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Autonomy to adhere to non-pharmaceutical interventions on COVID-19 infections in the first year of the pandemic in the UK

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Contributions
MCM, XD, DMB designed the study and MCM wrote the report, to which all authors contributed. MCM, XD and DMB designed the models. XD and DMB prepared the data and ran the models. MCM designed the time-varying graphic. All authors read and approved the final article.

Declaration of interests
MCM is a member of the UK Scientific Advisory Group for Emergencies sub-groups SPI-B (behavioural insights), ethnicity and Vaccines Science Coordination Group and member of the Royal Society's SET-C (Science in Emergencies Tasking – COVID) group, all which respond to requests from government departments and the Government Office for Science.

Data Sharing
This work contains statistical data from Office of National Statistics (ONS) which is Crown Copyright. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates. The Covid Infection Study (CIS) data are available via a formal request to the ONS Secure Research Service for accredited researchers.

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The authors declare no competing interest.

ABSTRACT

Objective

Non-pharmaceutical interventions (NPIs) have been introduced to control SARS-CoV-2 infections, we provide individual-level empirical evidence of whether adherence reduces infections.

Setting and participants

The Covid-19 Infection Study (CIS) was used from 10 May 2020 to 02 February 2021 with 409,009 COVID-19 nose and throat swab tests nested in 72,866 households for 100,138 individuals aged 18-64.

Analysis

Odds ratios (ORs) for a positive COVID-19 test were calculated using multilevel logistic regression models, stratified by sex and time, by an index of autonomy to abide to NPIs, adjusted for various socioeconomic and behavioural covariates.

Results

Inability to comply with NPIs predicts higher infections when individuals reported not wearing a face-covering outside. The youngest 18-29 age groups had a significantly higher risk of infection, with larger households having significantly higher infections for women. Male smokers had a significantly lower risk. Effects varied over time with autonomy to follow NPIs only significant in the pre-second lockdown May- November 2020 period. Wearing a face covering outside was a significant predictor of lower chance of infection before mid-December 2020 when a stricter second lockdown was implemented. Black, Asian and minority ethnic groups were more likely to be infected. The random effects variance estimates were larger at the household than the individual level OR: 3.34 (95%CI 3.05 to 3.63) versus OR: 1.02 (95% CI 0.78 to 1.26), suggesting that there is more unexplained variation in infection risk in households.

Conclusion

The inability to comply with NPIs results in higher COVID infections only when individuals do not adhere to protective. Higher infection rates are in younger groups, women in large households and vary by time and type of lockdown restriction, with wearing a face-covering or mask outside the home consistently and significantly predicting lower infection among females and before the 2020 Christmas.

Strengths and limitations of this study

- Our study is that it is to our knowledge the first large-scale study that links the reporting of individual and household level adherence to NPIs and their ability or challenges to adhere to actual measured infections.
- This representative population-based study went beyond the self-reporting of SARS-CoV-2 to use throat and swab SARS-CoV-2 positivity testing opposed to population-wide case data, which is subject to significant selection bias. This is also an advantage over other measures such as hospitalisation or death, which only pick up the most severe cases.
- By measuring infections in this manner, we are also able capture those who might be asymptomatic or whose infections are relatively mild.
- Although the dataset is the most representative data to date, some groups such as ethnic minorities (termed BAME in the UK) is still underrepresented in the sample.
- Participation in the study is voluntary and thus self-selection bias may affect the results.
- Finally, as others have noted, we are unable to determine the sensitivity and specificity of the PCR test, but it is likely close to 100%.

INTRODUCTION

Although most countries have introduced non-pharmaceutical interventions (NPIs) to lower the spread of infectious diseases such as SARS-CoV-2, there is limited empirical research on the relationship of adherence to infections or how an individuals' autonomy or ability to follow measures relates to infections,[1]. To form evidence-based health policy, it is crucial to have empirical evidence that tests whether the adherence to NPIs is effective in reducing infection. The lack of compliance to NPIs has been generally positioned as an attitude or choice,[2], but it may be related to the inability to follow measures and exacerbate existing health inequalities. This includes employment that does not accommodate working at home, the necessity to take public transport, or being in workplaces or households where recommended social distancing is not possible.

Due to data limitations, existing research examining the effects of NPIs on COVID-19 related outcomes has almost exclusively used aggregated data to model the correlation between the timing of various national, state or regional level NPIs with COVID-19 case rates,[1,3-6]. These types of studies risk producing an ecological fallacy, since the interpretation of statistical data about individuals are deduced from an inference for the group to which those individuals belong to,[1]. In the early stages of the pandemic in 2020, some simulations also estimated the potential ebb and flow of infections in relation to the introduction of various NPIs and how this might impact healthcare demands,[7]. There have been various systematic reviews and meta-analyses, some with mixed results, but generally demonstrating the protective nature of NPIs,[8,9]. Other studies examining the effectiveness of face coverings and masks have been largely carried out in health settings examining N95 or surgical masks, with critiques that findings cannot be transferred to community settings or do not properly control for confounders,[9].

Although a handful of individual-level studies more directly examined the relationship between individual adherence NPIs and individual-level case data of infections, they were carried out in the early stages of the pandemic, had small samples (1,000,[10] or 1,500 cases,[11]), and used general NPI measures. A previous review concluded that although many studies have assessed NPIs, few were able directly examine or quantify their impact,[12]. We aimed to measure the association between COVID-19 infections and the autonomy to follow NPIs, key sociodemographic factors, and changes over time, using individual- and household-level data in a large nationally representative sample in the UK collected over almost one year from May 2020 to February 2021.

METHODS

Study design and participants

The Covid Infection Study (CIS) is one of the largest regular surveys of coronavirus infections and antibodies,[13]. The CIS has been used to examine multiple aspects of the pandemic and to monitor community prevalence of SARS-CoV-2 infection,[14]. Samples, demographic information and a short questionnaire are collected from individuals aged 2 and older living in private households in England, randomly selected from address lists and the Office of National Statistics (ONS) surveys. It is a repeated household survey with additional serial sampling and longitudinal follow-up. Data includes a questionnaire and nose and throat swabs. If multiple household members agreed to participate, a home visit was made to collect information. Following the first visit, participants who agree, are visited every week for the first five weeks and then receive optional monthly visits. All study protocol and questionnaires are available online (https://www.ndm.ox.ac.uk/covid-19/covid-19-infection-survey).

A positive COVID-19 test was determined from nose and throat swabs using the TaqPath RT-PCR COVID-19 kit (Thermo Fisher Scientific, Waltham, MA, USA), analysed using UgenTec Fast Finder 3.300.5 (TaqMan 2019-nCoV assay kit V2 UK NHS ABI 7500 v2.1; UgenTec, Hasselt, Belgium), described in detail in the sources listed above. Tests are considered positive when at least one gene is present – N, ORF1ab, or both – but could be accompanied by the gene for S protein (detection of S protein alone is not considered reliable),[14]. For the analyses in this study, the Covid-19 Infection Study (CIS) from 10 May 2020 to 02 February 2021 was used with 409,009 valid COVID-19 tests from nose and throat swabs nested in 72,866 households for 100,138 individuals aged 18-64 years.

Statistical analysis

We estimated the likelihood of testing positive for SARS-CoV-2 from nose and throat swabs using three-level multivariate multilevel logistic regression models, also stratified by sex and time period. The outcome is a positive Covid-19 test, with the main predictors of sex, Black, Asian or minority ethnicity (BAME), age group, visit date, household size, smoking status, region, occupation, days since contact with any COVID-19 positive person, compliance with wearing a face covering or mask and autonomy to comply with NPIs.

Autonomy to adhere to NPIs is measured via the sum of several situations that might limit the respondents' ability to comply. Each situation is assigned points which is then summed into one index. These include that the respondent reports it is: 1) possible to work outside the home at least one day per week (1 point), 2) 'easy to maintain 2 metres' distance in workplace (0 points), 3) 'relatively easy to maintain 2 metres' distance in the workplace (1 point), 4) 'difficult to maintain 2 metres, but can be 1 metre' in the workplace (2 points), 5) 'very difficult to be more than 1 metre away' in the workplace (3 points), 6) a main working location that is 'somewhere else (not your home)' (1 point), 7) common to go to and from work/school by bus, coach or minibus (1 point); and, 8) work that involved direct contact with patients, clients, residents, service users or customers on a day-to-day basis (1 point). We included transportation by bus, coach or minibus only since sensitivity analyses that included other means of transportation such as underground, tram or motorbike, scooter, or car all showed a reverse correlation with other autonomy items and reduced the reliability of our autonomy index. The autonomy index passed the Cronbach's alpha test with the reliability coefficient of 0.73.

To interpret the index, for instance, a person who reports working outside home for 5 days a week (+1), who working in a job where it is difficult to maintain 2 metre distancing, but can maintain 1 metre (+2) and whose main work location is not home (+1) and does not take public transportation of a bus (0'), but works directly with people (+1) will score 5 in autonomy. After summing the scores, we reverse coded the autonomy variable so that a lower score indicates low autonomy (i.e., more situations that limit the individuals' ability to comply) and a higher autonomy score indicates a better ability to comply with NPIs. The range for the autonomy variable is from 0-7, with the person described in the previous example is scored 2 given reverse coding.

Mixed-level logistic regression models were estimated with COVID-19 tests (level 1) nested within individuals (level 2) nested within households (level 3) with the outcome variable of COVID-19 positive infections. The main model estimates sex, ethnicity, age group, reporting to wear a face covering or mask, our autonomy to comply index and additional control variables. Model 2 adds an interaction term between autonomy to adhere and wearing a face

covering or mask. Model 3 is the same as model 2 but only includes females. Model 4 is the same as the main model but only includes males. We estimated sex-specific models since when we added the interaction term for men only in the model, the interaction terms were not significant, the model fit did not increase, and the main effect also disappeared. We therefore consider the interaction terms in the male model as an unnecessary control and only reported the main models for men. Next, we stratified the models by three periods that broadly reflect the various phases of restrictions in the UK of: 1) 10 May - November 04 (pre-lockdown 2), 2) 05 November to December 19 (lockdown 2 'light version'), and 3) 20 December to Feb 02 (Lockdown 2 stricter) (See Figure 1). These periods follow the general guidelines, which varied somewhat across the four nations of England, Scotland, Wales and Northern Ireland. For the first periods, we were able to fit the model with the interaction term, and for the second and third period we fit the main model without the interaction term for the same reason mentioned above in relation to sex. Occupation was not included in the models by time periods due to the small sample sizes in each categories.

Patient and public involvement

Patients and the public were not involved in the development of research questions, design of the study, recruitment, and conduct of the study, or dissemination of the study results.

RESULTS

We find that the level of autonomy to adhere to NPIs does not predict COVID-19 infection alone, rather the risk of infection is lessened when individuals comply to NPIs (Figure 2, or Table S1). Autonomy to comply with NPIs predicts higher infections (OR: 0.79; 95% CI 0.67 to 0.92) when individuals do not engage in protective measures of wearing a face covering or mask outside. We visualise this interaction effect based on model 3 in Figure 3. The interaction effect is the most prominent among females.

The youngest 18-29 year old age groups have a significantly higher odds of infection (OR 1.17; 95%CI 1.00 to 1.37), with living in a larger household only related to a significantly higher odds of infection for women (OR: 1.04; 95%CI 1.02 to 1.06). Male smokers had a significantly lower risk (OR: 0.84; 95%CI 0.74 to 0·94]). This is in line with a recent review of 17 studies that also found that current smokers had a reduced risk of testing positive for COVID-19,[15].

To test whether our key predictors change in relation to key policy restrictions put in place to restrict infections, hospitalisation and deaths (Figure 1, or Table S2), we divided the analysis into three policy periods (available in our data) of: (1) 10 May 2020 – 04 November 2020 (first lockdown to pre-second lockdown), (2) 05 November – 19 December (second lockdown and pre-Christmas period of 'lockdown light'); and, (3) 20 December – 02 February (stricter second lockdown with schools closed and introduction of Tier 4). Figure 1 illustrates the clear time-lag between infections leading to deaths, with the expectation that this will be disrupted by vaccinations as time elapses. Black, Asian and minority ethnic groups are more likely to be infected, especially during the second lockdown (05 Nov-19 December) (OR: 1.36; 95%CI 1.04 to1.79).

Effects varied over the year with autonomy to follow NPIs only significant in the pre-Second lockdown period (May- November 2020). Wearing a face covering or mask outdoors was a significant predictor of a lower chance of infection before 19 December 2020 (OR: 0.44; 95%CI 0.27 to 0.73) when a stricter second lockdown was implemented. One possible explanation is that the percentage of people not wearing face covering/masks was low and declined from 2% to 1% from May 2020 to Feb 2021. The variable may also be capturing

both the social environment (i.e., wearing a face covering may be influenced on the level of individuals wearing masks around you) and correlated health behaviours (i.e., those who wear face coverings are more cautious in other ways).

In the full models, the random effects variance estimates were larger at the household level than at the individual level OR: 3.34 (95%CI 3·05 to 3·63) versus OR: 1.02 (95% CI 0.78 to 1.26), suggesting that more unexplained variation in infection risk exists at the household level. This difference was smaller or non-existent in the sex-stratified models, with the residual intraclass coefficients also reflecting a loss of household information.

DISCUSSION

Using multivariate multilevel logistic regression models, we examined the relationship between individual adherence to NPIs and COVID-19 infection, controlling for key sociodemographic, behavioural and time-related policy changes. We found that autonomy to comply with NPIs predicts higher infections when individuals do not engage in other protective measures of wearing a face covering or mask outside their home. Our results suggest that engaging in protective behaviours such as face coverings can reduce the unequal effects of exposure to COVID-19, noted in previous literature reviews,[9]. Our findings emphasise the need to move to more complex models beyond comparing aggregated percentages of general population compliance to a more nuanced understanding that stratifies groups in meaningful ways to develop tailored health policy interventions and communications. We found that women living a larger household had a significantly higher risk of infection, reflecting more domestic and care duties and time in the household, but also multiple individuals leaving and returning the home from diverse environments.

The 18-29 year old age group had a significantly higher risk of infection, suggesting that this is an important group to consider given that many countries are engaging in age-related vaccine roll-outs. Effects varied over the year with autonomy to follow NPIs only significant in the pre-Second lockdown period (May- November 2020). This was a period where initially many UK governments were reluctant to introduce certain policy interventions, such as the relatively late introduction of face-coverings for the general public in late June or July 2020, first in public transport only,[2].

Wearing a face covering or mask outside the home was a significant predictor of a lower chance of infection before 19 December 2020 when a stricter second lockdown was implemented. BAME groups are more likely to be infected, especially during the second lockdown (05 Nov-19 December). We note, however, that although we see some period variation, given the overlap in CIs and the fact that we are not strictly testing a difference between the coefficients in our model, they are not statistically different.

A strength of our study is that it is to our knowledge the first large-scale study that links the reporting of individual and household level adherence to NPIs and their ability or challenges to adhere to actual measured infections. This representative population-based study went beyond the self-reporting of SARS-CoV-2 to use throat and swab SARS-CoV-2 positivity testing opposed to population-wide case data, which is subject to significant selection bias. This is also an advantage over other measures such as hospitalisation or death, which only pick up the most severe cases. By measuring infections in this manner, we are also able capture those who might be asymptomatic or whose infections are relatively mild. Given the multilevel design based on a sample that was designed to be a random sample of households stratified by gender and time period, we also avoid problems in interpretation over this period

due to changes in testing practice. Another advantage is that we have longitudinal, regularly collected data over this period which allows us to examine changes in behaviour over time.

Our study is also subject to several limitations. Although the dataset is the most representative data to date, some groups such as ethnic minorities (termed BAME in the UK) is still underrepresented in the sample. Whereas we have 7% BAME, amongst the UK population, around 14% are from a minority ethnic background. Therefore, our estimates may not reflect the full range of the population. The number of tests in the lockdown 2 'stricter version' period is much smaller, meaning that we may not have the power to detect some effects. Participation in the study is voluntary and thus self-selection bias may affect the results. Finally, as others have noted, we are unable to determine the sensitivity and specificity of the PCR test, but it is likely close to 100%,[16].

