The impact of local and national restrictions in response to COVID-19 on social contacts in the UK: a longitudinal natural experiment

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Abstract

Background:

The United Kingdom's (UK) COVID-19 response transitioned from a national lockdown to more localised interventions with less restrictive national measures. In September 2020, the UK imposed three national restrictions; the Rule of Six, pubs and restaurants closing at 10pm, and encouraging individuals to work from home (WFH).

The impact of these local and national restrictions on transmission is unclear and difficult to estimate. In this paper, we used paired measurements of individuals' contacts from the national CoMix survey to test whether restrictions altered epidemiologically relevant contacts and estimate these effects.

Methods:

We compared paired measures on setting-specific contacts before and after each restriction started and tested for differences using paired permutation tests on the mean change in contacts and the proportion of individuals decreasing their contacts.

Results:

Among 3,222 individuals, we found strong evidence ($p<0.001$) that following the rule of six more people reduced their non-work and non-home contacts than expected by chance, though the data were consistent ($p=0.827$) with an absolute effect of zero. For 1,868 participants, the data were consistent with no change ($p=0.18$) in other contacts due to 10pm closure. For 639 employed adults, the data suggested ($p=0.001$) more people reduced their work contacts than expected by chance but results were consistent ($p=0.213$) with an absolute effect of zero. Among 293 individuals, there was evidence ($p=0.01$) that following local restrictions more

participants had reduced their contacts. On average, participants reported 0.74 (0.16 to 1.55) fewer non-work and non-school contacts than before the restrictions (p=0.005).

Conclusions:

We determine that the rule of six and encouraging people to WFH, has seen the average person reduce contacts but these reductions are likely small. There was little suggestion that 10pm closure has affected the number of contacts that participants make outside home, work and school. In contrast to national restrictions, there was a strong suggestion that local restrictions reduced the number of contacts individuals make outside of work and school, though again, this effect was small in comparison to the national lockdown.

Key words

Covid-19, Contact survey, Lockdowns, Pandemic, Disease Outbreak, non-pharmaceutical interventions, United Kingdom.

Background

On the 23rd of March 2020, the United Kingdom (UK) went into a national lockdown in response to Covid-19 [1]. This required people to only leave their house for essential shopping or medical needs, or to undertake one form of exercise per day. Educational establishments and non-essential retail were closed, as were the leisure and hospitality sectors [1]. Many European countries also implemented national lockdowns and the combinations of large-scale restrictions resulted in marked decreases in contacts, mobility and transmission, eventually leading to a reduction in daily cases and deaths [2–4].

As the incidence of cases declined, national restrictions were relaxed [5]. The UK transitioned to a localised response and only applied more stringent restrictions to specific areas with rising cases. The first of these local measures was announced on the 29th of June in Leicester [6], then subsequently in other areas, mostly in the North of England [7]. Local restrictions vary in magnitude but may include early business closures, take-away services only for bars and restaurants, bans on meeting with other households, and travel restrictions.

Alongside local restrictions, in response to rising cases, several national measures were also introduced. On the 14th of September, the *Rule of Six* was announced preventing individuals from meeting in groups with more than six people [8]. On the 24th of September, it was announced that pubs and restaurants would be required to close at 10pm and individuals were encouraged to work from home (WFH) [9].

The impact of these measures remains unclear, with cases continuing to rise in most localities after measures were implemented, though picking up (perhaps modest) changes in cases, hospitalisations or deaths some time after restrictions are introduced would be expected to be difficult. In this paper, we avoid these problems by using repeated measures of individuals'

epidemiologically relevant setting-specific contacts before and after restrictions were imposed to estimate whether these measures had any effect and if so their magnitude.

Methods

Ethics Statement

Participation in this opt-in study was voluntary, and all analyses were carried out on anonymised data. The study was approved by the ethics committee of the London School of Hygiene & Tropical Medicine Reference number 21795.

