of the Hospital Anxiety and Depression Scale (HADS) throughout the follow-up period. (a) $P < 0.05$ compared with the pre-COVID-19 period. (b) $P < 0.05$ compared with the Jun–July 2020 period.

HADS in wave 1 followed by a significant reduction in wave 2 although still higher than before the pandemic. A similar pattern was observed among participants non-symptomatic for anxiety levels before the pandemic. Those with a mild risk for anxiety showed increased scores in wave 1 with no reduction in wave 2, whereas those with moderate-to-severe risk remained with elevated scores throughout the follow-up. No interaction effect was observed for other variables.

Younger adults and people with chronic diseases reported higher level of anxiety symptoms before the pandemic, as shown in Table 1. Age, conjugal status, and anxiety level before the pandemic were associated with the velocity of changes in such domain. Participants aged ≥60 years (b = −0.61 [95% CI: −1.20 to −0.02]) as well as those with mild (b = −0.41 [95% CI: −0.75 to −0.08]) and moderate-to-severe risk of anxiety before the pandemic (b = −1.80 [95% CI: −2.46 to −1.13]) reported slower aggravation during social distancing. However, adults living alone had a faster increase in anxiety symptoms than those who lived with a partner (b = 0.44 [95% CI: 0.07–0.82]).

Women, younger adults, and people with chronic diseases reported higher levels of depressive symptoms before the pandemic, as shown in Table 2. Some participants reported faster worsening of depressive and anxiety symptoms since social distancing began. Cohort members who were living alone (b = 0.23 [95% CI: 0.09–0.37]) and had an diagnosed chronic disease (0.32 [95% CI: 0.18–0.46]) had a faster increase in depressive symptoms than their respective counterparts. A similar pattern was observed for those with a mild-to-moderate risk of depression and anxiety before the COVID-19 pandemic. On the other hand, participants aged ≥60 years (b = −0.45 [95% CI: −0.71 to −0.18]) showed a slower trajectory of depressive symptoms.

Discussion

This is the first longitudinal state-level study addressing the frequency of depressive and anxiety symptoms over 10 months of the COVID-19 pandemic in Brazil. The country is the current epicenter of the pandemic, with a total of 422,340 deaths by May 9,

Table 1
Association between sociodemographic, behavioral, and health-related factors with anxiety trajectory evaluated by latent growth curve model, Rio Grande do Sul, Brazil (N = 674).

Variables	Intercept		Slope	
	β (95% CI)	*P* value	β (95% CI)	*P* value
Sex		0.063		0.531
Male	1.00		1.00	
Female	0.29 (−0.01–0.59)		0.13 (−0.28–0.55)	
Age (years)		0.007		0.003
18–30	1.00		1.00	
31–59	−0.22 (−0.47–0.04)		0.34 (−0.07–0.76)	
60+	−0.65 (−1.13–−0.17)		−0.61 (−1.20–−0.02)	
Ethnicity		0.896		0.572
White	1.00		1.00	
Black	0.01 (−0.64–0.66)		0.43 (−0.42–1.28)	
Mixed	0.16 (−0.42–0.74)		−0.37 (−1.26–0.52)	
Other	−0.87 (−4.02–2.27)		1.18 (0.89–1.48)	
Living situation		0.283		0.021
Living with a partner	1.00		1.00	
Living alone	0.14 (−0.12–0.40)		0.44 (0.07–0.82)	
Highest education level		0.816		0.077
High school or lower	1.00		1.00	
University degree	−0.10 (−0.43–0.23)		−0.02 (−0.53–0.50)	
Specialized, Masters, PhD	−0.08 (−0.39–0.22)		−0.42 (−0.85–0.02)	
Decreased monthly income		0.316		0.453
No	1.00		1.00	
Yes	0.13 (−0.12–0.37)		0.14 (−0.22–0.50)	
Self-reported body mass index		0.307		0.361
Normal	1.00		1.00	
Overweight	0.22 (−0.06–0.50)		−0.04 (−0.43–0.35)	
Obese	0.11 (−0.22–0.44)		−0.32 (−0.79–0.14)	
Chronic diseases		0.006		0.224
No	1.00		1.00	
Yes	0.36 (0.10–0.61)		0.23 (−0.14–0.59)	
Physical activity before COVID-19 pandemic		0.519		0.658
Inactive	1.00		1.00	
Active	−0.08 (−0.33–0.17)		0.08 (−0.29–0.46)	
Online services to practice home-based physical activity		0.948		0.830
No	1.00		1.00	
Yes	0.02 (−0.52–0.55)		0.04 (−0.33–0.41)	
Depressive symptoms		<0.001		0.528
Non-symptomatic	1.00		1.00	
Mild	0.58 (0.19–0.98)		0.28 (−0.28–0.84)	
Moderate-to-severe	1.01 (0.38–1.65)		0.36 (−0.65–1.37)	
Anxiety symptoms		<0.001		0.001
Non-symptomatic	1.00		1.00	
Mild	3.89 (3.59–4.19)		−0.50 (−0.99–−0.02)	
Moderate-to-severe	6.65 (6.07–7.24)		−1.70 (−2.78–−0.63)	

Adjusted for sex, age, skin color, living situation, highest education level, decreased monthly income, self-reported body mass index, chronic diseases, physical activity, and depressive and anxiety symptoms pre-COVID-19.

Table 2
Association between sociodemographic, behavioral, and health-related factors with depression trajectory evaluated by latent growth curve model, Rio Grande do Sul, Brazil (N = 674).

Variables	Intercept		Slope	
	β(95% CI)	*P* value	β (95% CI)	*P* value
Sex		0.025		0.084
Male	1.00		1.00	
Female	0.25 (0.03–0.47)		0.16 (−0.02–0.35)	
Age (years)		0.002		0.001
18–30	1.00		1.00	
31–59	0.07 (−0.13–0.27)		0.03 (−0.16–0.23)	
60+	−0.63 (−0.97–−0.28)		−0.46 (−0.73–−0.18)	
Ethnicity		0.778		0.275
White	1.00		1.00	
Black	0.14 (−0.33–0.61)		0.22 (−0.14–0.59)	
Mixed	−0.18 (−0.60–0.24)		−0.20 (−0.58–0.18)	
Other	−0.10 (−2.39–2.18)		−0.13 (−0.33–0.07)	
Living situation		0.051		0.011
Living with a partner	1.00		1.00	
Living alone	0.25 (−0.01–0.50)		0.24 (0.06–0.42)	
Highest education level		0.430		0.231
High school or lower	1.00		1.00	
University degree	−0.15 (−0.39–0.09)		−0.19 (−0.40–0.03)	
Specialized, Masters, PhD	−0.04 (−0.26–0.18)		−0.13 (−0.33–0.07)	
Decreased monthly income		0.149		0.113
No	1.00		1.00	
Yes	0.17 (−0.06–0.41)		0.13 (−0.04–0.29)	
Self-reported body mass index		0.399		0.718
Normal	1.00		1.00	
Overweight	0.12 (−0.08–0.33)		0.06 (−0.13–0.24)	
Obese	−0.02 (−0.26–0.22)		−0.03 (−0.24–0.18)	
Chronic diseases		<0.001		<0.001
No	1.00		1.00	
Yes	0.33 (0.15–0.52)		0.32 (0.18–0.46)	
Physical activity before COVID-19 pandemic		0.540		0.462
Inactive	1.00		1.00	
Active	−0.06 (−0.24–0.12)		−0.27 (−0.44–−0.09)	
Online services to practice home-based physical activity		0.821		0.821
No	1.00		1.00	
Yes	0.03 (−0.25–0.31)		0.02 (−0.17–0.22)	
Depressive symptoms		<0.001		<0.001
Non-symptomatic	1.00		1.00	
Mild	0.97 (0.69–1.25)		0.85 (0.60–1.11)	
Moderate-to-severe	1.80 (1.35–2.25)		1.24 (0.84–1.65)	
Anxiety symptoms		<0.001		0.003
Non-symptomatic	1.00		1.00	
Mild	0.58 (0.36–0.80)		0.36 (0.15–0.57)	
Moderate-to-severe	0.36 (−0.07–0.79)		0.30 (−0.06–0.66)	

Adjusted for sex, age, skin color, living situation, highest education level, decreased monthly income, self-reported body mass index, chronic diseases, physical activity, depressive and anxiety symptoms pre-COVID-19.

2021, and 53% of them occurred in 2021. We observed that the prevalence of moderate-to-severe symptoms of anxiety and depression did not change significantly compared with wave 1, supporting our initial hypothesis. However, some groups had different trajectories of symptoms in the follow-up period.

We identified that depression and anxiety scores remained elevated compared with before the COVID-19 pandemic, despite a reduction from wave 1 to 2. This decreased burden in anxiety and depressive symptoms suggests a populational adaptation to the COVID-19 pandemic situation.[15,26] The government of the Rio Grande do Sul started with state-level social distancing policies in March 2020. Since then, a plethora of online and home-based leisure activities such as physical exercise classes, the amplified use of virtual communication tools, and the increased availability of psychological services via telemedicine might have contributed to lessen the aggravation in anxiety and depressive symptoms in our population.[27] For example, 38.9% of the included sample reported using online-based services to practice physical activity during wave 2 although this strategy was not associated with changes in anxiety and depressive symptoms. Furthermore, although most macroregions were classified with the red and black flags by the state government throughout the fieldwork, some restrictions were eased during the December holidays. For example, restaurants and pubs were allowed to open with reduced capacity and opening hours. A misleading perception of normality in social life also encouraged by the federal government might have contributed to the reduced frequency of anxiety and depressive symptoms. Also, the news that a vaccine could be soon available might have induced a feeling of safety, reducing the burden on mental health.

Those aged ≥60 years reported lower levels of anxiety and depression symptoms before the pandemic, followed by lower variation in the scores of such mental health domains. On the other hand, the frequency of anxiety symptoms was reduced between waves 1 and 2, whereas depressive symptoms were persistently high during wave 2 among adults <60 years. Previous studies have indicated that people aged up to 45 years were at higher risk for

worse depressive and anxiety symptoms during the COVID-19 pandemic.[5,8] Adults from this age group might have been more affected by schools closing and interrupted commercial activities such as business centers. Although these approaches are important to reduce virus transmission, they represent, in most cases, reduced monthly income and uncertainty about the near future. Appropriated financial and psychological support followed by timely interventions to reduce anxiety and depressive symptoms among young and middle-aged adults is urgently needed, mainly in populations from developing countries such as Brazil, which have both a large number of COVID-19 cases and economically frail individuals.

Depressive symptoms increased in wave 1 but decreased in the subsequent period in some groups. However, in those living alone, the scores from depressive-specific HADS remained elevated compared with before the pandemic, with no significant difference before social distancing (i.e. intercept) and between waves 1 and 2. Social isolation, sometimes wrongly confounded as social distancing, is a leading cause of depression and suicide.[28] While social distancing requires people to keep a safe distance (i.e. 2 m) from each other and stay at home when possible, social isolation is a lack of social connections. Social isolation might contribute to the risk of future neurological diseases such as dementia.[29] Although the population must stay at home whenever is possible, strategies to improve social activities must be promoted, especially for the vulnerable population such as those living in areas with no internet access.[30]

Participants non-symptomatic for anxiety and depression before the pandemic reported an increased frequency of these symptoms during wave 1 followed by a reduction in wave 2. However, the scores in the latest wave remained significantly higher than those observed in the pre-COVID-19 period, suggesting an inverted J-shaped curve in the frequency of symptoms for this group. Based on previous findings,[15,26] this decrease could be attributable to the development of coping strategies by participants. A similar process was seen in other types of isolation such as incarcerations where a remarkable increase in depressive symptoms is followed by a steady decline.[26] Nevertheless, the prevalence of moderate-to-severe symptoms of anxiety and depression in wave 2 persisted remarkably higher than the period before the COVID-19 pandemic. As previously noted, the easing of some restrictions might also have stimulated this reduction. However, transmission rate in Brazil was high during wave 2. The weekly switching from less to more severe restrictions (and vice-verse, depending on the situation) might have limited the decrease in the frequency of anxiety and depressive symptoms. It is well-known that this pandemic can trigger an unpredictable increase in the prevalence of depression and anxiety, especially in low- and middle-income countries.[31] Until a large proportion of the population get vaccinated, strategies to protect people's mental health need to be promoted by federal, state, and local governments.

Some methodological limitations of our study must be acknowledged. First, our retention rate was lower than expected (52% vs 70%[7]). However, large, population-based cohort studies found similar or even lower (e.g. 28%) response rates using online-based questionnaires.[32] Second, we used self-reported measurements to evaluate anxiety and depressive symptoms, physical activity, and other variables. In-person interviews or assessments were not allowed by the local research ethics committee. Third, the retrospective design used during wave 1 may have led to recall bias. Nevertheless, as stated previously, there were no data from large, state-level prospective studies in south Brazil.[8] Fourth, the proportion of participants with an academic degree was overexpressed. Although 17% of adults aged ≥25 years had at least one academic degree, this proportion reached 42.4% (95% CI: 37.6% to 47.3%) in our sample. As data collection was online, we expected this sampling bias as less educated people might have limited internet access. However, the COVID-19 has a deeper impact in lower economic groups, so sampling bias is likely to underestimate our occurrence measurements.

In summary, we report the changes on anxiety and depressive symptoms in adults from southern Brazil over 10 months of the COVID-19 pandemic. The frequency of these symptoms decreased from June/July 2020 to December 2020/January 2021 yet remained elevated compared with the pre-COVID-19 period. Long-lasting strategies to control the burden of social distancing on mental health at a population level are warranted as the COVID-19 pandemic in Brazil is likely to last longer, be more aggressive, and continuously increase the health disparities in the country.

Author statements

Ethical approval

Ethical approval was given by the Ethics Committee of the Federal University of Pelotas (31906920.7.0000.5313).

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Competing interests

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2021.12.019.

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Short Communication

Effect of vaccination on SARS-CoV-2 reinfection risk: a case–control study in the Republic of Cyprus

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ABSTRACT

Objectives: We explored the effectiveness of COVID-19 vaccines in preventing reinfection in the Republic of Cyprus.
Study design: This was a matched case–control study (1:2).
Methods: Cases were adults with a first episode of SARS-CoV-2 infection in 2020 and a second episode (i.e. reinfection) between June and August 2021. Controls were adults with only one infection episode in 2020 (i.e. not reinfected). Matching was performed by age, gender, and week of diagnosis for the first episode. The reinfection date of a case was applied to the matched controls for estimating full or partial vaccination status. Cases and controls were classified as unvaccinated, partially vaccinated (i.e. vaccination series not completed or final dose received ≤14 days before the reinfection date), or fully vaccinated (i.e. final dose received >14 days before the reinfection date). Conditional logistic regression was performed to calculate odds ratios and 95% confidence intervals for full or partial vaccination, against no vaccination, between controls and cases.
Results: This study showed that controls were more likely to be vaccinated (odds ratio for full vaccination: 5.51, 95% confidence interval: 2.43–12.49) than cases.
Conclusions: This finding answers a pressing question of the public and supports the offer of vaccination to people with previous SARS-CoV-2 infection.

Background

Reinfection rates after the initial acquisition of SARS-CoV-2, the virus that causes COVID-19, seem to be low.[1] This could be explained, at least partly, by the establishment of immunological memory after SARS-CoV-2 infection,[2] although questions are still lingering regarding the long-lasting protection from clinical disease. Vaccines have further shielded human populations because of their high effectiveness against COVID-19 infection, hospitalization, and death.[3] The emergence of variants, the predominance of the more infectious Delta SARS-CoV-2 variant of concern (1.617.2), and waning humoral immunity pose significant challenges on the level of vaccination coverage that is needed to impede viral spread.

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Nevertheless, vaccines continue to offer, at the moment, high-level protection from hospitalization and death.[4]

As the pandemic progresses and transmission continues to occur, the likelihood of reinfection increases. We have previously reported a reinfection rate of 0.08% among COVID-19 cases diagnosed in Cyprus until February 2021, within a median period of 7 months after the first infection.[5] Public Health England reported a cumulative 1.2% reinfection rate between April and June 2021, with higher risk of reinfection >6 months after the first episode due to the Delta variant.[6] More recently, a reinfection rate around 1%, due to Delta variant, has been confirmed in the United Kingdom by the Scientific Advisory Group for Emergencies (https://www.gov.uk/government/publications/sage-99-minutes-coronavirus-covid-19-response-16-december-2021).

Given the above, we sought to explore the effectiveness of vaccines in preventing reinfection in the Republic of Cyprus.

Methods

During the COVID-19 pandemic, the Unit for Surveillance and Control of Communicable Diseases, within the Department of Medical and Public Health Services of the Ministry of Health, is responsible for surveillance and public health interventions. A Scientific Advisory Committee consisting of national experts provides scientific advice and recommends data analyses.

From the national COVID-19 surveillance system, all persons aged ≥18 years diagnosed with SARS-CoV-2 infection either by real-time polymerase chain reaction (PCR) or rapid antigen test (RAT) within the period March–December 2020 were eligible for inclusion. A suspected COVID-19 reinfection (hereafter defined as reinfection) was defined as one with positive PCR or RAT on a sample collected ≥60 days after previous positive: (1) PCR or (2) RAT or (3) serology (anti-spike IgG Ab).

For this analysis, a case was defined as a person aged ≥18 years with a first episode of SARS-CoV-2 infection between March and December 2020 and a second episode (i.e. reinfection) between June and August 2021. The period for reinfection was selected based on the following two reasons: (1) all persons aged ≥18 years in Cyprus were offered, during that period, the choice of vaccination and thus were considered eligible for vaccination; and (2) the Delta variant predominated in Cyprus between June and August 2021. A control was defined as a person aged ≥18 years with only one episode of SARS-CoV-2 infection that occurred between March and December 2020 (i.e. not reinfected). Cases were randomly matched to controls at 1:2 ratio based on age group (5-year age bands), gender, and International Organization for Standardization (ISO) week of diagnosis for the first episode (i.e. March to December 2020).

Vaccination status of cases and controls was determined using data from the national vaccination registry. The reinfection date of a case was applied to the matched control for estimating full or partial vaccination status. Cases and controls were considered fully vaccinated if a single dose of Janssen (Johnson & Johnson) or a second dose of any other vaccine administered in Cyprus (Pfizer-BioNTech, Moderna, or Astrazeneca) had been received >14 days before the reinfection date. Partial vaccination was defined when either the vaccination series was not completed or the final dose was received ≤14 days before the reinfection date.

Conditional logistic regression was performed to calculate odds ratios (ORs) and 95% confidence intervals (CIs) for full vaccination or partial vaccination (against no vaccination) in controls vs. cases. Furthermore, stratified analysis was performed by vaccine brands (Pfizer-BioNTech, which was delivered to the majority of the population, and all other brands combined). For all analyses, Stata v.16 was used.

