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

43   participants had reduced their contacts. On average, participants reported 0.74 (0.16 to 1.55)

44   fewer non-work and non-school contacts than before the restrictions (p=0.005).

45   **Conclusions:**

46   We determine that the rule of six and encouraging people to WFH, has seen the average

47   person reduce contacts but these reductions are likely small. There was little suggestion that

48   10pm closure has affected the number of contacts that participants make outside home, work

49   and school. In contrast to national restrictions, there was a strong suggestion that local

50   restrictions reduced the number of contacts individuals make outside of work and school,

51   though again, this effect was small in comparison to the national lockdown.

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53   Key words

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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'

82   epidemiologically relevant setting-specific contacts before and after restrictions were imposed to

83   estimate whether these measures had any effect and if so their magnitude.

Methods

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Ethics Statement

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86   Participation in this opt-in study was voluntary, and all analyses were carried out on anonymised

87   data. The study was approved by the ethics committee of the London School of Hygiene &

88   Tropical Medicine Reference number 21795.

Data

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90   We combined data from the UK CoMix survey and information on local and national restrictions

91   from Gov.uk. Details of the CoMix study including the protocol and survey instrument have been

92   published previously [2]. In short, CoMix is an online survey where individuals record details of

93   direct (i.e. potentially risky) contacts in the 24 hours prior to the survey. A direct contact was

94   defined as anyone who was met in person and with whom at least one word was exchanged, or

95   anyone with whom the participants had any sort of skin-to-skin contact. Contacts of individuals

96   under the age of 18 were collected by asking parents to answer on behalf of their child.

97   Information is collected weekly from alternating, broadly representative, panels (each about

98   2,500 in size), with each person surveyed once every two weeks.

99   We extracted the start and end dates of restrictions and their locations from Gov.uk between 31

100   August and 29 September 2020. CoMix participants were considered affected by local

101   restrictions if they reported living within a Lower Tier Local Authority (UK administrative zone)

102   that was under restrictions. We restricted the data to two weeks before and after each restriction

103   came into place. We then extracted the closest survey response before and after each

104 restriction date. Participants with missing survey responses either side of the start of a

105 restriction were removed, giving two records per person.

Study design

107 Our study is a longitudinal natural experiment. For each participant, we have one observation

108 prior to and one observation after the restriction. These observations are at most two weeks

109 from the date of the start of the restriction. This allows individuals within our study to be their

110 own control and thus reduces the effect of between-person variation as well as the effect of

111 longer-term temporal trends. The types of contact reported were categorized as home-based,

112 work contact, school contact, and in other settings. We compared the number of contacts before

113 implementation of restrictions to the number of contacts after to assess the impact of i. local

114 restrictions and ii.three national restrictions (1) Rule of six (2) 10pm closure (3) Work from

115 home. To pick up the effect of the different restrictions we concentrated on changes in setting-

116 specific contacts, e.g. local restrictions are largely targeted at leisure contacts. In addition, the

117 Rule of Six does not apply for business or schools. Hence, for these two restrictions we

118 analysed changes in contacts excluding work and school. The 10pm closure rule requires

119 restaurants, pubs, and bars to close early. This restriction should not have a direct effect on

120 contacts made at home, work, or school. Thus, we used the remaining contacts as the outcome

121 for this restriction referred to as *Other* contacts. To analyse the effect of the work from home

122 restriction we focused on the work contacts of respondents who were employed.

Statistical analysis

124 R version 4.0.0 was used for all analyses and the code and data are available on github (see

125 Availability of data and materials) [10–12]. Descriptive and graphical summaries of participant

126 characteristics for age, gender, employment and socio-economic status were created for each

127 restriction. We compared contacts before and during restrictions by calculating the mean,

128   median, and interquartile range. The change in contacts were categorised into increased, same,

129   and decreased. The mean of the paired differences was calculated and uncertainty assessed by

130   constructing a 95% confidence interval (95% CI) from 10,000 bootstrap samples [13] of the

131   paired differences.