Data

We combined data from the UK CoMix survey and information on local and national restrictions from Gov.uk. Details of the CoMix study including the protocol and survey instrument have been published previously [2]. In short, CoMix is an online survey where individuals record details of direct (i.e. potentially risky) contacts in the 24 hours prior to the survey. A direct contact was defined as anyone who was met in person and with whom at least one word was exchanged, or anyone with whom the participants had any sort of skin-to-skin contact. Contacts of individuals under the age of 18 were collected by asking parents to answer on behalf of their child. Information is collected weekly from alternating, broadly representative, panels (each about 2,500 in size), with each person surveyed once every two weeks.

We extracted the start and end dates of restrictions and their locations from Gov.uk between 31 August and 29 September 2020. CoMix participants were considered affected by local restrictions if they reported living within a Lower Tier Local Authority (UK administrative zone) that was under restrictions. We restricted the data to two weeks before and after each restriction came into place. We then extracted the closest survey response before and after each

restriction date. Participants with missing survey responses either side of the start of a restriction were removed, giving two records per person.

Study design

Our study is a longitudinal natural experiment. For each participant, we have one observation prior to and one observation after the restriction. These observations are at most two weeks from the date of the start of the restriction. This allows individuals within our study to be their own control and thus reduces the effect of between-person variation as well as the effect of longer-term temporal trends. The types of contact reported were categorized as home-based, work contact, school contact, and in other settings. We compared the number of contacts before implementation of restrictions to the number of contacts after to assess the impact of i. local restrictions and ii.three national restrictions (1) Rule of six (2) 10pm closure (3) Work from home. To pick up the effect of the different restrictions we concentrated on changes in setting-specific contacts, e.g. local restrictions are largely targeted at leisure contacts. In addition, the Rule of Six does not apply for business or schools. Hence, for these two restrictions we analysed changes in contacts excluding work and school. The 10pm closure rule requires restaurants, pubs, and bars to close early. This restriction should not have a direct effect on contacts made at home, work, or school. Thus, we used the remaining contacts as the outcome for this restriction referred to as *Other* contacts. To analyse the effect of the work from home restriction we focused on the work contacts of respondents who were employed.

Statistical analysis

R version 4.0.0 was used for all analyses and the code and data are available on github (see Availability of data and materials) [10–12]. Descriptive and graphical summaries of participant characteristics for age, gender, employment and socio-economic status were created for each restriction. We compared contacts before and during restrictions by calculating the mean,

median, and interquartile range. The change in contacts were categorised into increased, same, and decreased. The mean of the paired differences was calculated and uncertainty assessed by constructing a 95% confidence interval (95% CI) from 10,000 bootstrap samples [13] of the paired differences.

For each restriction, we conducted paired permutation tests [14] with 50,000 permutations per test. We chose permutation tests as they are robust to distributional assumptions of the underlying data [14]. In order to preserve the study structure, we calculated the paired difference by subtracting the observation during the restriction from the observation before the restriction and then randomly changed the sign of each pair. In practice this means generating a vector of values taking -1 and 1 of the same length as the number of participants and then multiplying the change in contacts by this vector.

For each permutation, a test statistic is calculated. In our study we chose to calculate two test statistics for each restriction; (1) the proportion of individuals whose contacts decreased after restrictions, (2) the mean of the change in contacts before and after restrictions. The proportion of decreases is robust to large values and skewed distributions treating a difference of -1 and -1000 in the same way. This measure tests the relative effect of the restriction but does not estimate the effect size. The mean difference estimates the absolute effect but is affected by skewed data.

In the case of the local restrictions, one individual reported 101 contacts excluding work and school before and 1 contact after and another reported 81 contacts before and 57 contacts after restrictions giving differences of -100 and -24 contacts, respectively. We performed a sensitivity analysis with these observations removed in order to assess the impact that these extreme values had on the conclusions of the analysis.