Table 1
Characteristics of people with (cases) and without (controls) SARS-CoV-2 reinfection, Republic of Cyprus (government-controlled area), June to August 2021.

Characteristics		Controls ($n = 186$)		Cases (reinfections; $n = 93$)		OR[a]	95% CI
		n	%	*n*	%		
Sex	Males	94	50.5	47	50.5		
	Females	92	49.5	46	49.5		
Age group (years)	18–29	96	52.2	52	55.9		
	30–39	51	27.4	19	20.4		
	40–49	22	11.8	15	16.1		
	50–59	13	7.0	5	5.4		
	60–69		0.0		0.0		
	70–79	3	1.6	1	1.1		
	80+	1	0.5	1	1.1		
Month of initial infection (2020)	March	8	4.3	3	3.2		
	April	13	7.0	8	8.6		
	May	3	1.6	1	1.1		
	June	1	0.5	0	0.0		
	July	3	1.6	2	2.2		
	August	10	5.4	5	5.4		
	September	0	0	0	0		
	October	37	19.9	18	19.4		
	November	49	26.3	26	28.0		
	December	62	33.3	30	32.3		
Vaccination status[b]	Fully vaccinated	61	32.8	8	8.6	5.51	2.43–12.49
	Partially vaccinated	24	12.9	7	7.5	2.60	1.04–6.47
	Unvaccinated	101	54.3	78	83.9	Ref	

[a] Odds ratios (OR) and their 95% confidence intervals (CI), from conditional regression, refer to odds of full or partial vaccination (against no vaccination) in controls (without reinfection from SARS-CoV-2) vs. cases (with reinfection).

[b] Cases were considered fully vaccinated if a complete COVID-19 vaccine series was received >14 days before the cases' reinfection date. Cases were considered partially vaccinated if ≥1 dose of vaccine was received, but the vaccination series was either not completed or the final dose was received ≤14 days before their reinfection date. For control participants, the same criteria were applied using the matched case's reinfection date.

Results

During the study period (June to August 2021), 44,227 laboratory-confirmed infections with SARS-CoV-2 were diagnosed in Cyprus. Among them, 93 (0.2%) were reinfections (cases), which were matched to 186 people diagnosed with only one episode of SARS-CoV-2 infection (controls). The population included in the analysis ($n = 279$) had a similar proportion of males and females, mainly comprised individuals aged <40 years (78.1%), and 222 people (79.6%) were initially infected during October to December 2020 (Table 1).

Among cases, 7.5% and 8.6% were partially vaccinated and fully vaccinated, respectively, compared with 12.9% and 32.8% of controls. A total of nine individuals were admitted to hospitals during the study period; eight patients were from the control group and one from the cases group (4.3% vs. 1.1%; $P = 0.151$).

Considering all vaccine brands, the odds of full vaccination were 4.5 times greater in controls than in cases ($n = 233$; OR = 5.51; 95% CI = 2.43–12.49). Similarly, partial vaccination was almost twice as likely in controls than in cases ($n = 193$, OR = 2.60; 95% CI = 1.04–6.47; Table 1).

From subgroup analysis for Pfizer-BioNTech, the odds of full vaccination were six times greater in controls than in cases ($n = 209$; OR = 7.06; 95% CI = 2.46–20.30). However, the odds of partial vaccination were barely not significant between cases and controls ($n = 185$, OR = 2.62; 95% CI = 0.96–7.17). Furthermore, subgroup analysis for all other vaccine brands combined did not reach nominal statistical significance at 5%, although the direction of association was always positive (odds of full vaccination, $n = 166$; OR = 3.00; 95% CI = 0.84–10.75; and odds of partial vaccination, $n = 151$; OR = 2.50; 95% CI = 0.29–21.40).

Discussion

Vaccination decreases the likelihood of infection and offers high-level protection from severe disease; thus, increasing vaccination coverage has allowed societies to resume activity. The spread of the Delta variant has altered the course of the pandemic, leading to a significant surge in many settings in the summer of 2021, including Cyprus, and increasing the necessary level of population immunity to limit viral spread. The dynamics of long-term protection through natural immunity remain largely unknown; despite evidence for the establishment of immune memory,[2] waning of neutralizing antibody levels raise the potential for reinfection. Moreover, although vaccine effectiveness against severe disease is preserved, protection against infection wanes through time.[4]

Estimation of vaccine effectiveness was not among the aims of our study; we sought to evaluate the effectiveness of vaccination on the risk of breakthrough infection among people with a first episode of SARS-CoV-2 infection by comparing it with the effectiveness of previous infection alone on preventing reinfection. To this end, we showed that the odds of vaccination were greater in people without reinfection than in those who had been reinfected, thus supporting findings of previous epidemiological research on additional protective effect of vaccination compared with natural immunity.[7] The pattern of association was observed both for the Pfizer-BioNTech vaccine, which was primarily used in Cyprus, and for the other vaccines combined, although statistical significance was not reached in the latter case, probably because of the smaller sample size. Of interest, in our analysis, the estimated reinfection risk for the unvaccinated was higher. A recent study from the basic sciences field also showed that the neutralization capacity of antibodies of vaccinated individuals with previous SARS-CoV-2 infection was better than that of people who got the vaccine without previous exposure to the virus.[8] The Delta variant is considered an immune evasive variant with an increased risk of reinfection. Hence, our findings are even more timely, given the fact that the reinfections in this study were observed during the surge of the Delta wave in Cyprus. It is likely that the synergy of natural and vaccine-generated immunity provides stronger and broader immune responses than what is expected including against multiple variants.[9]

The interpretation of our results is subject to certain limitations. Possible bias could be present because of inconsistencies in the matching variables between the different registries of vaccination and surveillance. Lack of genomic sequencing data did not allow the confirmation of suspected reinfections. In addition, small numbers precluded the risk analysis for hospitalization. Furthermore, although Cyprus has a high testing rate per population, as of 10 May 2021, testing became thereafter a requirement for unvaccinated persons to resume certain activities;[10] this may have led to sampling bias, thus overestimating the ORs in our analyses.

In conclusion, our findings support the benefit of vaccination for persons previously infected with SARS-CoV-2. Although access to vaccination has increased, public health actions should be directed toward maximizing protection among vaccine-eligible individuals.

Author statements

Ethical approval

The study was approved by the Cyprus Bioethics Committee (approval number ΕΕΒΚ ΕΠ 2021.01.197, 7 October , 2021).

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Competing interests

None declared.

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Original Research

How survey mode affects estimates of the prevalence of gambling harm: a multisurvey study

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ABSTRACT

Recent general population surveys have produced highly variable estimates of the extent of problem gambling in Great Britain, ranging from as low as 0.4% to as high as 2.7% of adults. This level of uncertainty over the true level of problem gambling creates difficulties for policy makers and those planning treatment and support services for individuals and families affected by problem gambling. In this article, we assess the extent to which differences in approaches to sampling and measurement between surveys contribute to variability in estimates of problem gambling. We compare estimates of problem gambling using the Problem Gambling Severity Index across eight different surveys conducted at approximately the same time but which use different sampling and measurement strategies. Our findings show that surveys conducted online produce substantially higher estimates of problem gambling compared with in-person interview surveys. This is because online surveys, whether using probability or non-probability sampling, overrepresent people who are more likely to gamble online and to gamble frequently, relative to the proportions of these groups in the general population.

Introduction

Since 2012, official statistics on the prevalence of gambling and gambling harm in Great Britain have been collected using a combined version of the national health surveys for England and Scotland and a bespoke survey in Wales. These surveys use what are considered "gold standard" methodologies of random sampling and in-person interviewing. They have estimated comparatively low rates of gambling harm in the adult population. The 2016 survey estimated the rate of problem gamblers to be 0.7% and the rate of adults at risk of gambling harm to be 4.2%. Similar rates of 0.4% and 3.9% were estimated in the 2018 Health Survey for England (covering England only).

In 2019, a survey carried out by YouGov found 2.7% of British adults identified as problem gamblers and 13.2% at risk of gambling harm, more than three times higher than the health survey had estimated less than a year previously for England. This survey had a quite different methodological approach using non-probability sampling and online self-completion of questionnaires. Such a large discrepancy in estimates raises questions about what the true level of gambling harm is in the general population, which, in turn, makes it difficult for policy makers and planners to determine the appropriate level of resource allocation for treatment and support services.

In the context of the global trend toward increased online surveying, it is essential to better understand how survey mode affects the accuracy of estimates of problematic gambling. Recent evidence suggests that non-probability online samples substantially overestimate problem gambling compared with probability samples collected in person and by phone because of both selection bias and poor measurement quality.[1,2] However, it is not clear to what extent this is because of online interviewing on the one hand or non-probability sampling on the other.

Our objective in this article is to assess how sample design and survey mode affect estimates of harmful gambling. We do this by comparing estimates of gambling behavior and gambling harm across a set of contemporaneously conducted surveys using a consistent set of questions but different sampling and data collection methodologies. We evaluate how differences in the designs of the surveys are related to variation in estimates of gambling behavior and gambling harm, using this to draw conclusions about the likely prevalence of problem gambling in the adult population of England.

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Survey designs and measures of gambling harm

To assess how survey design features affect estimates of harmful gambling, we consider eight near-contemporaneous surveys, which all included the same measure of gambling harm, the Problem Gambling Severity Index (PGSI). These were the 2016 and 2018 rounds of the Health Survey for England, the 2019 and 2020 GambleAware Treatment and Support surveys carried out by YouGov, and three surveys conducted for the purposes of this study in November and December 2020 by Yonder, NatCen, and Kantar Public. In addition, Ipsos-MORI has provided us with data from a survey they collected for their own purposes in January 2021. The key design features of the surveys are described in detail in Appendix 1 and summarized in Table 1.

The Health Survey for England uses probability sampling with in-person interviewing, and the NatCen, Kantar, and Ipsos-MORI surveys are online probability surveys, which draw random samples from established panels of respondents who have been pre-recruited to complete surveys on a regular basis for monetary incentives.[3] The panels are established via a "recruitment survey," which also uses probability sampling, although the mode of contact differs between postal (Ipsos-MORI and Kantar) and face-to-face interview (NatCen). Of particular note is the markedly lower response rates achieved for the probability panels (4%–15%) compared with the health surveys (~55%). The YouGov and Yonder surveys use a similar approach, but the established panels of respondents are not drawn randomly. Instead, these panels comprise people who have signed up to take surveys in return for monetary incentives through a range of online and offline recruitment strategies.[4]

The key variable of comparison is the PGSI.[5] It is based on answers to nine questions about gambling, each with four response alternatives: 0 = never, 1 = sometimes, 2 = most of the time, and 3 = almost always. The total PGSI score is the sum of the individual items. The total score is recoded into four categories, indicating "non-gambler," "low-risk," "moderate-risk," and "problem gambling" for scores of 0, 1–2, 3–7, and ≥8, respectively. We focus here primarily on the proportion with a score of ≥1 on the PGSI, which we refer to hereafter as PGSI+1.

Before the PGSI, respondents were asked a set of questions asking whether they had participated in a range of gambling activities during the previous 12 months. Those who reported no gambling were not administered the PGSI and are given a score of zero. Respondents were also asked how frequently they gamble. The small number of respondents who did not provide responses to the PGSI are excluded from analyses. The question wordings and response alternatives are provided in the Appendix.

Results

Fig. 1 shows that estimates for the two health surveys, at 3.9% and 4.1%, are substantially lower than all of the online surveys[a], which range from a low of 7.4% for Ipsos-MORI to a high of 16% for Yonder.[b] The 95% confidence intervals for the health surveys do not overlap with any of the online surveys, so sampling variability can be ruled out as a potential cause of the differences.

[a] For simplicity, we refer to the surveys that used online self-completion as "the online surveys," although the Kantar and NatCen surveys used both online and telephone interviews.

[b] For the random probability surveys, confidence intervals are calculated using Taylor series linearization to account for complex design features. For the non-probability samples, the same approach is used to account for the calibration weights. Although this is technically not correct due to the non-random selection of population elements, it serves as a reasonable approximation.

The Ipsos-MORI estimate is the lowest of the online surveys, but it is not directly comparable because it uses a 4-week reference period for previous gambling behavior, whereas all other surveys refer to 12 months. This likely reduces the PGSI+1 by 1–2 percentage points for this survey.[6] Note also that the health surveys use a target population of adults aged ≥16 years, whereas the online surveys, apart from Kantar (which also uses 16+), use 18+. It is not possible to derive equivalent bands because the health surveys and the Kantar survey do not contain a continuous age in years variable. Given the small size of the 16–17 years age group and the low incidence of PGSI+1 in the general population, this difference will have little or no effect on the point estimate for the general population.

True change over time

Although we cannot rule the possibility of true change in gambling behavior, it does not seem likely to be a major contributory factor for two reasons. First, 12 months is an implausibly short interval to accommodate such a substantial increase in gambling harm. Second, independent surveys conducted during the first lockdown in 2020 found a *decline* in the frequency of gambling.[7,8] It therefore seems highly unlikely that the increase in harmful gambling observed between the 2018 HSE and the online surveys conducted in 2019/20 could be because of a real increase in gambling harm in the population.

Coverage error

There are differences in the covered populations between the health surveys and the YouGov survey, which might have caused some of the difference in estimates. For example, the Postcode Address File (PAF), which is the sampling frame for the health surveys, excludes people who live in institutional addresses, such as halls of residence, hospitals, prisons, and military barracks. The YouGov and Yonder surveys, on the other hand, can include members of these groups but exclude the offline population completely. However, the Kantar, NatCen, and Ipsos-MORI surveys also draw their samples from PAF and therefore have the same coverage properties as the health survey. This means that coverage error can also be ruled out as a potential cause of the differences in estimates.

Measurement error

It is possible that some of the variability in estimates of gambling harm derives from differences in the measurement properties of the survey instruments. For example, answers to the gambling questions might have been differentially affected by the content of questions that preceded them, so-called "order effects."[9] The gambling questions in the health surveys were preceded by questions focusing on mental health and well-being, whereas for all but the Ipsos-MORI survey (which first asked questions about politics and vaccination), the online surveys asked the gambling questions first. Although this pattern is consistent with the possibility that preceding the gambling items with questions about mental health and well-being reduces the frequency of self-reported gambling harm, there is no obvious theoretical reason why this should be so. Without experimental evidence to support such a hypothesis, we conclude that the case for order effects of any notable magnitude is weak.

There are also differences between surveys in the questions and response alternatives. Respondents who report no gambling in the previous 12 months on these questions are assigned a score of zero on the PGSI, so differences in these questions could affect the

Table 1
Summary information on the sample designs of the eight surveys.

Survey	Sample design	Mode	Sample size	Fieldwork	Age range	Response rate	Question order
HSE 2016	Probability sample, Postcode Address File (PAF) as the first-stage sampling frame, all adults in a household are interviewed, £10 unconditional incentive	Paper self-completion in face-to-face (f-t-f) interview	6691	Annual continuous	16+	55%	After mental health questions at the end of f-t-f interview
HSE 2018	As for 2016 HSE	Paper self-completion in f-t-f interview	6927	Annual continuous	16+	54%	After mental health questions at the end of f-t-f interview
Kantar	Probability, PAF, up to two adults, £5 conditional incentive	Online + phone	1795	November 24, 2020, to December 13, 2020	16+	5%	First in questionnaire
Ipsos	Probability, PAF, up to two adults, £10 conditional incentive	Online		January 21, 2021, to January 27, 2021	18+	4%	After politics, vaccination, views of local area
NatCen	Probability, PAF, one adult, £10 conditional incentive	Online + phone	2049	November 19, 2020, to December 20, 2020	18+	14%	
YouGov 2019	Quota sample (with age, gender, ethnicity, social grade, and region as quota variables), incentive = points toward money	Online	10499	September 24, 2019, to October 13, 2019	18+	N/A	First in questionnaire
YouGov 2020	Quota (age, gender, ethnicity, social grade, region), incentive = point toward money	Online	16401	November 19, 2020, to December 11, 2020	18+	N/A	First in questionnaire
Yonder	Quota (age, gender, region, social grade), incentive = points toward money	Online	6944	November 18, 2020 to November 29, 2020	18+	N/A	Not known

Sample sizes for England only.

estimates of gambling harm. That being said, the two sets of questions cover a large range of gambling activities, and both include an "any other type of gambling" question, so it is not clear why they would produce strongly different rates of gambling prevalence. Our assessment is, therefore, that these differences in question content and format are unlikely to be a notable contributory factor.

The health surveys include a skip instruction at the bottom of the page of questions on gambling activities. The instructions advise respondents who answered "no" to all these questions to skip further forward in the questionnaire. It is possible this led some respondents to answer "no" to all the questions to proceed more quickly to the end of the questionnaire. However, these instructions are at the bottom of the page and are not especially prominent. As there had been no similar filter questions in the self-completion questionnaire up to that point, there was no opportunity for respondents to learn that skipping questions in this way could help them to progress faster. We therefore consider it unlikely that this had a material impact on the estimates of gambling prevalence in the health surveys.

It is well known that people are less willing to admit to socially undesirable attitudes and behaviors in the presence of another person.[10] For this reason, we might expect online surveys to be more accurate because no interviewer is present. To minimize the risk of this kind of bias, the health surveys use a paper self-completion questionnaire for the gambling questions. Nonetheless, it is still possible that the presence of an interviewer or other household members might lead to underreporting of gambling in the self-completion questionnaire.

We can obtain some insight on this by comparing PGSI+1 between respondents who completed the 2016 HSE questionnaire alone or in the presence of another household member. This shows a small difference for the 2016 HSE; of the 63% who completed the gambling questions in the presence of another household member,

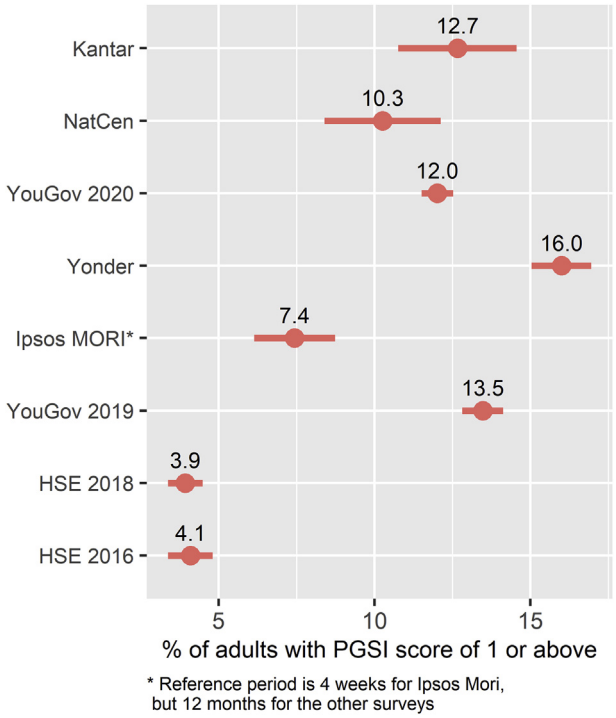

Fig. 1. Estimates of the percentage of adults with PGSI+1 across surveys.