The results we present here summarise key parts of the analyses we presented to senior decision makers in the UK over February – March 2021, in a context with rapidly evolving information and changes in vaccine deployment and other relevant policies. As the pandemic evolves and politicians and civil servants continue to make difficult decisions on lifting or re-instating NPIs, this study provides novel and nuanced evidence of the relationship of autonomy to follow NPIs with infection varies and where support or public communication could be directed.

CONCLUSION

Many countries introduced multiple non-pharmaceutical interventions (NPIs) to control COVID-19 infections, hospitalization and deaths and will continue to implement them during vaccine roll-outs. There have been limited empirical studies using individual-level data to examine how individual adherence to NPIs predicts infections by sociodemographic factors, individual autonomy to abide by NPIs and how these relationships change over time in relation to different restrictions.

We move beyond aggregated figures showing macro correlations of NPI policy stringency with national-level COVID-19 outcomes, to produce individual- and household-level models that properly control for confounders, key sociodemographic and behavioural factors and changes in policy interventions over time. Using the Covid Infection Study (CIS) in the UK with almost one year of data from 10 May 2020 to 02 February 2021, with 409,009 valid COVID-19 tests nested in 72,866 households for 100,138 individuals aged 18-64 years, we estimate multivariate multilevel logistic regression models, stratified by sex and time-period. We create a novel index measuring individual autonomy to abide by NPIs index (i.e., ability to work at home and number of days at home, ability to maintain physical distancing at work, travel to work requires public transport, or work involves direct contact).

Although autonomy or inability to abide by NPIs is a significant predictor of higher infection rates amongst certain groups, it does not predict infection alone. Wearing a face covering or mask outside the home can reduce the unequal effects of exposure to COVID-19 due to individual and employment circumstances. Autonomy to follow NPIs was only a significant predictor of infection risk from May to November 2020 but those who reported wearing a face covering or mask outdoors significantly had lower rates of infection for individuals with lower level of autonomy between 10 May to 04 November and for all people between 05 November to 19 December 2020.

The results we present here summarise key parts of the analyses we presented to senior decision makers in the UK over February – March 2021, in a context with rapidly evolving information and changes in vaccine deployment and other relevant policies. As the pandemic evolves and politicians and civil servants continue to make difficult decisions on lifting or re-instating NPIs, this study provides novel and nuanced evidence of the relationship of autonomy to follow NPIs with infection varies and where support or public communication could be directed.

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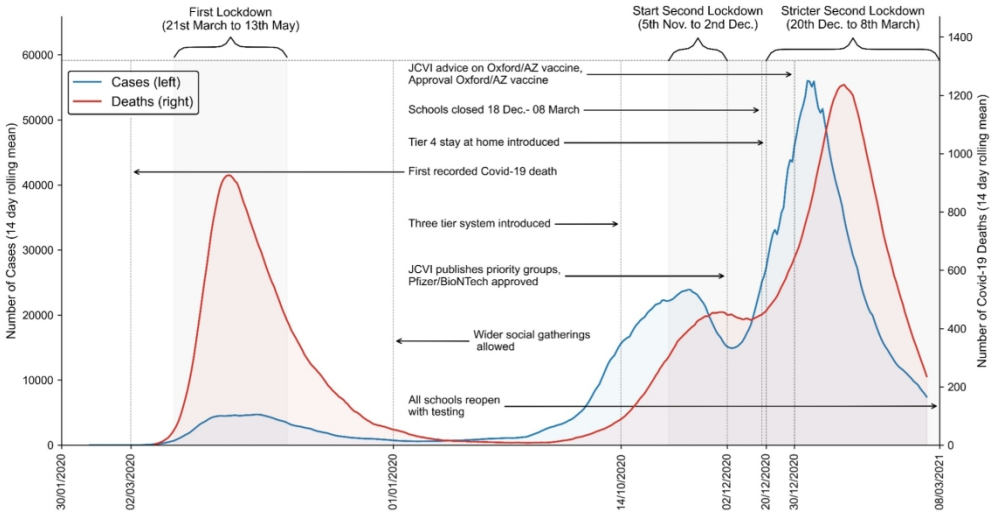
Figure 1. Timeline of key restrictions in England by COVID-19 cases (left) and deaths (right), January 01 2020 to March 08 2021

Note: JCVI (Joint Committee on Vaccination and Immunisation); AZ (Astra Zeneca). Graph produced by authors using policy data for England,[17,18] and official UK Government data on COVID-19 cases and deaths,[19] smoothed into 14 day rolling means. Deaths are in red (read from right axis) and cases in blue (read from left axis), with magnitudes representing smoothed 14 day rolling means and not cumulative figures. The restrictions shown here are for England and we note there was some variation in the detail of some policies and slight variation in timing in Scotland, England, Wales and Northern Ireland.

Figure 2. Three-level logistic regression models of COVID-19 positive tests, 10 May 2020 – 02 February 2021 by key fixed-effect predictors and interaction effects (see Appendix for full tables), ONS Covid Infection Study

Figure 3. Association between infection and autonomy by level of compliance to wearing face covering/mask (estimates from Model 3).



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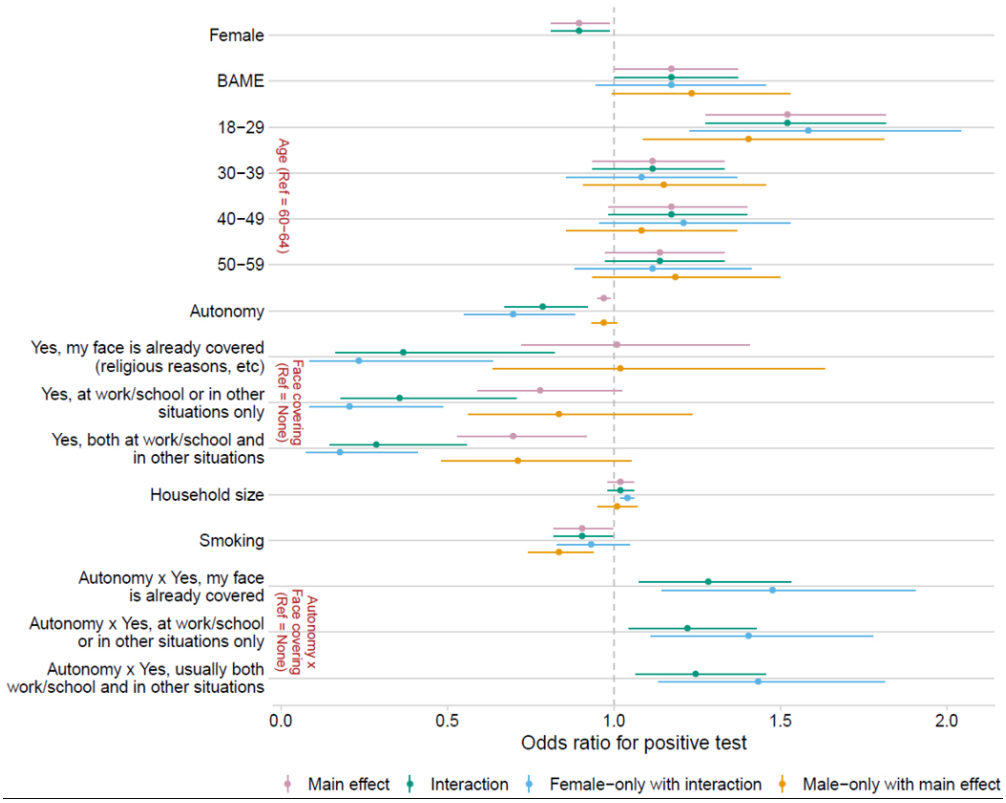

Figure 2. Three-level logistic regression models of COVID-19 positive tests, 10 May 2020 – 02 February 2021 by key fixed-effect predictors and interaction effects (see Appendix for full tables), ONS Covid Infection Study

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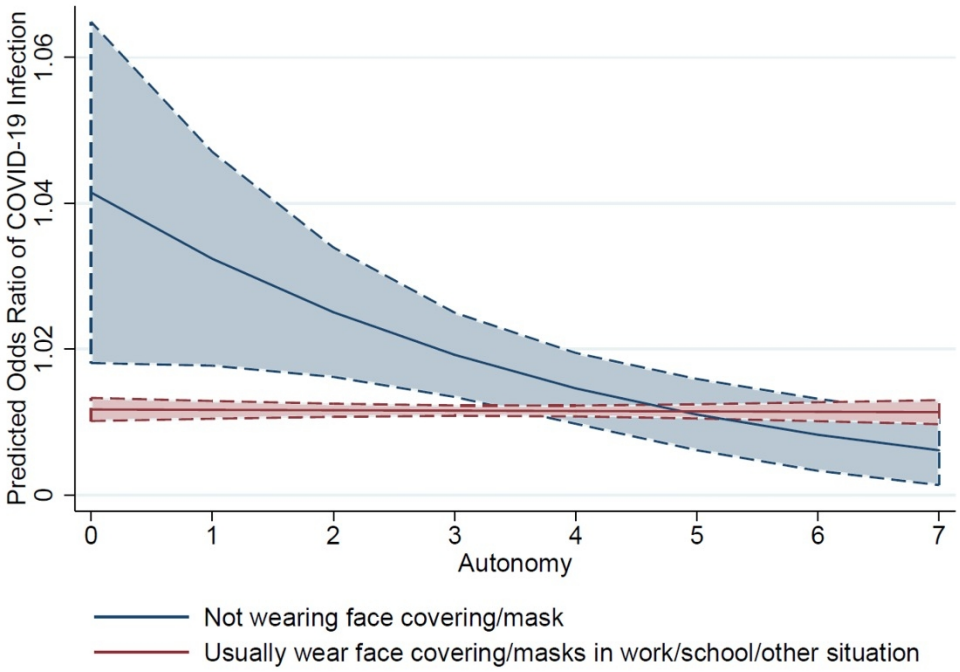

Figure 3. Association between infection and autonomy by level of compliance to wearing face covering/masks (estimates from Model 3).

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Table S1. Multilevel logistic regression models of Covid-19 testing positive, ONS Covid Infection Study

Outcome: Test positive	Model 1: Main effect			Model 2: Interaction			Model 3: Female only with interaction			Model 4: Male only main effect		
	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI
Female	0.90	0.81	0.99	0.90	0.81	0.99	-	-	-	-	-	-
BAME	1.17	1.00	1.37	1.17	1.00	1.37	1.17	0.95	1.46	1.23	0.99	1.53
Age group (Ref = 60-64)												
18-29	1.52	1.28	1.82	1.52	1.28	1.82	1.58	1.23	2.04	1.40	1.09	1.81
30-39	1.12	0.94	1.33	1.12	0.94	1.33	1.08	0.86	1.37	1.15	0.91	1.46
40-49	1.17	0.98	1.40	1.17	0.98	1.40	1.21	0.96	1.53	1.08	0.86	1.37
50-59	1.14	0.97	1.33	1.14	0.97	1.33	1.12	0.88	1.41	1.19	0.94	1.50
Visit date	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Autonomy	0.97	0.95	0.99	0.79	0.67	0.92	0.70	0.55	0.88	0.97	0.93	1.01
Face covering or masks (Ref = not wearing face covering or mask)												
Yes my face is already covered	1.01	0.72	1.41	0.37	0.16	0.82	0.23	0.09	0.64	1.02	0.64	1.63
Yes at work/school/other situations only	0.78	0.59	1.02	0.36	0.18	0.71	0.21	0.09	0.49	0.84	0.56	1.24
Yes usually both work/school/other	0.70	0.53	0.92	0.29	0.15	0.56	0.18	0.08	0.41	0.71	0.48	1.05
Autonomy x Face covering/masks (Ref = No face covering/mask)												
Autonomy x Yes my face is already covered	-	-	-	1.28	1.08	1.53	1.48	1.14	1.91	-	-	-
Autonomy x Yes at work/school/other situations only	-	-	-	1.22	1.04	1.43	1.40	1.11	1.78	-	-	-
Autonomy x Yes usually both work/school/other	-	-	-	1.25	1.07	1.46	1.43	1.13	1.81	-	-	-
Contact with COIVD-19 positive people (Ref = no contact)												

0-14 days	13.74	12.45	15.15	13.74	12.45	15.15	15.03	13.10	17.24	7.64	15.38	20.23
15-28 days	4.53	3.95	5.19	4.53	3.95	5.19	4.76	3.99	5.68	5.58	4.59	6.79
29-60 days	1.62	1.38	1.89	1.62	1.38	1.89	1.63	1.32	2.03	2.05	1.62	2.60
61-90 days	0.89	0.69	1.14	0.89	0.69	1.14	1.09	0.78	1.53	0.84	0.56	1.27
91+ days	1.00	0.76	1.32	1.00	0.76	1.32	0.98	0.66	1.45	1.14	0.77	1.69
Household size	1.02	0.98	1.06	1.02	0.98	1.06	1.04	1.02	1.06	1.01	0.95	1.07
Smoke	0.90	0.82	1.00	0.90	0.82	1.00	0.93	0.83	1.05	0.84	0.74	0.94
Region (Ref = Northeast)												
Northwest	1.32	1.07	1.64	1.32	1.07	1.64	1.22	0.93	1.61	1.36	1.02	1.83
Yorks Humber	0.95	0.75	1.20	0.95	0.75	1.20	0.95	0.71	1.28	0.91	0.67	1.25
East midlands	0.80	0.63	1.02	0.79	0.63	1.01	0.70	0.51	0.96	0.91	0.65	1.28
West midlands	0.77	0.61	0.98	0.77	0.61	0.98	0.79	0.59	1.07	0.71	0.51	0.99
East	0.54	0.43	0.68	0.54	0.43	0.68	0.53	0.39	0.71	0.52	0.38	0.71
London	0.95	0.77	1.18	0.94	0.76	1.17	0.89	0.67	1.17	1.01	0.75	1.36
South East	0.69	0.56	0.86	0.69	0.56	0.86	0.68	0.51	0.92	0.69	0.50	0.95
South West	0.41	0.32	0.53	0.41	0.32	0.52	0.41	0.29	0.57	0.41	0.28	0.59
Occupation (Ref = Health professionals)												
Corporate managers and directors	1.79	1.41	2.26	1.77	1.40	2.24	1.86	1.33	2.59	2.18	1.45	3.29
Other managers and proprietors	2.46	1.87	3.24	2.41	1.83	3.17	2.05	1.36	3.10	3.00	1.91	4.72
Science research engineering and technology professionals	1.51	1.15	1.98	1.49	1.13	1.96	1.11	0.68	1.80	2.01	1.31	3.10
Teaching and educational professionals	1.60	1.32	1.95	1.58	1.30	1.93	1.43	1.13	1.81	2.12	1.40	3.20
Business media and public service professionals	1.54	1.19	1.98	1.51	1.17	1.94	1.52	1.09	2.12	1.77	1.15	2.72

Science engineering and technology associate professionals	1.51	1.02	2.23	1.49	1.01	2.21	1.38	0.74	2.58	2.01	1.14	3.56
Health and social care associated professionals	1.48	1.04	2.10	1.46	1.03	2.08	1.30	0.86	1.96	2.16	1.15	4.04
Protective service occupations	1.82	1.33	2.49	1.80	1.32	2.47	2.59	1.62	4.14	1.86	1.16	2.98
Culture media and sports occupations	1.46	1.05	2.04	1.43	1.03	2.00	1.62	1.05	2.49	1.46	0.84	2.53
Business and public service associated professionals	1.73	1.37	2.19	1.72	1.36	2.17	1.62	1.18	2.21	2.18	1.45	3.29
Administrative occupations	1.97	1.59	2.45	1.95	1.58	2.42	1.90	1.47	2.45	2.41	1.57	3.71
Secretarial and related occupations	2.41	1.80	3.23	2.39	1.78	3.20	2.34	1.71	3.20	1.22	0.33	4.54
Skilled agricultural and related trades	0.89	0.46	1.73	0.87	0.45	1.69	1.15	0.33	3.95	1.11	0.49	2.52
Skilled metal electrical and electronic trades	2.25	1.68	3.02	2.20	1.64	2.96	2.92	0.78	10.84	2.80	1.86	4.23
Skilled construction and building trades	2.41	1.76	3.30	2.36	1.73	3.23	0.48	0.05	5.06	3.32	2.16	5.11
Textiles printing and other skilled trades	1.42	0.87	2.32	1.39	0.85	2.27	1.77	0.89	3.51	1.62	0.80	3.27
Caring personal service occupations	2.03	1.64	2.52	2.01	1.62	2.50	1.93	1.53	2.45	2.75	1.68	4.48
Leisure travel and related personal service occupations	1.84	1.17	2.89	1.82	1.16	2.86	1.43	0.80	2.58	4.31	2.00	9.25
Sales occupation	1.95	1.51	2.52	1.92	1.48	2.47	1.72	1.25	2.35	3.06	1.88	5.00
Customer service occupations	1.73	1.17	2.57	1.72	1.16	2.54	1.49	0.93	2.39	2.77	1.42	5.40
Process plant and machine operatives	2.10	1.44	3.04	2.05	1.42	2.98	2.94	1.24	6.98	2.51	1.54	4.10