Results

Participant characteristics

There were 3,222 participants included in the analysis for the rule of six; 1,868 for 10pm closure; 639 for WFH; and 293 participants affected by local restrictions (Table 1). The age distributions of the samples for Rule of six, 10pm closure, and local restrictions were very similar with the age group 60-69 making up nearly 20% of the samples in all three analyses. The WFH category by definition only included participants 18 years of age or older and nearly 70% of participants were between 30 and 59. The gender split was close to 50% for all restrictions. Excluding the WFH analysis, over 60% of participants were unemployed for each restriction. Socio-economic status was consistent across the four populations with lowest numbers in the A - Upper middle class, and E - Lower level of subsistence categories and the modal group being C1 - Lower middle class for all restrictions (Table 1).

Setting-specific contacts

The setting-specific contacts were positively skewed for all restrictions (Figure 1A). The rules of six and and local restrictions had similar distributions with the modal response being one contact before and after the restrictions. The 10pm and WFH distributions were also similar despite the contacts being ‘other’ and work contacts, respectively. The magnitudes of the change in contacts were small, with magnitude being less than 10 for nearly all observations (Figure 1B). The majority of individuals had no change in the number of contacts they reported. This proportion of participants reporting the same number of contacts was highest in the WFH category with 68% versus the lowest of 42% for the rule of six restriction (Figure 1C, Table 2). In order to see the patterns in the data the axes were restricted and the zero values were

removed for Figure 1B. Figure S1A and S1B reproduces the same graph without removal of zero values or restriction of axes for comparison.

National restrictions

Rule of Six

We compared non-work and non-school contacts for 3,222 individuals before and after the rule of six came into effect. There was very strong evidence ($p<0.0001$) to suggest that more people reduced their contacts (excluding work and school) following the rule of six restriction than expected due to chance, with 1,023 (31.8%) recording fewer contacts compared to 837 (26.0%) recording a greater number of contacts. However, the majority of participants 1,362 (42.3%) recorded the same number of contacts and the median number of contacts was 2 (IQR 1 to 3) before and after the rule of six. There was no evidence ($p=0.827$) of a change in the mean number of non-work and non-school contacts recorded with the difference equal to -0.08 (-0.48 to 0.40) contacts per day (Table 2).

10pm closure

We compared ‘other’ contacts (excluding home, work, or school) among 1,868 participants before and after the 10pm closure. There was little evidence to suggest ($p=0.18$) that respondents changed contacts after the 10pm rule, with near identical numbers of people decreasing and increasing (479 versus 450) ‘other’ contacts. The data were also consistent with no absolute effect ($p=0.325$) with the change in mean ‘other’ contacts estimated as 0.15 (-0.15 to 0.44) (Table 2).

Work from Home

Over two thirds of participants 435 (68.1%) had the same number of work contacts before and after being encouraged to WFH. Despite this, the data strongly suggest (p=0.001) that a greater number reduced their work contacts after the restriction came into place than would be expected due to chance. Differences in work contacts were highly skewed with eight participants reporting a difference of more than 50 contacts, yet the 25th, 50th, and 75th quantile of the difference being zero (Figure 1, Table 2). The data were compatible (p=0.213) with a mean difference in work contacts of zero, though this was due to large uncertainty around the point estimate (-0.88 contacts per day, 95% CI -2.37 to 0.44) (Table 2).

Local restrictions

There was evidence (p = 0.01) that following local restrictions more participants reduced their non-work and non-school contacts than would be expected due to chance. Of the 293 participants 94 (32.1%) individuals reported fewer contacts, 64 (21.8%) reported greater contacts, and 135 (46.4%) reported the same number of contacts. On average, participants reported 0.74 (0.16 to 1.55) fewer non-work and non-school contacts than before the restrictions (p=0.005), corresponding to a reduction of 23.5% (5.1% to 49%). We conducted a sensitivity analysis and removed two large outliers (-100, -24) and repeated these analyses, which resulted in a weaker mean reduction of -0.32 (-0.59 to -0.08) but did not affect the conclusions (Table 2).