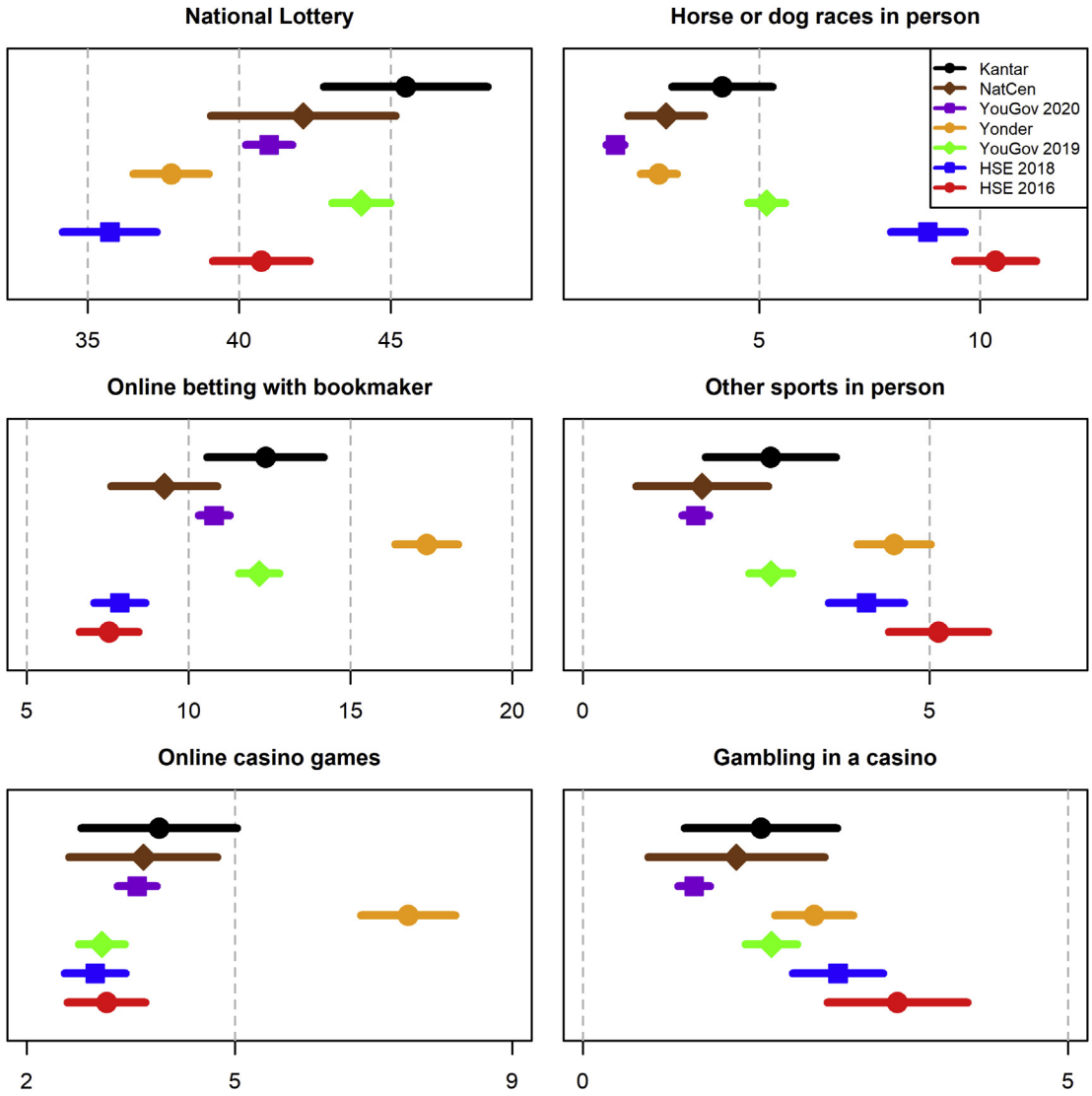

Fig. 2. Estimates of the percentage of adults who have taken part in different gambling activities over the previous 12 months.

3.9% had a PGSI+1 compared with 4.7% for the 37% who completed the questions alone. This difference, however, is not statistically significant (Chi-square = 0.92, df = 1, $P = 0.354$), which leads us to conclude that socially desirable responding in the health surveys is unlikely to be a significant contributory factor to the lower estimates of gambling harm.

Non-response error/selection bias

In probability sampling, non-response bias results from the failure to contact sampled individuals or from their refusal to take part in the survey once contacted. If the propensity to respond to the survey is correlated with the population parameter of interest, estimates will be biased.[11] In general, the magnitude of non-response bias is unknown, and we can only say that the *risk* of it increases as the response rate declines.

In non-probability sampling, there is no directly equivalent number to the response rate because recruitment typically continues until the sampling quotas are filled, and it is therefore more appropriate to refer to the more general concept of selection bias. If, after weighting adjustments, the kinds of people who agree to complete the survey are different from people in the target population on the characteristic(s) of interest, estimates will be biased.[12] A number of existing studies have found that, on average, non-probability surveys tend to be more biased than probability samples because of unrepresentative samples.[13]

Fig. 2 presents point estimates and 95% confidence intervals for a selection of gambling activities. At the top of the chart, we see that all surveys give similar estimates of the proportion who purchased a National Lottery ticket, ranging from 36% in the 2018 HSE to 46%

Table 2
Frequency of spending money on gambling (estimated percentage of adults in England).

Frequency	Kantar	NatCen	YouGov 2020	Yonder	HSE 2018	HSE 2016
More than once a week	15.1	14.6	18.8	25.7	10.2	12.7
Once a week	22.9	27.9	26.4	27.8	23.7	27.3
Less than once a week	8.6	10.9	8.6	9.3	10.8	10.1
Once a month	18.9	19.0	17.7	16.3	13.3	12.0
Every 2–3 months	14.9	11.2	12.7	10.8	14.2	13.6
Once-twice a year	19.5	16.4	15.8	10.0	27.9	24.2
Total	*100*	*100*	*100*	*100*	*100*	*100*

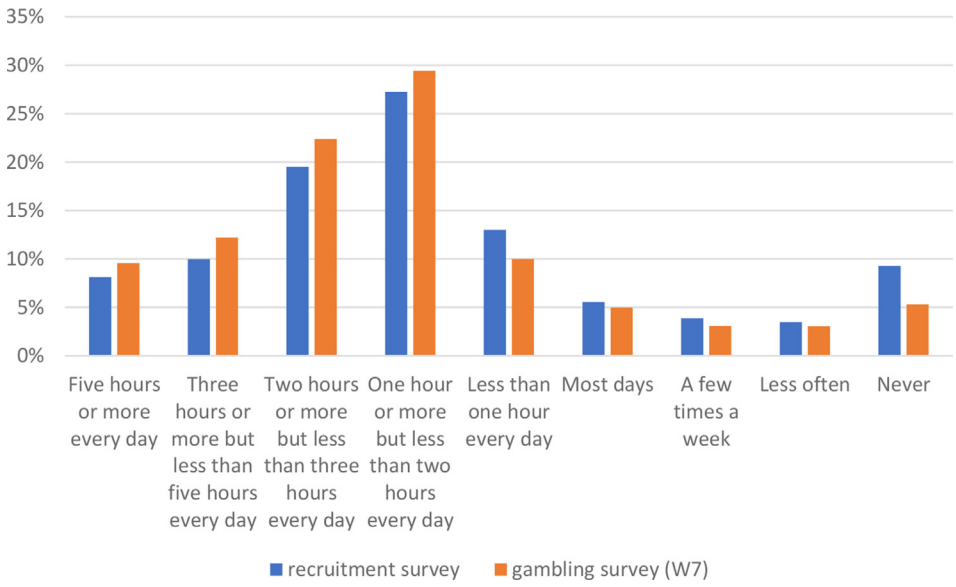

Fig. 3. Frequency of Internet use, Kantar Public Voice survey: percentages of adults estimated from the recruitment survey and wave 7.

in the Kantar survey. For in-person betting on horse or dog races, however, the estimates are notably and significantly higher for the health surveys (9%–10%) than for the online surveys (1%–5%).

The same pattern is evident for gambling at "other sports event in person," for which the health survey estimates are generally higher compared with the online surveys. Some of this difference likely reflects the cessation of in-person events in March 2020, although the 2019 YouGov survey also shows a lower estimate than the health surveys for in-person gambling activities, so change in gambling behavior due to lockdown restrictions does not completely account for the difference.

The opposite pattern is evident for online betting at bookmakers, for which the health surveys have lower estimates than the online surveys and for online casino games, where the health surveys are among the lowest estimates. The health surveys, then, also detect different types of gambling activities, with in-person gambling more common and online gambling less common compared with the online surveys.

Table 2 reveals a marked difference in the reported frequency of gambling, with the online surveys showing a range of 15%–26% gambling more than once a week, compared with 10% for the 2018 HSE. The higher rate of gambling in the online surveys is also evident at the opposite end of the scale, with 10%–20% reporting gambling only once or twice a year compared with 28% in the 2018 HSE.

Existing studies have found that online and higher frequency gambling are associated with an increased risk of gambling harm.[3,14] This is also the case here, where in all the surveys, the

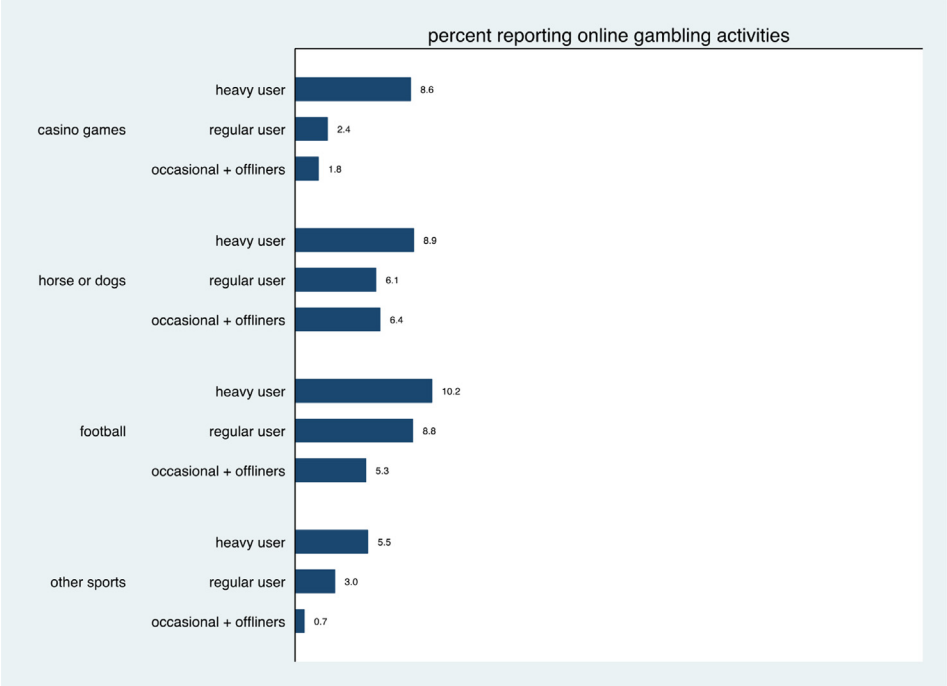

Fig. 4. Percentages of adults who engage in different online gambling activities, by frequency of Internet use, estimated from the Kantar Public Voice survey.

estimated proportions of people with PGSI+1 broadly increase with higher frequency of gambling (these figures are shown in Table A2 of Appendix 2). However, it is also the case that at all levels of frequency, this proportion is higher in the online surveys than in the face-to-face health surveys. It therefore seems likely that differences in sample composition in both frequency of gambling and type of gambling activity are responsible for the higher rates of problem gambling in the online surveys. The online surveys contain more people more likely to gamble online and to gamble frequently, and these characteristics are associated with an elevated risk of harmful gambling.

We can also examine differences between the surveys in other characteristics of the respondents, although this is limited to a small number of variables, which are consistently available for them. Table A3 in Appendix 2 shows the estimated distributions of four demographic characteristics. For gender and age, these are similar by construction because these variables are typically incorporated in the survey weights. Estimated distributions of ethnic group (as White vs non-White) are also very similar. Larger differences are observed only for educational qualifications, where the online surveys estimate more people with degree-level qualifications and fewer with no qualifications than do the health surveys. Higher education is in turn associated with more online betting (results not shown here), which could account for some of the differences discussed previously.

How might these differences in sample composition have come about? First, non-probability online panels have been shown to produce substantially biased estimates of behaviors relating to the Internet and technology use.[15,16] Two possibilities are germane to the question of why an online bias might be evident for the probability panel surveys. First, although the offline population and infrequent Internet users *can* join these panels, they may still be underrepresented. Fig. 3 shows the amount of time people spend on the Internet is higher at wave 7 than at the recruitment interview survey of the Kantar Public Voice panel. Because the comparison here is on a variable measured at the recruitment survey, this change over time is driven by less frequent Internet users dropping out of the panel rather than an increase in Internet use by panel members.

Finally, Fig. 4 shows the rates of four types of online gambling in the Kantar survey for heavy, regular, and occasional users combined with offliners. Heavy Internet users are considerably more likely to report all four online gambling activities. This lends additional support to the contention that the online surveys select for people who are more likely to be online and frequent gamblers and who, in turn, are more likely to report gambling harm.

Discussion

Until 2018, official statistics on gambling in Great Britain were delivered using probability sampling and in-person interviewing, an approach that produced comparatively low estimates of gambling harm. However, a survey carried out by YouGov in 2019 estimated a total of more than 6 million adults falling in the “at risk” category. Such wide variability in estimates raises questions about what the true level of harmful gambling is in the general population and what the most appropriate approaches are for estimating gambling harm. The question of how survey mode affects the accuracy of estimates of gambling behavior is particularly pressing as the COVID-19 pandemic has accelerated the shift from interviewer administered to online interviewing.[17,18]

Our objective in this article has been to provide insight on the likely rate of gambling harm in England by identifying the sources of error that are driving disparities in estimates. To do this, we have made comparisons between eight surveys containing a consistent set of gambling questions but varying approaches to sample design and data collection. For six of the surveys, data collection was done via online self-completion with two using a mixed-mode (online and telephone) design, although for the mixed-mode surveys, the vast majority of interviews (90%) were carried out online. Three of the online surveys used probability sampling, and three used non-probability (quota) sampling.

These comparisons have enabled us to identify selection bias as the primary source of the differences in estimates of gambling harm. Comparisons across a range of estimates revealed a systematic pattern: the online surveys contained gamblers who were more likely to gamble online and to gamble frequently. Other potential causes of the differences, including true change in harmful gambling, sampling variability, coverage error, and differential measurement error, seem unlikely to exert a notable influence.

These differences in sample composition are likely to be driving the discrepancies in rates of problem gambling between surveys, with online surveys—whether based on probability or non-probability samples—tending to overestimate gambling harm relative to interviewer-administered in-person surveys. A similar pattern of online surveys overstating the true level of problem gambling has also been observed in a recent systematic review[1] (but see also Russell et al[19]). When samples contain disproportionate quantities of online and frequent gamblers (compared with the general population), surveys will tend also to overestimate gambling harm because online and frequent gambling are independently associated with a higher probability of gambling harm.

Author statements

Ethical approval

None declared.

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Competing interests

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2021.12.014.

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Short Communication

Impact of SARS-CoV-2 Alpha variant (B.1.1.7) on prisons, England

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ABSTRACT

Objectives: Prisons are high-risk settings for infectious disease outbreaks because of their highly dynamic and crowded nature. During late 2020, prisons in England observed a surge in COVID-19 infection. This study describes the emergence of the Alpha variant in prisons during this period.
Methods: Alpha and non-Alpha variant COVID-19 cases were identified in prisoners in England using address-matched laboratory notifications and genomic information from COG-UK.
Results: Of 14,094 COVID-19-positive prisoner cases between 1 October 2020 and 28 March 2021, 11.5% (n = 1621) had sequencing results. Of these, 1082 (66.7%) were identified as the Alpha variant. Twenty-nine (2.7%) Alpha cases required hospitalisation compared with only five (1.0%; $P = 0.02$) non-Alpha cases. A total of 14 outbreaks were identified with the median attack rate higher for Alpha (17.9%, interquartile range [IQR] 3.2%–32.2%; $P = 0.11$) than non-Alpha outbreaks (3.5%, IQR 2.0%–10.2%).
Conclusion: Higher attack rates and increased likelihood of hospitalisations were observed for Alpha cases compared with non-Alpha. This suggests a key contribution to the rise in cases, hospitalisations and outbreaks in prisons in the second wave. With prisons prone to COVID-19 outbreaks and the potential to act as reservoirs for variants of concern, sequencing of prison-associated cases alongside whole-institution vaccination should be prioritised.

Introduction

In November 2020, a rise in SARS-CoV-2 infections was observed in the United Kingdom despite lockdown measures, coinciding with the emergence of a new SARS-CoV-2 variant, Alpha (B.1.1.7), first identified in Southeast England. Surveillance and modelling data indicated that this variant had greater transmissibility compared with non-Alpha cases,[1,2] leading to widespread concern and immediate foreign travel restrictions.

During late 2020, prisons in England observed a rise in COVID-19 outbreaks as well as increased case and age-standardised mortality rates compared with community settings.[3] To protect residents and staff, the Ministry of Justice implemented measures across the prison estate, which included restricting regimes to implement social distancing, stopping all visits, limiting movement of prisoners between facilities and compartmentalising prisons to isolate symptomatic prisoners, shield the vulnerable and quarantine new entrants.[4] Reception testing of prisoners and mass testing of prison residents during outbreaks were also introduced during the second wave of the pandemic in England.

Given the increased risk of SARS-CoV-2 transmission and illness due to both the prison environment and the susceptibility of the population, understanding the introduction of variants into such institutional settings is a public health priority.

The aim of this study was to describe the impact of the emergence of the Alpha variant on prison-associated cases and outbreaks of COVID-19.