Transport and mobile machine driver and operatives	2.36	1.76	3.17	2.32	1.73	3.11	1.62	0.64	4.06	3.19	2.07	4.91
Elementary trades and related occupations	2.75	1.53	4.94	2.69	1.49	4.85	2.92	0.54	15.73	3.53	1.78	7.00
Elementary administration and service occupations	2.16	1.71	2.73	2.14	1.69	2.71	1.90	1.39	2.60	3.03	1.97	4.67
Variance (Household)	3.34	3.05	3.63	3.34	3.05	3.63	2.38	1.64	3.12	2.00	0.94	3.06
Residual intraclass correlation (Household)	0.44	0.41	0.47	0.44	0.41	0.47	0.32	0.23	0.42	0.27	0.15	0.43
Variance (Individuals)	1.02	0.78	1.26	1.02	0.78	1.26	1.88	1.14	2.62	2.11	1.03	3.19
Residual intraclass correlation (Individuals)	0.57	0.55	0.59	0.57	0.55	0.59	0.56	0.54	0.59	0.56	0.53	0.58
N	409,009			409,009			217,920			191,089		
No. of household	72,866			72,866			50,405			44,822		
No. of participant	100,138			100,138			53,015			47,123		

Table S2. Multilevel logistic regression models of Covid-19 testing positive by period, ONS Covid Infection Study

Outcome: Test positive	10 May 2020 - 04 Nov 2020			05 Nov 2020 - 19 Dec 2020			20 Dec 2020 - 02 Feb 2020		
	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI
Female	0.83	0.69	0.99	0.92	0.80	1.06	0.77	0.66	0.90
BAME	1.27	0.89	1.81	1.36	1.04	1.79	0.97	0.72	1.30
Age group (Ref = 60-64)									
18-29	1.80	1.22	2.67	1.26	0.92	1.72	1.68	1.18	2.39
30-39	0.99	0.68	1.44	1.03	0.77	1.38	1.14	0.82	1.59
40-49	0.85	0.59	1.24	1.07	0.80	1.44	1.36	1.00	1.87
50-59	1.20	0.84	1.70	0.99	0.74	1.33	1.22	0.89	1.67
Visit date	1.04	1.04	1.04	1.00	1.00	1.00	1.01	1.01	1.01
Autonomy	0.58	0.36	0.92	0.98	0.94	1.02	0.96	0.92	1.00
Face covering or masks (Ref = not wearing face covering or mask)									
Yes my face is already covered	0.27	0.04	1.90	0.59	0.34	1.03	1.38	0.59	3.20
Yes at work/school/other situations only	0.30	0.05	1.71	0.50	0.31	0.82	0.64	0.33	1.22
Yes usually both work/school/other	0.20	0.04	1.13	0.44	0.27	0.73	0.58	0.31	1.11
Autonomy x Face covering/masks (Ref = No face covering/mask)									
Autonomy x Yes my face is already covered	1.73	1.04	2.89	-	-	-	-	-	-
Autonomy x Yes at work/school/other situations only	1.63	1.02	2.61	-	-	-	-	-	-
Autonomy x Yes usually both work/school/other	1.75	1.09	2.80	-	-	-	-	-	-
Contact with COIVD-19 positive people (Ref = no contact)									
0-14 days	14.01	11.30	17.38	15.03	12.35	18.28	27.66	21.02	36.39
15-28 days	3.56	2.50	5.07	5.16	4.00	6.65	7.10	5.40	9.34

29-60 days	1.79	1.01	3.15	2.32	1.76	3.05	1.93	1.41	2.65
61-90 days	1.73	0.44	6.83	1.15	0.65	2.03	1.20	0.81	1.77
91+ days	0.90	0.38	2.14	1.23	0.69	2.22	1.15	0.75	1.77
Household size	1.04	0.96	1.13	1.05	0.99	1.11	1.01	0.93	1.09
Smoke	0.82	0.66	1.02	0.95	0.81	1.11	0.93	0.78	1.11
Region (Ref = Northeast)									
Northwest	1.79	1.18	2.70	1.46	0.99	2.16	0.97	0.64	1.46
Yorks Humber	1.25	0.81	1.92	1.32	0.89	1.96	0.36	0.22	0.59
East midlands	0.73	0.45	1.20	1.15	0.75	1.77	0.52	0.32	0.85
West midlands	0.55	0.34	0.90	0.91	0.61	1.38	0.76	0.49	1.20
East	0.25	0.15	0.42	0.53	0.35	0.80	0.66	0.43	1.02
London	0.55	0.35	0.87	0.85	0.58	1.26	1.36	0.92	2.02
South East	0.35	0.22	0.56	0.70	0.47	1.06	0.89	0.59	1.34
South West	0.29	0.16	0.51	0.45	0.28	0.72	0.34	0.21	0.55
Variance (Household)	6.01	4.99	7.03	5.21	4.43	5.99	7.21	5.98	8.44
Residual intraclass correlation (Household)	0.49	0.43	0.54	0.50	0.45	0.54	0.58	0.54	0.62
Variance (Individuals)	3.04	2.16	3.92	2.03	1.34	2.72	1.94	1.16	2.72
Residual intraclass correlation (Individuals)	0.73	0.70	0.76	0.69	0.65	0.72	0.74	0.70	0.77
N	187453			142056			79500		
No. of household	54383			57203			47594		
No. of participant	73262			75682			60252		

Figure S1 Visualization of Table 2 using selected key variables.

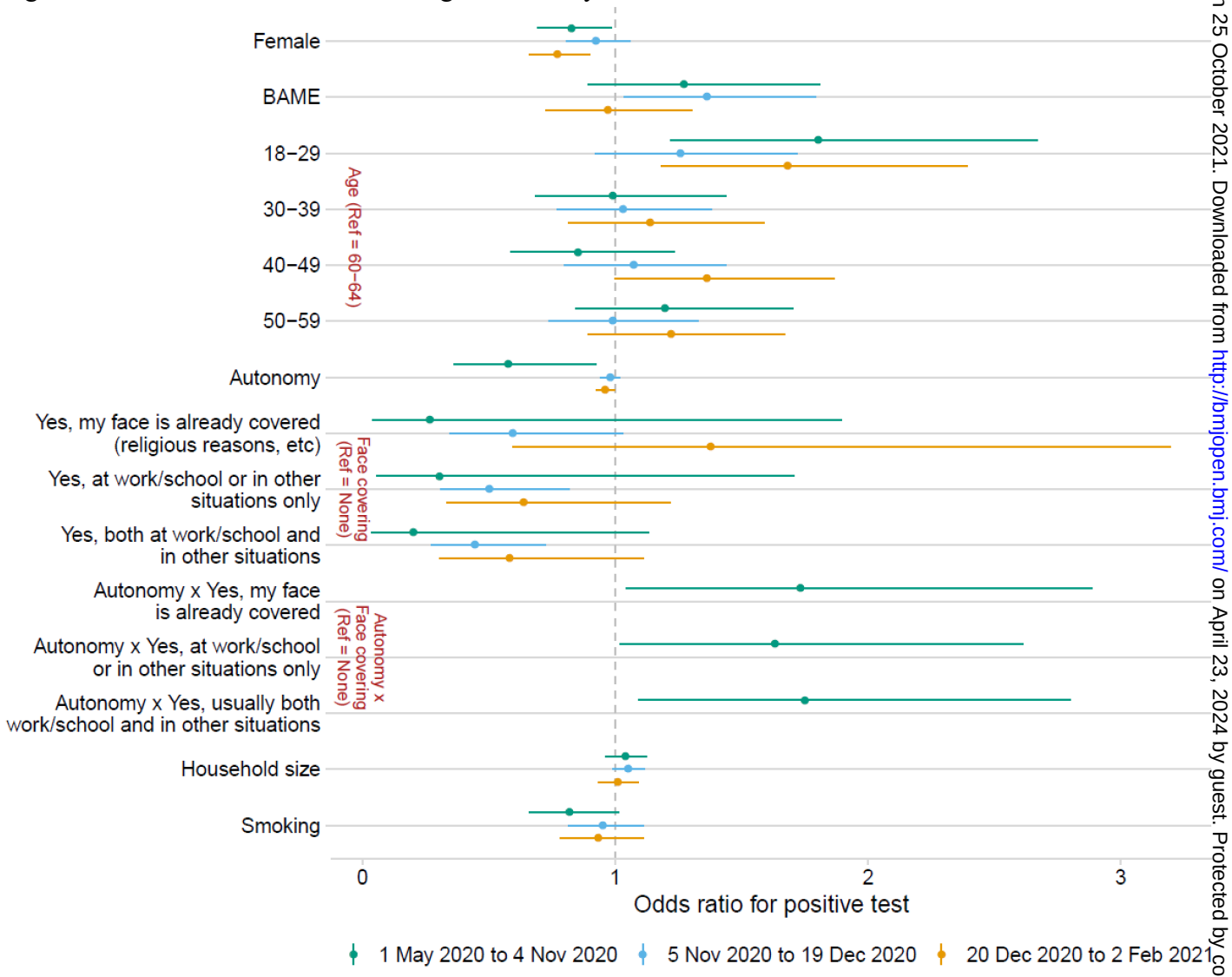

Table S3. Descriptive statistics N = 409, 009

	All				Male		Female	
	mean	sd	min	max	mean	sd	mean	sd
COVID-19 positive	0.0118		0	1	0.0120		0.0117	
Female	0.5328		0	1	0.0000		1.0000	
BAME	0.0766		0	1	0.0763		0.0770	
Age at visit	44.6401	(11.5266)	20	64	44.5303	(11.5765)	44.7364	(11.4819)
Age group								
18-29	0.1269		0	1	0.1266		0.1271	
30-39	0.2146		0	1	0.2212		0.2088	
40-49	0.2650		0	1	0.2639		0.2659	
50-59	0.2949		0	1	0.2859		0.3029	
60+	0.0986		0	1	0.1024		0.0953	
Autonomy	4.2061	(1.8174)	0	7	4.5345	(1.6413)	3.9181	(1.9129)
Face mask								
No face mask	0.0149		0	1	0.0163		0.0137	
Yes my face is already covered	0.0290		0	1	0.0281		0.0297	
Yes at work/school/other situations only	0.4855		0	1	0.5054		0.4680	
Yes usually both work/school/other	0.4707		0	1	0.4502		0.4886	
Number of test	6.9757	(1.9761)	1	10+	6.9541	(1.9721)	6.9946	(1.9794)
Household size	2.6550	(1.1957)	1	10+	2.7384	(1.2039)	2.5819	(1.1836)
Work outside home days	3.0201	(2.0517)	0	7	3.1415	(2.1295)	2.9036	(1.9749)
Contact with COVID-19 positive								
No contact	0.7911		0	1	0.8102		0.7743	
0-14 days	0.0834		0	1	0.0730		0.0925	
15-28 days	0.0384		0	1	0.0350		0.0413	
29-60 days	0.0441		0	1	0.0402		0.0475	
61-90 days	0.0189		0	1	0.0179		0.0198	
91+ days	0.0242		0	1	0.0238		0.0246	

Work social distancing					
Easy to maintain 2m	0.4914	0	1	0.5602	0.4912
Relatively easy to maintain 2m	0.1621	0	1	0.1818	0.1848
Difficult to maintain 2m but can be 1m	0.1362	0	1	0.1272	0.1440
Very difficult to be more than 1m	0.2103	0	1	0.1309	0.2799
Work location					
Working from home	0.2417	0	1	0.2561	0.2291
Working somewhere else(not your home)	0.6186	0	1	0.5985	0.6362
Both(from home and somewhere else)	0.1397	0	1	0.1454	0.1348
Work travel method					
Underground/metro/light rail/tram	0.0252	0	1	0.0259	0.0246
Train	0.0383	0	1	0.0443	0.0331
Bus/minibus/coach	0.0266	0	1	0.0206	0.0318
Motorbike/scooter or moped	0.0040	0	1	0.0071	0.0014
Car or van	0.6985	0	1	0.6995	0.6977
Taxi/minicab	0.0038	0	1	0.0037	0.0040
Bicycle	0.0358	0	1	0.0470	0.0260
On foot	0.1355	0	1	0.1181	0.1508
Other method	0.0323	0	1	0.0339	0.0308
Smoking	0.3007	0	1	0.3257	0.2788
Work direct with patients	0.2184	0	1	0.1501	0.2883
Occupation					
Corporate managers and directors	0.0787	0	1	0.1101	0.0512
Other managers and proprietors	0.0371	0	1	0.0495	0.0263
Science research engineering and technology professionals	0.0516	0	1	0.0842	0.0231
Health professionals	0.0640	0	1	0.0275	0.0960
Teaching and educational professionals	0.1065	0	1	0.0665	0.1416

Business media and public service professionals	0.0678	0	1	0.0796	0.0776
Science engineering and technology associate professionals	0.0152	0	1	0.0203	0.0106
Health and social care associated professionals	0.0178	0	1	0.0097	0.0250
Protective service occupations	0.0210	0	1	0.0312	0.0121
Culture media and sports occupations	0.0252	0	1	0.0266	0.0239
Business and public service associated professionals	0.0812	0	1	0.0891	0.0743
Administrative occupations	0.1023	0	1	0.0603	0.1391
Secretarial and related occupations	0.0257	0	1	0.0031	0.0455
Skilled agricultural and related trades	0.0080	0	1	0.0128	0.0037
Skilled metal electrical and electronic trades	0.0303	0	1	0.0634	0.0113
Skilled construction and building trades	0.0259	0	1	0.0537	0.0115
Textiles printing and other skilled trades	0.0097	0	1	0.0123	0.0074
Caring personal service occupations	0.0722	0	1	0.0188	0.1190
Leisure travel and related personal service occupations	0.0094	0	1	0.0051	0.0132
Sales occupation	0.0397	0	1	0.0263	0.0515
Customer service occupations	0.0142	0	1	0.0096	0.0183
Process plant and machine operatives	0.0149	0	1	0.0279	0.0036
Transport and mobile machine driver and operatives	0.0261	0	1	0.0516	0.0038
Elementary trades and related occupations	0.0044	0	1	0.0084	0.0009
Elementary administration and service occupations	0.0511	0	1	0.0527	0.0497
Region					
Northeast	0.0503	0	1	0.0483	0.0521
Northwest	0.1435	0	1	0.1422	0.1446

Yorks Humber	0.1021	0	1	0.1019	0.1022
East midlands	0.0776	0	1	0.0776	0.0775
West midlands	0.0943	0	1	0.0960	0.0929
East	0.1241	0	1	0.1262	0.1223
London	0.1743	0	1	0.1759	0.1730
South East	0.1474	0	1	0.1480	0.1469
South West	0.0863	0	1	0.0840	0.0884
N	409,009			191,089	217,920

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cohortreporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	#3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	#4	Present key elements of study design early in the paper	3-5

Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-5
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	3-5
Eligibility criteria	#6b	For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	3-5
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	3-5
Bias	#9	Describe any efforts to address potential sources of bias	3-5
Study size	#10	Explain how the study size was arrived at	3-5
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	3-5
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	3-5
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	3-5
Statistical methods	#12c	Explain how missing data were addressed	3-5
Statistical methods	#12d	If applicable, explain how loss to follow-up was addressed	n/a
Statistical methods	#12e	Describe any sensitivity analyses	3-5

Results

Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	5-6
Participants	#13b	Give reasons for non-participation at each stage	n/a
Participants	#13c	Consider use of a flow diagram	
n/a			
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	5-6
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	
n/a			
Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)	
n/a			
Outcome data	#15	Report numbers of outcome events or summary measures over time. Give information separately for exposed and unexposed groups if applicable.	
n/a			
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5-6
Main results	#16b	Report category boundaries when continuous variables were categorized	5-6
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
n/a			

Other analyses	#17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5-6
Discussion			
Key results	#18	Summarise key results with reference to study objectives	6-7
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	6-7
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	6-7
Generalisability	#21	Discuss the generalisability (external validity) of the study results	6-7
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

This checklist was completed on 04. June 2021 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

BMJ Open

Factors affecting adherence to non-pharmaceutical interventions for COVID-19 infections in the first year of the pandemic in the UK: Analysis of the repeated household Covid Infection Study (CIS)

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Manuscript ID	bmjopen-2021-054200.R1
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Factors affecting adherence to non-pharmaceutical interventions for COVID-19 infections in the first year of the pandemic in the UK: Analysis of the repeated household Covid Infection Study (CIS)

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Contributions
MCM, XD, DMB designed the study and MCM wrote the report, to which all authors contributed. MCM, XD and DMB designed the models. XD and DMB prepared the data and ran the models. MCM designed the time-varying graphic. All authors read and approved the final article.