132   For each restriction, we conducted paired permutation tests [14] with 50,000 permutations per

133   test. We chose permutation tests as they are robust to distributional assumptions of the

134   underlying data [14]. In order to preserve the study structure, we calculated the paired

135   difference by subtracting the observation during the restriction from the observation before the

136   restriction and then randomly changed the sign of each pair. In practice this means generating a

137   vector of values taking -1 and 1 of the same length as the number of participants and then

138   multiplying the change in contacts by this vector.

139   For each permutation, a test statistic is calculated. In our study we chose to calculate two test

140   statistics for each restriction; (1) the proportion of individuals whose contacts decreased after

141   restrictions, (2) the mean of the change in contacts before and after restrictions. The proportion

142   of decreases is robust to large values and skewed distributions treating a difference of -1 and -

143   1000 in the same way. This measure tests the relative effect of the restriction but does not

144   estimate the effect size. The mean difference estimates the absolute effect but is affected by

145   skewed data.

146   In the case of the local restrictions, one individual reported 101 contacts excluding work and

147   school before and 1 contact after and another reported 81 contacts before and 57 contacts after

148   restrictions giving differences of -100 and -24 contacts, respectively. We performed a sensitivity

149   analysis with these observations removed in order to assess the impact that these extreme

150   values had on the conclusions of the analysis.

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152 Results

153 Participant characteristics

154 There were 3,222 participants included in the analysis for the rule of six; 1,868 for 10pm

155 closure; 639 for WFH; and 293 participants affected by local restrictions (Table 1). The age

156 distributions of the samples for Rule of six, 10pm closure, and local restrictions were very similar

157 with the age group 60-69 making up nearly 20% of the samples in all three analyses. The WFH

158 category by definition only included participants 18 years of age or older and nearly 70% of

159 participants were between 30 and 59. The gender split was close to 50% for all restrictions.

160 Excluding the WFH analysis, over 60% of participants were unemployed for each restriction.

161 Socio-economic status was consistent across the four populations with lowest numbers in the A

162 - Upper middle class, and E - Lower level of subsistence categories and the modal group being

163 C1 - Lower middle class for all restrictions (Table 1).

164 Setting-specific contacts

165 The setting-specific contacts were positively skewed for all restrictions (Figure 1A). The rules of

166 six and and local restrictions had similar distributions with the modal response being one

167 contact before and after the restrictions. The 10pm and WFH distributions were also similar

168 despite the contacts being 'other' and work contacts, respectively. The magnitudes of the

169 change in contacts were small, with magnitude being less than 10 for nearly all observations

170 (Figure 1B). The majority of individuals had no change in the number of contacts they reported.

171 This proportion of participants reporting the same number of contacts was highest in the WFH

172 category with 68% versus the lowest of 42% for the rule of six restriction (Figure 1C, Table 2).

173 In order to see the patterns in the data the axes were restricted and the zero values were

174   removed for Figure 1B. Figure S1A and S1B reproduces the same graph without removal of

175   zero values or restriction of axes for comparison.

National restrictions

Rule of Six

178   We compared non-work and non-school contacts for 3,222 individuals before and after the rule

179   of six came into effect. There was very strong evidence (p<0.0001) to suggest that more people

180   reduced their contacts (excluding work and school) following the rule of six restriction than

181   expected due to chance, with 1,023 (31.8%) recording fewer contacts compared to 837 (26.0%)

182   recording a greater number of contacts. However, the majority of participants 1,362 (42.3%)

183   recorded the same number of contacts and the median number of contacts was 2 (IQR 1 to 3)

184   before and after the rule of six. There was no evidence (p=0.827) of a change in the mean

185   number of non-work and non-school contacts recorded with the difference equal to -0.08 (-0.48

186   to 0.40) contacts per day (Table 2).