Methods

Data sources

As a statutory requirement, positive SARS-CoV-2 tests are notified to the national Second Generation Surveillance System,

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capturing both laboratory and point-of-care tests. Records for cases among prisoners were identified between 1 October 2020 and 28 March 2021 using an address-matching process described elsewhere.[5] Alpha and non-Alpha variant cases were identified from the national COG-UK consortium database. As no other variants of concern (VOC) or variant under investigation (VUI) were identified within this cohort, non-Alpha refers to non-VOC/VUI samples identified in this study. Hospitalisation data were obtained by linkage to national hospital admission and accident and emergency data.[6]

Definitions

Outbreaks in prisons were defined as ≥2 cases within a 14-day rolling window (by specimen date) residing at the same prison. Outbreaks were classified as Alpha or non-Alpha according to sequencing results available. Outbreaks still ongoing at the end of the study period were excluded, as were outbreaks containing mixed sequencing results. Outbreaks with at least one sequenced case were included regardless of the order of sequenced and non-sequenced cases. Analyses were conducted on all cases within the outbreaks regardless of whether sequenced. Attack rates were defined as the number of cases among prisoners in the outbreak (numerator) divided by the population of prisoners in that specific facility (denominator) derived from the February 2021 Prison Population Bulletin.[7] Attack rates were only calculated on the first outbreak in prisons where multiple outbreaks were identified.

Hospitalisation was defined as an admission to hospital within 14 days following a positive COVID-19 test. Associated deaths were defined as deaths in cases occurring up to 60 days following the earliest positive specimen date or where COVID-19 was stated on their death certificate.

Analysis

Alpha and non-Alpha cases were compared using the Mann–Whitney U and Chi-squared tests as appropriate. The distribution of attack rates was compared using Kruskal–Wallis tests.

Results

We identified 14,094 SARS-CoV-2 cases among those residing in prisons during the study period, with every prison in England (n = 112) identified as having ≥1 confirmed case. Of these cases, 11.5% (n = 1621) were sequenced with 79.5% of all prisons (n = 89) having at least one sequenced case. Sequenced cases were broadly reflective of prison cases during the study period in terms of sex, age, ethnicity and prison type (Supplementary Table 1). A smaller proportion of Alpha cases were female (0.7 vs 6.7%; $P < 0.001$) or of White ethnicity (55.9 vs 75.3%, $P < 0.001$) compared with non-Alpha variants (Supplementary Table 1). Most Alpha cases (55.2%) were in male category C trainer prisons, whereas most non-Alpha cases were in local prisons.

The majority of sequenced cases (n = 1,082, 66.7%) were Alpha (Fig. 1), accounting for 0.74% of all sequenced Alpha variant cases in England (n = 146,479). Of the 1621 sequenced cases associated with prisons, 2.7% (n = 29) of Alpha cases required hospitalisation compared with only 0.9% (n = 5) of non-Alpha cases ($P = 0.02$); however, there were no significant differences observed regarding mortality, likely because of the small number of deaths observed.

Prison outbreaks

There were 74 prison outbreaks included in the analysis, of which 33 were Alpha outbreaks and 41 non-Alpha outbreaks, involving 1803 and 1756 number of prisoners, respectively. The majority (27; 81.8%) of Alpha outbreaks started between December 2020 and January 2021.

The median size of Alpha outbreaks (24; interquartile range [IQR] 6-63) was slightly greater than non-Alpha outbreaks (18; IQR 9-63), but the median outbreak duration was greater in non-Alpha outbreaks (31 days; IQR 17-46) compared with Alpha variant outbreaks (22 days; IQR 14-51); however, these differences were not statistically significant ($P > 0.05$).

Attack rates were just over five times higher in Alpha only outbreaks compared with non-Alpha only, 17.9% (IQR 3.2%–32.2%)

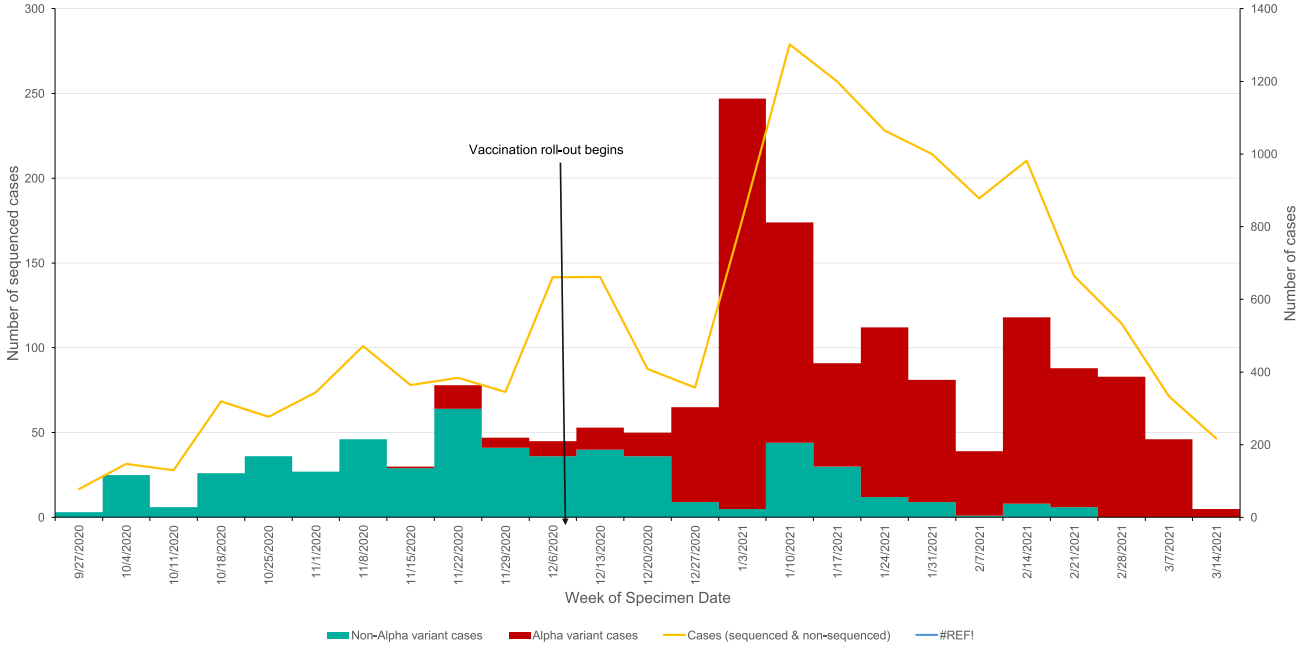

Fig. 1. Weekly number of COVID-19-positive prisoners (n = 14,094) and sequencing results (n = 1621), England.

and 3.5% (IQR 2.0%–10.2%) respectively; however, there was only weak evidence for a difference ($P = 0.11$).

Discussion

This study is the first nationwide assessment of the impact of the Alpha variant in prisons, benefiting from a robust enrichment process of residential property assignment and genomic sequencing results.

We identified Alpha as the predominant variant in prisons during England's second pandemic wave, reflecting the COVID-19 trend nationally. Prisons are not isolated from society, and ingress of infection from staff, visitors and new receptions remains an ongoing threat.[8] In its assessment of emerging threats during the pandemic, the Scientific Advisory Group for Emergencies (SAGE) in England has cited prisons as a particular infection hazard to the community, given the risk that these establishments can become 'reservoirs and amplifiers of infection, including variants of concern'.[9] This risk is not limited to SARS-CoV-2, and a recent systematic review has identified examples of the public health risk of prison outbreaks, including the release of prisoners exposed to TB into the community.[10] Among sequenced cases, there was some evidence for greater hospitalisations in Alpha cases when compared with non-Alpha cases, consistent with findings in the wider population.[6] Attack rates were five times higher in Alpha variant outbreaks compared with non-Alpha only outbreaks, which suggest increased transmissibility of the Alpha variant, in line with other published findings[1] and its contribution to the rise in cases in prisons in the second wave. However, with the majority of Alpha outbreaks in December and January, this finding may also be reflective of greater indoor mixing during the winter months, higher community incidence and change in testing regimes.[4]

Limitations of this study include low sequencing coverage over the study period, hence the need to assume that non-sequenced cases within an outbreak were of the same variant as the sequenced cases and, second, the crude assessment of hospitalisations, potentially limiting generalizability. Furthermore, we were unable to discern whether there were multiple introductions of Alpha into the prison rather than a continuous outbreak using our data set.

Prisons are prone to infectious disease outbreaks because of their highly dynamic and crowded nature and the vulnerability of residents. These factors can lead to prisons acting as potential reservoirs for VOC; therefore, alongside early whole-institution vaccination, prioritisation of prison-associated cases for sequencing is important. This would allow for early identification of VOC, improve understanding of transmission dynamics and changing epidemiology, thus informing disease control measures to prevent further spread of COVID-19 in prisons and the wider community.

Author statements

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Ethical approval

All data were collected within statutory approvals granted to Public Health England for infectious disease surveillance and control. Information was held securely and in accordance with the Data Protection Act 2018 and Caldicott guidelines.

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Competing interests

The authors have no relevant financial or non-financial conflicts of interest to disclose.

Availability of data and material

Data are incorporated into the article and material contained within. Individual-level data cannot be shared due to ethical/privacy reasons.

Authors' contributions

A.V., T.L. and D.C. were the principal investigators, and A.V. led the writing of this report. T.L., D.C. and A.V. made significant contributions to conception of the study design. All authors contributed to the interpretation of results and critical review.

Consent to participate

All data were collected within statutory approvals granted to Public Health England for infectious disease surveillance and control. Information was held securely and in accordance with the Data Protection Act 2018 and Caldicott guidelines.

Consent for publication

All data were collected within statutory approvals granted to Public Health England for infectious disease surveillance and control. Information was held securely and in accordance with the Data Protection Act 2018 and Caldicott guidelines.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2021.12.018.

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Original Research

Low uptake of COVID-19 lateral flow testing among university students: a mixed methods evaluation

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ABSTRACT

Objective: This study aimed to evaluate COVID-19 lateral flow testing (LFT) among asymptomatic university students.
Study design: This study was a mixed methods evaluation of LFT among University of Bristol students.
Methods: We conducted (1) an analysis of testing uptake and exploration of demographic variations in uptake using logistic regression; (2) an online student survey about views on university testing; and (3) qualitative interviews to explore participants' experiences of testing and subsequent behaviour, analysed using a thematic approach.
Results: A total of 12,391 LFTs were conducted on 8025 of 36,054 (22.3%) students. Only one in 10 students had the recommended two tests. There were striking demographic disparities in uptake with those from ethnic minority groups having lower uptake (e.g. 3% of Chinese students were tested vs 30.7% of White students) and variations by level and year of study (ranging from 5.3% to 33.7%), place of residence (29.0%–35.6%) and faculty (15.2%–32.8%). Differences persisted in multivariable analyses. A total of 436 students completed the online survey, and 20 in-depth interviews were conducted. Barriers to engagement with testing included a lack of awareness, knowledge and understanding, and concerns about the accuracy and safety. Students understood the limitations of LFTs but requested further information about test accuracy. Tests were used to inform behavioural decisions, often in combination with other information, such as the potential for exposure to the virus and perceptions of vulnerability.
Conclusions: The low uptake of testing brings into question the role of mass LFT in university settings. Innovative strategies may be needed to increase LFT uptake among students.

Introduction

Lateral flow testing (LFT) of asymptomatic people remains an integral part of the UK's COVID-19 response. Since 9 April 2021, everyone in England has been eligible to take an LFT twice weekly.[1–4] There is an ongoing and polarised debate around mass testing to detect asymptomatic infections using this technology. As approximately one-third of people infected with SARS-CoV-2 have no symptoms, it is argued that identifying infections among this group so that they can isolate and their contacts be traced is key to controlling the pandemic.[3,4] Although this policy was well received by some,[5–7] others have raised concerns, particularly around test accuracy and the potential consequences of inaccurate results.[8–11] Although the accuracy of LFT is important, much less attention has been paid to the levels of uptake of testing, which could pose a major barrier for the use and effectiveness of asymptomatic testing.

In Autumn 2020, COVID cases were high among university students in the United Kingdom.[12] In November 2020, the government recommended LFT for university students, recommending that all students should have two negative tests before travelling home for the winter break.[1,13] In line with these recommendations, the University of Bristol announced that free LFT would be available for all students between 30 November and 18 December. During

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this period, students were able to book an appointment online and receive an LFT at one of two testing sites within the University. Students were offered two tests and were encouraged to leave 3 days between the first and the second test. The testing procedure was undertaken by the students themselves, but full instructions and support were available. The results were sent to the student by text and email approximately 30 min after their appointment. Evaluation of this testing strategy, including equity in testing uptake, is crucial if testing continues to be used to control the pandemic in the future.

University populations offer a unique opportunity to quantify testing uptake in a well-defined group of individuals. Our study aims to (1) assess uptake of LFT among University of Bristol students, including demographic variations, (2) explore the acceptability and feasibility of asymptomatic testing, and (3) explore the barriers and facilitators to uptake and effective implementation of testing.

Methods

We conducted a mixed methods evaluation of LFT among University of Bristol students who did not have COVID-19 symptoms, comprising a quantitative analysis of testing uptake data, a student survey and qualitative interviews.

Quantitative analysis

We analysed data on the uptake of LFT from 30 November to 18 December 2020. Students prebooked their tests online. On arrival at testing venues, they were asked to swipe their university identity card. A list of all students enrolled at the university, held by student records, was matched with the date of any tests undertaken, as collected via card swipes at testing venues using student ID number. Information held by student records included student's demographic data, level and year of study, faculty and place of residence (whether in halls or not). Testing uptake percentages were calculated among all students enrolled at the university. Information on location of students during the study period was not available. However, a sensitivity analysis was conducted by excluding students who were either enrolled on a distance learning course or completed a 'location of study' form, indicating that they were likely not going to be on campus. The total number of positive results was recorded at testing sites but was not documented for individual students. Univariable and multivariable analyses were conducted using logistic regression to explore demographic factors associated with being tested. All explanatory variables were included in the multivariable model *a priori*. Analyses were conducted in STATA 16.1 (StataCorp LLC, College Station, TX).

Survey

Participants were invited to complete a confidential online survey about their views of university testing (Supplement 1). A link to the survey was shared by the university communications team via social media (Facebook, Twitter and Instagram) and to all students enrolled at the University via the student newsletter. Informed consent was obtained.

Frequencies and descriptive statistics are presented for closed survey questions. Free text answers were used to offer further insight into answers given to closed survey questions. We identified key barriers to engagement with testing using qualitative content analysis in three stages[14–16] – survey responses were coded independently by two authors, codes were then categorised into a list of barriers and facilitators, and data assigned to each category.

Interviews

Volunteers who took part in the survey and provided consent to be contacted by the research team were invited to take part in an online interview. Participants were aged >18 years and a registered student at the university. We purposely sampled for diversity in key factors, including ethnicity, living arrangements, enrolled course, and whether or not they had taken a test at the university. Sample size was informed by the concept of 'information power',[17] with continuous assessment of the data in relation to study objectives.

Potential participants were provided with a study information sheet and given an opportunity to ask questions, informed of the voluntary nature of the study, and assured of the confidentiality of their data. All interviews were conducted via the telephone or online, and audio recorded verbal consent was obtained.

The semistructured topic guide (Supplement 2) aimed to explore participants' views about testing, understanding and interpretation of test results and impact on behaviour.

Data from interviews were analysed using a thematic approach.[18,19] Two researchers independently read and assigned codes to transcripts. Possible themes were identified and refined. Charts were developed for each theme, and relevant text from transcripts was copied verbatim. Charts were then used to compare data within and between individuals.

Results

Testing uptake

A total of 12,391 LFD tests were conducted on 8025 (22.3%) of the 36,054 students enrolled at the university. Of those tested, 3921 (48.9%) had one test, 3880 (48.3%) had the recommended two tests, 189 (2.4%) had three tests and 35 (0.4%) had four to six tests. There were 13 positive results.

Demographic variations in testing uptake (Tables 1 and 2)

Although the absolute percentage of students taking up testing was similar across genders (21.9% for men and 22.5% for women), women were more likely to be tested than men (adjusted odds ratio [aOR]: 1.18, 95% confidence interval [CI]: 1.11–1.25). There were striking variations in uptake by ethnic group. Uptake was highest in ethnically White students, with 30.7% taking at least one test. Uptake was lower among all other groups – it was lowest among students belonging to the Chinese ethnic group (3%, aOR: 0.17, 95% CI: 0.14–0.20), followed by the Black African, Black Caribbean and Black other group (12.3%, aOR: 0.34, 95% CI: 0.28–0.42). It was also low among the Indian, Pakistani and Bangladeshi groups (17.5%, aOR: 0.53, 95% CI: 0.47–0.61).

When compared with Year 1 undergraduate students living in halls of residence, Year 1 undergraduate students not living in halls were less likely to be tested (aOR: 0.20, 95% CI:0.17–0.24), as were postgraduate students, particularly postgraduate taught students (aOR: 0.15, 95% CI:0.14–0.17). Testing uptake also varied by faculty. Compared with students in the Faculty of Science, uptake was lower among those in all other faculties. It was lowest in the Faculty of Social Sciences and Law and the Faculty of Arts.

A sensitivity multivariable analysis excluding students who were likely not to have been on campus during the testing period ($n = 4907$, 13.6% of all students) did not alter the observed patterns

Table 1
Demographic characteristics of students according to uptake of testing ($n = 36,054$).

Characteristic	Not tested		Tested		Total
	n	%	*n*	%	*n*
Gender					
Male	12,430	78.1	3489	21.9	15,919
Female	15,557	77.5	4526	22.5	20,083
Other	40	80.0	10	20.0	50
Ethnic group					
White	14,675	69.3	6508	30.7	21,183
Indian, Pakistani, Bangladeshi	1423	82.5	301	17.5	1724
Black African, Black Caribbean, Black other	742	87.7	104	12.3	846
Chinese	5543	97.0	172	3.0	5715
Mixed	1220	72.2	470	27.8	1690
Other	1464	86.9	220	13.1	1684
Not reported	2962	92.2	250	7.8	3212
Level of study					
Undergraduate	15,700	69.3	6960	30.7	22,660
Postgraduate – research	3645	86.4	575	13.6	4220
Postgraduate – taught	8684	94.7	490	5.3	9174
Year of study[a]					
Year 1[b]	5898	72.6	2225	27.4	8123
Year 2	4384	68.4	2025	31.6	6409
Year 3	3873	66.8	1926	33.2	5799
Year 4+	1545	66.3	784	33.7	2329
Place of residence[a]					
In halls	3779	64.4	2093	35.6	5872
Not in halls	11,921	71.0	4867	29.0	16,788
Faculty					
Faculty of Science	2945	67.2	1438	32.8	4383
Faculty of Arts	4833	74.1	1694	26.0	6527
Faculty of Engineering	4267	81.6	960	18.4	5227
Faculty of Health Sciences	3232	75.1	1072	24.9	4304
Faculty of Life Sciences	2712	71.8	1065	28.2	3777
Faculty of Social Science and Law	10,039	84.8	1796	15.2	11,835

[a] Restricted to undergraduate students only.
[b] Includes 153 presessional students.