Declaration of interests
MCM is a member of the UK Scientific Advisory Group for Emergencies sub-groups SPI-B (behavioural insights), ethnicity and Vaccines Science Coordination Group and member of the Royal Society's SET-C (Science in Emergencies Tasking – COVID) group, all which respond to requests from government departments and the Government Office for Science.

Data Sharing
This work contains statistical data from Office of National Statistics (ONS) which is Crown Copyright. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates. The Covid Infection Study (CIS) data are available via a formal request to the ONS Secure Research Service for accredited researchers.

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The authors declare no competing interest.

ABSTRACT

Objective

Non-pharmaceutical interventions (NPIs), including wearing face covering/masks, social distancing and working-from-home, have been introduced to control SARS-CoV-2 infections. We provide individual-level empirical evidence of whether adherence reduces infections.

Setting and participants

The Covid-19 Infection Study (CIS) was used from 10 May 2020 to 02 February 2021 with 409,009 COVID-19 nose and throat swab tests nested in 72,866 households for 100,138 individuals in the labour force aged 18-64.

Analysis

Odds ratios (ORs) for a positive COVID-19 test were calculated using multilevel logistic regression models, stratified by sex and time, by an index of autonomy to abide to NPIs, adjusted for various socioeconomic and behavioural covariates.

Results

Inability to comply with NPIs predicted higher infections when individuals reported not wearing a face-covering outside. The main effect for inability to comply was OR: 0.79 (95% CI 0.67–0.92), for wearing face-covering/masks was OR: 0.29 (95% CI 0.15–0.56), and the interaction term being OR: 1.25 (95% CI 1.07–1.46). The youngest age groups had a significantly higher risk of infection (OR: 1.52, 95% CI 1.28–1.82) as did women in larger households (OR: 1.06, 95% CI 1.02–1.06). Effects varied over time with autonomy to follow NPIs only significant in the pre-second lockdown May–November 2020 period. Wearing a face-covering outside was a significant predictor of a lower chance of infection before mid–December 2020 when a stricter second lockdown was implemented (OR: 0.44, 95% CI 0.27–0.73).

Conclusion

The protective effect of wearing a face-covering/mask was the strongest for those who were the most unable to comply with NPIs. Higher infection rates were in younger groups and women in large households. Wearing a face-covering or mask outside the home consistently and significantly predicted lower infection before the 2020 Christmas period and amongst women.

Strengths and limitations of this study

- The first large-scale study that links individual and household level adherence to NPIs plus their autonomy to adhere with actual measured infections.
- This representative population-based study went beyond the use of aggregated population-wide case data or individual self-reporting of SARS-CoV-2 to use individual throat and swab SARS-CoV-2 positivity testing.
- Our measure of infection captured those who might be asymptomatic or whose infections are relatively mild.
- Although the dataset is the most representative to date, some groups such as ethnic minorities (termed BAME in the UK) are still underrepresented in the sample.
- Participation in the study is voluntary and thus self-selection bias may affect the results.

INTRODUCTION

Although most countries have introduced non-pharmaceutical interventions (NPIs) to lower the spread of infectious diseases such as SARS-CoV-2, there is limited empirical research on the relationship of adherence to NPIs with infections or how an individuals' autonomy or ability to follow NPI measures relates to infections,[1]. To form evidence-based health policy, it is crucial to have empirical evidence that tests whether the adherence to NPIs is effective in reducing infection. The lack of compliance to NPIs has been generally positioned as an attitude or choice [2], but it may be related to the inability to follow measures and thus exacerbate existing health inequalities. This includes employment that does not accommodate working at home, the necessity to take public transport, or being in workplaces or households where recommended social distancing is not possible.

Due to data limitations, existing research examining the effects of NPIs on COVID-19 related outcomes has almost exclusively used aggregated data to model the correlation between the timing of various national, state or regional level NPIs with COVID-19 case rates [1,3-6]. These types of studies risk producing an ecological fallacy, since the interpretation of statistical data about individuals are deduced from an inference for the group to which those individuals belong [1]. In the early stages of the pandemic in 2020, some simulations also estimated the potential ebb and flow of infections in relation to the introduction of various NPIs and how this might impact healthcare demands [7]. There have been various systematic reviews and meta-analyses, some with mixed results, but generally demonstrating the protective nature of NPIs [8,9]. Other studies examining the effectiveness of face coverings and masks have been largely carried out in health settings examining N95 or surgical masks, with critiques that findings cannot be transferred to community settings or do not properly control for confounders [9].

Although a handful of individual-level studies more directly examined the relationship between individual adherence to NPIs and individual-level case data of infections, they were carried out in the early stages of the pandemic, had small samples (1,000,[10] or 1,500 cases [11]), and used very general NPI measures. A previous review concluded that although many studies have assessed NPIs, few were able directly examine or quantify their impact [12]. We aimed to measure the association between COVID-19 infections and the autonomy to follow NPIs, key sociodemographic factors, and changes over time, using individual- and household-level data in a large nationally representative sample in the UK collected over almost one year from May 2020 to February 2021.

METHODS

Study design and participants

The Covid Infection Study (CIS) is one of the largest regular surveys of coronavirus infections and antibodies,[13]. The CIS has been used to examine multiple aspects of the pandemic and to monitor community prevalence of SARS-CoV-2 infection,[14]. Samples, demographic information and a short questionnaire are collected from individuals aged 2 and older living in private households in England, randomly selected from address lists and the Office of National Statistics (ONS) surveys. It is a repeated household survey with additional serial sampling and longitudinal follow-up. Data includes a questionnaire and nose and throat swabs. If multiple household members agreed to participate, a home visit was made to collect information. Following the first visit, participants who agree, are visited every week for the first five weeks and then receive optional monthly visits. All study protocol and questionnaires are available online (https://www.ndm.ox.ac.uk/covid-19/covid-19-infection-survey).

A positive COVID-19 test was determined from nose and throat swabs using the TaqPath RT-PCR COVID-19 kit (Thermo Fisher Scientific, Waltham, MA, USA), analysed using UgenTec Fast Finder 3.300.5 (TaqMan 2019-nCoV assay kit V2 UK NHS ABI 7500 v2.1; UgenTec, Hasselt, Belgium), described in detail in the sources listed above. Tests are considered positive when at least one gene is present – N, ORF1ab, or both – but could be accompanied by the gene for S protein (detection of S protein alone is not considered reliable) [14]. For the analyses in this study, the Covid-19 Infection Study (CIS) from 10 May 2020 to 02 February 2021 was used with 409,009 valid COVID-19 tests from nose and throat swabs nested in 72,866 households for 100,138 individuals in the labour force aged 18-64 years.

Measurement of autonomy

Autonomy to adhere to NPIs is measured by summing conditions that might limit their ability to comply. Each question was asked at every visit to each participant. We assigned points to these conditions which were then summed into one index that measures autonomy. The measures are that the respondent reports that they: (1) work outside the home at least one day per week (1 point), (2) find it 'easy to maintain 2 metres' distance in workplace (0 points), (3) find it 'relatively easy to maintain 2 metres' distance in the workplace (1 point), (4) find it 'difficult to maintain 2 metres, but can be 1 metre' in the workplace (2 points), (5) 'very difficult to be more than 1 metre away' in the workplace (3 points), (6) are at a main working location that is 'somewhere else (not your home)' (1 point), (7) find it common to go to and from work/school by bus, coach or minibus (1 point); and, (8) engage in work that involves direct contact with patients, clients, residents, service users or customers on a day-to-day basis (1 point). We included transportation by bus, coach or minibus only since sensitivity analyses that included other means of transportation such as underground, tram or motorbike, scooter, or car all showed a reverse correlation with other autonomy items and reduced the reliability of our autonomy index.

The autonomy index passed the Cronbach's alpha test with the reliability coefficient of 0.73. Exact questions used for the construction of the measurement of autonomy can be found in the supplementary materials (Table S1). Spearman correlation amongst each item and the final autonomy score is documented in the supplementary materials (Table S2 & Figure S1).

To interpret the index we consider an example. A person who reports working outside home for 5 days a week (+1), in a job where it is difficult to maintain 2 metre distancing, but can maintain 1 metre (+2) and whose main work location is not home (+1) and does not take public transportation of a bus (0), but works directly with people (+1) will score 5 in autonomy. After summing the scores, we reverse coded the autonomy variable so that a lower score indicates low autonomy (i.e., more situations that limit the individuals' ability to comply) and a higher autonomy score indicates a higher ability to comply with NPIs. The range for the autonomy score is from 0-7, with the person described in the previous example scored as 2 given reverse coding.

Statistical analysis

We estimated the likelihood of testing positive for SARS-CoV-2 from nose and throat swabs using three-level multivariate multilevel logistic regression models, also stratified by sex and time period. The outcome is a positive SARS-CoV-2 test, with the main predictors of sex, Black, Asian or minority ethnicity (BAME), age group, visit date, household size, smoking

status, region, occupation, days since contact with any COVID-19 positive person, compliance with wearing a face covering or mask and autonomy to comply with NPIs.

Mixed-level logistic regression models were estimated with COVID-19 tests (level 1) nested within individuals (level 2) nested within households (level 3) with the outcome variable of COVID-19 positive infections. The main model estimates sex, ethnicity, age group, reporting to wear a face covering or mask, our autonomy to comply index and additional control variables. Model 2 adds an interaction term between autonomy to adhere and wearing a face covering or mask. Model 3 is the same as model 2 but only includes females. Model 4 is the same as the main model but only includes males. We estimated sex-specific models since when we added the interaction term for men only in the model, the interaction terms were not significant, the model fit did not increase, and the main effect also disappeared. We therefore consider the interaction terms in the male model as an unnecessary control and only reported the main models for men. Next, we stratified the models by three periods that broadly reflect the various phases of restrictions in the UK of: (1) 10 May - November 04 (pre-lockdown 2), (2) 05 November to December 19 (lockdown 2 'light version'), and (3) 20 December to Feb 02 (Lockdown 2 stricter) (See Figure 1). These periods follow the general guidelines, which varied somewhat across the four nations of England, Scotland, Wales and Northern Ireland. For the first periods, we were able to fit the model with the interaction term, and for the second and third period we fit the main model without the interaction term for the same reason mentioned above in relation to sex. Occupation was not included in the models by time periods due to the small sample sizes in each category.

Patient and public involvement

Patients and the public were not involved in the development of research questions, design of the study, recruitment, and conduct of the study, or dissemination of the study results.

RESULTS

The autonomy score ranges from 0 to 7 (Mean = 4.21, SD = 1.82), with a higher score indicating more autonomy. The distribution of the autonomy score for the entire sample and by sub-groups is presented in Figure 2. The autonomy score follows a normal distribution. Men, and particularly men above 40 years of age, report more autonomy than women and younger counterparts.

We find that the level of autonomy to adhere to NPIs does not predict COVID-19 infection alone, but rather the risk of infection is diminished when individuals wear face-covering/masks (Figure 3, or Table S3). For example, the main effect model in Figure 3 and Model 1 in Table S3 shows that with one higher score in autonomy (i.e., one more condition that limited the respondents' ability to comply to NPIs), there is a 3% lower likelihood of testing positive for SARS-CoV-2 (OR: 0.97; 95% CI 0.95 to 0.99). The coefficient is however marginally statistically significant, and the magnitude is small.

In Figure 2 (also see supplementary materials, Table S3, Model 2), we add interaction terms between autonomy and compliance of wearing face covering/mask. We found that the protective effect of wearing a face covering/mask is stronger when autonomy is low. We visualise this interaction effect based on model 3 in Figure 4. The interaction effect is the most pronounced amongst females.

The youngest 18-29 year old age groups have a significantly higher odds of infection (OR 1.17; 95% CI 1.00–1.37), with living in a larger household only related to a significantly

higher odds of infection for women (OR: 1.04; 95%CI 1.02–1.06). Male smokers had a significantly lower risk (OR: 0.84; 95%CI 0.74– 0·94]). This is in line with a recent review of 17 studies that also found that current smokers had a reduced risk of testing positive for COVID-19 [15].

To test whether our core predictors change in relation to key policy restrictions put in place to restrict infections, hospitalisation and deaths (Figure 1, or Table S2), we divided the analysis into three policy periods (available in our data) of: (1) 10 May 2020 – 04 November 2020 (first lockdown to pre-second lockdown), (2) 05 November – 19 December (second lockdown and pre-Christmas period of 'lockdown light'); and, (3) 20 December – 02 February (stricter second lockdown with schools closed and introduction of Tier 4). Figure 1 illustrates the clear time-lag between infections leading to deaths, with growing evidence that this link is disrupted by vaccinations as time elapses. Black, Asian and minority ethnic groups were more likely to be infected, especially during the second lockdown (05 Nov-19 December) (OR: 1.36; 95%CI 1.04–1.79).

Effects varied over the year with autonomy to follow NPIs only significant in the pre-Second lockdown period (May–November 2020). Wearing a face covering or mask outdoors was a significant predictor of a lower chance of infection before 19 December 2020 (OR: 0.44; 95%CI 0.27–0.73) when a stricter second lockdown was implemented. One possible explanation is that the percentage of people not wearing face covering/masks was low and declined from 2% to 1% from May 2020 to Feb 2021. The variable may also be capturing both the social environment (i.e., wearing a face covering may be influenced by the level of individuals wearing masks around you) and correlated health behaviours (i.e., those who wear face coverings are more cautious in other ways).

In the full models, the random effects variance estimates were larger at the household level than at the individual level OR: 3.34 (95%CI 3.05–3.63) versus OR: 1.02 (95% CI 0.78–1.26), suggesting that more unexplained variation in infection risk exists at the household level. This difference was smaller or non-existent in the sex-stratified models, with the residual intraclass coefficients also reflecting a loss of household information.

DISCUSSION

Using multivariate multilevel logistic regression models, we examined the relationship between individual adherence to NPIs and COVID-19 infection, controlling for key sociodemographic, behavioural and time-related policy changes. We found that an individuals' autonomy to comply with NPIs predicts higher infections when individuals do not engage in other protective measures of wearing a face covering or mask outside their home. Our results suggest that engaging in protective behaviours such as wearing face coverings can reduce the unequal effects of exposure to COVID-19, noted in previous literature reviews [9]. Our findings emphasise the need to move to more complex models beyond comparing aggregated percentages of general population compliance to a more nuanced understanding that stratifies groups in meaningful ways to develop tailored health policy interventions and communications. We found that women living in larger households had a significantly higher risk of infection, reflecting more domestic and care duties and time in the household, but also multiple individuals leaving and returning the home from diverse environments.

The 18-29 year old age group had a significantly higher risk of infection, suggesting that this is an important group to consider given that many countries have been engaging in age-

related vaccine roll-outs. Effects varied over the year with autonomy to follow NPIs only significant in the pre-Second lockdown period (May- November 2020). This was a period where initially many UK governments were reluctant to introduce certain policy interventions, such as the relatively late introduction of face-coverings for the general public in late June or July 2020, first in public transport only [2].