10pm closure

188   We compared 'other' contacts (excluding home, work, or school) among 1,868 participants

189   before and after the 10pm closure. There was little evidence to suggest (p=0.18) that

190   respondents changed contacts after the 10pm rule, with near identical numbers of people

191   decreasing and increasing (479 versus 450) 'other' contacts. The data were also consistent with

192   no absolute effect (p=0.325) with the change in mean 'other' contacts estimated as 0.15 (-0.15

193   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.

240   Furthermore, the longitudinal, panel nature of the data, means that individuals act as their own

241   temporal control group, making it easier to pick up relatively small changes in contact patterns.

242   This work has several limitations. We were unable to distinguish between the types of measures

243   used in local restrictions and therefore the effect that we see is a combination of a range of

244   interventions. Individuals may also not accurately report their contacts, due to recall or social

245   desirability bias. A further limitation is that the restrictions were not randomly allocated and thus

246   the effects we see may be due to other confounding factors. However, we did use a repeated

247   measure on the same individuals, which will reduce between-person variability, though

248   confounding factors could remain constant on individuals and affect the generalisability of

249   results. The contact data is bounded at zero and skewed, therefore using the mean can be a

250   less relevant summary measure; this is why we also performed a permutation test that focused

251   on the sign of the difference rather than the magnitude. Furthermore, we did not distinguish

252   between the length of time spent with different contacts.

253   Despite these limitations, we have attempted to provide insight into the highly relevant issue of

254   whether different restrictions in response to COVID-19 work and if so how effective they are. We

255   have focused on one metric of epidemiological relevant setting-specific contacts, though the

256   impact of the different restrictions will have broader implications that need to be considered for

257   policy change.

258   Future work could assess whether restrictions reduce the amount of time spent with individuals

259   as may well be the case for the 10pm rule. Further exploration of the effect of restrictions on

260   different age groups, and the potential of regional adherence to the national restrictions could

261   help disentangle whether lack of effects was due to sampling biases rather than lack of

262   effectiveness of restrictions.