Table 2
Univariable and multivariable logistic regression analyses of demographic characteristics associated with testing uptake.

Characteristic	Univariable analysis			Multivariable analysis ($n = 36,051$)		
	Odds ratio[a]	95% CI	*P* value	Adjusted odds ratio[a]	95% CI	*P* value
Gender						
Male	Reference			Reference		
Female	1.04	0.99–1.09	0.161	1.18	1.11–1.25	<0.001
Other	0.89	0.44–1.78	0.744	1.42	0.67–3.02	0.360
Ethnic group						
White	Reference			Reference		
Indian, Pakistani, Bangladeshi	0.48	0.42–0.54	<0.001	0.53	0.47–0.61	<0.001
Black African, Black Caribbean, Black other	0.32	0.26–0.39	<0.001	0.34	0.28–0.42	<0.001
Chinese	0.07	0.06–0.08	<0.001	0.17	0.14–0.20	<0.001
Mixed	0.87	0.78–0.97	0.012	0.84	0.75–0.95	0.004
Other	0.34	0.29–0.39	<0.001	0.44	0.38–0.51	<0.001
Not reported	0.19	0.17–0.22	<0.001	0.20	0.17–0.22	<0.001
Student group						
Undergraduate – Year 1[b] – In halls	Reference			Reference		
Undergraduate – Year 1[b] – Not in halls	0.13	0.11–0.15	<0.001	0.20	0.17–0.24	<0.001
Undergraduate – Year 2	0.82	0.76–0.88	<0.001	0.85	0.79–0.92	<0.001
Undergraduate – Year 3	0.88	0.82–0.95	0.001	0.88	0.81–0.95	0.001
Undergraduate – Year 4+	0.90	0.81–1.00	0.042	0.85	0.76–0.95	0.004
Postgraduate - Research	0.28	0.25–0.31	<0.001	0.28	0.25–0.31	<0.001
Postgraduate – Taught	0.10	0.09–0.11	<0.001	0.15	0.14–0.17	<0.001
Faculty						
Faculty of Science	Reference			Reference		
Faculty of Arts	0.72	0.66–0.78	<0.001	0.64	0.59–0.70	<0.001
Faculty of Engineering	0.46	0.42–0.51	<0.001	0.70	0.63–0.77	<0.001
Faculty of Health Sciences	0.68	0.62–0.75	<0.001	0.67	0.61–0.75	<0.001
Faculty of Life Sciences	0.80	0.73–0.88	<0.001	0.75	0.68–0.83	<0.001
Faculty of Social Sciences and Law	0.37	0.34–0.40	<0.001	0.63	0.58–0.69	<0.001

CI, confidence interval.
[a] An odds ratio of <1 indicates lower uptake of testing compared with the reference group.
[b] Includes 153 presessional students.

in testing uptake. Odds ratios changed a little (all <10%) and were within the confidence intervals reported in Table 2.

Survey

A total of 436 students completed the survey, of which 328 (75%) had taken part in testing and 108 (25%) had not (Supplement 3).

Attitudes towards testing

Among students who engaged in the university testing service and those who did not, the majority described their views of getting regular tests as either somewhat positive (31% and 31%, respectively) or very positive (51% vs 31%). Few participants described their views of testing as somewhat negative or very negative (18% of those who did not participate in testing vs 5% of those who did: Table 3).

Interpretation of test results

Most students understood that a negative test result meant that the person is probably not infectious (84% of those who had a test vs 75% of those who did not – Table 3). Only a minority of students in both groups thought a negative test means the person is definitely not infectious (6% of those engaging in testing vs 12% of those who did not) or that they did not know (4% of those engaging in testing vs 9% of those who did not).

Behaviour

Approximately half of the students engaging in testing reported that the level of contact with others had not changed in the seven days after the testing period (55%). Nineteen percent of students reported that close contact increased, and 17% reported that close contact had decreased following tests (Table 3).

Self-reported adherence to the guidance was similar between the groups, with 90% of those engaging in testing and 81% of those not engaging in testing reporting that they had been adherent to the guidance all or most of the time (Table 3).

Barriers

A total of 108 comments were coded and used to identify barriers to engagement in testing (Table 4). Barriers were categorised as (1) perceived lack of need or demand, (2) problems accessing the service, (3) safety concerns, (4) knowledge and understanding, and (5) lack of support for self-isolation.

Interviews

Twenty-one students were interviewed, including 14 who reported that they had taken a test at the university in December 2020 and seven who had not. Of the 14 students who had been tested, two had received one test and 12 had received two or more tests. Fifteen participants were women, and six participants were men. Eight participants were from minority ethnic groups. Six participants were postgraduate students, five were in Year 1, six were in Year 2, three were in Year 3, and one participant was in Year 4.

Data are presented under three main themes: (1) motives for engaging in testing, (2) barriers to testing, (3) and using test results to inform behavioural decisions.

Motives for engaging in testing

Three main motives for taking part in university testing procedures included (1) to reduce the risk of transmitting the virus, (2) for information and (3) following recommendations and guidance.

To reduce the risk of transmission to others

Most students were more concerned about the risk to others than to themselves (Table 5 quote 1) and were willing to take tests to protect other people from the virus. Tests provided reassurance that they were not spreading the virus to others (quote 2). This was particularly important for those planning to relocate for the holidays (quote 3), those with vulnerable family members (quote 4) or those who considered themselves to have been at risk of exposure to the virus (quote 5).

Table 3
Responses to survey questions.

Survey question	Participated in testing, N = 328	Did not participate in testing, N = 108
Views on getting tested regularly		
Very negative	2 (1%)	5 (5%)
Somewhat negative	14 (4%)	14 (13%)
Neither positive or negative	31 (9%)	16 (14%)
Somewhat positive	103 (31%)	39 (31%)
Very positive	169 (51%)	33 (31%)
Interpretation of negative test results		
The person is definitely infectious	6 (2%)	1 (1%)
The person is probably infectious	11 (3%)	3 (3%)
The person is probably not infectious	277 (84%)	81 (75%)
The person is definitely not infectious	21 (6%)	13 (12%)
Don't know	13 (4%)	10 (9%)
Close contact following test		
Much more contact	12 (4%)	NA
Slightly more contact	49 (15%)	NA
About the same	180 (55%)	NA
Slightly less	22 (7%)	NA
Much less	35 (10%)	NA
Missing	30 (%)	NA
Adherence to social distancing recommendations		
All of the time	139 (42%)	41 (38%)
Most of the time	156 (48%)	47 (43%)
Some of the time	19 (6%)	7 (6%)
Not at all	1 (0%)	5 (5%)
Missing	13 (4%)	8 (7%)

Table 4
Coded survey responses relating to barriers and facilitators to testing.

Theme	Description	Example quote	Count
Perceived lack of need/demand			
Lack of exposure/self-isolating	Includes comments about not requiring tests due to not being exposed to the virus (e.g. as a result of students self-isolating).	*"I had already been isolating (by choice) for two weeks, so that I was able to go home."*	6
Lack of travel plans	Includes comments by participants who are not intending to leave Bristol.	*"As I had no plans to go home over Christmas I didn't go for a test."*	11
(Low) priority	Captures comments by participants who do not think COVID is a threat.	*"Completely unnecessary, cancer has a higher chance of death but I don't get tested for cancer."*	1
Students not in Bristol	Many students were not in Bristol at the time of testing.	*"I had already returned home for lockdown before tests were available."*	13
Previously tested positive	Comments about tests not being necessary due to having previously tested positive.	*"I have already had the virus so would not be expected to contract it again."*	9
Accessing the service			
Location	Includes comments about testing sites being inaccessible to those who live off campus, are based at a different campus (e.g. Langford) and/or who are new to the University and not familiar with the layout.	*"Test site are too far away for many students in private housing."*	12
Timing of testing	Includes comments relating to a too narrow testing window for some students – in particular international students, those on placement, and/or those with jobs were not able to travel within the window specified.	*"I was travelling after the student travel window as I'm an EU student, and the student travel window was very inconvenient. The testing during the travel window was stopped before I needed to get a test in coordination with my travel plans, as the University testing was too early for me so wouldn't have been helpful."*	5
Inaccessible to key groups	Includes comments about testing facilities being inaccessible to those with additional needs and/or with caring responsibilities.	*"Current testing facilities and practice fail the disabled population."*	2
Booking issues	Includes comments about students being unable to use the booking system and/or book tests.	*"Tried to book a slot on website and it was not easy so I gave up."*	5
Safety concerns			
Risk of exposure at the testing site	Comments about concerns of risk of exposure whilst accessing tests.	*"After watching the virtual tour of the testing facilities (on Instagram), and also showing this to my family, it seemed the booths were all very close together in an enclosed space. This, combined with the high rates of Covid among the student population, made me feel that getting a test in these conditions would put me at greater risk of catching the virus."*	10
Accuracy of tests	Includes comments about tests not being suitable or accurate enough to facilitate safe travel. Also includes comments by students who had had a confirmatory PCR with conflicting result.	*"The lateral flow tests were advertised as a green card to go home safely without self isolating. It was made to seem like people who test negative are safe. I feel like I was misled because I was not aware that half of positive cases are missed and I felt like I had a false sense of security. Lateral flow tests literally say not for asymptomatic testing on the packaging."*	11
Knowledge and understanding			
Of testing	Including comments about a lack of/unclear instructions about how to take the test and/or number of tests needed.	*"I thought the testing instructions weren't clear enough for someone who isn't familiar with anatomy. "Swab your tonsils for 10 s" is only a useful instruction if you know where the tonsils actually are."*	5
Of eligibility	Includes comments in which participants explain that they did not take part in the testing program as they did not have symptoms/had previously tested positive and/or did not understand who testing was for.	"*I didn't know the testing facility was for even if you didn't have symptoms.*"	7
Impact of test results			
Lack of support for self-isolation	Includes concerns about the lack of support for those who test positive.	*"My other main concern is the lack of mental health support for those isolating and/or following all guidelines."*	2

For information

In some cases, students wanted to take tests for information (quote 6). Although these students were not necessarily planning to travel, they were keen to take tests for their own benefit (quote 7), including for their mental health (quote 8).

Following recommendations

Students reported taking tests simply because they were available (quote 9) and supported by the University (quote 10). For some, tests were a requirement for attendance at in-person lectures (quote 11) or travel (quote 12).

Barriers

Barriers to uptake of testing include (1) lack of need, (2) lack of awareness, (3) access, and (4) risk of exposure at the testing site.

Lack of need

One reason for not engaging in testing was that the student did not think that tests were required or intended for them. For example, one student explained that she had not taken a test at the university because she was not planning to travel away from Bristol (quote 13). In some cases, participants did not think tests were

Table 5
Key quotes from interview participants.

Motives for engaging in testing	
Reduce the risk of transmission to others	
Quote 1	"I'm most nervous about passing it on to somebody …. I know a lot of people live with parents or older people or just people on the street. Obviously I don't want to get it myself because that would not be fun but I'm more nervous about passing it onto someone … I'm more worried about hurting someone else." [female, Asian, tested]
Quote 2	"I think it's good for that reason to make sure that you're fine and you know that just going to the shops you're less likely to spread it to someone." [female, Asian, tested]
Quote 3	"Because I was going home, I guess I wanted to lower the chance of me bringing COVID home." [female, White, tested]
Quote 4	"The first time was when the government told us we could all go back home and I wanted to do two tests because if I did get positive and I had to stay here a bit longer, but I would really rather not bring the disease back to my family. Both my parents are a little bit older and my brother's girlfriend is in the vulnerable category." [female, White, tested]
Quote 5	"I had two tests before Christmas because I'm on a PGC programme so I've been in school up until Christmas, then I went to see my family at Christmas." [female, White, tested]
For information	
Quote 6	"I just thought one of the main issues is not knowing whether you have it or not. Information is important so it was an opportunity to get information." [male, White, tested]
Quote 7	"I just wanted to have an idea. I mean I've been pretty good with isolating. I hadn't really been around many people since the beginning of December but … I just wanted to double check, yes … I wanted it for me." [female, mixed ethnicity, tested]
Quote 8	"So I think it's really important just on a mental health level to get tested to make sure that you're not spreading it around. I was negative. I was just worrying for no reason." [female, Asian, tested]
Following recommendations	
Quote 9	"I think just the fact that it was there, so there was obviously the opportunity to [get tested]." [female, White, tested]
Quote 10	"I think I just thought it must be quite important for us to get tested if the University was offering them." [female, White, tested]
Quote 11	"I came back to university and the university asked us all to get tested before our first practical." [female, White, tested]
Quote 12	So in my country, they don't really care about Coronavirus, to put it simply but because my mum is a doctor, she expected me to get tested basically." [female, Asian, tested]
Barriers to the uptake of testing	
Perceived lack of need	
Quote 13	"I wasn't getting tested at university because it was people before they were going home. I stayed in [Bristol]." [female, mixed ethnicity, did not get tested]
Quote 14	"I wanted to go home for Christmas so I just isolated to make sure … most of my friends were also isolating and even if they weren't my dad's part of the vulnerable group so it just felt like the proper thing to do." [female, White, did not get tested]
Quote 15	"Most of the others just straight out went to get PCR tests 'cause they were also going back home' …" [female, mixed ethnicity, did not get tested]
Lack of awareness	
Quote 16	"To be honest I only became aware of it when I received an email asking me why people weren't – like or asking me why I thought students weren't taking up this offer. So I didn't even know it was there before." [female, mixed ethnicity, did not get tested]
Quote 17	"I don't know if I would have found that information out if I didn't have friends telling me that. I mean I know a lot of people in other places didn't get tested and I don't know if they even knew there was testing going on." [male, White, did not get tested]
Access	
Quote 18	"I couldn't get the links to work and they changed location and something else so it's that sort of booking process and also not knowing where it is that's prevented me from doing it this term." [male, White, did not get tested]
Quote 19	"To be honest, by the time I sort of got round to it and got like, you know, kind of – because you had to get two and one of them I think was clashing with when I was going back [home]." [female, Asian, did not get tested]
Quote 20	"I had one [test].. I left it too late to have them both." [female, White, tested]
Risk of exposure at the testing site	
Quote 21	"What if going to the test centre I come in contact with someone who is positive and I get it there?" [female, White, did not get tested]
Quote 22	"I think practically it was about half an hour walk to the nearest station and because I was already isolating it didn't seem that practical for me to go out and expose myself and then get tested." [female, White, did not get tested]
Quote 23	"I know cases are going up and I'd rather just be in my house where I know I'm safe." [female, White, did not get tested]
Using test results to inform behavioural decisions	
Quote 24	"The accuracy of the test is something that I've discussed quite a lot with friends so I was aware that they were not very good at picking up asymptomatic cases, so I feel like I kind of took the negative result with like a pinch of salt." [male, mixed ethnicity, tested]
Quote 25	"I just thought it was like an additional bit of information." [male, White, tested]
Quote 26	"We had this testing I was kind of confident that, well okay I already had those tests. Nobody had any symptoms so I thought, okay it might be okay." [female, Asian, tested]
Quote 27	"I think I was just much less worried about travelling home with COVID. I think I was able to travel home with a bit more sort of like okay, the chances are I probably don't have COVID right now, like I've done everything I can anyway." [male, White, tested]
Quote 28	"I mean I accept that there is a margin for error with anything really but I was willing to accept the results as sufficient, as good enough to make decisions on, like to make my decisions on." [female, White, tested]
Quote 29	"I mean I think it does reassure you doesn't it … it is reassuring because even though it's not very accurate, you still haven't tested positive, so it is a level of reassurance, but it's very, it should be less than what it is, but even though someone who like knows about it and understands, I was still reassured and I think it's hard not to be and I guess isn't that sort of the point of testing anyway." [male, White, tested]
Quote 30	"I definitely wouldn't be visiting anyone who was vulnerable. Everyone in the household I was going to are not in their 60s but I think late 50s max and healthy and young." [female, mixed ethnicity, tested]
Quote 31	

(*continued on next page*)

Table 5 (*continued*)

	Obviously I wouldn't say get tested and go to parties because that's ridiculous but going to the shops and going on a walk and just going to places that you have to be." [female, White, tested]
Quote 32 and 33	"but then I was very aware that if I went into the supermarket then I could just easily have gone and got infected again so it was like yeah for now but [laugh] 'cause the wording was like at the time you took your test, you tested negative but reinforces like this is very temporary assessment of your situation but it's still better than like having no idea'."
	"my confidence in [the negative test result] decreases with the more contacts I have with people or the more public places I got to or when I'm with people. My confidence decreases the more exposure I have to people." [female, Asian, tested]
Quote 34	"I'm sure for some that it would but I'm sure for most that it wouldn't and I think the people who would probably act differently following one of those negative tests would probably act like that anyway. So I don't think, for the good impact it would have I think the negative impact would be very small."[female, White, tested]

needed because they were not considered capable of achieving perceived needs (e.g. of keeping themselves and their families safe). Indeed, those who were able and willing to isolate often considered this preferable to testing (quote 14) or demonstrated a preference for polymerase chain reaction (PCR) tests over LFT (quote 15).

Lack of awareness

A lack of awareness prevented some students from accessing the service (quote 16). Students thought that more could be done to promote awareness of testing, particularly among those who do not have a strong network of peers (quote 17).

Access

A number of practical barriers were described, including access issues (quote 18) and issues with the timing and location of test sites (quote 19). At times, access issues resulted in students only being able to have one test before travelling (quote 20).

Risk of exposure at the testing site

Concerns of catching the virus at or on route to the testing centre prevented some students from taking a test (quote 21), particularly among those who had to travel long distances (quote 22). It was noted that cases of the virus were high among the student population, and some considered the risk of exposure to outweigh the benefits of getting tested (quote 23).

Using test results to inform behavioural decisions

Most students were very aware of the ongoing debate about the accuracy of LFTs and reported having discussions with their friends and families and, in some cases, with the university about how accurate the tests were (quote 24). Tests were considered just one piece of information from which to inform decisions (quote 25), often being used alongside other key indicators – such as whether the person had been in contact with someone with the virus or if they had any symptoms (quote 26). Some students reported that testing had reassured them that they had 'done everything they could' before travelling (quote 27). Despite limitations, tests were seen as 'good enough' to inform decisions (quote 28), and although students reported feeling somewhat reassured by negative test results (quote 29), they described being unlikely to drastically increase contact or to visit anyone considered to be vulnerable (quote 30). Activities were limited to those that were considered essential, such as shopping and exercise (quote 31), and it was recognised that any negative rest result was only 'valid' for a limited time, and any subsequent contact was a potential risk (quotes 32 and 33).