Wearing a face covering or mask outside the home was a significant predictor of a lower chance of infection before 19 December 2020 when a stricter second lockdown was implemented. BAME groups are more likely to be infected, especially during the second lockdown (05 November–19 December). We note, however, that although we see some period variation, given the overlap in CIs and the fact that we are not strictly testing a difference between the coefficients in our model, they are not statistically different.

A strength of our study is that it is to our knowledge the first large-scale study that links the reporting of individual and household level adherence to NPIs and their ability or challenges to adhere with actual measured infections. This representative population-based study went beyond the self-reporting of SARS-CoV-2 to use throat and swab SARS-CoV-2 positivity testing opposed to population-wide case data, which is subject to significant selection bias. This is also an advantage over other measures such as hospitalisation or death, which only pick up the most severe cases. By measuring infections in this manner, we are also able capture those who might be asymptomatic or whose infections are relatively mild. Given the multilevel design based on a sample that was designed to be a random sample of households stratified by gender and time period, we also avoid problems in interpretation over this period due to changes in testing practice. Another advantage is that we have longitudinal, regularly collected data over this period which allows us to examine changes in behaviour over time.

Our study is also subject to several limitations. Although the dataset is the most representative to date, some groups such as ethnic minorities (termed BAME in the UK) remain underrepresented in the sample. Whereas we have 7% BAME, amongst the UK population, around 14% are from a minority ethnic background. Therefore, our estimates may not reflect the full range of the population. Future work may incorporate our individual- and household- level approach with the aggregate level approach [16, 17] together to analyse population scale NPIs and risk attitudes/behaviours. The number of tests in the lockdown 2 'stricter version' period is much smaller, meaning that we may not have the power to detect some effects. Participation in the study is voluntary and thus self-selection bias may affect the results. In addition, as others have noted, we are unable to determine the sensitivity and specificity of the PCR test, but it is likely close to 100% [18]. Finally, the mixed logit models assume linearity between the continuous predictors and the log odds of the outcome of interest. Violating linearity can affect prediction and inference. Since most of our predictors are categorical/binary and we only include three continuous predictors – visit date, autonomy, and household size – in the analyses, it is unlikely that the linearity assumption is severely violated. The plot of the logit for continuous predictors (Supplementary materials, Figure S2) also alleviates the concern.

CONCLUSION

Many countries introduced multiple non-pharmaceutical interventions (NPIs) to control COVID-19 infections, hospitalization and deaths and continue to implement or re-introduce them during spikes in infections even during vaccine roll-out. There have been limited empirical studies using individual-level data to examine how individual adherence to NPIs

predicts infections by sociodemographic factors, individual autonomy to abide by NPIs and how these relationships change over time in relation to different restrictions.

We move beyond aggregated figures showing macro correlations of NPI policy stringency with national-level COVID-19 outcomes, to produce individual- and household-level models that properly control for confounders, key sociodemographic and behavioural factors and changes in policy interventions over time. Using the Covid Infection Study (CIS) in the UK with almost one year of data from 10 May 2020 to 02 February 2021, with 409,009 valid COVID-19 tests nested in 72,866 households for 100,138 individuals aged 18-64 years, we estimate multivariate multilevel logistic regression models, stratified by sex and time-period. We create a novel index measuring individual autonomy to abide by NPIs index (i.e., ability to work at home and number of days at home, ability to maintain physical distancing at work, travel to work requires public transport, or work involves direct contact).

Although autonomy or inability to abide by NPIs is a significant predictor of higher infection rates amongst certain groups, it does not predict infection alone. Wearing a face covering or mask outside the home can reduce the unequal effects of exposure to COVID-19 due to individual and employment circumstances. Autonomy to follow NPIs was only a significant predictor of infection risk from May to November 2020 but those who reported wearing a face covering or mask outdoors significantly had lower rates of infection for individuals with lower level of autonomy between 10 May to 04 November and for all people between 05 November to 19 December 2020.

The results we present here summarise key parts of the analyses we presented to senior decision makers in the UK over February–March 2021, in a context with rapidly evolving information, vaccine deployment and other relevant policies. As the pandemic evolves, new variants of concern emerge and vaccines are rolled-out across the world, experts, politicians and civil servants will continue to make difficult decisions on lifting or re-instating NPIs. This study provides novel and nuanced empirical evidence of the relationship of autonomy to follow NPIs with infection, how this varies and where support or public communication could be directed.

Ethical Approval Statement. Participants provided informed consent when they took part in the CIS study. More information can be found here: https://www.ons.gov.uk/surveys/informationforhouseholdsandindividuals/householdandindividualsurveys/covid19infectionsurveycis/howtotakepart

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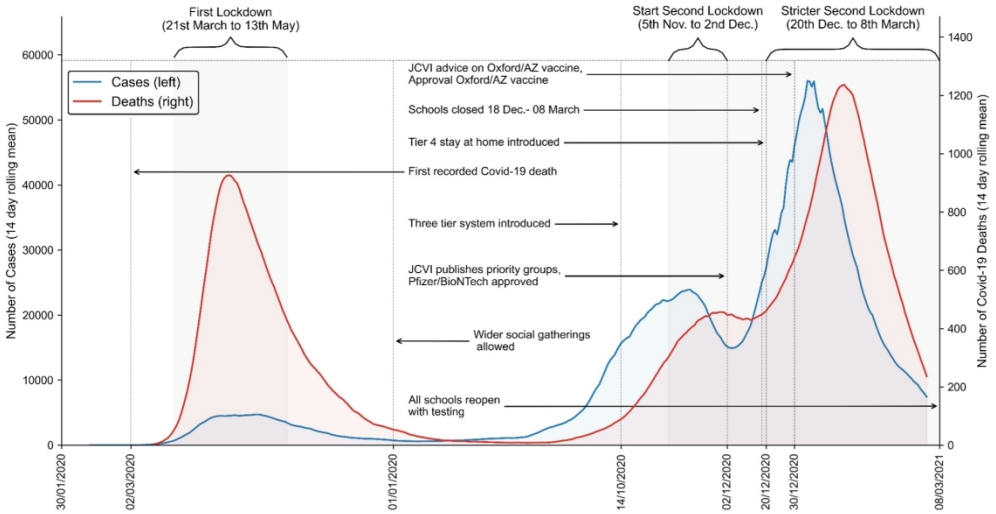
Figure 1. Timeline of key restrictions in England by COVID-19 cases (left) and deaths (right), January 01 2020 to March 08 2021.

Note: JCVI (Joint Committee on Vaccination and Immunisation); AZ (Astra Zeneca). Graph produced by authors using policy data for England,[17,18] and official UK Government data on COVID-19 cases and deaths,[19] smoothed into 14 day rolling means. Deaths are in red (read from right axis) and cases in blue (read from left axis), with magnitudes representing smoothed 14 day rolling means and not cumulative figures. The restrictions shown here are for England and we note there was some variation in the detail of some policies and slight variation in timing in Scotland, England, Wales and Northern Ireland.

Figure 2. Distribution of the measure of autonomy within the sample and by sample subgroups.

Figure 3. Three-level logistic regression models of COVID-19 positive tests, 10 May 2020 – 02 February 2021 by key fixed-effect predictorsand interaction effects (see supplementary materials for full tables), ONS Covid Infection Study.

Figure 4. Association between infection and autonomy by level of compliance to wearing face-covering/masks (estimates from Model 3).



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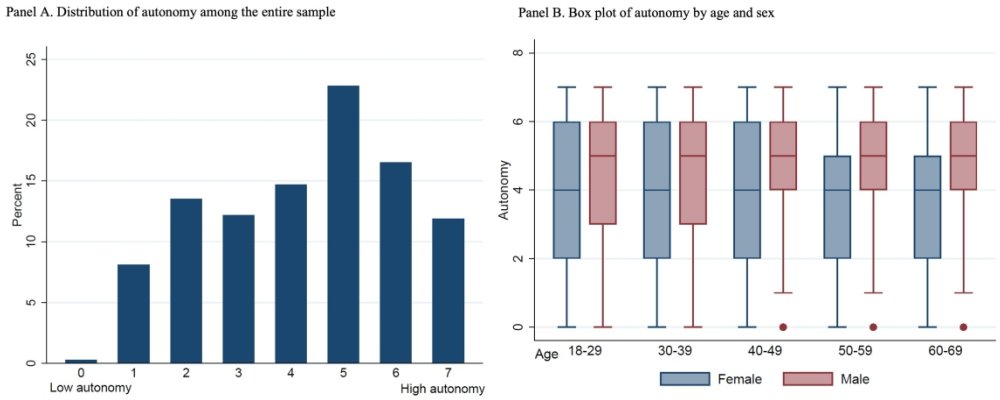

Figure 2. Distribution of the measure of autonomy within the sample and by sample subgroups.

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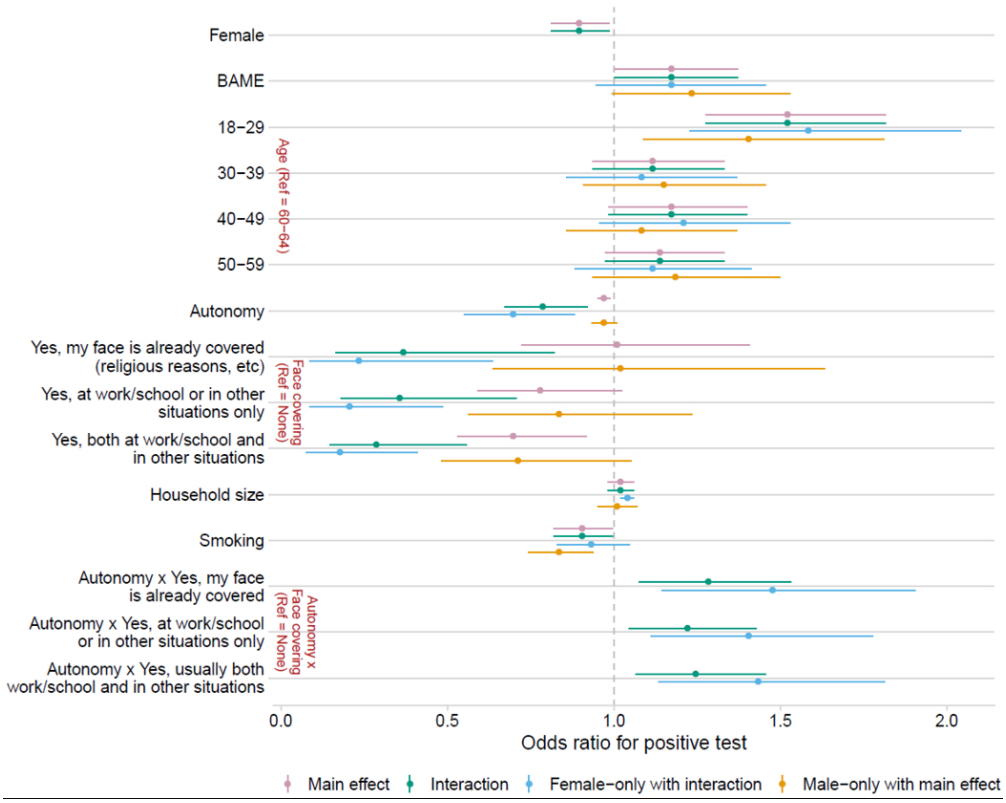


Figure 3. Three-level logistic regression models of COVID-19 positive tests, 10 May 2020 – 02 February 2021 by key fixed-effect predictorsand interaction effects (see supplementary materials for full tables), ONS Covid Infection Study.

184x147mm (144 x 144 DPI)

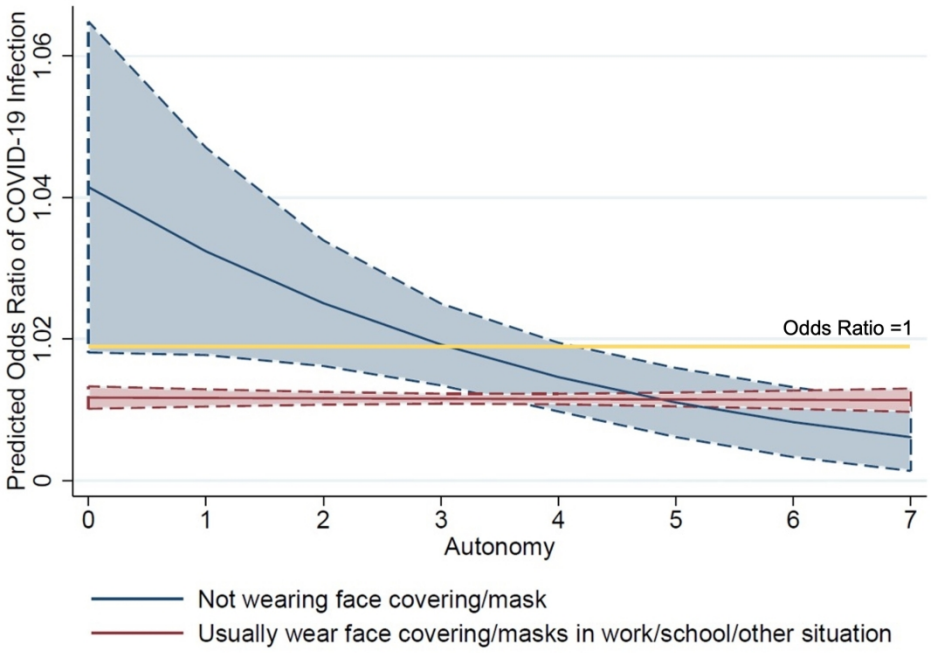


Figure 4. Association between infection and autonomy by level of compliance to wearing face-covering/masks (estimates from Model 3).

208x145mm (300 x 300 DPI)

Factors affecting adherence to non-pharmaceutical interventions for COVID-19 infections in the first year of the pandemic in the UK:
Analysis of the repeated household Covid Infection Study (CIS)
Supplementary Materials

1. Construction of the Measurement of Autonomy

Autonomy to adhere to NPIs is measured via the sum of several situations that might limit the respondents' ability to comply. Each question was asked repeatedly at each visit to every participant. We assigned points to these situations and summed the points into one index measuring the autonomy. The exact questions we used and the points assigned are listed in Table S1.

Table S1. Exact question, response item and score assignment used to construct the measurement of autonomy.

	Exact Question	Response Item and score assigned in the bracket
1	On average, on how many days of the week are you currently working somewhere else (not at your home, defined as the same grounds or building as your home), or currently attending, in person, your place of education, school, nursery, pre-school or childminder? (select one)	*1)* 0 *(0')* 2) 1 *(1')* 3) 2 *(1')* 4) 3 *(1')* 5) 4 *(1')* 6) 5 *(1')* 7) 6 *(1')* 8) 7 *(1')*
2	On average how easy is it to maintain 1-2m between yourself and other people at your place of work/full-time education/school/nursery, etc? (select one)	1) Easy to maintain 2m, it is not a problem to stay this far away from other people *(0')* 2) Relatively easy to maintain 2m, most of the time I can be 2m away from other people *(1')* 3) Difficult to maintain 2m, but I can usually be at least 1m from other people *(2')* 4) Very difficult to be more than 1m away, as my work means I am in close contact with others on a regular basis *(3')*
3	Currently, where are you mainly working now? (select one)	1) Working from home (in the same grounds or building as your home) *(0')* 2) Working somewhere else (not at your home) *(1')* 3) Both (working from home and working somewhere else) *(0')*
4	How do you mainly get to and from work/nursery/school? (select	1) Underground, metro, light rail, tram *(0')* 2) Train *(0')*

	one: if use multiple modes, choose the longest part of your journey in time)	3) Bus, minibus, coach *(1')* 4) Motorbike, scooter or moped *(0')* 5) Car or van *(0')* 6) Taxi/minicab *(0')* 7) Bicycle *(0')* 8) On foot *(0')* 9) Other method *(0')*
5	Does your current role primarily involve direct contact, in person, with patients/clients/residents/service users/customers on a day-to-day basis? (Please answer 'no' if primarily office-based)	1) Yes *(1')* 2) No *(0')*

Note: We included transportation by bus, coach or minibus only since sensitivity analyses that included other means of transportation such as underground, tram or motorbike, scooter, or car all showed a reverse correlation with other autonomy items and reduced the reliability of our autonomy index.