There is some suggestion that the local restrictions were less effective in young adults (18-29 year of age) as there were as many individuals who increased contacts following these measures as reduced them (Table 3), though the numbers are very small.

Discussion

Along with many other countries, the UK transitioned from a national lockdown approach to more localised interventions with less restrictive national measures. We determine that the impact of two of the national measures, the rule of six and encouraging people to work from home, has seen the average person reduce their contacts but the magnitudes of these reductions are likely small. There was no suggestion that 10pm closure of bars and restaurants has had an effect on reducing the mean number of contacts that participants make outside home, work, and school. In contrast to national restrictions, there was a strong suggestion that local restrictions reduced the number of contacts individuals make outside of work and school. Local restrictions were estimated to reduce non-work and non-school contacts by -0.74 per day (95% CI -1.55 to -0.16). This reduction, whilst statistically significant, needs to be put in context however. The full national lockdown in March reduced the average daily contacts from about 10.8 to 2.8 [2]. This 74% reduction, in turn, reduced the effective reproduction number (R_0) of COVID-19 from about 2.6 before lockdown to about 0.6 after lockdown [2]. Thus, the reduction in mean non-work and non-school contacts made under local restrictions (0.74 per day) would likely have a marginal impact on R_0.

Determining the epidemiological effect of restrictions has proved challenging. This is because of delays between the imposition of measures and their effect on reported cases, hospitalisations and deaths. Furthermore, reported numbers of cases might be biased upwards in areas of local restrictions if additional effort are put in place to find and test cases in these regions. Estimating the counterfactual - how many cases might have occurred without the restrictions - is also very difficult to do. For these reasons, evidence on the effect of local and national restrictions is weak. This study takes a different approach. Contacts might be expected to change immediately after restrictions are in place and would be less affected by changes in case finding.

Furthermore, the longitudinal, panel nature of the data, means that individuals act as their own temporal control group, making it easier to pick up relatively small changes in contact patterns.

This work has several limitations. We were unable to distinguish between the types of measures used in local restrictions and therefore the effect that we see is a combination of a range of interventions. Individuals may also not accurately report their contacts, due to recall or social desirability bias. A further limitation is that the restrictions were not randomly allocated and thus the effects we see may be due to other confounding factors. However, we did use a repeated measure on the same individuals, which will reduce between-person variability, though confounding factors could remain constant on individuals and affect the generalisability of results. The contact data is bounded at zero and skewed, therefore using the mean can be a less relevant summary measure; this is why we also performed a permutation test that focused on the sign of the difference rather than the magnitude. Furthermore, we did not distinguish between the length of time spent with different contacts.