There was an acknowledgement that receiving a negative test could increase close contact behaviour, but generally, it was noted that students who were likely to break the rules would do so regardless of testing status (quote 34).

Discussion

Our research revealed that one in 10 students had the recommended two LFTs and highlighted demographic disparities in uptake by ethnic group, level of study and year group and faculty. Data collected from survey and interview participants suggested that whilst students were generally positive about testing, key barriers to uptake remain. Our qualitative data revealed that many participants were motivated to take tests to protect those around them and avoid transmitting the virus to their friends and family. However, students reported a number of barriers to uptake, including a lack of awareness of the testing service, problems accessing the service, a lack of knowledge and understanding of testing procedures and concerns about the accuracy and safety of testing. Although overall uptake was low, many of those who did not take tests described a lack of need for tests because they were not travelling, were unlikely to have been exposed to the virus, were already isolating or were tested elsewhere.

Mass testing for COVID-19 is relatively new, and the results of testing programmes are ongoing. Our data revealed low testing uptake, particularly among those from ethnic minority groups. Similar patterns in testing uptake have been observed with some other public health interventions such as home HIV testing.[20] The mass COVID-19 LFT pilot conducted in Liverpool also reported a lower test uptake, as well as a higher positivity rate, among those from minority ethnic groups.[21] The very small number of positive tests during the study period precluded analyses on demographic variations in positivity, both due to a lack of power and the potential for deductive disclosure. Further research is urgently needed to explore barriers to testing among these populations and co-create interventions to support the uptake of tests if and when required.

Consistent with findings from other settings[22] and other universities, students engaging in testing were motivated to do so to protect those around them.[22,23] In line with survey studies that have explored knowledge, attitudes and behaviours in relation to COVID-19,[22] awareness and access issues often prevented students from receiving tests. Through the present study, we have been able to build on previous work and present a detailed consideration of these and other barriers to uptake among student populations. In particular, participants in the present study were able to describe a perceived lack of need for testing either due to personal circumstances or because they did not think that tests were able to achieve their perceived need. This highlights the need for additional information about the role and benefits of taking LFTs before travel.

Despite concerns that testing would increase risky contact, we did not find evidence to support this. Students were well informed about the limitations of the tests and used them with caution to inform behavioural decisions. Students were well informed about the limitations of tests, often describing test results as just one piece of information, and using them with caution to inform their behaviour.[24] Many students had done their own research and had

discussions with their friends, family, tutors and lecturers to maximise their knowledge of testing. This highlights the need for improved communications from universities to enable students to make their own informed decisions. Indeed, recent research that has shown basic and simple messages may not be suitable for communicating complex information about how to behave during the pandemic,[25] and students are likely to appreciate having the opportunity to access information about the sensitivity and specificity of the tests.

A key strength of this research is the use of a mixed methods approach. Additionally, though some other universities have evaluated their LFT programmes[26,27] we are not aware of any reporting data on testing uptake and exploring demographic variations in uptake among the whole student body. This is a unique strength of our work and provides crucial information to inform future university testing strategies. Our work identified several ways in which engagement may be enhanced. In particular, we recommend a persuasive, targeted and personalised campaign. Such a campaign should include encouragement from trusted sources and emphasise the benefits of testing to encourage participation among those who may be apathetic. It would also need to reassure those who are anxious about accessing the testing services. To maximise engagement, all messages should be co-created with the intended recipients of campaign. A limitation of the analyses on testing uptake is that denominator was all students enrolled at the university. The university does not hold comprehensive and reliable information on which students were resident in Bristol during the testing period. However, in our sensitivity analysis in which excluded students who were likely not to be in Bristol at the time of testing, the findings were little altered. A key limitation of the survey and interview data is that participant recruitment occurred via social media, and it is likely key communities (e.g. those who do not engage with university managed social media accounts) were missed.

It should also be noted that most participants who took part in the interviews had received two tests as part of University testing. Only a small number of participants had not taken a test or had only taken one test. It is therefore likely that the participants recruited had more positive attitudes toward testing than those who did not take part in the interview, and the full range of barriers to uptake of both first and second tests may not have been identified. Our results must be interpreted with this in mind. Indeed, the fact that only a small number of participants had chosen not to take a test precludes our ability to explore relationships between demographic variables and barriers to uptake of tests. Although a key finding from the analysis of the uptake of LFT is that uptake was lower among minority ethnic students, there did not appear to be any relationship between barriers and demographic variables among the seven participants who did not have a test. However, as this is only based on seven participants, this must be interpreted with caution. In addition, it was not possible to explore the impact of demographic variables for the survey phase of the research, as there were only a very small number of comments coded as each barrier. Likewise, as only a small number of participants reported having increased contact, it was not possible to explore any impact of demographic variables on behaviour.

Conclusions

LFT continues to play an important and expanding role in the UK's COVID strategy.[3,4] If regular LFT is considered appropriate and worthwhile going forwards, then work is needed to monitor trends in testing uptake among student, and other, populations. Importantly, we need to strive for equity in access to and uptake of testing. Our findings should be used to inform the wider debate around the usefulness and appropriateness of the widespread use of LFT for asymptomatic people.

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Ethical approval

Ethical approval was provided by the University of Bristol – Ethical approval was obtained from the University of Bristol faculty ethics committee (Reference 115084). All interview participants verbally consented to take part in the study.

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Competing interests

None declared.

Appendix A. Supplementary data

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Original Research

Tiered restrictions for COVID-19 in England: knowledge, motivation and self-reported behaviour

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ABSTRACT

Objectives: To test whether public knowledge and confidence in one's understanding of the local restrictions, motivation to adhere to local restrictions, and self-reported behaviour (going out for exercise, to work, socially) differed according to tier level.
Study design: Cross-sectional, nationally representative, online survey of 1728 participants living in England (data collection: 26 to 28 October 2020).
Methods: We conducted logistic regression analyses to investigate whether knowledge of restrictions, confidence in knowledge of restrictions, motivation to adhere to restrictions, and self-reported behaviour were associated with personal characteristics and tier.
Results: Between 81% (tier 2) and 89% (tier 3) of participants correctly identified which tier they lived in. Knowledge of specific restrictions was variable. 73% were confident that they understood which tier was in place in their local area, whereas 71% were confident they understood the guidance in their local area. Confidence was associated with being older and living in a less deprived area. 73% were motivated to adhere to restrictions in their local area. Motivation was associated with being female and older. People living in tiers with greater restrictions were less likely to report going out to meet people from another household socially; reported rates of going out for exercise and for work did not differ.
Conclusions: Although recognition of local tier level was high, knowledge of specific guidance for tiers was variable. There was some indication that nuanced guidance (e.g. behaviour allowed in some settings but not others) was more poorly understood than guidance which was absolute (i.e. behaviour is either allowed or not allowed).

Introduction

The first COVID-19 pandemic restrictions in England were nationwide. As the pandemic progressed, different infection rates in areas across the country led to a more localised approach being applied. For example, the city of Leicester continued to follow more stringent restrictions when those in the rest of the country were eased on 4 July 2020.[1,2] Over time, additional restrictions were imposed and eased in other areas.[3] This led to a complicated patchwork of restrictions throughout England. On 14 October 2020, a three tiered system was introduced in an attempt to simplify local restrictions for COVID-19.[4] English areas were assigned to tiers by the UK Government based on transmission levels, rates of increase of infection, age distributions, and the capacity of local healthcare services. The main restrictions that were in place in each tier are shown in Table 1. In response to growing infection rates, a second period of national lockdown was imposed from 5 November to 2 December 2020,[5] before reverting to a slightly stricter three-tier system.[6] The devolved nations have each taken their own approach, with Scotland implementing a five-level system,[7] and Wales implementing a four-level alert system.[8] Northern Ireland also implemented localised COVID-19 restrictions.[9]

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Table 1
Main restrictions in place in each tier from October to November 2020 in England.

Tier 1	Tier 2	Tier 3
Up to six people could meet indoors, outdoors in private gardens, and outdoors in public spaces	Up to six people could meet outdoors in private gardens and outdoors in public spaces No household mixing indoors	Up to six people could meet outdoors in public spaces No household mixing indoors
Hospitality venues remained open, but the majority had to close between 10pm and 5am	Hospitality venues remained open, but the majority had to close between 10pm and 5am	Hospitality venues such as pubs and bars had to close, unless they operated as a restaurant, serving 'substantial meals'. Closures between 10pm and 5am remained in place Travelling to areas in other tiers discouraged

Knowledge of the restrictions in place to prevent the spread of COVID-19 has been sub-optimal throughout the pandemic.[10] People have found guidance about social distancing and self-isolation confusing,[11] with frequent changes to the guidance contributing to this.[12,13] Throughout the pandemic, the use of clear and specific guidance has been emphasised to promote adherence to restrictions.[14] As clarity in the guidance around tiers appears to increase as restrictions tighten, it is plausible that understanding of the guidance and potentially motivation to adhere,[15] is higher in tiers with more stringent restrictions.

Regional restrictions have also been used in other countries, for example, color-coded zones (e.g. red, orange, yellow zones) have been used in Italy, France, and the Quebec province in Canada, and tiered local alert levels have been used in New Zealand.[16] At the time of writing, tiers are still being used in Scotland. Although the influence of tiered restrictions on infection rates has been investigated,[17–19] there is limited information available on how well members of the public understand and tiered levels of restrictions and how restrictions affect general behaviour.

The aim of this study was to investigate people's knowledge of and confidence in understanding restrictions in place in their local area, motivation to adhere to these restrictions, and self-reported behaviour (going out for exercise, to work, and socially) under the tier system implemented in October 2020, and whether there were differences by tier.

Methods

Design

Throughout the COVID-19 pandemic, BMG Research (a Market Research Society Company Partner) has been conducting a series of cross-sectional nationally representative surveys for the Department of Health and Social Care, England. We analyzed these data as part of the COVID-19 Rapid Survey of Adherence to Interventions and Responses (CORSAIR) study. For this paper, we used data collected on 26 to 28 October 2020 (wave 31) as it gave insight into participants' knowledge and self-reported behaviour while the tier system was in place in October to November 2020. As participants were asked to report their behaviour in the previous 7 days, this was the only survey wave that reported solely on the time under the English tier system. Additional methodological details are described in Smith et al., 2021.[20]

Participants

Participants were eligible for the survey if they were aged 16 years or over and living in the United Kingdom. Of 2043 participants who completed wave 31, 1728 lived in England. Participants were recruited from two specialist research panel providers (Respondi, n = 50,000; Savanta, n = 31,500). These are panels of people who have signed up to take part in online surveys. Panel members who are eligible to take part in a specific survey based on their characteristics are sent a survey link. In line with industry standards, completion of the survey implies consent to take part. Where a participant's responses do not meet quality assurance standards (e.g. completing the survey too quickly, or giving the same answer for multiple consecutive questions), that participant's data are removed from the sample. Quota sampling (based on age and gender combined) was used to ensure that the sample was broadly representative of the population. Targets for recruitment were set based on participants' age and gender. Where quotas were already filled, participants of that age and gender combination were not able to complete the survey. Participants were reimbursed for having completed the survey in points, which could be redeemed as cash, gift vouchers or charitable donations (up to 70p per survey).

Measures

We asked participants which COVID-19 'local alert level' they thought applied to where they lived. Response options were 'Tier 1 (medium)', 'Tier 2 (high)', 'Tier 3 (very high)', and 'don't know'. We recoded participants as knowing their COVID-19 level if they correctly identified which tier their local area was in. For this variable, we coded answers of 'don't know' as incorrect. We used a 4-point scale to measure participants' confidence in their understanding of the tier that applied to where they lived (recoded to a binary variable: 'not at all confident' and 'not very confident' vs 'fairly confident' and 'very confident').

To investigate knowledge of individual guidance in one's local area, we asked participants a series of statements about the guidance on socializing 'where [you] live'. These statements covered meeting in groups outdoors in public spaces, in private gardens and indoors; meeting with members of your 'support' or 'childcare' bubbles[a] outdoors and indoors; staying overnight in someone else's home; travelling to other parts of the United Kingdom for leisure; sharing a car with someone not in your household; and taking part in group worship. Possible answers were 'true', 'false', and 'don't know'. We also asked participants how confident they were that they understood the guidance currently in place in their local area (recoded to a binary variable using groupings described above).

Participants were asked how motivated they were to adhere to restrictions put in place by the Government in their local area on a 4-point scale (recoded to a binary variable: 'not at all' and 'slightly' vs 'quite a bit' and 'strongly').

We asked participants how many times in the last seven days they had left their home for different reasons, including for exercise; spending time outdoors for recreational purposes; work; and meeting up with friends and/or family that they did not live with.

[a] Support and childcare bubbles were introduced to provide social support to people who live alone and to allow informal childcare for people who have children. Guidance about support bubbles can be found here: https://www.gov.uk/guidance/making-a-support-bubble-with-another-household. Guidance about childcare bubbles can be found here: https://www.gov.uk/guidance/making-a-childcare-bubble-with-another-household.

We grouped going out for a walk or some exercise and spending time outdoors for recreational purposes into a single variable. We recoded these variables to indicate whether participants reported going out for that reason at least once in the last week.

Personal characteristics

Participants were asked their age, gender, whether there was a dependent child in the household, their employment status, socio-economic grade, highest educational or professional qualification, ethnicity, and how many people lived in their household.

Participants had to provide their full postcode, from which they were assigned region, index of multiple deprivation and whether they were categorised as living in a tier 1, 2, or 3 area at the time of data collection.

Ethics

This work was conducted as a service evaluation of the Department of Health and Social Care's public communications campaign, rather than being constituted as research, and, following advice from King's College London Research Ethics Subcommittee, was exempt from ethical approval.

Analysis

Logistic regression analyses were undertaken to investigate whether personal characteristics and tier level were associated with: knowledge of which tier you live in, confidence in understanding your local tier, confidence in guidance in place in your local area, motivation to adhere to restrictions in your local area, and self-reported outings (separate analyses for outings for exercise or recreation outside, going to work, and meeting up with friends or family from another household). We restricted analyses of people going out to work to those who reported working (n = 868). For each set of analyses, we ran univariable analyses and multivariable analyses (controlling for region, gender, age [raw and quadratic], presence of dependent children in the household, employment status, socio-economic grade, index of multiple deprivation, highest educational or professional qualification, ethnicity, and living alone). We controlled for these variables based on theoretical grounds and the results of previous analyses on this data set.[20–22]

We assumed that people might be most likely to understand a rule if it directly related to activities that they personally engaged in. We, therefore, conducted an additional analysis, restricting the sample only to those who reported having met up with friends and family not living in their household in the last week. We created a

Table 2
Associations between correct knowledge of tier, and participant characteristics and tier. Bolding signifies significant results ($P < 0.003$).

		Incorrect knowledge of tier or did not know n = 282, n (%)	Correct knowledge of tier n = 1446, n (%)	Odds ratio for correct knowledge of tier (95% CI)	*P*-value	Adjusted odds ratio for correct knowledge of tier (95% CI)[a]	*P*-value
Region	Overall	–	–	$\chi^2(2) = 7.4$	0.03	$\chi^2(2) = 5.8$	0.06
	Midlands (East and West)	58 (16.1)	303 (83.9)	Reference	–	Reference	–
	North England (Northeast, Northwest, Yorkshire, and the Humber)	62 (12.7)	425 (87.3)	1.31 (0.89–1.93)	0.17	1.32 (0.87–2.02)	0.20
	South England (Southeast, Southwest, London, and East of England)	162 (18.4)	718 (81.6)	0.85 (0.61–1.18)	0.33	0.86 (0.60–1.24)	0.42
Gender	Male	145 (19.4)	604 (80.6)	Reference	–	Reference	–
	Female	136 (14.0)	834 (86.0)	1.47 (1.14–1.90)	0.003	**1.68 (1.27 to 2.22)**	**<0.001**
Age	Raw age (range 16–90)	M = 40.9, SD = 17.8	M = 50.7, SD = 17.4	**1.03 (1.02 to 1.04)**	**<0.001**	**1.02 (1.01 to 1.03)**	**<0.001**
Age: quadratic (age-mean)^2	-	–	–	–	–	0.9995 (0.9990–1.0000)	0.05
Presence of dependent children in the household	None	158 (13.2)	1037 (86.8)	Reference	–	Reference	–
	Child present	124 (23.3)	409 (76.7)	**0.50 (0.39 to 0.65)**	**<0.001**	0.65 (0.47–0.89)	0.01
Employment status	Not working	118 (14.2)	715 (85.8)	Reference	–	Reference	–
	Working	153 (17.6)	715 (82.4)	0.77 (0.59–1.00)	0.05	0.96 (0.70–1.32)	0.82
Socio-economic grade	ABC1	188 (15.6)	1016 (84.4)	Reference	–	Reference	–
	C2DE	87 (18.0)	395 (82.0)	0.84 (0.64–1.11)	0.22	1.07 (0.78–1.45)	0.69
Index of multiple deprivation	1st quartile (least deprived) to 4th quartile (most deprived)	M = 2.8, SD = 1.1	M = 2.6, SD = 1.1	**0.81 (0.72 to 0.91)**	**<0.001**	0.90 (0.79–1.02)	0.09
Highest educational or professional qualification	GCSE/vocational/A-level/ no formal qualifications	202 (16.5)	1022 (83.5)	Reference	–	Reference	–
	Degree or higher (Bachelor's, Master's, PhD)	80 (15.9)	424 (84.1)	1.05 (0.79–1.39)	0.75	1.30 (0.94–1.79)	0.11
Ethnicity	Overall	–	–	**$\chi^2(2)$=43.5**	**<0.001**	$\chi2(2) = 7.3$	0.03
	White British	193 (13.5)	1237 (86.5)	Reference	–	Reference	–
	White Other	34 (29.6)	81 (70.4)	**0.37 (0.24 to 0.57)**	**<0.001**	0.55 (0.34–0.89)	0.02
	Black/Asian/Mixed/Other	52 (29.5)	124 (70.5)	**0.37 (0.26 to 0.53)**	**<0.001**	0.69 (0.45–1.05)	0.08
Living alone	Not living alone	228 (16.3)	1170 (83.7)	Reference	–	Reference	–
	Living alone	54 (16.4)	276 (83.6)	1.00 (0.72–1.38)	0.98	0.66 (0.46–0.97)	0.03
Tier (local COVID-19 alert level)	Overall	–	–	$\chi^2(2) = 8.3$	0.02	$\chi^2(2) = 3.9$	0.14
	Tier 1 (medium)	133 (16.0)	700 (84.0)	Reference	–	Reference	–
	Tier 2 (high)	122 (18.9)	525 (81.1)	0.82 (0.62–1.07)	0.14	0.97 (0.70–1.34)	0.86
	Tier 3 (very high)	27 (10.9)	221 (89.1)	1.56 (1.00–2.42)	0.05	1.77 (0.93–3.37)	0.08

[a] Adjusted for region, gender, age (raw and quadratic), presence of dependent children in the household, employment status, socio-economic grade, index of multiple deprivation, highest educational or professional qualification, ethnicity, and living alone.

single binary variable denoting if participants knew the guidance in their local area regarding meeting in groups in public spaces, in private gardens, and indoors. For this variable, we coded answers of 'don't know' as incorrect. We used logistic regressions to investigate associations between knowledge about meeting others and personal characteristics and tier. In other words, we tested whether people who met up with others knew the guidance about meeting up with others.