263 Conclusions

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

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

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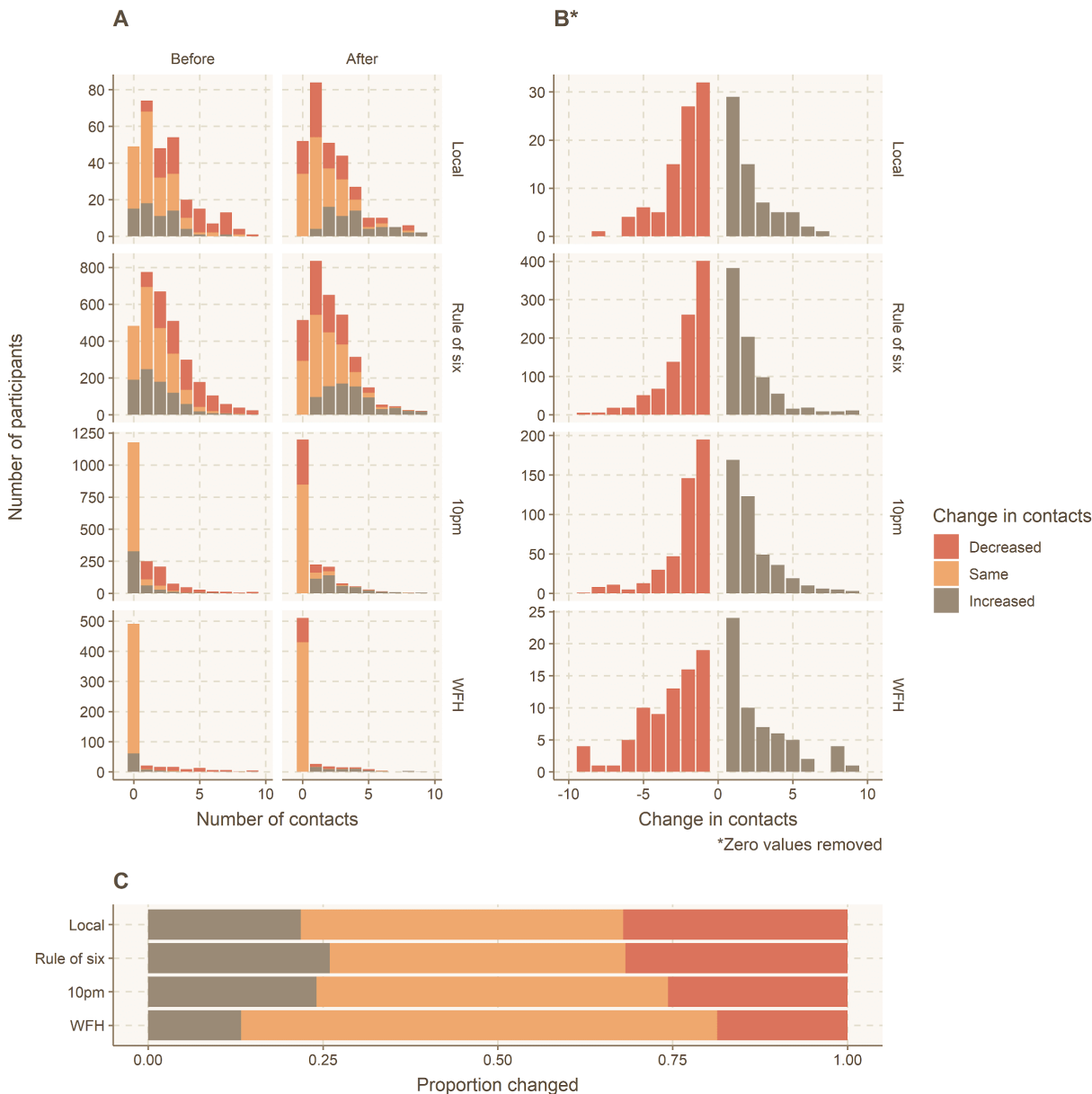
271　　Graph A shows the distribution of setting-specific contacts before and after each
272　　restriction came into place. It is coloured by whether the change in contacts increased,
273　　decreased, or stayed the same. Values greater than 10 are not shown on the graph. B
274　　shows the distributions of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

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

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

restrictions

	Rule of Six N (col %)	10pm closure N (col %)	Work from home N (col %)	Local 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	-	-	-	-

288 Table 2: Summary of permutation test on the proportion of individuals with decreased

289 contacts and paired mean difference before and after restrictions.

290

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

Restriction	Contacts	Median (IQR) Before	After		Mean 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

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

295

296   Table 3: Participant characteristics stratified by whether their contacts increased, stayed

297   the same or decreased following local restrictions.

Local	Decreased N (row %)	Same N (row %)	Increased N (row %)	Total
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	-	-	-	

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299

300   Abbreviations

301   CI confidence interval

302   IQR interquartile range

303 UK United Kingdom

304 WFH Work from home

305

Declarations

306

Authors' contributions

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308 KvZ, AG, WJE, and CIJ designed the study protocol and the questionnaire. CIJ and WJE
309 conceived of the analysis. CIJ conducted the analysis and wrote the first draft of the manuscript
310 with feedback from all other authors. AG, KW, KvZ, and CIJ were involved in collecting and
311 managing data. TW FC, and the Joint Biosecurity Centre provided data and insight on local
312 restrictions.
313

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314

359 Ethics approval and consent to participate

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

363 Consent for publication

364 Not applicable

365 Availability of data and materials

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

367 https://github.com/jarvisc1/comix_uk_covid_restrictions

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423

424   Additional Files

425   Figure S1A: A: The distribution of the number of setting-specific contacts before and after each

426   restriction came into place

427   Figure S1B: Change in contacts for each restriction.