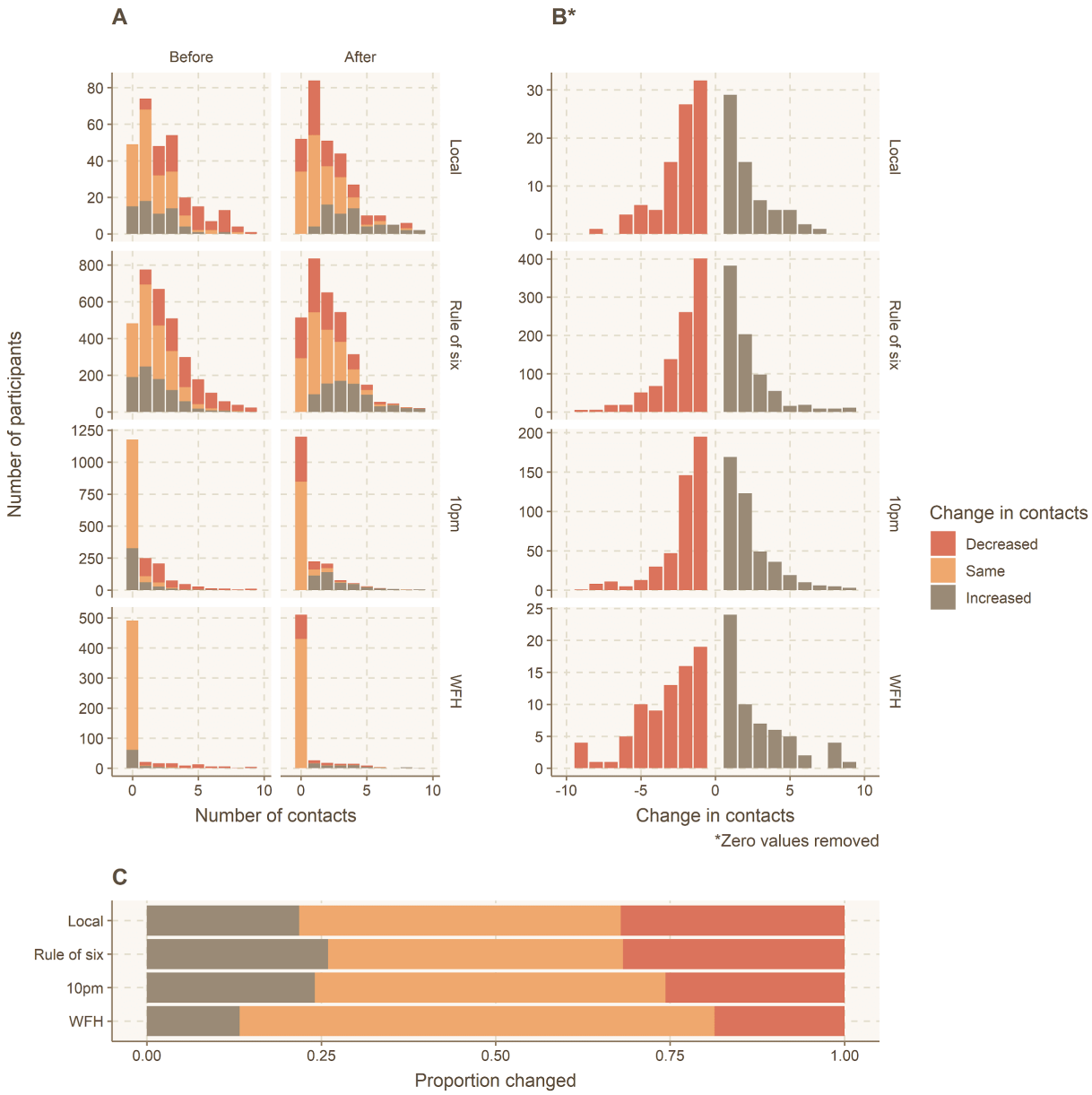
Despite these limitations, we have attempted to provide insight into the highly relevant issue of whether different restrictions in response to COVID-19 work and if so how effective they are. We have focused on one metric of epidemiological relevant setting-specific contacts, though the impact of the different restrictions will have broader implications that need to be considered for policy change.

Future work could assess whether restrictions reduce the amount of time spent with individuals as may well be the case for the 10pm rule. Further exploration of the effect of restrictions on different age groups, and the potential of regional adherence to the national restrictions could help disentangle whether lack of effects was due to sampling biases rather than lack of effectiveness of restrictions.

Conclusions

We have demonstrated that behavioural monitoring can allow the rapid evaluation of the impact of national and local restrictions on COVID-19 transmission. Although many of these restrictions appear to have led to behavioural change, the magnitude of these changes appears to be small.

Figure 1: A: The distribution of the number of setting-specific contacts before and after each restriction came into place. B: Change in contacts for each restriction. C: The proportion of changes comparing before and after the restrictions started.



Graph A shows the distribution of setting-specific contacts before and after each restriction came into place. It is coloured by whether the change in contacts increased, decreased, or stayed the same. Values greater than 10 are not shown on the graph. B shows the distributions of the difference in contacts with zero values removed as they make comparison between increases and decreases difficult as they make up the majority of cases. Differences of magnitude greater than 10 are not shown. Graph C shows the proportion of change in contacts due to each restriction, showing that the

modal group was that the number of contacts remained unchanged after restrictions. This graph without restrictions and with zero values included are provided in supplementary material Figure S1A and S1B.

Table 1: Participants characteristics in the CoMix survey for each of the four types of restrictions

	Rule of Six	**10pm closure**	**Work from home**	**Local**
	N (col %)	N (col %)	N (col %)	N (col %)
Total	3222	1868	639	293
Age groups				
0-4	117 (3.7%)	52 (2.8%)	0	8 (2.8%)
5-11	181 (5.7%)	116 (6.2%)	0	20 (6.9%)
12-17	199 (6.2%)	132 (7.1%)	0	30 (10.3%)
18-29	310 (9.7%)	147 (7.9%)	74 (11.6%)	23 (7.9%)
30-39	361 (11.3%)	206 (11.1%)	144 (22.6%)	31 (10.7%)
40-49	455 (14.2%)	235 (12.6%)	155 (24.3%)	46 (15.8%)
50-59	504 (15.7%)	336 (18.0%)	175 (27.4%)	36 (12.4%)
60-69	649 (20.3%)	348 (18.7%)	81 (12.7%)	65 (22.3%)
70+	429 (13.4%)	292 (15.7%)	10 (1.6%)	32 (11.0%)
Missing	17	4	-	-
Gender				
Female	1674 (52.1%)	947 (50.8%)	318 (49.9%)	141 (48.3%)
Male	1541 (47.9%)	917 (49.2%)	319 (50.1%)	151 (51.7%)
Missing	7	4	2	1
Employed				
Yes	1197 (37.2%)	644 (34.5%)	639 (100%)	100 (34.1%)
No	2025 (62.9%)	1224 (65.5%)	0	193 (65.9%)
Missing	-	-	-	-
Socio-economic status				
A - Upper middle class	174 (5.4%)	111 (5.9%)	33 (5.2%)	9 (3.1%)
B - Middle class	878 (27.3%)	523 (28.0%)	177 (27.7%)	80 (27.3%)
C1 - Lower middle class	1079 (33.5%)	647 (34.6%)	255 (39.9%)	95 (32.4%)
C2 - Skilled working class	455 (14.1%)	226 (12.1%)	89 (13.9%)	47 (16.0%)
D - Working class	462 (14.3%)	261 (14.0%)	83 (13.0%)	40 (13.7%)
E - Lower level of subsistence	174 (5.4%)	100 (5.4%)	2 (0.3%)	22 (7.5%)
Missing	-	-	-	-

Table 2: Summary of permutation test on the proportion of individuals with decreased contacts and paired mean difference before and after restrictions.

Comparison of proportion decreased with proportion increased

Restriction	Contacts	N	Adults	Children	Decreased	Same	Increased	P value
Rule of Six	exclude work and school	3222	2708	514	1023 (31.75%)	1362 (42.27%)	837 (25.98%)	<0.0001
10pm closure	Other	1868	1564	304	479 (25.64%)	939 (50.27%)	450 (24.09%)	0.1799
WFH*	Work	639	639	0	119 (18.62%)	435 (68.08%)	85 (13.3%)	0.0097
Local	exclude work and school	293	233	60	94 (32.08%)	135 (46.08%)	64 (21.84%)	0.0103
Local [sens]**	exclude work and school	291	231	60	92 (31.62%)	135 (46.39%)	64 (21.99%)	0.0163

Comparison in mean difference

		Median (IQR)			Mean			
Restriction	Contacts	Before	After		Before	After	Difference (95% CI)	P value^
Rule of Six	exclude work and school	2 (1 to 3)	2 (1 to 3)	0	2.91	2.84	-0.08 (-0.48 to 0.4)	0.8271
10pm closure	Other	0 (0 to 1)	0 (0 to 1)	0	1.31	1.46	0.15 (-0.15 to 0.44)	0.3252
WFH*	Work	0 (0 to 0)	0 (0 to 0)	0	5.74	4.86	-0.88 (-2.4 to 0.36)	0.2112
Local	exclude work and school	2 (1 to 3)	2 (1 to 3)	0	3.14	2.4	-0.74 (-1.55 to -0.16)	0.0046
Local [sens]**	exclude work and school	2 (1 to 3)	2 (1 to 3)	1	2.54	2.22	-0.32 (-0.59 to -0.08)	0.0168

* WFH = Encouraged to work from Home, ** Sensitivity analysis where two observations with a difference of more than 12 were removed. ^Two-sided p-value calculated counting the number of permutations where the magnitude of the test statistics is greater than the observed test statistics and dividing by the number of permutations.

Table 3: Participant characteristics stratified by whether their contacts increased, stayed the same or decreased following local restrictions.

Local	Decreased	Same	Increased	Total
	N (row %)	N (row %)	N (row %)	
Total	97 (33%)	133 (45%)	63 (22%)	293
Age groups				
0-4	2 (25%)	4 (50%)	2 (25%)	8
5-11	7 (35%)	11 (55%)	2 (10%)	20
12-17	10 (33%)	13 (43%)	7 (23%)	30
18-29	6 (26.%)	11 (48.%)	6 (26%)	23
30-39	12 (39%)	15 (48%)	4 (13%)	31
40-49	11 (24%)	27 (59%)	8 (17%)	46
50-59	14 (39%)	13 (36%)	9 (25%)	36
60-69	21 (32%)	28 (43%)	16 (25%)	65
70+	11 (34%)	13 (41.%)	8 (25%)	32
Missing	-	-	2	
Gender				
Female	41 (29%)	68 (48%)	32 (23%)	141
Male	53 (35%)	66 (44%)	32 (21%)	151
Missing	-	1	-	
Employed				
Yes	29 (29%)	49 (49%)	22 (22%)	100
No	65 (34%)	86 (45%)	42 (22%)	193
Missing	-	-	-	
Socio-economic status				
A - Upper middle class	3 (33%)	3 (33%)	3 (33%)	9
B - Middle class	29 (36%)	33 (41%)	18 (23%)	80
C1 - Lower middle class	28 (29%)	46 (48%)	21 (22%)	95
C2 - Skilled working class	16 (34%)	20 (43%)	11 (23%)	47
D - Working class	11 (28%)	23 (58%)	6 (15%)	40
E - Lower level of subsistence	7 (32%)	10 (45%)	5 (23%)	22
Missing	-	-	-	

Abbreviations

CI confidence interval

IQR interquartile range

UK United Kingdom

WFH Work from home

Declarations

Authors' contributions

KvZ, AG, WJE, and CIJ designed the study protocol and the questionnaire. CIJ and WJE conceived of the analysis. CIJ conducted the analysis and wrote the first draft of the manuscript with feedback from all other authors. AG, KW, KvZ, and CIJ were involved in collecting and managing data. TW FC, and the Joint Biosecurity Centre provided data and insight on local restrictions.

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Ethics approval and consent to participate

Participation in this opt-in study was voluntary, and all analyses were carried out on anonymised data. The study and method of informed consent was approved by the ethics committee of the London School of Hygiene & Tropical Medicine Reference number 21795.

Consent for publication

Not applicable

Availability of data and materials

The code and data used to conduct these analyses are found at

https://github.com/jarvisc1/comix_uk_covid_restrictions

Competing interests

None

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Additional Files

Figure S1A: A: The distribution of the number of setting-specific contacts before and after each restriction came into place

Figure S1B: Change in contacts for each restriction.