To take account of the number of analyses undertaken (n = 15), we only report narratively on adjusted results that remained statistically significant after a Bonferroni correction ($P < .003$). Uncorrected *P*-values are given in the results tables.

Results

Knowledge and confidence in understanding the tier system

There were no observable differences between tier levels in terms of correct identification of which tier level applied. Overall, between 81.1% (tier 2) and 89.1% (tier 3) of people knew their tier level (see Supplementary materials for full breakdown). When adjusting for other personal characteristics, correct knowledge of which tier applied was associated with being female and older (see Table 2).

72.8% (95% CI 70.7%–74.9%) of respondents reported being confident that they understood which tier applied to their local area. Confidence was associated with being older and living in a less deprived area; there was no association with tier (see Supplementary materials).

Knowledge and confidence in understanding local guidance

Knowledge of local guidance was mixed (see Table 3). Incorrect knowledge was particularly common for guidance about: staying overnight in someone else's home, travelling to other parts of the United Kingdom for leisure, sharing a car with someone not in your household, and taking part in group worship.

70.9% (95% CI 68.7%–73.0%) of respondents were confident that they understood the guidance currently in place in their local area. Confidence was associated with being older and living in a less deprived area. There was no association with tier (see Supplementary materials).

Meeting up with people from another household

There were 602 respondents (34.8%) who reported having met up with friends or family they did not live with, in the last week. Among these respondents, 50.8% (95% CI 46.8%–54.8%) knew the guidance surrounding meeting up with people from another household in their local area. Knowledge differed by tier, with people in tier 1 being most likely to know the guidance (see Table 4). Correct knowledge of the guidance was also associated with living in less deprived areas.

Motivation to adhere to restrictions and self-reported behaviour

73.1% (95% CI 71.1%–75.2%) of respondents were motivated to adhere to restrictions in place in their local area. Motivation to adhere to restrictions in place in one's local area was associated with being female and older; there was no association with tier (see Supplementary materials).

The percentage of people who reported having gone out in the last week to meet friends or family that they did not live with was lower in tiers 2 and 3 compared with tier 1 (see Table 5). Self-reported outings for exercise or recreation and going out to work did not differ by tier.

Going out for a walk or recreation was associated with region (with those in South England being more likely to than those in the Midlands), living in a less deprived area, and identifying as White Other (compared with White British; see Supplementary materials). Going out to work was associated with lower socio-economic grade (C2DE compared with ABC1; see Supplementary materials). Meeting up with others from another household was associated with region (although no individual region reached our threshold for statistical significance), younger age, living in a less

Table 3
Knowledge of guidance in your local area. Bolding denotes the correct answer.

You can…	Tier 1 (medium), total n = 833, n (%)			Tier 2 (high), total n = 647, n (%)			Tier 3 (very high), total n = 248, n (%)		
	True	False	Don't know	True	False	Don't know	True	False	Don't know
Meet in groups of up to six people from different households outdoors, in private gardens	**610 (73.2)**	133 (16.0)	90 (10.8)	**340 (52.6)**	230 (35.5)	77 (11.9)	47 (19.0)	**184 (74.2)**	17 (6.9)
Meet in groups of up to six people from different households outdoors, in a public space, for example, a park	**675 (81.0)**	91 (10.9)	67 (8.0)	**433 (66.9)**	145 (22.4)	69 (10.7)	**130 (52.4)**	93 (37.5)	25 (10.1)
Meet in groups of up to six people from different household indoors, for example, in a pub, restaurant or café or at someone's home	**549 (65.9)**	184 (22.1)	100 (12.0)	139 (21.5)	**438 (67.7)**	70 (10.8)	39 (15.7)	**189 (76.2)**	20 (8.1)
Meet with your support or childcare bubble indoors, if you have one	**594 (71.3)**	80 (9.6)	159 (19.1)	**431 (66.6)**	117 (18.1)	99 (15.3)	**146 (58.9)**	64 (25.8)	38 (15.3)
Meet with your support or childcare bubble outdoors, if you have one	**625 (75.0)**	57 (6.8)	151 (18.1)	**450 (69.6)**	94 (14.5)	103 (15.9)	**162 (65.3)**	46 (18.5)	40 (16.1)
Stay overnight in someone else's home	**276 (33.1)**	369 (44.3)	188 (22.6)	69 (9.1)	**508 (78.5)**	80 (12.4)	25 (10.1)	**197 (79.4)**	26 (10.5)
Travel to other parts of the United Kingdom for leisure (e.g. for a day trip or to see friends or family)	**415 (49.8)**	237 (28.5)	181 (21.7)	**188 (29.1)**	330 (51.0)	129 (19.9)	37 (14.9)	**190 (76.6)**	21 (8.5)
Share a car with someone not in your household but are advised to take precautions like wearing a mask or opening the windows	**494 (59.3)**	174 (20.9)	165 (19.8)	**209 (32.3)**	287 (44.4)	151 (23.3)	**82 (33.1)**	127 (51.2)	39 (15.7)
Take part in group worship at a place of worship	**365 (43.8)**	171 (20.5)	297 (35.7)	**213 (32.9)**	231 (35.7)	203 (31.4)	67 (27.0)	**112 (45.2)**	69 (27.8)

Table 4
Associations between correct knowledge of guidance about meeting others from another household, and participant characteristics and tier. Bolding signifies significant results ($P < 0.003$).

		Incorrect knowledge of guidance n = 296, n (%)	Correct knowledge of guidance n = 306, n (%)	Odds ratio for correct knowledge of guidance (95% CI)	*P*-value	Adjusted odds ratio for correct knowledge of guidance (95% CI)[a]	*P*-value
Region	Overall	–	–	$\chi^2(2) = 10.4$	0.01	$\chi^2(2) = 10.3$	0.01
	Midlands (East and West)	59 (48.0)	64 (52.0)	Reference	–	Reference	–
	North England (Northeast, Northwest, Yorkshire, and the Humber)	79 (61.7)	49 (38.3)	0.57 (0.35–0.94)	0.03	0.56 (0.33–0.97)	0.04
	South England (Southeast, Southwest, London, and East of England)	158 (45.0)	193 (55.0)	1.13 (0.75–1.70)	0.57	1.16 (0.74–1.82)	0.52
Gender	Male	135 (54.9)	111 (45.1)	Reference	–	Reference	–
	Female	159 (45.0)	194 (55.0)	1.48 (1.07–2.06)	0.02	1.46 (1.02–2.08)	0.04
Age	Raw age (range 16–90)	M = 43.8, SD = 19.6	M = 46.0, SD = 17.5	1.01 (1.00–1.02)	0.15	1.00 (0.99–1.01)	0.78
Age: quadratic (age-mean)^2	-	–	–	–	–	**0.9988 (0.9982 to 0.9994)**	**<0.001**
Presence of dependent children in the household	None	184 (47.9)	200 (52.1)	Reference	–	Reference	–
	Child present	112 (51.4)	106 (48.6)	0.87 (0.62–1.21)	0.41	0.75 (0.49–1.13)	0.17
Employment status	Not working	131 (49.1)	136 (50.9)	Reference	–	Reference	–
	Working	161 (49.2)	166 (50.8)	0.99 (0.72–1.37)	0.97	0.79 (0.53–1.19)	0.26
Socio-economic grade	ABC1	194 (48.0)	210 (52.0)	Reference	–	Reference	–
	C2DE	92 (51.1)	88 (48.9)	0.88 (0.62–1.26)	0.49	0.95 (0.65–1.40)	0.79
Index of multiple deprivation	1st quartile (least deprived) to 4th quartile (most deprived)	M = 2.7, SD = 1.1	M = 2.3, SD = 1.1	**0.71 (0.62 to 0.83)**	**<0.001**	**0.75 (0.64 to 0.88)**	**0.001**
Highest educational or professional qualification	GCSE/vocational/ A-level/no formal qualifications	210 (51.3)	199 (48.7)	Reference	–	Reference	–
	Degree or higher (Bachelor's, Master's, PhD)	86 (44.6)	107 (55.4)	1.31 (0.93–1.85)	0.12	1.35 (0.91–2.00)	0.14
Ethnicity	Overall	–	–	$\chi^2(2) = 7.7$	0.02	$\chi^2(2) = 4.2$	0.12
	White British	232 (47.3)	259 (52.7)	Reference	–	Reference	–
	White Other	29 (47.5)	32 (52.5)	0.99 (0.58–1.68)	0.97	1.15 (0.62–2.11)	0.66
	Black/Asian/Mixed/Other	33 (68.8)	15 (31.3)	0.41 (0.22–0.77)	0.01	0.50 (0.25–1.02)	0.06
Living alone	Not living alone	226 (48.2)	243 (51.8)	Reference	–	Reference	–
	Living alone	70 (52.6)	63 (47.4)	0.84 (0.57–1.23)	0.37	0.78 (0.49–1.24)	0.29
Tier (local COVID-19 alert level)	Overall	–	–	**$\chi^2(2)$=47.8**	**<0.001**	**$\chi 2(2)$=28.0**	**<0.001**
	Tier 1 (medium)	124 (36.6)	215 (63.4)	Reference	–	Reference	–
	Tier 2 (high)	141 (65.9)	73 (34.1)	**0.30 (0.21 to 0.43)**	**<0.001**	**0.32 (0.21 to 0.49)**	**<0.001**
	Tier 3 (very high)	31 (63.3)	18 (36.7)	**0.33 (0.18 to 0.62)**	**0.001**	0.41 (0.18–0.94)	0.04

[a] Adjusted for region, gender, age (raw and quadratic), presence of dependent children in the household, employment status, socio-economic grade, index of multiple deprivation, highest educational or professional qualification, ethnicity, and living alone.

deprived area, and living alone (see Supplementary materials). People identifying as Black, Asian, Mixed, or Other ethnicities were less likely to meet others from another household (compared with White British).

Discussion

Our analysis indicates that, in the case of the English tier system, recognition of which tier applied to a person's local area was high (81%–89%), but knowledge of the specific restrictions that were in place was poorer (29%–81%). Women and older participants were more likely to correctly identify their local tier. This is in line with other research finding that, overall, women and older adults have better knowledge, and confidence in their knowledge, about COVID-19.[20,23,24] This may be due to higher health literacy in these groups.[25]

Clearly, people do not need to understand all the rules that apply to their local area. There is no reason, for example, for people without children to have detailed knowledge of the rules relating to childcare. However, even restricting our analyses to the most common activity that is governed by COVID-19 restrictions (meeting up with people from another household), we found that people who reported that they had met with friends or family in the last week had poor knowledge about the restrictions for meeting people. Only 50% correctly identified the specific restrictions that applied in their local area. Guidance was particularly poorly understood by people living in tier 2 and in more deprived areas. In part, this may relate to the various nuances that existed within this guidance (e.g. specifying how many people could meet, and where meetings could occur). Restrictions that are absolute (e.g. behaviour is or is not permitted) may be clearer and more easily understood.

Although knowledge of specific guidance was poor, people's confidence in their understanding of guidance was higher. This may reflect the gap between actual and perceived knowledge that is seen in other health-related situations.[26,27] Although we did not find an association between motivation to adhere to local restrictions and living in a more deprived area, poorer confidence in knowledge about the tier system and local restrictions was

Table 5
Self-reported outings in the last 7 days, by tier. Bolding signifies significant results ($P < 0.003$).

Tier (local COVID-19 alert level)	Been out for a walk or some other exercise or to spend time outdoors for recreational purposes (including to sit in parks etc.)					
	Did not go out in last week n = 551, n (%)	Went out in last week n = 1177, n (%)	Odds ratio for having been out at least once in the last week (95% CI)	*P*-value	Adjusted odds ratio for having been out at least once in the last week (95% CI)[a]	*P*-value
Overall	–	–	$\chi^2(2) = 7.2$	0.03	$\chi^2(2) = 6.3$	0.04
Tier 1 (medium)	247 (29.7)	586 (70.3)	Reference	–	Reference	–
Tier 2 (high)	208 (32.1)	439 (67.9)	0.89 (0.71–1.11)	0.30	0.89 (0.69–1.15)	0.38
Tier 3 (very high)	96 (38.7)	152 (61.3)	0.67 (0.50–0.90)	0.01	0.57 (0.36–0.88)	0.01
	Been out to work (in those who reported working)					
	Did not go out in last week n = 363, n (%)	Went out in last week n = 505, n (%)	Odds ratio for having been out at least once in the last week (95% CI)	*P*-value	Adjusted odds ratio for having been out at least once in the last week (95% CI)[b]	*P*-value
Overall	–	–	$\chi^2(2) = 0.2$	0.89	$\chi^2(2) = 4.1$	0.13
Tier 1 (medium)	161 (41.5)	227 (58.5)	Reference	–	Reference	–
Tier 2 (high)	143 (41.4)	202 (58.6)	1.00 (0.75–1.34)	0.99	0.89 (0.63–1.26)	0.52
Tier 3 (very high)	59 (43.7)	76 (56.3)	0.91 (0.62–1.36)	0.65	0.52 (0.28–0.98)	0.04
	Been out to meet up with friends and/or family that you do not live with					
	Did not go out in last week n = 1126, n (%)	Went out in last week n = 602, n (%)	Odds ratio for having been out at least once in the last week (95% CI)	*P*-value	Adjusted odds ratio for having been out at least once in the last week (95% CI)[a]	*P*-value
Overall	–	–	**$\chi^2(2)$=36.9**	**<0.001**	**$\chi 2(2)$=12.8**	**0.002**
Tier 1 (medium)	494 (59.3)	339 (40.7)	Reference	–	Reference	–
Tier 2 (high)	433 (66.9)	214 (33.1)	0.72 (0.58–0.89)	0.003	0.74 (0.58–0.96)	0.02
Tier 3 (very high)	199 (80.2)	49 (19.8)	**0.36 (0.25 to 0.51)**	**<0.001**	**0.44 (0.27 to 0.70)**	**0.001**

[a] Adjusted for region, gender, age (raw and quadratic), presence of dependent children in the household, employment status, socio-economic grade, index of multiple deprivation, highest educational or professional qualification, ethnicity, and living alone.
[b] Adjusted for region, gender, age (raw and quadratic), presence of dependent children in the household, socio-economic grade, index of multiple deprivation, highest educational or professional qualification, ethnicity, and living alone.

associated with living in a more deprived area and younger age. Poorer adherence in these groups has been a common theme throughout the pandemic.[20] Greater attention to ensuring that regulations and guidelines are clearly communicated may be helpful to improve adherence in these groups.

We found a complex and varied impact of tiered guidance on general behaviour. All behaviours we investigated (going out for a walk or exercise, to work, and to meet friends or family from another household) were allowed in all tiers. Going out to meet someone from another household was associated with tier level, with fewer people reporting meeting up with others in higher tiers. One explanation for this is that people had control over this behaviour, which they adjusted in accordance with higher perceptions of risk in their local area. Another explanation is that people had less opportunity to meet up, for example in indoor settings such as restaurants. There was no evidence that going out to work differed by tier. However, going out for a walk or exercise, a behaviour which participants had control over, but which was not explicitly mentioned by tiered guidance, showed a trend towards declining in higher tiers, suggesting a spill-over effect of the guidance that may have related to risk perception.[28] COVID-19 restrictions have increased sedentary behaviour.[29,30] Going out for a walk or exercise alone or with members of one's own household is a low risk activity with respect to COVID-19 transmission and should be encouraged for its effects on well-being. There is also evidence that those who are consistently inactive are at a higher risk of hospitalization, admission to intensive care, and death from COVID-19.[31] It is, therefore, a concern if people avoid these behaviours.

Strengths of this study include that data were collected soon after the behaviour, limiting recall bias. However, behaviour was self-reported and may have been subject to social desirability bias. The use of an anonymous online survey should have mitigated the impact of this. Limitations include the use of cross-sectional data meaning that we cannot infer causation. While the sample was recruited to be representative of the population based on age and gender, we cannot be certain that the views and behaviours of survey respondents are representative of those of the general population. We did not investigate whether participants who reported meeting up with people from other households did so in a manner adherent to the restrictions in their local area.

Results from our study suggest that although overall tier level was well recognised, individual restrictions were poorly understood. Clear, unambiguous restrictions (e.g. behaviour is or is not allowed), where possible, are likely to be better understood than nuanced restrictions. Better communications may be needed to reach people in groups with poorer understanding and confidence in their understanding. It was notable that two behaviours over which people had control (meeting others and going out for exercise) declined with more restrictive tier. This suggests that the impact of tiers is not solely due to the specific guidance involved, but has a broader impact.

Author statements

Ethical approval

This work was conducted as a service evaluation of the Department of Health and Social Care's public communications campaign and, following advice from King's College London Research Ethics Subcommittee, was exempt from ethical approval.

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Competing interests

All authors had financial support from NIHR for the submitted work. RA is an employee of the UK Health Security Agency; HWWP has received additional salary support from Public Health England and NHS England; HWWP receives consultancy fees to his employer from Ipsos MORI and has a PhD student who works at and has fees paid by Astra Zeneca; NTF is a participant of an independent group advising NHS Digital on the release of patient data. All authors are participants of the UK's Scientific Advisory Group for Emergencies or its subgroups. There are no other financial relationships with any organizations that might have an interest in the submitted work in the previous three years and no other relationships or activities that could appear to have influenced the submitted work.

Data availability statement

The data are owned by England's Department of Health and Social Care, so no additional data are available from the authors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2021.12.016.