All study protocol and questionnaires are available online (https://www.ndm.ox.ac.uk/covid-19/covid-19-infection-survey)

Table S2. Correlation among the autonomy score and the items used for constructing the score.

	Work outside home more than 1 day per week	Relatively easy to maintain 2m	Difficult to maintain 2m	Very difficult to be more than 1m away	Mainly work outside home	Take bus, minibus, and coach to work	Work primarily involve direct contact in person with patients	**Autonomy**
Work outside home more than 1 day per week	1							
Relatively easy to maintain 2m	0.23	1						
Difficult to maintain 2m	0.18	0.71	1					
Very difficult to be more than 1m away	0.13	0.50	0.70	1				
Mainly work outside home	0.36	0.37	0.35	0.27	1			
Take bus, minibus, and coach to work	0.02	0.03	0.03	0.01	0.04	1		
Work primarily involve direct contact in person with patients	0.14	0.26	0.30	0.30	0.19	0.02	1	
Autonomy	**-0.50**	**-0.80**	**-0.80**	**-0.68**	**-0.67**	**-0.12**	**-0.51**	**1**

Table S3. Multilevel logistic regression models of Covid-19 testing positive, ONS Covid Infection Study

Outcome: Test positive	Model 1: Main effect			Model 2: Interaction			Model 3: Female only with interaction			Model 4: Male only main effect		
	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI
Female	0.90	0.81	0.99	0.90	0.81	0.99	-	-	-	-	-	-
BAME	1.17	1.00	1.37	1.17	1.00	1.37	1.17	0.95	1.46	1.23	0.99	1.53
Age group (Ref = 60-64)												
18-29	1.52	1.28	1.82	1.52	1.28	1.82	1.58	1.23	2.04	1.40	1.09	1.81
30-39	1.12	0.94	1.33	1.12	0.94	1.33	1.08	0.86	1.37	1.15	0.91	1.46
40-49	1.17	0.98	1.40	1.17	0.98	1.40	1.21	0.96	1.53	1.08	0.86	1.37
50-59	1.14	0.97	1.33	1.14	0.97	1.33	1.12	0.88	1.41	1.19	0.94	1.50
Visit date	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Autonomy	0.97	0.95	0.99	0.79	0.67	0.92	0.70	0.55	0.88	0.97	0.93	1.01
Face covering or masks (Ref = not wearing face covering or mask)												
Yes my face is already covered	1.01	0.72	1.41	0.37	0.16	0.82	0.23	0.09	0.64	1.02	0.64	1.63
Yes at work/school/other situations only	0.78	0.59	1.02	0.36	0.18	0.71	0.21	0.09	0.49	0.84	0.56	1.24
Yes usually both work/school/other	0.70	0.53	0.92	0.29	0.15	0.56	0.18	0.08	0.41	0.71	0.48	1.05
Autonomy x Face covering/masks (Ref = No face covering/mask)												
Autonomy x Yes my face is already covered	-	-	-	1.28	1.08	1.53	1.48	1.14	1.91	-	-	-
Autonomy x Yes at work/school/other situations only	-	-	-	1.22	1.04	1.43	1.40	1.11	1.78	-	-	-
Autonomy x Yes usually both work/school/other	-	-	-	1.25	1.07	1.46	1.43	1.13	1.81	-	-	-
Contact with COIVD-19 positive people (Ref = no contact)												

0-14 days	13.74	12.45	15.15	13.74	12.45	15.15	15.03	13.10	17.24	7.64	15.38	20.23
15-28 days	4.53	3.95	5.19	4.53	3.95	5.19	4.76	3.99	5.68	5.58	4.59	6.79
29-60 days	1.62	1.38	1.89	1.62	1.38	1.89	1.63	1.32	2.03	2.05	1.62	2.60
61-90 days	0.89	0.69	1.14	0.89	0.69	1.14	1.09	0.78	1.53	0.84	0.56	1.27
91+ days	1.00	0.76	1.32	1.00	0.76	1.32	0.98	0.66	1.45	1.14	0.77	1.69
Household size	1.02	0.98	1.06	1.02	0.98	1.06	1.04	1.02	1.06	1.01	0.95	1.07
Smoke	0.90	0.82	1.00	0.90	0.82	1.00	0.93	0.83	1.05	0.84	0.74	0.94
Region (Ref = Northeast)												
Northwest	1.32	1.07	1.64	1.32	1.07	1.64	1.22	0.93	1.61	1.36	1.02	1.83
Yorks Humber	0.95	0.75	1.20	0.95	0.75	1.20	0.95	0.71	1.28	0.91	0.67	1.25
East midlands	0.80	0.63	1.02	0.79	0.63	1.01	0.70	0.51	0.96	0.91	0.65	1.28
West midlands	0.77	0.61	0.98	0.77	0.61	0.98	0.79	0.59	1.07	0.71	0.51	0.99
East	0.54	0.43	0.68	0.54	0.43	0.68	0.53	0.39	0.71	0.52	0.38	0.71
London	0.95	0.77	1.18	0.94	0.76	1.17	0.89	0.67	1.17	1.01	0.75	1.36
South East	0.69	0.56	0.86	0.69	0.56	0.86	0.68	0.51	0.92	0.69	0.50	0.95
South West	0.41	0.32	0.53	0.41	0.32	0.52	0.41	0.29	0.57	0.41	0.28	0.59
Occupation (Ref = Health professionals)												
Corporate managers and directors	1.79	1.41	2.26	1.77	1.40	2.24	1.86	1.33	2.59	2.18	1.45	3.29
Other managers and proprietors	2.46	1.87	3.24	2.41	1.83	3.17	2.05	1.36	3.10	3.00	1.91	4.72
Science research engineering and technology professionals	1.51	1.15	1.98	1.49	1.13	1.96	1.11	0.68	1.80	2.01	1.31	3.10
Teaching and educational professionals	1.60	1.32	1.95	1.58	1.30	1.93	1.43	1.13	1.81	2.12	1.40	3.20
Business media and public service professionals	1.54	1.19	1.98	1.51	1.17	1.94	1.52	1.09	2.12	1.77	1.15	2.72

Science engineering and technology associate professionals	1.51	1.02	2.23	1.49	1.01	2.21	1.38	0.74	2.58	2.01	1.14	3.56
Health and social care associated professionals	1.48	1.04	2.10	1.46	1.03	2.08	1.30	0.86	1.96	2.16	1.15	4.04
Protective service occupations	1.82	1.33	2.49	1.80	1.32	2.47	2.59	1.62	4.14	1.86	1.16	2.98
Culture media and sports occupations	1.46	1.05	2.04	1.43	1.03	2.00	1.62	1.05	2.49	1.46	0.84	2.53
Business and public service associated professionals	1.73	1.37	2.19	1.72	1.36	2.17	1.62	1.18	2.21	2.18	1.45	3.29
Administrative occupations	1.97	1.59	2.45	1.95	1.58	2.42	1.90	1.47	2.45	2.41	1.57	3.71
Secretarial and related occupations	2.41	1.80	3.23	2.39	1.78	3.20	2.34	1.71	3.20	1.22	0.33	4.54
Skilled agricultural and related trades	0.89	0.46	1.73	0.87	0.45	1.69	1.15	0.33	3.95	1.11	0.49	2.52
Skilled metal electrical and electronic trades	2.25	1.68	3.02	2.20	1.64	2.96	2.92	0.78	10.84	2.80	1.86	4.23
Skilled construction and building trades	2.41	1.76	3.30	2.36	1.73	3.23	0.48	0.05	5.06	3.32	2.16	5.11
Textiles printing and other skilled trades	1.42	0.87	2.32	1.39	0.85	2.27	1.77	0.89	3.51	1.62	0.80	3.27
Caring personal service occupations	2.03	1.64	2.52	2.01	1.62	2.50	1.93	1.53	2.45	2.75	1.68	4.48
Leisure travel and related personal service occupations	1.84	1.17	2.89	1.82	1.16	2.86	1.43	0.80	2.58	4.31	2.00	9.25
Sales occupation	1.95	1.51	2.52	1.92	1.48	2.47	1.72	1.25	2.35	3.06	1.88	5.00
Customer service occupations	1.73	1.17	2.57	1.72	1.16	2.54	1.49	0.93	2.39	2.77	1.42	5.40
Process plant and machine operatives	2.10	1.44	3.04	2.05	1.42	2.98	2.94	1.24	6.98	2.51	1.54	4.10

Transport and mobile machine driver and operatives	2.36	1.76	3.17	2.32	1.73	3.11	1.62	0.64	4.06	3.19	2.07	4.91
Elementary trades and related occupations	2.75	1.53	4.94	2.69	1.49	4.85	2.92	0.54	15.73	3.53	1.78	7.00
Elementary administration and service occupations	2.16	1.71	2.73	2.14	1.69	2.71	1.90	1.39	2.60	3.03	1.97	4.67
Variance (Household)	3.34	3.05	3.63	3.34	3.05	3.63	2.38	1.64	3.12	2.00	0.94	3.06
Residual intraclass correlation (Household)	0.44	0.41	0.47	0.44	0.41	0.47	0.32	0.23	0.42	0.27	0.15	0.43
Variance (Individuals)	1.02	0.78	1.26	1.02	0.78	1.26	1.88	1.14	2.62	2.11	1.03	3.19
Residual intraclass correlation (Individuals)	0.57	0.55	0.59	0.57	0.55	0.59	0.56	0.54	0.59	0.56	0.53	0.58
N	409,009			409,009			217,920			191,089		
No. of household	72,866			72,866			50,405			44,822		
No. of participant	100,138			100,138			53,015			47,123		

Table S4. Multilevel logistic regression models of Covid-19 testing positive by period, ONS Covid Infection Study

Outcome: Test positive	10 May 2020 - 04 Nov 2020			05 Nov 2020 - 19 Dec 2020			20 Dec 2020 - 02 Feb 2020		
	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI	Odds Ratio	Lower 95% CI	Upper 95% CI
Female	0.83	0.69	0.99	0.92	0.80	1.06	0.77	0.66	0.90
BAME	1.27	0.89	1.81	1.36	1.04	1.79	0.97	0.72	1.30
Age group (Ref = 60-64)									
18-29	1.80	1.22	2.67	1.26	0.92	1.72	1.68	1.18	2.39
30-39	0.99	0.68	1.44	1.03	0.77	1.38	1.14	0.82	1.59
40-49	0.85	0.59	1.24	1.07	0.80	1.44	1.36	1.00	1.87
50-59	1.20	0.84	1.70	0.99	0.74	1.33	1.22	0.89	1.67
Visit date	1.04	1.04	1.04	1.00	1.00	1.00	1.01	1.01	1.01
Autonomy	0.58	0.36	0.92	0.98	0.94	1.02	0.96	0.92	1.00
Face covering or masks (Ref = not wearing face covering or mask)									
Yes my face is already covered	0.27	0.04	1.90	0.59	0.34	1.03	1.38	0.59	3.20
Yes at work/school/other situations only	0.30	0.05	1.71	0.50	0.31	0.82	0.64	0.33	1.22
Yes usually both work/school/other	0.20	0.04	1.13	0.44	0.27	0.73	0.58	0.31	1.11
Autonomy x Face covering/masks (Ref = No face covering/mask)									
Autonomy x Yes my face is already covered	1.73	1.04	2.89	-	-	-	-	-	-
Autonomy x Yes at work/school/other situations only	1.63	1.02	2.61	-	-	-	-	-	-
Autonomy x Yes usually both work/school/other	1.75	1.09	2.80	-	-	-	-	-	-
Contact with COIVD-19 positive people (Ref = no contact)									
0-14 days	14.01	11.30	17.38	15.03	12.35	18.28	27.66	21.02	36.39
15-28 days	3.56	2.50	5.07	5.16	4.00	6.65	7.10	5.40	9.34

29-60 days	1.79	1.01	3.15	2.32	1.76	3.05	1.93	1.41	2.65
61-90 days	1.73	0.44	6.83	1.15	0.65	2.03	1.20	0.81	1.77
91+ days	0.90	0.38	2.14	1.23	0.69	2.22	1.15	0.75	1.77
Household size	1.04	0.96	1.13	1.05	0.99	1.11	1.01	0.93	1.09
Smoke	0.82	0.66	1.02	0.95	0.81	1.11	0.93	0.78	1.11
Region (Ref = Northeast)									
Northwest	1.79	1.18	2.70	1.46	0.99	2.16	0.97	0.64	1.46
Yorks Humber	1.25	0.81	1.92	1.32	0.89	1.96	0.36	0.22	0.59
East midlands	0.73	0.45	1.20	1.15	0.75	1.77	0.52	0.32	0.85
West midlands	0.55	0.34	0.90	0.91	0.61	1.38	0.76	0.49	1.20
East	0.25	0.15	0.42	0.53	0.35	0.80	0.66	0.43	1.02
London	0.55	0.35	0.87	0.85	0.58	1.26	1.36	0.92	2.02
South East	0.35	0.22	0.56	0.70	0.47	1.06	0.89	0.59	1.34
South West	0.29	0.16	0.51	0.45	0.28	0.72	0.34	0.21	0.55
Variance (Household)	6.01	4.99	7.03	5.21	4.43	5.99	7.21	5.98	8.44
Residual intraclass correlation (Household)	0.49	0.43	0.54	0.50	0.45	0.54	0.58	0.54	0.62
Variance (Individuals)	3.04	2.16	3.92	2.03	1.34	2.72	1.94	1.16	2.72
Residual intraclass correlation (Individuals)	0.73	0.70	0.76	0.69	0.65	0.72	0.74	0.70	0.77
N	187453			142056			79500		
No. of household	54383			57203			47594		
No. of participant	73262			75682			60252		

Figure S1 Visualization of Table S2 using selected key variables.

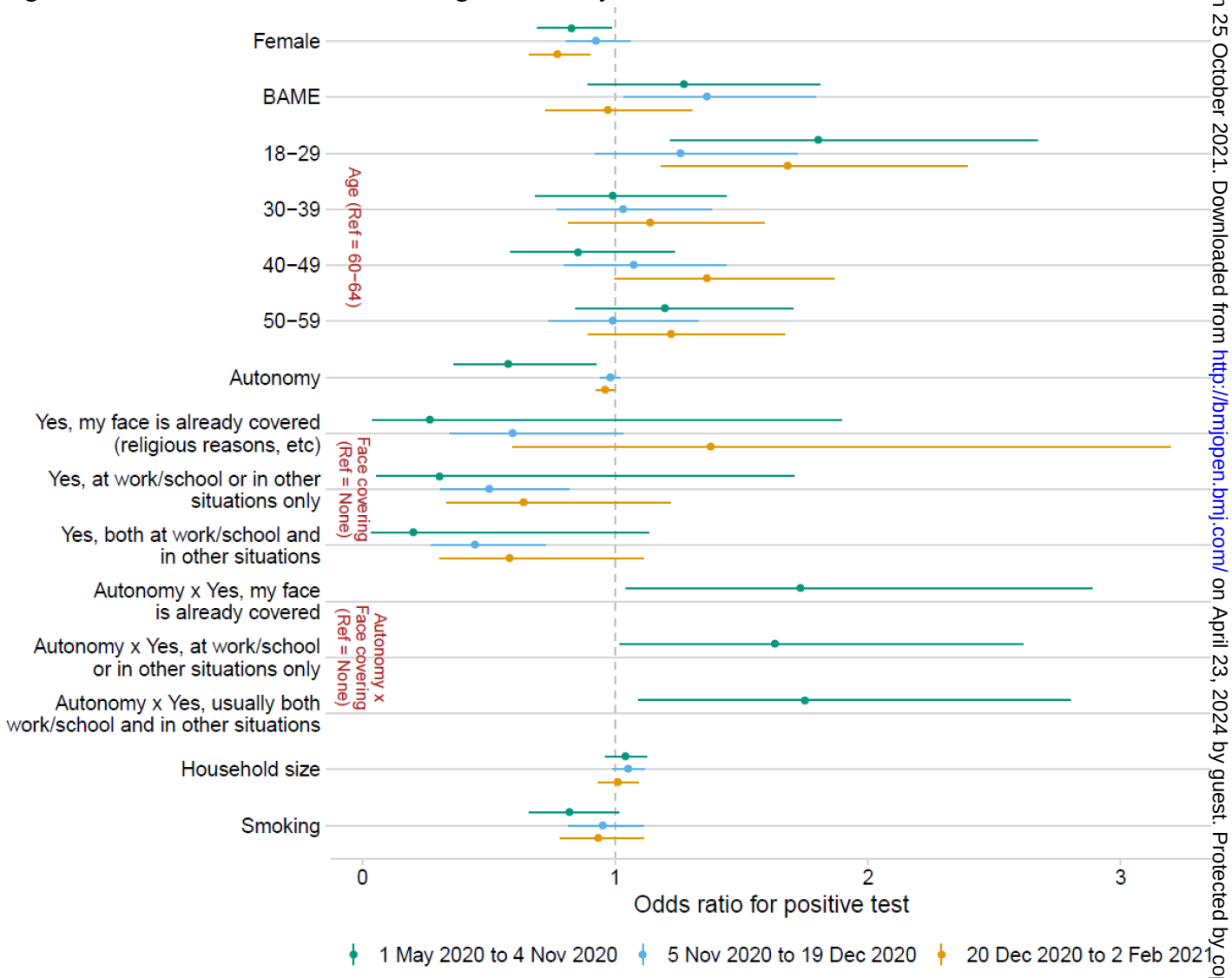
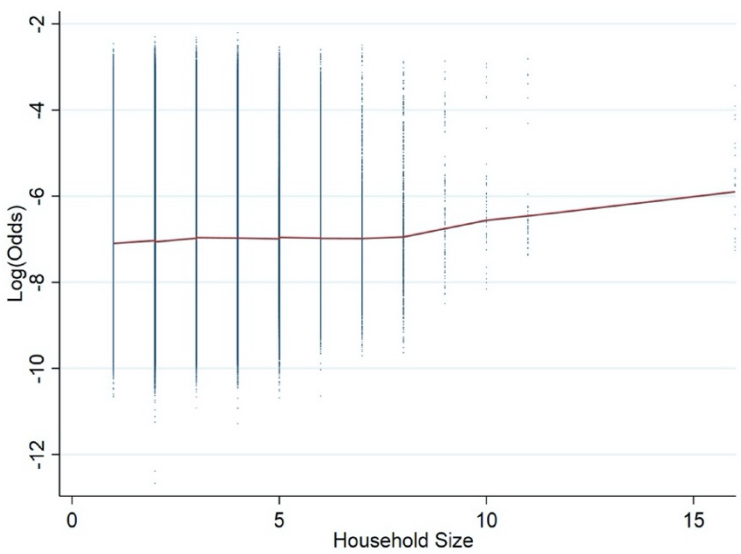
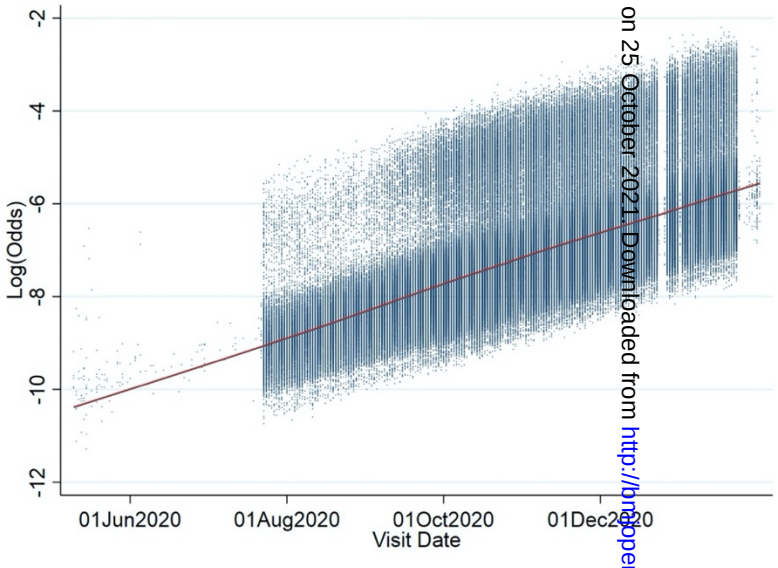


Figure S2 Relationship between continuous predictors and Log odds of the outcome with Locally Weighted Scatterplot Smoothing





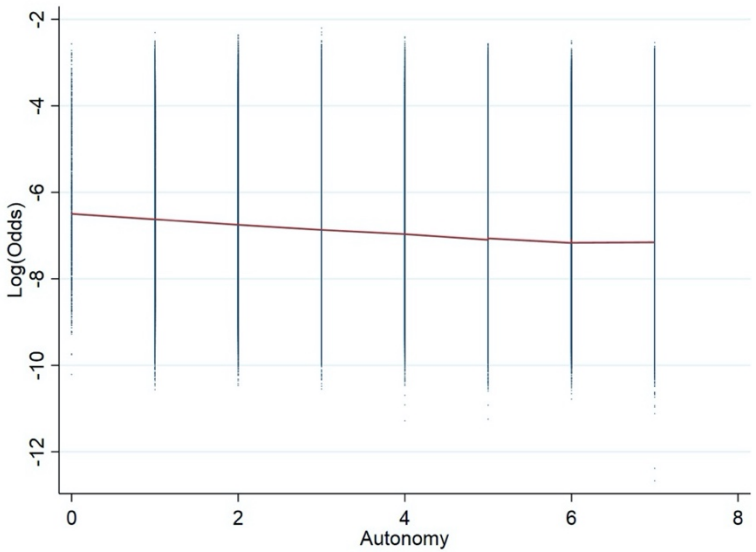


Table S5. Descriptive statistics N = 409, 009

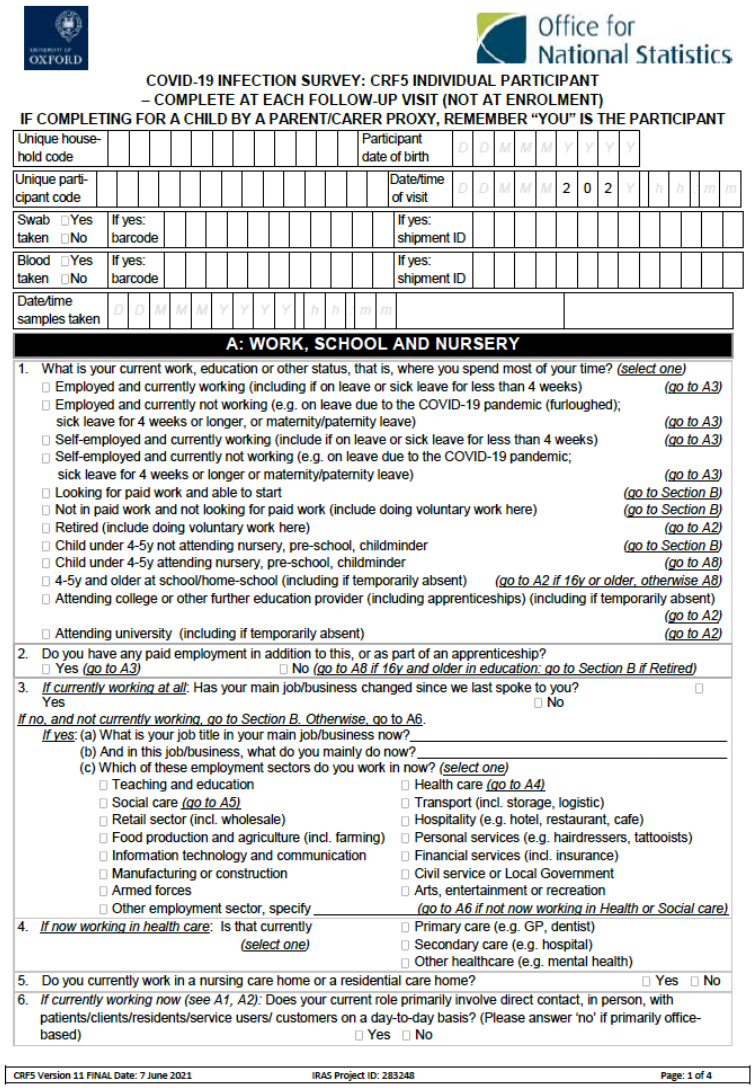
	All				Male		Female	
	mean	sd	min	max	mean	sd	mean	sd
COVID-19 positive	0.0118		0	1	0.0120		0.0117	
Female	0.5328		0	1	0.0000		1.0000	
BAME	0.0766		0	1	0.0763		0.0770	
Age at visit	44.6401	(11.5266)	20	64	44.5303	(11.5765)	44.7364	(11.4819)
Age group								
18-29	0.1269		0	1	0.1266		0.1271	
30-39	0.2146		0	1	0.2212		0.2088	
40-49	0.2650		0	1	0.2639		0.2659	
50-59	0.2949		0	1	0.2859		0.3029	
60+	0.0986		0	1	0.1024		0.0953	
Autonomy	4.2061	(1.8174)	0	7	4.5345	(1.6413)	3.9181	(1.9129)
Face mask								
No face mask	0.0149		0	1	0.0163		0.0137	
Yes my face is already covered	0.0290		0	1	0.0281		0.0297	
Yes at work/school/other situations only	0.4855		0	1	0.5054		0.4680	
Yes usually both work/school/other	0.4707		0	1	0.4502		0.4886	
Number of test	6.9757	(1.9761)	1	10+	6.9541	(1.9721)	6.9946	(1.9794)
Household size	2.6550	(1.1957)	1	10+	2.7384	(1.2039)	2.5819	(1.1836)
Work outside home days	3.0201	(2.0517)	0	7	3.1415	(2.1295)	2.9036	(1.9749)
Contact with COVID-19 positive								
No contact	0.7911		0	1	0.8102		0.7743	
0-14 days	0.0834		0	1	0.0730		0.0925	
15-28 days	0.0384		0	1	0.0350		0.0413	
29-60 days	0.0441		0	1	0.0402		0.0475	
61-90 days	0.0189		0	1	0.0179		0.0198	
91+ days	0.0242		0	1	0.0238		0.0246	

Work social distancing					
Easy to maintain 2m	0.4914	0	1	0.5602	0.4912
Relatively easy to maintain 2m	0.1621	0	1	0.1818	0.1848
Difficult to maintain 2m but can be 1m	0.1362	0	1	0.1272	0.1440
Very difficult to be more than 1m	0.2103	0	1	0.1309	0.2799
Work location					
Working from home	0.2417	0	1	0.2561	0.2291
Working somewhere else(not your home)	0.6186	0	1	0.5985	0.6362
Both(from home and somewhere else)	0.1397	0	1	0.1454	0.1348
Work travel method					
Underground/metro/light rail/tram	0.0252	0	1	0.0259	0.0246
Train	0.0383	0	1	0.0443	0.0331
Bus/minibus/coach	0.0266	0	1	0.0206	0.0318
Motorbike/scooter or moped	0.0040	0	1	0.0071	0.0014
Car or van	0.6985	0	1	0.6995	0.6977
Taxi/minicab	0.0038	0	1	0.0037	0.0040
Bicycle	0.0358	0	1	0.0470	0.0260
On foot	0.1355	0	1	0.1181	0.1508
Other method	0.0323	0	1	0.0339	0.0308
Smoking	0.3007	0	1	0.3257	0.2788
Work direct with patients	0.2184	0	1	0.1501	0.2883
Occupation					
Corporate managers and directors	0.0787	0	1	0.1101	0.0512
Other managers and proprietors	0.0371	0	1	0.0495	0.0263
Science research engineering and technology professionals	0.0516	0	1	0.0842	0.0331
Health professionals	0.0640	0	1	0.0275	0.0960
Teaching and educational professionals	0.1065	0	1	0.0665	0.1416

Business media and public service professionals	0.0678	0	1	0.0796	0.0776
Science engineering and technology associate professionals	0.0152	0	1	0.0203	0.0106
Health and social care associated professionals	0.0178	0	1	0.0097	0.0250
Protective service occupations	0.0210	0	1	0.0312	0.0121
Culture media and sports occupations	0.0252	0	1	0.0266	0.0239
Business and public service associated professionals	0.0812	0	1	0.0891	0.0743
Administrative occupations	0.1023	0	1	0.0603	0.1391
Secretarial and related occupations	0.0257	0	1	0.0031	0.0455
Skilled agricultural and related trades	0.0080	0	1	0.0128	0.0037
Skilled metal electrical and electronic trades	0.0303	0	1	0.0634	0.0113
Skilled construction and building trades	0.0259	0	1	0.0537	0.0115
Textiles printing and other skilled trades	0.0097	0	1	0.0123	0.0074
Caring personal service occupations	0.0722	0	1	0.0188	0.1190
Leisure travel and related personal service occupations	0.0094	0	1	0.0051	0.0132
Sales occupation	0.0397	0	1	0.0263	0.0515
Customer service occupations	0.0142	0	1	0.0096	0.0183
Process plant and machine operatives	0.0149	0	1	0.0279	0.0036
Transport and mobile machine driver and operatives	0.0261	0	1	0.0516	0.0038
Elementary trades and related occupations	0.0044	0	1	0.0084	0.0009
Elementary administration and service occupations	0.0511	0	1	0.0527	0.0497
Region					
Northeast	0.0503	0	1	0.0483	0.0521
Northwest	0.1435	0	1	0.1422	0.1446

Yorks Humber	0.1021	0	1	0.1019	0.1022
East midlands	0.0776	0	1	0.0776	0.0775
West midlands	0.0943	0	1	0.0960	0.0929
East	0.1241	0	1	0.1262	0.1223
London	0.1743	0	1	0.1759	0.1730
South East	0.1474	0	1	0.1480	0.1469
South West	0.0863	0	1	0.0840	0.0884
N	409,009			191,089	217,920

2. Sample of Questionnaire (All study protocol and questionnaires are available online https://www.ndm.ox.ac.uk/covid-19/covid-19-infection-survey)



COVID-19 INFECTION SURVEY: CRF5 INDIVIDUAL PARTICIPANT
– COMPLETE AT EACH FOLLOW-UP VISIT (NOT AT ENROLMENT)
IF COMPLETING FOR A CHILD BY A PARENT/CARER PROXY, REMEMBER "YOU" IS THE PARTICIPANT

Unique household code | Participant date of birth (D D M M Y Y Y Y)
Unique participant code | Date/time of visit (D D M M 2 0 2 Y h h m m)
Swab taken ☐Yes ☐No | If yes: barcode | If yes: shipment ID
Blood taken ☐Yes ☐No | If yes: barcode | If yes: shipment ID
Date/time samples taken (D D M M Y Y Y Y h h m m)

A: WORK, SCHOOL AND NURSERY

1. What is your current work, education or other status, that is, where you spend most of your time? *(select one)*
   - ☐ Employed and currently working (including if on leave or sick leave for less than 4 weeks) *(go to A3)*
   - ☐ Employed and currently not working (e.g. on leave due to the COVID-19 pandemic (furloughed); sick leave for 4 weeks or longer, or maternity/paternity leave) *(go to A3)*
   - ☐ Self-employed and currently working (include if on leave or sick leave for less than 4 weeks) *(go to A3)*
   - ☐ Self-employed and currently not working (e.g. on leave due to the COVID-19 pandemic; sick leave for 4 weeks or longer or maternity/paternity leave) *(go to A3)*
   - ☐ Looking for paid work and able to start *(go to Section B)*
   - ☐ Not in paid work and not looking for paid work (include doing voluntary work here) *(go to Section B)*
   - ☐ Retired (include doing voluntary work here) *(go to A2)*
   - ☐ Child under 4-5y not attending nursery, pre-school, childminder *(go to Section B)*
   - ☐ Child under 4-5y attending nursery, pre-school, childminder *(go to A8)*
   - ☐ 4-5y and older at school/home-school (including if temporarily absent) *(go to A2 if 16y or older, otherwise A8)*
   - ☐ Attending college or other further education provider (including apprenticeships) (including if temporarily absent) *(go to A2)*
   - ☐ Attending university (including if temporarily absent) *(go to A2)*
2. Do you have any paid employment in addition to this, or as part of an apprenticeship? ☐ Yes *(go to A3)* ☐ No *(go to A8 if 16y and older in education: go to Section B if Retired)*
3. *If currently working at all*: Has your main job/business changed since we last spoke to you? ☐ Yes ☐ No

If no, and not currently working, go to Section B. Otherwise, go to A6.