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Original Research

Transmission of SARS-CoV-2 arising from international flights arriving in Ireland in December 2020: a descriptive analysis using national surveillance data

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ABSTRACT

Objectives: There is limited evidence on the risk of in-flight transmission of SARS-CoV-2. This study estimated the extent of in-flight SARS-CoV-2 transmission on international flights arriving in Ireland during December 2020.
Study design: This was a cross-sectional analysis.
Methods: National surveillance data identified all notified cases of COVID-19 who were infectious while travelling on international flights to Ireland during December 2020. Close contacts of cases were tested for SARS-CoV-2, and the results were collated to estimate the pooled secondary attack rate across all flights. Laboratory and epidemiological data were obtained from the Health Service Executive Covid Care Tracker, a national database of COVID-19 cases in Ireland.
Results: A total of 165 infectious cases of COVID-19 were identified on 134 incoming flights; 40.0% were symptomatic on board. There were 2099 flight close contacts identified, of whom 40.9% had results of a SARS-CoV-2 polymerase chain reaction test within 14 days of arrival. The pooled secondary attack rate for these contacts was 7.0% and was higher among those on flights of ≥5-hour duration ($P = 0.008$). More than half (59.1%) of close contacts had no SARS-CoV-2 test result recorded; the reasons included incorrect or absent contact details (26.5%) and no response when contacted (17.8%).
Conclusions: In this national study investigating transmission of SARS-CoV-2 from international flights arriving into Ireland, the pooled secondary attack rate was 7.0%. International travel is likely to have contributed to the third wave of SARS-CoV-2 infections in Ireland in early 2021. Application of non-pharmaceutical interventions remains central to mitigating the risk of in-flight transmission.

Introduction

The COVID-19 pandemic has reduced air travel worldwide since 2020 because of governmental policies to limit non-essential travel within and across states.[1]

The role of air travel in the transmission of SARS-CoV-2 has been reviewed.[2] Most published studies have evaluated the extent of transmission on individual flights[3,4] or have reported on isolated outbreaks.[5–9] Large outbreaks on aircraft have been reported,[5,7,8] with secondary attack rates (SARs) varying considerably from 4.8% to 62%.[6,7] Few studies have examined transmission across multiple flights. Those that have have reported lower SARs of 0.2%–3.8%.[10,11]

December 2020 was a phase of rapidly rising COVID-19 case numbers in Ireland, as the country entered its third and largest

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wave. Wild type was the dominant variant at this time; the first alpha variant case was notified in Ireland in week 51 (14 December to 20 December 2020) and the first beta variant case in week 52 (21 December 2020 to 27 December 2020).

In December 2020, predeparture polymerase chain reaction (PCR) testing, postarrival testing and flight contact tracing were standardised. Evidence of a negative predeparture SARS-CoV-2 PCR test taken within the 72 h before arrival in Ireland was required of passengers from 'orange' regions within the European Union (EU), in line with the EU Traffic Light System, which became operational in Ireland on 8 November 2020.[12] SARS-CoV-2 PCR testing was also offered to incoming travellers from 'red' regions and from the United Kingdom on day 5 after arrival.

At the time of the study, close contacts of any infectious case on a flight were identified as per European Centre for Disease Prevention and Control (ECDC) guidance, systematically contacted and referred for a free SARS-CoV-2 PCR test as soon as possible and 10 days after exposure to the infectious case.[13]

The aim of this study was to estimate the rate of SARS-CoV-2 transmission arising from international flights arriving in Ireland in December 2020, where at least one infectious case was on board, by measuring the pooled SAR.

Methods

All notified cases of COVID-19 who flew into Ireland from 30 November 2020 to 31 December 2020 inclusive were identified through the Health Service Executive's Covid Care Tracker, the national COVID-19 surveillance database. Every case with a SARS-CoV-2 PCR positive swab was notified to the Medical Officers of Health (MOHs) and recorded in the Covid Care Tracker, which triggered a systematic process of contact tracing. If a confirmed case flew during his or her infectious period, the passenger manifest for that flight was sought from the airline. The contact details of the passengers were uploaded to the Covid Care Tracker and contact tracing of the relevant passengers commenced. Where contact information for close contacts was missing from passenger manifests, passenger locator forms (PLFs; both electronic and paper), which travellers to Ireland were required to complete since May 2020,[14] were inspected to obtain additional contact information.

Definitions

A *primary case* was defined as a case who was infectious on the flight. This included any case whose COVID-19 illness began up to 10 days before, or up to 48 h after, the flight's arrival in Ireland, and any asymptomatic case who tested positive up to 10 days before, or within 24 h after, the flight's arrival.

A *secondary case* was defined as a close contact of a primary case who had a positive SARS-CoV-2 PCR result between 48 h and 14 days after a flight.

A *close contact* was defined as an individual sitting within a two seat radius of an infectious case, where one infectious case was identified on a flight. If any close contact sitting within a two seat radius of an infectious case tested positive, all passengers on board were then considered close contacts.[13] If there were two or more unrelated infectious cases on board the same flight, all passengers were considered close contacts.

Where a secondary case was identified on a flight, an investigation was conducted to determine whether the primary and secondary cases had epidemiological links outside of the flight (e.g. household links). Where needed, an outbreak control team was convened by the MOH for investigation and control.

The details of the primary cases' flights, including flight origin, destination, dates of departure and arrival, flight duration, as well as the details and test results of all cases and close contacts, were obtained from the Covid Care Tracker. The primary cases' details, including date of symptom onset, or positive PCR test result if asymptomatic, were recorded. The close contacts of the primary cases were identified, and their PCR swab results were obtained to determine the SAR. Where close contacts had no SARS-CoV-2 swab result, the reasons for this were sought from the Covid Care Tracker. The SAR was calculated by dividing the total number of secondary flight cases by the total number of close contacts tested.

The SARS-CoV-2 PCR swabs of all linked primary and secondary cases were sought and, where available, were sent to the National Virus Reference Laboratory (NVRL) for phylogenetic analysis to analyse and compare the pair's SARS-CoV-2 genomes and deduce whether in-flight transmission was likely to have occurred. Where pairs of primary and secondary cases had epidemiological links outside of the flight, phylogenetic analysis was not requested for their pairs of swabs.

All statistical analyses were conducted using Stata version 15 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC.). Categorical variables were expressed as counts and percentages. Differences between groups for categorical variables were estimated using Chi-squared tests. Statistical significance at the level of $P < 0.05$ was assumed throughout.

Results

One hundred sixty-five passengers on 134 flights were identified as primary cases. A total of 135,900 passengers arrived in Ireland by air in December 2020, and there were an estimated 2098 flights arriving in Ireland in December 2020.[15] Of these flights, 6.4% had a notified case of COVID-19 on board, who was infectious during the flight.

Of 134 flights with primary cases, 60 (45%) originated in Great Britain (GB), 53 (40%) in mainland Europe, 14 (10%) in North America, and 7 (5%) in the Middle East. The highest number of primary cases arrived in Ireland on flights on 19 December 2020 (Fig. 1). Twenty flights (14.9%) had a duration of ≥5 h. Residents of Ireland accounted for 152 primary cases (92.1%), with 2 (1.2%) primary cases residing in Northern Ireland, 2 (1.2%) residing outside the island of Ireland, and 9 (5.5%) with unknown addresses. Of the primary cases resident in Ireland, they resided in 22 of 26 counties across all regions of Ireland.

Sixty-six (40%) primary cases were symptomatic, 60 (36.4%) were presymptomatic, 27 (16.3%) were asymptomatic on the flight, and the symptom status was unknown for 12 (7.3%). In total, the 165 primary cases had 2099 close contacts identified on their respective flights. The median number of close contacts per primary case was 12 (interquartile range: 8–16). A total of 859 (40.9%) close contacts had a recorded SARS-CoV-2 test result within 14 days of exposure to a primary case.

Of the 859 close contacts tested, 60 were identified as secondary cases, indicating an SAR of 7.0% (Table 1). The SAR in flights of ≥5 h duration was significantly higher than shorter flights ($P = 0.008$, Chi-squared = 7.0522). The highest SAR was measured on flights containing presymptomatic primary cases, followed by flights containing already symptomatic and asymptomatic cases, but this finding was non-significant ($P = 0.3$, Chi-squared = 2.4110).

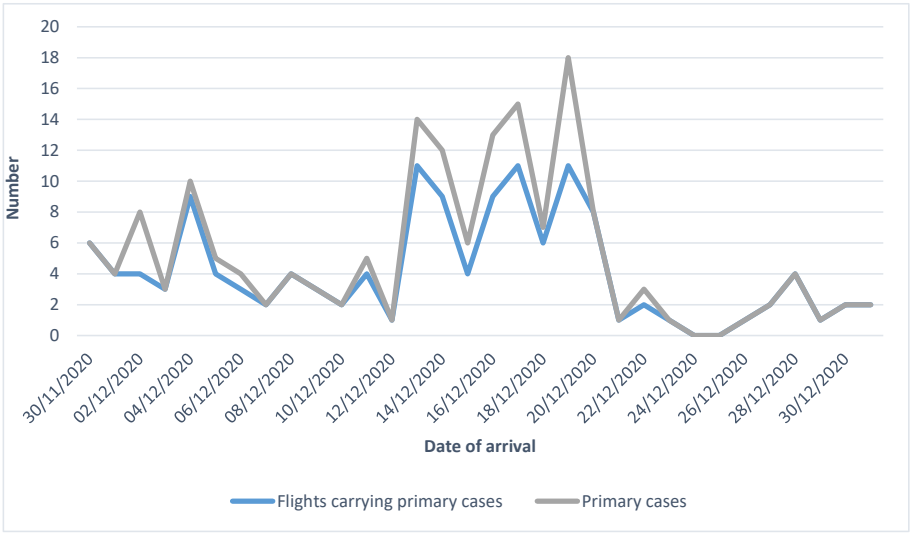

Fig. 1. Arrival of primary cases (n = 165) and their affected flights (n = 134) in Ireland, 30 November to 31 December 2020.

Table 1
SARS-CoV-2 secondary attack rates related to international flights arriving in Ireland, 30 November to 31 December 2020.

Variable	*N*	%	*P* value
SAR (overall)	60/859	7.0%	
SAR (flight-only close contacts)	45/844	5.3%	
SAR (flights ≥5 h)	10/67	14.9%	
SAR (flights <5 h)	50/792	6.3%	0.008
SAR (flights originating in GB)	22/467	4.7%	
SAR (flights originating outside GB)	38/392	9.6%	0.004
SAR (flights with only symptomatic cases)	24/302	7.9%	
SAR (flights with only presymptomatic cases)	20/177	11.3%	
SAR (flights with only asymptomatic cases)	5/82	6.1%	0.3

GB = Great Britain, SAR = secondary attack rate.

Of the 60 secondary cases, 15 had epidemiological links to the primary case outside of the flight. Among flight-only close contacts, 45 secondary cases emerged from 844 close contacts, giving an SAR of 5.3%. It is unknown, however, how many of these 844 close contacts were flight-only close contacts and how many had epidemiological links to the primary cases outside of the flight.

Nine laboratories were contacted to request whole genome sequencing in relation to the primary and secondary cases; 12 swabs were available to be sent to the NVRL, and seven swabs were amenable to sequencing. Of the seven sequenced swabs, four were alpha variants, two were wild-type variants, and one was beta variant. No pairs of swabs for primary and secondary cases, where in-flight transmission was suspected, were available for sequencing. Therefore, phylogenetic analysis of epidemiologically linked swabs could not be performed.

Most close contacts identified (59.1%) had no SARS-CoV-2 test result recorded on the Covid Care Tracker. The principal reasons for this included the following: incorrect or absent close contacts' phone numbers on the contact tracing system (26.5%); close contacts did not answer the phone to be informed of their close contact status (17.8%); and unknown reasons (47.3%; Table 2).

Discussion

In this descriptive analysis, we demonstrated a pooled SARS-CoV-2 SAR of 7.0% on international flights arriving in Ireland in December 2020. This pooled SAR is higher than in earlier studies. In-flight transmission of SARS-CoV-2 on 18 flights to and from Greece over a 13-day period in February to March 2020 yielded a pooled SAR of 0.56%.[10] A study of transmission on 18 international flights to the United Kingdom in January to March 2020 demonstrated a pooled SAR of 3.8% among successfully contact traced close contacts.[11] The findings of earlier studies, which have measured lower SARs, may be explained by limited access to testing or under-recognition of asymptomatic transmission of SARS-CoV-2. Another key difference is that wild-type variants of SARS-CoV-2 were circulating during the study periods of earlier studies, as opposed to the more transmissible alpha variant, which emerged was captured in our study.

We found that 6.4% of flights had an infectious case on board. This tallies with a recent modelling study from the Netherlands,

Table 2
Reasons close contacts were not tested for SARS-CoV-2 on flights to Ireland, 30 November to 31 December 2020 (n = 1240).

Reason for lack of testing	*N*	%
Unknown reason[a]	587	47.3%
Incorrect or absent contact details	329	26.5%
No response when contact made	221	17.8%
Already departed Ireland	50	4.0%
Already tested negative on private testing post-flight	40	3.2%
Refused to be tested	9	0.7%
Previous positive case in prior 3 months[b]	4	0.3%

[a] Routine testing of asymptomatic close contacts in the community, as opposed to close contacts identified on flights, was halted in Ireland in late December 2020 due to the surge in case numbers. This may have led to some flight close contacts not attending for testing.

[b] In Ireland in December 2020, the duration of presumptive immunity after SARS-CoV-2 infection was 3 months, and repeat testing within this period was not required for individuals identified as close contacts.

which estimated that 3–10% of flights would be expected to have an infectious passenger on board.[16] We measured a significantly higher pooled SAR related to flights of ≥5 h duration. This is consistent with other studies, where it has been observed previously that outbreaks with higher SARs have occurred on long-haul flights.[5,7,16] We observed a non-significant trend of a higher pooled SAR where the infectious case was presymptomatic on board, with the lowest SAR measured when asymptomatic cases were on board. A systematic review cited reports of viral load peaks during the prodromal phase of illness or at the time of symptom onset.[17]

The testing of contacts proved challenging. Only two-fifths (40.9%) of close contacts had a SARS-CoV-2 test result recorded postarrival, despite advice to travellers from a large number of countries in December 2020 to get a SARS-CoV-2 PCR test at least 5 days after arrival.[18] Flight close contacts are typically identified by contact tracing later than 5 days after arrival, and many close contacts in our study may have had already undergone private testing by the time they were contacted. Private laboratories are not required to report negative results to the Covid Care Tracker. The COVID-19 case numbers were increasing so rapidly in Ireland by the end of 2020 that public health resources became overstretched, and this hindered the effectiveness and timeliness of contact tracing for flights.

Our analysis found that incorrect or absent contact details for over one-fourth of close contacts (26.5%), alongside unanswered calls (17.8%), played an important role in reducing the offering, and thus the uptake, of testing among close contacts. Passenger manifests may have contained inaccurate contact information, as passengers were not obliged to provide a correct phone number to airlines; close contacts may have ceased using international phones or international subscriber identification module cards on arrival in Ireland; PLFs, which were used to obtain additional contact information, may have contained inaccurate information, and there may have been errors as phone numbers were transcribed from passenger manifests onto the Covid Care Tracker.

It was not possible to conduct phylogenetic analysis on any pair of epidemiologically linked PCR specimens due to a number of factors, including early disposal of specimens due to storage issues and inadequate samples. Of interest, the first known COVID-19 cases in Ireland caused by both alpha and beta variants were found in primary cases on flights and captured in this study, and the increased transmissibility of variants of concern may be reflected in this study's pooled SAR. It is noteworthy that although only a very small proportion of PCR specimens in this study underwent sequencing, COVID-19 cases caused by the alpha and beta variants were detected, giving evidence that these variants of concern were imported into Ireland via air travel and indicating that the importation of variants of concern may have been underestimated, as many specimens could not be sequenced.

The need for ongoing mitigation of in-flight transmission is highlighted by our study. It has been postulated that SARS-CoV-2 transmission can be suppressed on aircraft through the implementation of various infection prevention and control measures, including enhanced cleaning and the use of face masks by passengers and crew.[19] In previous studies, flights where mask-wearing was rare or optional recorded higher SARs.[7,20] The design of aircraft, which limits passenger movement and face-to-face interaction and features an air exchange system that reduces the spread of respiratory particles, may decrease the risk of transmission on board.[19] Air cabins tend to have low levels of relative humidity, however, which may facilitate easier transmission of viral particles.[21]

The strengths of this study include the use of national surveillance data to estimate the extent of SARS-CoV-2 transmission related to international flights arriving in Ireland. This study had a larger number of identified close contacts, as distinct from co-passengers, than previously published studies. We accessed a national database, which maximised the likelihood of identifying true cases of COVID-19.

Although we demonstrated a pooled SARS-CoV-2 SAR of 7.0% in our study, the true pooled SAR is unknown. First, this SAR was estimated by calculating the positivity rate among all flight close contacts, including those who had epidemiological links to primary cases outside of the flight. Although we estimated an SAR of 5.3% when we included only the secondary cases who were flight-only close contacts, it is not known how many flight-only close contacts there were among the total number of close contacts tested. Second, not all infectious cases on flights are likely to have been identified, as testing on arrival in Ireland was advisory only, and we may have underestimated imported infectious cases. We cannot rule out the possibility of selection bias: the close contacts who were not tested for SARS-CoV-2 may have been more likely to be feeling well on arrival in Ireland and perhaps less likely to have COVID-19, leading to potential overestimation of SAR.

This study did not focus on the impact of imported COVID-19 cases on the dynamics of the epidemic in Ireland at the time. It is noteworthy, however, that Ireland had one of the lowest 14-day incidences of COVID-19 in the EU and European Economic Area in early to mid-December 2020[22] but had the highest 14-day incidence 1 month later.[23] The risk associated with the importation of cases of COVID-19 into a country potentially poses a greater risk to the control of the epidemic within a population than the risk posed by SARS-CoV-2 transmission on aircraft itself.[24,25] We found that infectious cases resided in various locations around the country and likely, alongside undetected cases, seeded infection in disparate locations after arrival in Ireland. In addition, 45% of the flights containing infectious cases in our analysis came from GB, where the alpha variant was rapidly becoming the predominant variant at the time. It is plausible, therefore, that international travel played a role in seeding infections caused by the alpha variant in Ireland, which, in turn, contributed to the occurrence of a third wave of infections in the country in early 2021.

National contact tracing systems are being strengthened, including the validation of contact information through Ireland's electronic PLF as a condition of boarding and to supplement airline information where needed. The proposed multicountry digital approach to flight contact tracing should be progressed to increase efficiency and timeliness.[26] Whole genome sequencing capacity is important to facilitate genomic surveillance of all imported cases. All imported COVID-19 cases' swabs continue to be referred for whole genome sequencing, which will facilitate further study on patterns of importation.

The findings from this study lend support to the continued implementation of non-pharmaceutical interventions as well as widespread vaccination to further reduce the risk of transmission of SARS-CoV-2 on flights.

Author statements

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Ethical approval

This analysis was undertaken in conjunction with the HSE Port Health Network as part of the public health response to the COVID-19 pandemic. It was undertaken by public health physicians and Medical Officers of Health in line with Infectious Disease Regulations 1981.[27] Therefore, ethical approval was not required.

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Competing interests

None declared.

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