If yes: (a) What is your job title in your main job/business now?_____
(b) And in this job/business, what do you mainly do now?_____
(c) Which of these employment sectors do you work in now? *(select one)*

☐ Teaching and education	☐ Health care *(go to A4)*
☐ Social care *(go to A5)*	☐ Transport (incl. storage, logistic)
☐ Retail sector (incl. wholesale)	☐ Hospitality (e.g. hotel, restaurant, cafe)
☐ Food production and agriculture (incl. farming)	☐ Personal services (e.g. hairdressers, tattooists)
☐ Information technology and communication	☐ Financial services (incl. insurance)
☐ Manufacturing or construction	☐ Civil service or Local Government
☐ Armed forces	☐ Arts, entertainment or recreation
☐ Other employment sector, specify _____	*(go to A6 if not now working in Health or Social care)*

4. *If now working in health care*: Is that currently *(select one)* ☐ Primary care (e.g. GP, dentist) ☐ Secondary care (e.g. hospital) ☐ Other healthcare (e.g. mental health)
5. Do you currently work in a nursing care home or a residential care home? ☐ Yes ☐ No
6. *If currently working now (see A1, A2)*: Does your current role primarily involve direct contact, in person, with patients/clients/residents/service users/ customers on a day-to-day basis? (Please answer 'no' if primarily office-based) ☐ Yes ☐ No

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7. *If currently working now (see A1, A2)*: Currently, do you work? *(select one)*
   - ☐ From home (in the same grounds or building as your home) *(go to Section B)*
   - ☐ Somewhere else (not at your home) *(go to A8)*
   - ☐ Both (work from home and work somewhere else) *(go to A8)*
8. *If currently working not at your home, or in education or attending school or nursery, etc*: On average, on how many days of the week are you currently working somewhere else (not at your home, defined as the same grounds or building as your home), or currently attending, in person, your place of education, school, nursery, pre-school or childminder? *(select one)* ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7
9. *If currently working not at your home, or in education or attending school or nursery, etc*: How do you mainly get to and from work/nursery/education provider? (*select one only*: if use multiple modes, choose the longest part of your journey in time)
   - ☐ Underground, metro, light rail, tram ☐ Train ☐ Bus, minibus, coach ☐ Motorbike, scooter or moped
   - ☐ Car or van ☐ Taxi/minicab ☐ Bicycle ☐ On foot ☐ Other method
10. *If currently working or in education or attending school or nursery, etc*: On average how easy is it to maintain 1-2m between yourself and other people at your place of work/education/school/nursery, etc? *(select one)*
    - ☐ Easy to maintain 2m, it is not a problem to stay this far away from other people
    - ☐ Relatively easy to maintain 2m, most of the time you can be 2m away from other people
    - ☐ Difficult to maintain 2m, but you can usually be at least 1m from other people
    - ☐ Very difficult to be more than 1m away, as your work means you are in close contact with others on a regular basis

B: YOUR HEALTH STATUS TODAY

1. Have you had any of these symptoms **in the last 7 days**?

Fever	☐ Yes	☐ No	Headache	☐ Yes	☐ No	Muscle ache	☐ Yes	☐ No
Weakness/tiredness	☐ Yes	☐ No	Nausea/vomiting	☐ Yes	☐ No	Abdominal pain	☐ Yes	☐ No
Diarrhoea	☐ Yes	☐ No	Sore throat	☐ Yes	☐ No	Cough	☐ Yes	☐ No
Shortness of breath	☐ Yes	☐ No	Loss of taste	☐ Yes	☐ No	Loss of smell	☐ Yes	☐ No

(a) Please confirm: have you had any of these symptoms **in the last 7 days**? ☐ Yes ☐ No
(b) If yes: date first symptom onset: (D D M M 2 0 2 Y)

2. Are you currently self-isolating due to COVID-19 (meaning you are not leaving your home)? *(select one)*
   - ☐ No
   - ☐ Yes because you have/have had symptoms of COVID-19 or a positive test
   - ☐ Yes because you live with someone who has/has had symptoms or a positive test, but you haven't had symptoms yourself
   - ☐ Yes, for other reasons related to you having had an increased risk of getting COVID-19 (e.g. having been in contact with a known case, quarantining after travel abroad)
   - ☐ Yes, for other reasons related to reducing your risk of getting COVID-19 (e.g. going into hospital, shielding)
3. Do you currently think you have symptoms consistent with COVID-19 infection? ☐ Yes ☐ No
4. Do you have any physical or mental health conditions or illnesses lasting or expected to last 12 months or more (excluding any long-lasting COVID-19 symptoms)? ☐ Yes ☐ No
   If yes: (a) Do any of your conditions or illnesses reduce your ability to carry-out day-to-day activities? *(select one)* ☐ Yes, a lot ☐ Yes, a little ☐ Not at all
5. Have you ever smoked cigarettes regularly? ☐ Yes ☐ No
6. Do you currently smoke or vape at all? ☐ Yes ☐ No
   If yes: (a) please tick all that apply: ☐ Cigarettes ☐ Cigar ☐ Pipe ☐ Vape/e- cigarettes ☐ Hookah/shisha pipes

C: CONTACT WITH OTHER PEOPLE

1. In the last 28 days, have you been in direct contact, in person, with someone that you definitely know, because they had a positive test result, was infected with COVID-19 **at the time** you were in contact with them? ☐ Yes ☐ No
   If yes: (a) Date of last contact of this type: (D D M M 2 0 2 Y)
   (b) Was this last person you had this type of contact with ☐ living in your own home ☐ outside your home
2. In the last 28 days, have you been in direct contact, in person, with someone that you think was infected with COVID-19 **at the time** you were in contact with them – this could include: someone who has not been tested; someone who has been tested but you do not know the result; or someone who has tested negative? ☐ Yes ☐ No
   If yes: (a) Date of last contact of this type: (D D M M 2 0 2 Y)
   (b) Was this last person you had this type of contact with ☐ living in your own home ☐ outside your home
3. In the last 28 days, have you been inside a hospital for any reason (e.g. for work, for a consultation or treatment, to visit someone, to take someone else)? ☐ Yes ☐ No

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If no: (a) In the last 28 days, has anyone that you usually live with been inside a hospital at all for any reason (e.g. for work, for consultation or treatment, to visit someone, to take someone else)? ☐Yes ☐No

4. In the last 28 days, have you been inside a care/residential home for any reason (e.g. for work, to visit someone, to take someone else)? ☐Yes ☐No
   If no: (a) In the last 28 days, has anyone that you usually live with been inside a care/residential home at all (e.g. for work, to visit someone, to take someone else)? ☐Yes ☐No
5. In the last 7 days, how many hours a day on average have you spent within 2m of someone else in your home, including sleeping? [ ][ ]
6. Over the last 7 days, how many children and young adults <18y not living in your home have you had physical contact with (e.g. handshake, personal care), including with PPE if you wear it? *(select one)* ☐0 ☐1-5 ☐6-10 ☐11-20 ☐21 or more
7. Over the last 7 days, how many adults 18-69y not living in your home have you had physical contact with (e.g. handshake, personal care), including with PPE if you wear it? *(select one)* ☐0 ☐1-5 ☐6-10 ☐11-20 ☐21 or more
8. Over the last 7 days, how many older adults 70y and over not living in your home have you had physical contact with (e.g. handshake, personal care), including with PPE if you wear it? *(select one)* ☐0 ☐1-5 ☐6-10 ☐11-20 ☐21 or more
9. Over the last 7 days, how many children and young adults <18y not living in your home have you had direct, but not physical, contact with in person, e.g. with social distancing only? *(select one)* ☐0 ☐1-5 ☐6-10 ☐11-20 ☐21 or more
10. Over the last 7 days, how many adults 18-69y not living in your home have you had direct, but not physical, contact with in person, e.g. with social distancing only? (*select one*) ☐0 ☐1-5 ☐6-10 ☐11-20 ☐21 or more
11. Over the last 7 days, how many older adults 70y and over not living in your home have you had direct, but not physical, contact with in person, e.g. with social distancing only? *(select one)* ☐0 ☐1-5 ☐6-10 ☐11-20 ☐21 or more
12. In the last 7 days, how many times have you spent one hour or longer inside the buildings of another person's home? *(select one)* ☐None ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 times or more
13. In the last 7 days, how many times has someone who doesn't live with you spent one hour or longer inside the buildings of your home? *(select one)* ☐None ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 times or more
14. In the last 7 days, how many times have you been outside of your home for shopping? *(select one)* ☐None ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 times or more
15. In the last 7 days, how many times have you been outside of your home to socialise, including visiting restaurants, etc? *(select one)* ☐None ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 times or more
16. Do you wear any kind of face covering or mask when you are at work/your place of education, because of COVID-19? *(select one)* ☐Not going to place of work or education ☐Yes, always ☐Yes, sometimes ☐Never ☐My face is already covered for other reasons (e.g. religious or cultural reasons)
17. Do you wear any kind of face covering or mask when you are in other enclosed public spaces, such as shops, or using public transport, because of COVID-19? *(select one)* ☐Not going to other enclosed public spaces or using public transport ☐Yes, always ☐Yes, sometimes ☐Never ☐My face is already covered for other reasons (e.g. religious or cultural reasons)

D: COVID-19 INFECTION AND YOU

1. Do you know or think you have had coronavirus (COVID-19) since we last spoke to you? (*if not sure, select No*) ☐Yes ☐No

   If yes: (a) On what date did you first know or think you had COVID-19: D D M M M 2 0 2 Y

   (b) Did you have any symptoms when you knew or thought you had COVID-19? ☐Yes ☐No

   (c) *If yes:* Did you have any of the following symptoms? (answer Yes or No for each one)

Fever	☐Yes	☐No	Headache	☐Yes	☐No	Muscle ache	☐Yes	☐No
Weakness/tiredness	☐Yes	☐No	Nausea/vomiting	☐Yes	☐No	Abdominal pain	☐Yes	☐No
Diarrhoea	☐Yes	☐No	Sore throat	☐Yes	☐No	Cough	☐Yes	☐No
Shortness of breath	☐Yes	☐No	Loss of taste	☐Yes	☐No	Loss of smell	☐Yes	☐No

   (d) Did you contact the NHS when you thought you had COVID-19 (e.g. 111, GP, Walk-in Centre, A&E)? ☐Yes ☐No

   (e) Were you admitted to hospital when you thought you had COVID-19? ☐Yes ☐No

2. Have you had a swab test of your nose and throat to test for COVID-19 since we last spoke to you (not including any tests done as part of this study)? ☐Yes ☐No

If yes: (a) What was the result/were the results of all tests you've had since we last spoke to you? *(select one)*
☐One or more positive test(s) ☐One or more negative tests, but none were positive
☐All tests failed ☐Waiting for all results

(b) *If any test positive*: What was the date of first positive test you've had since we last spoke to you? D D M M M 2 0 2 Y

(c) *If all tests negative*: What was the date of last negative test you've had since we last spoke to you? D D M M M 2 0 2 Y

3. *If yes to Q2: had a swab test of your nose and throat to test for COVID-19 infection*. Are you regularly testing yourself for COVID-19 using a lateral flow test: that's the test you can do yourself and you do not have to send it to a laboratory because the result shows in the device in about 30 minutes? ☐Yes ☐No

4. Have you had a blood test to test for COVID-19 antibodies since we last spoke to you (not including any tests done as part of this study)? ☐Yes ☐No

   If yes: (a) What was the result/were the results of all tests you've had since we last spoke to you? *(select one)*
   ☐One or more positive test(s) ☐One or more negative tests, but none were positive
   ☐All tests failed ☐Waiting for all results

   (b) Where was the test done? *(if more than one test, provide for the most recent positive test, otherwise the most recent negative test, otherwise the most recent test)* *(select one)*
   ☐In the NHS (e.g. GP, hospital) ☐Private lab ☐Home test

   (c) *If any test positive*: What was the date of first positive test you've had since we last spoke to you? D D M M M 2 0 2 Y

   (d) *If all tests negative*: What was the date of last negative test you've had since we last spoke to you? D D M M M 2 0 2 Y

5. *If week 4 or later*: Would you describe yourself as having "long COVID", that is, you are still experiencing symptoms more than 4 weeks after you first had COVID-19, that are not explained by something else? ☐Yes ☐No

   If yes: (a) Does this reduce your ability to carry-out day-to-day activities compared with the time before you had COVID-19? *(select one)* ☐Yes, a lot ☐Yes, a little ☐Not at all

   (b) Do you have any of the following symptoms as part of your experience of long COVID? Please include any pre-existing symptoms which long COVID has made worse (answer Yes or No for each one)

Fever	☐Yes	☐No	Headache	☐Yes	☐No	Muscle ache	☐Yes	☐No
Weakness/tiredness	☐Yes	☐No	Nausea/vomiting	☐Yes	☐No	Abdominal pain	☐Yes	☐No
Diarrhoea	☐Yes	☐No	Loss of appetite	☐Yes	☐No	Loss of taste	☐Yes	☐No
Loss of smell	☐Yes	☐No	Sore throat	☐Yes	☐No	Cough	☐Yes	☐No
Shortness of breath	☐Yes	☐No	Chest pain	☐Yes	☐No	Palpitations	☐Yes	☐No
Vertigo/dizziness	☐Yes	☐No	Worry/anxiety	☐Yes	☐No	Low mood/not enjoying anything	☐Yes	☐No
Trouble sleeping	☐Yes	☐No	Memory loss or confusion	☐Yes	☐No	Difficulty concentrating	☐Yes	☐No

6. Have you been vaccinated against COVID-19 since we last spoke to you? (*select Yes if you have received a second or later dose since we last spoke to you*) ☐Yes ☐No

   If no to Q6: (a) Have you been offered a vaccination against COVID-19 since we last spoke to you? ☐Yes ☐No (go to Q7)

   If yes to Q6: (b) Type of vaccination *(select one)* ☐Don't know type ☐Pfizer/BioNTech ☐Moderna ☐Oxford/AstraZeneca ☐Janssen\Johnson&Johnson ☐Novavax ☐Sinovac ☐Sputnik ☐Valneva ☐Sinopharm ☐From a research study/trial ☐Other, specify_____

   (c) Number of doses received to date ☐1 ☐2 ☐3 or more

   (d) Date of most recent vaccination D D M M M 2 0 2 Y

7. Have you been outside of the UK since we last spoke to you? ☐Yes ☐No

   If yes: (a) Last country visited _____ (b) Date last returned to the UK D D M M M 2 0 2 Y

E: ADDITIONAL CONSENT – Do not take additional consent if database is unavailable

COMPLETED BY: Name (study worker)	Signature (study worker)	Date
		D D M M M 2 0 2 Y

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cohortreporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	#3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	#4	Present key elements of study design early in the paper	3-5

Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-5
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	3-5
Eligibility criteria	#6b	For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	3-5
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	3-5
Bias	#9	Describe any efforts to address potential sources of bias	3-5
Study size	#10	Explain how the study size was arrived at	3-5
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	3-5
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	3-5
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	3-5
Statistical methods	#12c	Explain how missing data were addressed	3-5
Statistical methods	#12d	If applicable, explain how loss to follow-up was addressed	n/a
Statistical methods	#12e	Describe any sensitivity analyses	3-5

Results

Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	5-6
Participants	#13b	Give reasons for non-participation at each stage	n/a
Participants	#13c	Consider use of a flow diagram	
n/a			
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	5-6
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	
n/a			
Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)	
n/a			
Outcome data	#15	Report numbers of outcome events or summary measures over time. Give information separately for exposed and unexposed groups if applicable.	
n/a			
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5-6
Main results	#16b	Report category boundaries when continuous variables were categorized	5-6
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
n/a			

Other analyses	#17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5-6
Discussion			
Key results	#18	Summarise key results with reference to study objectives	6-7
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	6-7
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	6-7
Generalisability	#21	Discuss the generalisability (external validity) of the study results	6-7
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

This checklist was completed on 04. June 2021 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai