

# COVID-19, smoking and inequalities: a study of 53 002 adults in the UK

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## ABSTRACT

**Background** This study aimed to examine associations between smoking and COVID-19 relevant outcomes, taking into account the influence of inequalities and adjusting for potential confounding variables.

**Methods** Cross-sectional data were used from an online study of adults in the UK (n=53 002). Main outcome measures were confirmed and suspected COVID-19, worry about catching or becoming seriously ill from COVID-19 and adherence to protective behaviours. Covariates included age, sex, ethnicity, education (post-16 qualifications: yes/no), key worker status and comorbid health conditions.

**Results** Compared with never smokers (0.26% (95% CI 0.21% to 0.33%)), prevalence of confirmed COVID-19 was higher among current (0.56% (0.41% to 0.75%)) but not ex-smokers (0.19% (0.13% to 0.28%)). Associations were similar before (current: OR=2.14 (1.49–3.08); ex-smokers: OR=0.73 (0.47–1.14)) and after (current: OR=1.79 (1.22–2.62); ex-smokers: OR=0.85 (0.54–1.33)) adjustment. For current smokers, this was moderated by socio-economic position, with higher rates only seen in those without post-16 qualifications (OR=3.53 (2.04–6.10)). After including suspected cases, prevalence was higher among current smokers (11.2% (10.6% to 11.9%), OR=1.11 (1.03–1.20)) and ex-smokers (10.9% (10.4% to 11.5%), OR=1.07 (1.01–1.15)) than never smokers (10.2% (9.9% to 10.6%)), but remained higher only among ex-smokers after adjustment (OR=1.21 (1.13–1.29)). Current and ex-smokers had higher odds than never smokers of reporting significant stress about becoming seriously ill from COVID-19 (current: OR=1.34 (1.27–1.43); ex-smokers: OR=1.22 (1.16–1.28)). Adherence to recommendations to prevent spread of COVID-19 was high (96.3% (96.1% to 96.4%)), but lower among current than never smokers (OR=0.70 (0.62–0.78)).

**Conclusions** In a population sample, current smoking was independently associated with self-reported confirmed COVID-19 infection. There were socio-economic disparities, with the association only apparent among those without post-16 qualifications. Smokers reported lower adherence to guidelines despite being more worried than non-smokers about catching or becoming seriously ill from COVID-19.

## INTRODUCTION

The influence of smoking on COVID-19 infection and outcomes is unclear. More than a billion people around the world smoke tobacco, and the vast majority live in low-income and middle-income countries or belong to more disadvantaged socio-economic groups.<sup>1,2</sup> Early data have not provided clear evidence on whether smokers are more

likely than non-smokers to experience adverse outcomes from COVID-19.<sup>3–5</sup> Other unanswered questions are whether smokers are more worried about contracting or becoming ill from COVID-19, how smoking relates to adherence to protective behaviours, whether the amount people are smoking is changing in the context of the pandemic and how far any of these factors are moderated by socio-economic position. Understanding these issues is important for evaluating clinical risk, developing clear public health messaging and identifying targets for intervention.

Former or current smoking increases the risk of respiratory viral<sup>6,7</sup> and bacterial<sup>8,9</sup> infections and is associated with worse outcomes for those infected. Cigarette smoke reduces respiratory immune defences<sup>10</sup> and behavioural aspects of smoking (eg, hand-to-mouth action) may contribute to increased transmission.<sup>11</sup> However, evidence on smoking and COVID-19 specifically is less clear. Several studies have indicated that smokers may be more likely than non-smokers to develop severe respiratory disease from COVID-19,<sup>3,4</sup> but this has not been observed consistently.<sup>5</sup> A review of 28 observational studies concluded that there was limited evidence that disease severity in those hospitalised for COVID-19 is greater in current/former smokers than never smokers, but there was insufficient evidence to draw conclusions on infection, hospitalisation or mortality.<sup>4</sup> Another meta-analysis of 19 peer-reviewed studies found that history of smoking was associated with increased risk of COVID-19 disease progression.<sup>12</sup> Further complicating the picture are data that suggest smoking prevalence is disproportionately low among hospitalised patients with COVID-19.<sup>4,13–15</sup> The number of cases in the descriptive studies conducted to date has typically been small and lack of adjustment for relevant confounders means that it is not possible to disentangle the effect of smoking.<sup>16</sup> For example, smoking is known to increase the risk of chronic health conditions associated with poorer COVID-19 outcomes.<sup>17–19</sup> It should also be noted that much of the available evidence is currently in preprint form and has not yet been peer-reviewed. Population-level data collected outside of hospital settings are required.

How the pandemic is affecting smoking behaviour has implications for provision and targeting of cessation support. On the one hand, concerns about respiratory health may prompt some smokers to cut down or attempt to quit to reduce their risk of complications from COVID-19. It is not known whether smokers are more worried about developing COVID-19 or becoming seriously ill from the disease, which could affect their intention to quit.<sup>20</sup>



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On the other hand, people may be smoking more than usual in an attempt to cope with higher than usual levels of stress<sup>21-23</sup> or relieve boredom.<sup>23 24</sup> Public health messaging may also influence smoking behaviour. Several organisations have warned of increased risk to smokers.<sup>25-27</sup> Public Health England has advised smokers to quit to reduce their risk<sup>27</sup> and online campaigns are encouraging smokers to ‘#QuitForCovid’. However, these efforts may be undermined by headlines heralding a potential protective effect of smoking and nicotine<sup>28</sup> based on the reports of disproportionate hospitalisation rates,<sup>13 29</sup> which has led to governments having to restrict the sale of nicotine replacement therapy to avoid panic buying.<sup>30</sup>

In understanding associations between smoking and COVID-19, it is also important to consider the influence of socio-economic position. Smoking is a socially patterned behaviour; substantially higher prevalence of smoking in groups with greater socio-economic disadvantage is a key driver of health inequalities.<sup>2 31</sup> Despite continuing rhetoric that ‘we are all in this together’, the COVID-19 pandemic does not affect everyone equally.<sup>32</sup> Understanding how socio-economic position affects associations between smoking and COVID-19 relevant outcomes is essential for developing and targeting appropriate advice for smokers and evaluating the potential impact of interventions on health inequalities.

To summarise, there is a need for robust, population-based evidence on the association of smoking with COVID-19, taking into account the influence of inequalities and adjusting for potential confounding variables. Using cross-sectional data from a large study of adults in the UK, we aimed to address the following research questions:

1. Among adults in the UK, is smoking status associated with diagnosed or suspected COVID-19, after adjustment for socio-demographic characteristics, key worker status and comorbid health conditions?
2. Is smoking status associated with worry or significant stress about contracting or becoming seriously ill with COVID-19, after adjustment for socio-demographic characteristics, key worker status, comorbid health conditions and anxiety disorders?
3. Is smoking status associated with adherence to COVID-19 protective behaviours, after adjustment for socio-demographic characteristics, key worker status and comorbid health conditions?
4. Among smokers, what proportions report smoking more, about the same, and less than usual over the past week?
5. Are recent changes in smoking associated with heaviness of smoking, socio-demographic characteristics, comorbid health conditions, confirmed or suspected COVID-19 or stress about becoming seriously ill with COVID-19?
6. Do the above associations differ by post-16 education as an indicator of socio-economic position?

## METHOD

### Design

We used cross-sectional data from the UCL COVID-19 Social Study’s baseline survey. The UCL COVID-19 Social Study is a longitudinal panel survey of adults ( $\geq 18$  years) in the UK designed to provide insights into psychological and social experiences during the SARS-CoV-2 outbreak. The study sampling does not aim to be representative of the population, but it is intended to have good representation across major socio-demographic groups. Thus, the sample has been recruited through a variety of channels including the media, targeted advertising by online

advertising companies and partnerships with organisations representing vulnerable groups, enabling meaningful subgroup analysis. The protocol and user guide for the study providing full details on recruitment, retention and data dictionary are available on the study website ([www.covidsocialstudy.org](http://www.covidsocialstudy.org)).

The UK Coronavirus Action Plan<sup>33</sup> was published on 3 March 2020, followed by government advice to practice social distancing on 16 March and behavioural restrictions enforceable by law (‘lockdown’) on 23 March. An estimated 2.7% of the UK population were infected by 28 March 2020.<sup>34</sup> Data collection for the UCL COVID-19 Social Study began on 21 March 2020. For this analysis, we aggregated data collected daily through 20 April 2020 (the most recent data available at the time of analysis).

### Measures

All measures were self-reported. Additional details on the measures used are provided in online supplementary file 1.

#### Smoking status

Smoking status was categorised as never smoker, ex-smoker or current smoker.

#### Socio-demographic information

Socio-demographic variables included age, sex, ethnicity (white/other), highest level of education (post-16 qualifications: yes/no) and key worker status (yes/no). We selected education over other markers of socio-economic position (eg, income or employment) because it provides a more reliable indication of socio-economic position prior to COVID-19 (because it is not affected by recent job loss or furlough) and previous studies have shown level of education to be robustly associated with smoking status<sup>35 36</sup> and health outcomes.<sup>37</sup>

#### Health conditions

We included information on presence of smoking-associated health conditions (any of high blood pressure, diabetes, heart disease, lung disease or cancer: yes/no) and clinically diagnosed anxiety disorders (yes/no).

#### Confirmed and suspected COVID-19

Participants were asked: ‘Have you had COVID-19 (coronavirus)?’ with response options (a) yes diagnosed and recovered, (b) yes diagnosed and still ill, (c) not formally diagnosed but suspected and (d) no. Confirmed COVID-19 was coded 1 for those who responded (a) or (b) and 0 for those who responded (c) or (d). Confirmed/suspected COVID-19 was coded 1 for those who responded (a), (b) or (c) and 0 for those who responded (d).

#### Worry about COVID-19

Two questions asked: ‘Over the past week, have any of the following been worrying you at all, even if only in a minor way?’ and ‘Have any of these things been causing you significant stress? (eg, they have been constantly on your mind or have been keeping you awake at night)’. Response options included ‘catching COVID-19’ and ‘becoming seriously ill from COVID-19’. We analysed four variables: (i) worry about catching COVID-19, (ii) significant stress about catching COVID-19, (iii) worry about becoming seriously ill from COVID-19 and (iv) significant stress about becoming seriously ill from COVID-19. For each variable, those who reported worry/stress about the relevant outcome were coded 1, else they were coded 0.

### Adherence to COVID-19 protective behaviours

The primary measure of adherence was based on responses to the question: 'Are you following the recommendation from authorities to prevent spread of COVID-19?' with responses on a scale from 1 (not at all) to 7 (very much so). Details of the recommendations at the time are included in online supplementary file 1. Responses  $\geq 5$  were coded 1 (indicating general adherence) and responses  $\leq 4$  were coded 0. As a secondary measure of (non)adherence, we examined the proportion who responded 'I am living my life as normal' (coded 1) in response to the question: 'What is your current isolation status?' Those who reported cutting down on usual activities, staying at home and/or self-isolating were coded 0.

### Recent changes in smoking

Past-week changes in smoking were assessed with the question: 'Over the past week have you smoked more than usual?' with response options (a) less than usual, (b) about the same, (c) more than usual and (d) I don't smoke. We analysed two variables: smoking less (vs about the same/more) and smoking more (vs about the same/less).

### Statistical analysis

The analysis plan was pre-registered on Open Science Framework (<https://osf.io/pcs49/>). Analyses were conducted on complete cases using SPSS V.24. To account for the non-random nature of the sample, all data were weighted to the proportions of sex, age, ethnicity, education and country of living obtained from the Office for National Statistics.<sup>38</sup>

We used logistic regression to examine associations between smoking status (never smoker (referent), ex-smoker and current smoker) and confirmed and confirmed/suspected COVID-19, worry about COVID-19 and adherence to protective behaviours. For each outcome, we report the unadjusted association and adjusted models with sequential adjustment for relevant covariates (see online supplementary file 1 or table footnotes for full details of each model tested). Among current smokers, we used logistic regression to analyse unadjusted and multivariable associations of socio-demographic characteristics, comorbid health

conditions, confirmed/suspected COVID-19, significant stress about becoming seriously ill from COVID-19 and survey date with recent changes in smoking.

### RESULTS

A total of 55 481 participants responded to the survey between 21 March and 20 April 2020, of whom 53 221 (95.9%; weighted  $n=53\ 002$ ) provided complete data on variables included in the present analyses. Of the analysed sample, 13 602 (25.7%) were ex-smokers and 8057 (15.2%) were current smokers. Sample characteristics in relation to smoking status are shown in [table 1](#) (corresponding sample characteristics on unweighted data are shown in online supplementary file 2).

### Confirmed and suspected COVID-19

Of the sample, 0.29% (95% CI 0.25% to 0.34%) reported having (had) a confirmed case of COVID-19 and a further 10.3% (95% CI 10.0% to 10.5%) reported experiencing symptoms of COVID-19. Compared with never smokers, prevalence of confirmed COVID-19 was higher among current smokers but not ex-smokers, and associations were similar after adjustment. Associations between smoking status and confirmed COVID-19 differed significantly by level of education. Odds of confirmed COVID-19 were 3.5 times higher among current smokers with no post-16 qualifications than never smokers after adjustment for covariates, but they did not differ significantly by smoking status among participants with post-16 qualifications ([table 2](#)).

After including suspected cases, prevalence was higher among current smokers and ex-smokers than never smokers, but remained higher only among ex-smokers after adjustment. Odds of confirmed/suspected COVID-19 were also significantly higher among current smokers with no post-16 qualifications after adjustment for socio-demographics, key worker status and comorbid health conditions (OR=1.16) but this association was attenuated when diagnosed anxiety disorders were controlled for (OR=1.13; [table 2](#)). Odds of confirmed/suspected COVID-19 were significantly higher among ex-smokers with post-16 qualifications than never smokers after full adjustment for covariates (OR=1.30; [table 2](#)).

**Table 1** Sample characteristics

	Whole sample	Never smokers	Ex-smokers	Current smokers	P value*
N	53 002	31 344	13 602	8057	–
Age in years, % (n)					
18–29	19.5 (10 333)	23.3 (7298)	8.7 (1177)	23.1 (1858)	<0.001
30–39	15.0 (7942)	14.8 (4634)	13.3 (1806)	18.6 (1502)	–
40–49	17.7 (9372)	15.7 (4934)	19.5 (2647)	22.2 (1791)	–
50–59	17.5 (9297)	16.7 (5228)	18.5 (2520)	19.2 (1549)	–
60–69	19.1 (10 100)	18.4 (5764)	24.5 (3326)	12.5 (1010)	–
$\geq 70$	11.2 (5959)	11.1 (3486)	15.6 (2126)	4.3 (347)	–
Female sex, % (n)	50.6 (26 825)	52.4 (16 432)	45.9 (6245)	51.5 (4148)	<0.001
White ethnicity, % (n)	87.2 (46 219)	85.5 (26 789)	91.0 (12 378)	87.5 (7052)	<0.001
No post-16 qualifications, % (n)	32.7 (17 324)	26.4 (8286)	38.3 (5205)	47.6 (3833)	<0.001
Key worker, % (n)	22.6 (11 956)	22.6 (7080)	20.9 (2840)	25.3 (2036)	<0.001
$\geq 1$ Health condition†, % (n)	32.2 (17 093)	28.8 (9029)	40.9 (5557)	31.1 (2507)	<0.001
Diagnosed anxiety disorder, % (n)	13.0 (6872)	11.1 (3474)	12.7 (1726)	20.8 (1672)	<0.001
Heavy smokers ( $\geq 10$ CPD), % (n)	–	–	–	50.3 (4056)	–

All data are weighted to match the UK adult population on sex, age, ethnicity, education and country of living.

\*P value for the association between each variable and smoking status.

†High blood pressure, diabetes, heart disease, lung disease (eg, asthma or chronic obstructive pulmonary disease) or cancer.

CPD, cigarettes per day.

**Table 2** Association of smoking status with confirmed and suspected COVID-19

	% (95% CI)	Model 1		Model 2		Model 3		Model 4		Interaction with post-16 qualifications*	
		OR (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value
<b>Confirmed COVID-19</b>											
<b>Whole sample</b>											
Never smoker	0.26 (0.21 to 0.33)	–	–	–	–	–	–	–	–	–	–
Ex-smoker	0.19 (0.13 to 0.28)	0.73 (0.47 to 1.14)	0.163	0.89 (0.57 to 1.40)	0.615	0.85 (0.54 to 1.33)	0.465	–	–	0.26 (0.09 to 0.79)	0.017
Current smoker	0.56 (0.41 to 0.75)	2.14 (1.49 to 3.08)	<0.001	1.87 (1.28 to 2.73)	0.001	1.79 (1.22 to 2.62)	0.003	–	–	3.74 (1.51 to 9.27)	0.004
<b>No post-16 qualifications</b>											
Never smoker	0.31 (0.21 to 0.46)	–	–	–	–	–	–	–	–	–	–
Ex-smoker	0.10 (0.03 to 0.22)	0.28 (0.10 to 0.76)	0.012	0.49 (0.18 to 1.37)	0.175	0.49 (0.18 to 1.37)	0.172	–	–	–	–
Current smoker	0.99 (0.70 to 1.36)	3.16 (1.91 to 5.21)	<0.001	3.64 (2.11 to 6.28)	<0.001	3.53 (2.04 to 6.10)	<0.001	–	–	–	–
<b>Post-16 qualifications</b>											
Never smoker	0.25 (0.19 to 0.32)	–	–	–	–	–	–	–	–	–	–
Ex-smoker	0.26 (0.16 to 0.40)	1.05 (0.64 to 1.72)	0.850	1.14 (0.69 to 1.88)	0.618	1.04 (0.63 to 1.72)	0.888	–	–	–	–
Current smoker	0.19 (0.08 to 0.37)	0.76 (0.36 to 1.59)	0.461	0.69 (0.33 to 1.47)	0.337	0.67 (0.32 to 1.43)	0.302	–	–	–	–
<b>Confirmed/suspected COVID-19</b>											
<b>Whole sample</b>											
Never smoker	10.2 (9.9 to 10.6)	–	–	–	–	–	–	–	–	–	–
Ex-smoker	10.9 (10.4 to 11.5)	1.07 (1.01 to 1.15)	0.033	1.22 (1.14–1.31)	<0.001	1.22 (1.14–1.31)	<0.001	1.21 (1.13–1.29)	<0.001	0.26 (0.09–0.79)	0.018
Current smoker	11.2 (10.6 to 11.9)	1.11 (1.03 to 1.20)	0.009	1.05 (0.97–1.14)	0.199	1.06 (0.97–1.14)	0.197	1.02 (0.94–1.11)	0.572	3.77 (1.52–9.35)	0.004
<b>No post-16 qualifications</b>											
Never smoker	8.0 (7.4 to 8.6)	–	–	–	–	–	–	–	–	–	–
Ex-smoker	7.9 (7.2 to 8.6)	0.99 (0.87 to 1.12)	0.850	1.03 (0.91–1.18)	0.625	1.03 (0.91–1.18)	0.620	1.02 (0.90–1.17)	0.747	–	–
Current smoker	10.8 (9.9 to 11.9)	1.40 (1.23 to 1.60)	<0.001	1.16 (1.01–1.32)	0.032	1.16 (1.01–1.32)	0.032	1.13 (0.98–1.29)	0.083	–	–
<b>Post-16 qualifications</b>											
Never smoker	11.1 (10.7 to 11.5)	–	–	–	–	–	–	–	–	–	–
Ex-smoker	12.8 (12.1 to 13.5)	1.18 (1.09 to 1.27)	<0.001	1.31 (1.21–1.42)	<0.001	1.31 (1.21–1.42)	<0.001	1.30 (1.20–1.40)	<0.001	–	–
Current smoker	11.6 (10.7 to 12.6)	1.06 (0.95 to 1.17)	0.302	0.96 (0.87–1.07)	0.474	0.96 (0.87–1.07)	0.477	0.94 (0.84–1.04)	0.216	–	–

All data are weighted to match the UK adult population on sex, age, ethnicity, education and country of living.

Model 1 is unadjusted. Model 2 is adjusted for age, sex, ethnicity, post-16 qualifications, key worker status and survey date. Model 3 is adjusted for age, sex, ethnicity, post-16 qualifications, key worker status, survey date and comorbid health conditions. Model 4 is adjusted for age, sex, ethnicity, post-16 qualifications, key worker status, survey date, comorbid health conditions and diagnosed anxiety disorders.

\*Interaction between smoking status and post-16 qualifications added to fully adjusted model with the exclusion of key worker status.

OR<sub>adj</sub> adjusted OR.

## Worry about COVID-19

Just under half of participants reported being worried about catching (45.1% (95% CI 44.7% to 45.6%)) or becoming seriously ill from COVID-19 (46.0% (95% CI 45.6% to 46.4%)), and one in five reported significant stress about these possibilities (19.1% (95% CI 18.7% to 19.4%) and 22.9% (95% CI 22.5% to 23.2%), respectively). Current and ex-smokers were significantly more likely than never smokers to report COVID-19 causing them worry or stress (table 3). The association between smoking and worry about catching COVID-19 was stronger for smokers without than those with post-16 qualifications, but

there was no interaction with education for associations between smoking status and other worry/stress variables (table 3).

## Adherence to COVID-19 protective behaviours

Adherence to COVID-19 protective behaviours was high: 96.3% (95% CI 96.1% to 96.4%) reported general adherence to recommendations from authorities to prevent the spread of COVID-19, and just 3.7% (95% CI 3.5% to 3.8%) reported living life as normal. Associations between smoking status and adherence to protective behaviours differed significantly by level of education. Current smokers had lower odds of reporting general adherence

**Table 3** Association of smoking status with worry about COVID-19

	% (95% CI)	Model 1		Model 2		Model 3		Interaction with post-16 qualifications*	
		OR (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value
<b>Worry about catching COVID-19</b>									
Whole sample									
Never smoker	43.4 (42.8 to 43.9)	–	–	–	–	–	–	–	–
Ex-smoker	46.5 (45.6 to 47.3)	1.13 (1.09 to 1.18)	<0.001	1.14 (1.09 to 1.19)	<0.001	1.10 (1.06 to 1.15)	<0.001	1.22 (1.12 to 1.33)	<0.001
Current smoker	49.8 (48.7 to 50.9)	1.30 (1.23 to 1.36)	<0.001	1.26 (1.19 to 1.32)	<0.001	1.20 (1.14 to 1.26)	<0.001	1.10 (1.00 to 1.22)	0.063
No post-16 qualifications									
Never smoker	43.0 (41.9 to 44.1)	–	–	–	–	–	–	–	–
Ex-smoker	49.0 (47.7 to 50.4)	1.28 (1.19 to 1.37)	<0.001	1.27 (1.18 to 1.36)	<0.001	1.24 (1.15 to 1.33)	<0.001	–	–
Current smoker	51.3 (49.1 to 52.2)	1.40 (1.29 to 1.51)	<0.001	1.31 (1.21 to 1.42)	<0.001	1.26 (1.16 to 1.36)	<0.001	–	–
Post-16 qualifications									
Never smoker	43.5 (42.9 to 44.2)	–	–	–	–	–	–	–	–
Ex-smoker	44.9 (43.8 to 45.9)	1.06 (1.00 to 1.11)	0.033	1.07 (1.02 to 1.13)	0.006	1.04 (0.98 to 1.09)	0.178	–	–
Current smoker	48.4 (46.9 to 49.9)	1.22 (1.14 to 1.30)	<0.001	1.22 (1.14 to 1.30)	<0.001	1.17 (1.10 to 1.25)	<0.001	–	–
<b>Significant stress about catching COVID-19</b>									
Whole sample									
Never smoker	16.8 (16.4–17.3)	–	–	–	–	–	–	–	–
Ex-smoker	19.9 (19.2–20.6)	1.23 (1.17–1.29)	<0.001	1.22 (1.16 to 1.29)	<0.001	1.15 (1.09 to 1.22)	<0.001	1.07 (0.96 to 1.20)	0.211
Current smoker	26.3 (25.4–27.3)	1.77 (1.67–1.87)	<0.001	1.56 (1.47 to 1.66)	<0.001	1.43 (1.35 to 1.52)	<0.001	1.00 (0.89 to 1.13)	0.998
<b>Worry about becoming seriously ill from COVID-19</b>									
Whole sample									
Never smoker	44.0 (43.4–44.5)	–	–	–	–	–	–	–	–
Ex-smoker	48.8 (48.0–49.6)	1.21 (1.17–1.26)	<0.001	1.25 (1.20 to 1.30)	<0.001	1.19 (1.14 to 1.24)	<0.001	1.04 (0.95 to 1.14)	0.395
Current smoker	49.2 (48.1–50.3)	1.23 (1.18–1.30)	<0.001	1.23 (1.17 to 1.29)	<0.001	1.15 (1.09 to 1.21)	<0.001	1.08 (0.97 to 1.19)	0.168
<b>Significant stress about becoming seriously ill from COVID-19</b>									
Whole sample									
Never smoker	20.4 (20.0–20.9)	–	–	–	–	–	–	–	–
Ex-smoker	24.7 (24.0–25.4)	1.28 (1.22–1.34)	<0.001	1.31 (1.24 to 1.37)	<0.001	1.22 (1.16 to 1.28)	<0.001	1.01 (0.91 to 1.12)	0.880
Current smoker	29.4 (28.4–30.4)	1.62 (1.53–1.71)	<0.001	1.49 (1.40 to 1.57)	<0.001	1.34 (1.27 to 1.43)	<0.001	1.09 (0.97 to 1.23)	0.156

All data are weighted to match the UK adult population on sex, age, ethnicity, education and country of living.

Model 1 is unadjusted. Model 2 is adjusted for age, sex, ethnicity, post-16 qualifications, key worker status and survey date. Model 3 is adjusted for age, sex, ethnicity, post-16 qualifications, key worker status, survey date, comorbid health conditions and diagnosed anxiety disorders.

\*Interaction between smoking status and post-16 qualifications added to fully adjusted model with the exclusion of key worker status.

OR<sub>adj</sub> adjusted OR.

relative to never smokers irrespective of education, but the association was stronger among those with post-16 qualifications (table 4). Current smokers with post-16 qualifications also had higher odds of reporting living life as normal (ie, lower odds of adherence) than never smokers, but there was no difference between current smokers and never smokers with no post-16 qualifications (table 4). Ex-smokers with no post-16 qualifications were less likely than never smokers and current smokers to report living life as normal (ie, more likely to adhere to recommendations; table 4).

### Recent changes in smoking

Among current smokers, 13.4% (95% CI 12.7% to 14.2%) reported smoking less than usual in the past week, 42.2% (95% CI 41.3% to 43.5%) reported smoking more than usual and 43.9% (95% CI 43.0% to 45.1%) reported smoking about the same amount as usual. Smoking less was independently associated with being a light smoker (<10 cigarettes per day), younger age, non-white ethnicity, having post-16 qualifications and confirmed or suspected COVID-19 (table 5). Among smokers

**Table 4** Association of smoking status with adherence to COVID-19 protective behaviours

	% (95% CI)	Model 1		Model 2		Model 3		Interaction with post-16 qualifications*	
		OR (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value
<b>General adherence†</b>									
<b>Whole sample</b>									
Never smoker	96.6 (96.4 to 96.8)	–	–	–	–	–	–	–	–
Ex-smoker	96.8 (96.5 to 97.1)	1.07 (0.96 to 1.20)	0.223	1.00 (0.89 to 1.12)	0.980	1.00 (0.89 to 1.13)	0.977	1.43 (1.14 to 1.81)	0.002
Current smoker	94.3 (93.8 to 94.8)	0.59 (0.53 to 0.66)	<0.001	0.69 (0.62 to 0.78)	<0.001	0.70 (0.62 to 0.78)	<0.001	1.35 (1.07 to 1.71)	0.012
<b>No post-16 qualifications</b>									
Never smoker	94.5 (94.0 to 95.0)	–	–	–	–	–	–	–	–
Ex-smoker	95.8 (95.2 to 96.3)	1.31 (1.11 to 1.54)	0.001	1.12 (0.94 to 1.33)	0.202	1.12 (0.94 to 1.33)	0.192	–	–
Current smoker	92.9 (92.0 to 93.6)	0.75 (0.64 to 0.88)	<0.001	0.80 (0.68 to 0.94)	0.007	0.80 (0.68 to 0.95)	0.009	–	–
<b>Post-16 qualifications</b>									
Never smoker	97.3 (97.1 to 97.5)	–	–	–	–	–	–	–	–
Ex-smoker	97.4 (97.1 to 97.8)	1.05 (0.90 to 1.23)	0.515	0.90 (0.76 to 1.06)	0.188	0.90 (0.77 to 1.06)	0.208	–	–
Current smoker	95.6 (95.0 to 96.2)	0.61 (0.52 to 0.73)	<0.001	0.60 (0.51 to 0.71)	<0.001	0.60 (0.51 to 0.71)	<0.001	–	–
<b>Living life as normal‡</b>									
<b>Whole sample</b>									
Never smoker	3.6 (3.4 to 3.8)	–	–	–	–	–	–	–	–
Ex-smoker	3.1 (2.8 to 3.4)	0.84 (0.75 to 0.95)	0.003	0.80 (0.71 to 0.90)	<0.001	0.81 (0.72 to 0.91)	<0.001	0.73 (0.58 to 0.91)	0.006
Current smoker	4.9 (4.4 to 5.4)	1.36 (1.21 to 1.53)	<0.001	1.11 (0.98 to 1.26)	0.089	1.12 (0.99 to 1.27)	0.073	0.68 (0.53 to 0.87)	0.002
<b>No post-16 qualifications</b>									
Never smoker	6.4 (5.9 to 7.0)	–	–	–	–	–	–	–	–
Ex-smoker	4.4 (3.9 to 5.0)	0.67 (0.57 to 0.79)	<0.001	0.73 (0.62 to 0.86)	<0.001	0.73 (0.62 to 0.86)	<0.001	–	–
Current smoker	6.4 (5.9 to 7.2)	0.99 (0.84 to 1.16)	0.874	0.92 (0.78 to 1.08)	0.298	0.92 (0.78 to 1.09)	0.322	–	–
<b>Post-16 qualifications</b>									
Never smoker	2.6 (2.4 to 2.8)	–	–	–	–	–	–	–	–
Ex-smoker	2.2 (1.9 to 2.6)	0.86 (0.73 to 1.01)	0.065	0.86 (0.73 to 1.02)	0.080	0.87 (0.73 to 1.03)	0.105	–	–
Current smoker	3.5 (3.0 to 4.1)	1.36 (1.13 to 1.63)	0.001	1.31 (1.09 to 1.57)	0.005	1.31 (1.09 to 1.57)	0.005	–	–

All data are weighted to match the UK adult population on sex, age, ethnicity, education and country of living.

Model 1 is unadjusted. Model 2 is adjusted for age, sex, ethnicity, post-16 qualifications, key worker status and survey date. Model 3 is adjusted for age, sex, ethnicity, post-16 qualifications, key worker status, survey date and comorbid health conditions.

\*Interaction between smoking status and post-16 qualifications added to fully adjusted model with the exclusion of key worker status.

†General adherence to recommendations from authorities to prevent the spread of COVID-19 (score of  $\geq 5/7$ ).

‡Versus cutting down on usual activities, staying at home and/or self-isolating.

OR<sub>adj</sub> adjusted OR.

with no post-16 qualifications, smoking less was also associated with male sex, being a key worker and absence of comorbid health conditions (table 5). Among smokers with post-16

qualifications, smoking less was also associated with not being a key worker and experiencing significant stress about becoming seriously ill from COVID-19 (table 5).

**Table 5** Correlates of smoking less than usual in the past week among current smokers

	% (95% CI)	Bivariate*: whole sample		Multivariable†: whole sample		Interaction with post-16 qualifications‡		Multivariable†: no post-16 qualifications		Multivariable†: post-16 qualifications	
		OR (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value
Light smoker (<10 CPD)	21.6 (20.4 to 22.9)	–	–	–	–	–	–	–	–	–	–
Heavy smoker (≥10 CPD)	5.3 (4.6 to 6.0)	0.20 (0.17 to 0.24)	<0.001	0.23 (0.20 to 0.27)	<0.001	0.91 (0.66 to 1.25)	0.556	–	–	–	–
Age 18–29	21.0 (19.2 to 22.9)	–	–	–	–	–	–	–	–	–	–
30–39	13.0 (11.4 to 14.8)	0.56 (0.47 to 0.68)	<0.001	0.68 (0.56 to 0.83)	<0.001	1.22 (0.81 to 1.84)	0.350	–	–	–	–
40–49	10.5 (9.2 to 12.1)	0.44 (0.37 to 0.54)	<0.001	0.60 (0.49 to 0.73)	<0.001	0.66 (0.43 to 1.01)	0.053	–	–	–	–
50–59	10.1 (8.7 to 11.7)	0.42 (0.35 to 0.52)	<0.001	0.67 (0.54 to 0.83)	<0.001	0.87 (0.56 to 1.34)	0.519	–	–	–	–
60–69	12.0 (10.2 to 14.2)	0.52 (0.41 to 0.64)	<0.001	0.95 (0.75 to 1.21)	0.678	0.89 (0.55 to 1.43)	0.622	–	–	–	–
≥70	8.1 (5.7 to 11.4)	0.34 (0.23 to 0.51)	<0.001	0.58 (0.38 to 0.89)	0.012	0.40 (0.17 to 0.94)	0.035	0.42 (0.21 to 0.85)	0.015	0.81 (0.47 to 1.41)	0.457
Male	13.8 (12.8 to 15.0)	–	–	–	–	–	–	–	–	–	–
Female	13.0 (12.0 to 14.1)	0.93 (0.82 to 1.06)	0.273	0.84 (0.73 to 0.97)	0.014	0.70 (0.53 to 0.92)	0.012	0.65 (0.52 to 0.83)	<0.001	0.97 (0.81 to 1.15)	0.691
Ethnicity: other	19.7 (17.3 to 22.2)	–	–	–	–	–	–	–	–	–	–
White	12.5 (11.8 to 13.3)	0.59 (0.49 to 0.70)	<0.001	0.76 (0.64 to 0.92)	0.004	0.86 (0.58 to 1.26)	0.432	–	–	–	–
Post-16 qualifications: yes	16.7 (15.6 to 17.8)	–	–	–	–	–	–	–	–	–	–
No	9.8 (8.9 to 10.8)	0.54 (0.48 to 0.62)	<0.001	0.72 (0.62 to 0.83)	<0.001	–	–	–	–	–	–
Key worker: no	13.5 (12.7 to 14.4)	–	–	–	–	–	–	–	–	–	–
Yes	13.1 (11.7 to 14.6)	0.96 (0.83 to 1.12)	0.621	0.94 (0.80 to 1.10)	0.428	1.92 (1.40 to 2.63)	<0.001	1.39 (1.08 to 1.78)	0.009	0.73 (0.59 to 0.89)	0.002
Comorbid health conditions: 0	15.0 (14.1 to 16.0)	–	–	–	–	–	–	–	–	–	–
≥1	9.8 (8.7 to 11.1)	0.62 (0.53 to 0.72)	<0.001	0.76 (0.65 to 0.90)	0.002	0.54 (0.39 to 0.75)	<0.001	0.58 (0.45 to 0.76)	<0.001	0.95 (0.77 to 1.18)	0.653
Confirmed or suspected COVID-19: no	12.2 (11.5 to 13.0)	–	–	–	–	–	–	–	–	–	–
Yes	22.9 (20.3 to 25.7)	2.13 (1.79 to 2.52)	<0.001	2.06 (1.72 to 2.48)	<0.001	1.12 (0.78 to 1.62)	0.543	–	–	–	–
Significant stress about becoming seriously ill from COVID-19: no	13.4 (12.5 to 14.3)	–	–	–	–	–	–	–	–	–	–
Yes	13.5 (12.2 to 15.0)	1.01 (0.88 to 1.17)	0.847	1.18 (1.01 to 1.38)	0.032	0.67 (0.49 to 0.91)	0.010	1.00 (0.78 to 1.30)	0.977	1.32 (1.09 to 1.60)	0.005
Survey date	–	1.00 (0.99 to 1.00)	0.342	0.99 (0.98 to 1.00)	0.045	1.03 (1.01 to 1.04)	0.001	1.01 (0.99 to 1.02)	0.378	0.98 (0.97 to 0.99)	<0.001

All data are weighted to match the UK adult population on sex, age, ethnicity, education and country of living. ORs reflect the odds of reporting smoking less than usual compared with smoking about the same amount as usual.

\*Bivariate (unadjusted) model.

†Multivariable model fully adjusted for all variables in the table.

‡Interaction between post-16 qualifications and each potential correlate added to multivariable model in turn. Key worker status was excluded from all interaction models with the exception of the interaction between post-16 qualifications and key worker status.

CPD, cigarettes per day; OR<sub>adj</sub>, adjusted OR.

Smoking more than usual was independently associated with being a heavy smoker (≥10 cigarettes per day), younger, female sex and experiencing significant stress about becoming seriously ill from COVID-19 (table 6). Among smokers with no post-16 qualifications, smoking more was also associated with not being a key worker, having comorbid health conditions and having confirmed or suspected COVID-19 (table 6). Among smokers with post-16 qualifications, smoking more was also associated with not having confirmed or suspected COVID-19 (table 6). Associations of smoking more with female sex and experiencing significant stress about becoming seriously ill from COVID-19

were stronger for smokers without post-16 qualifications than those with (table 6).

## DISCUSSION

In this large survey of adults in the UK, current smoking was associated with 1.8 times higher odds of confirmed COVID-19 relative to never smoking, independent of age, sex, ethnicity, key worker status and comorbid health conditions. This was driven by a substantially higher rate of confirmed COVID-19 among smokers with no post-16 qualifications, with no significant

**Table 6** Correlates of smoking more than usual in the past week among current smokers

	% (95% CI)	Bivariate*: whole sample		Multivariable†: whole sample		Interaction with post-16 qualifications‡		Multivariable†: no post-16 qualifications		Multivariable†: post-16 qualifications	
		OR (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value	OR <sub>adj</sub> (95% CI)	P value
Light smoker (<10 CPD)	35.5 (34.0 to 37.0)	–	–	–	–	–	–	–	–	–	–
Heavy smoker (≥10 CPD)	49.2 (47.7 to 50.8)	1.77 (1.62 to 1.93)	<0.001	2.07 (1.87 to 2.28)	<0.001	0.98 (0.81 to 1.19)	0.836	–	–	–	–
Age 18–29	49.2 (46.9 to 51.5)	–	–	–	–	–	–	–	–	–	–
30–39	51.1 (48.6 to 53.6)	1.08 (0.94 to 1.24)	0.279	0.98 (0.85 to 1.13)	0.801	0.83 (0.62 to 1.11)	0.209	–	–	–	–
40–49	41.6 (39.4 to 43.9)	0.74 (0.65 to 0.84)	<0.001	0.62 (0.54 to 0.71)	<0.001	0.82 (0.62 to 1.08)	0.152	–	–	–	–
50–59	36.9 (34.5 to 39.3)	0.60 (0.53 to 0.69)	<0.001	0.48 (0.42 to 0.56)	<0.001	1.04 (0.77 to 1.40)	0.801	–	–	–	–
60–69	33.7 (30.9 to 36.7)	0.53 (0.45 to 0.62)	<0.001	0.41 (0.34 to 0.48)	<0.001	0.86 (0.62 to 1.21)	0.386	–	–	–	–
≥70	22.3 (18.2 to 26.9)	0.30 (0.23 to 0.39)	<0.001	0.24 (0.18 to 0.33)	<0.001	0.73 (0.41 to 1.29)	0.282	–	–	–	–
Male	37.5 (36.0 to 39.0)	–	–	–	–	–	–	–	–	–	–
Female	47.0 (45.5 to 48.5)	1.47 (1.35 to 1.61)	<0.001	1.33 (1.21 to 1.46)	<0.001	1.26 (1.04 to 1.52)	0.016	1.47 (1.28 to 1.69)	<0.001	1.23 (1.08 to 1.40)	0.002
Ethnicity: other	38.5 (35.6 to 41.6)	–	–	–	–	–	–	–	–	–	–
White	42.9 (41.8 to 44.1)	1.20 (1.05 to 1.38)	0.009	1.09 (0.95 to 1.26)	0.231	1.30 (0.97 to 1.74)	0.085	–	–	–	–
Post-16 qualifications: yes	42.7 (41.2 to 44.2)	–	–	–	–	–	–	–	–	–	–
No	42.0 (40.5 to 43.6)	0.97 (0.89 to 1.06)	0.529	0.91 (0.83 to 1.00)	0.051	–	–	–	–	–	–
Key worker: no	43.2 (41.9 to 44.4)	–	–	–	–	–	–	–	–	–	–
Yes	40.0 (37.9 to 42.2)	0.88 (0.80 to 0.98)	0.017	0.79 (0.71 to 0.88)	<0.001	0.63 (0.50 to 0.78)	<0.001	0.59 (0.50 to 0.70)	<0.001	0.98 (0.85 to 1.13)	0.772
Comorbid health conditions: 0	42.3 (41.0 to 43.6)	–	–	–	–	–	–	–	–	–	–
≥1	42.6 (40.7 to 44.5)	1.01 (0.92 to 1.11)	0.810	1.18 (1.06 to 1.31)	0.003	1.51 (1.23 to 1.86)	<0.001	1.42 (1.22 to 1.66)	<0.001	0.96 (0.82 to 1.12)	0.601
Confirmed or suspected COVID-19: no	42.1 (41.0 to 43.3)	–	–	–	–	–	–	–	–	–	–
Yes	44.4 (41.2 to 47.7)	1.10 (0.96 to 1.26)	0.189	0.94 (0.81 to 1.09)	0.420	1.81 (1.35 to 2.43)	<0.001	1.30 (1.04 to 1.62)	0.019	0.72 (0.59 to 0.88)	0.001
Significant stress about becoming seriously ill from COVID-19: no	37.9 (36.7 to 39.2)	–	–	–	–	–	–	–	–	–	–
Yes	53.2 (51.2 to 55.2)	1.86 (1.69 to 2.05)	<0.001	1.84 (1.66 to 2.04)	<0.001	1.66 (1.35 to 2.03)	<0.001	2.35 (2.02 to 2.73)	<0.001	1.48 (1.28 to 1.71)	<0.001
Survey date	–	1.03 (1.02 to 1.03)	<0.001	1.03 (1.02 to 1.03)	<0.001	1.00 (0.99 to 1.01)	0.524	–	–	–	–

All data are weighted to match the UK adult population on sex, age, ethnicity, education and country of living. ORs reflect the odds of reporting smoking more than usual compared with smoking about the same amount as usual.

\*Bivariate (unadjusted) model.

†Multivariable model fully adjusted for all variables in the table.

‡Interaction between post-16 qualifications and each potential correlate added to multivariable model in turn. Key worker status was excluded from all interaction models with the exception of the interaction between post-16 qualifications and key worker status.

CPD, cigarettes per day; OR<sub>adj</sub>, adjusted OR.

difference by smoking status in those with post-16 qualifications. It should be noted that the low prevalence of confirmed cases (0.3%) resulted in wide confidence intervals. Nonetheless, our data provide no evidence to support a protective effect of smoking, in contrast with data from several countries documenting substantially lower smoking prevalence among hospitalised patients with COVID-19 than would be expected based on population smoking prevalence.<sup>4 13 29</sup>

There was no significant difference between current smokers and never smokers when confirmed cases were combined with

suspected cases of COVID-19, with higher raw prevalence among current smokers accounted for by socio-demographic characteristics, comorbid health conditions and anxiety disorders. However, former smokers with post-16 qualifications had 30% higher odds of confirmed/suspected COVID-19 even after full adjustment for covariates. It is possible that this association was driven by high rates of smoking cessation following the onset of COVID-19 symptoms (ie, reverse causation).<sup>4 39</sup> In tentative support of this theory, our analyses showed smokers with confirmed/suspected COVID-19 had twice the odds of



reporting smoking less than usual in the past week than those without COVID-19. Data from a hospital in France also indicate that while prevalence of current smoking was lower in hospitalised COVID-19 patients than the general population, prevalence of former smoking was much higher and prevalence of never smoking was similar.<sup>40</sup>

It has been theorised that there may be a potential protective effect of smoking on COVID-19 outcomes, possibly via interaction of nicotine with the renin–angiotensin system or effects of nicotine on the immune system.<sup>29 41–43</sup> However, the present results suggest that protection would need to be conferred independently of infection risk. Alternatively, there are several other explanations for the low smoking rates among hospitalised patients. Smokers quitting post-symptom onset—particularly among those with symptoms severe enough to warrant hospital treatment—may inflate the proportion of former smokers relative to current smokers. Recording smoking status is not likely to be high priority in acute clinical settings stretched to capacity in the midst of a pandemic, so prevalence of current smoking may be underestimated in hospital records or former smoking conflated with never smoking. Self-selection bias may also be present, with smokers less likely to present to hospital because they lack funds to pay for medical care<sup>2</sup> or are more likely to suffer fatal complications in the community. As further population-based data become available, we will gain a clearer picture of true differences in infection rates between current, former and never smokers. The Smoking Toolkit Study<sup>44</sup>, which surveys a different representative sample of adults in England each month, has begun to collect data on COVID-19 infection which will allow more detailed assessment of associations between smoking and COVID-19 in the near future. Any evidence of apparent protective effects of smoking should be interpreted cautiously with an awareness that it could encourage a surge in initiation of or relapse to smoking among never/ex-smokers looking to reduce their risk of COVID-19, the negative public health impact of which could far outweigh any purported benefit for COVID-19 outcomes.

Beyond differences in the odds of COVID-19 infection, we also observed associations between smoking status and other COVID-19 relevant variables. Adherence to recommendations from authorities to prevent the spread of COVID-19 was generally high (96.3%), but current smokers had lower odds of reporting adherence than never smokers. This discrepancy was more pronounced among smokers with post-16 qualifications, although absolute rates of adherence were higher in current smokers with post-16 qualifications (95.6%) than never smokers with no post-16 qualifications (94.5%). Despite being less likely to adhere to protective behaviours, current and former smokers were significantly more likely to report worry or significant stress about catching or becoming seriously ill from COVID-19. It should be noted that in the absence of a global pandemic, research has consistently found that smokers report higher levels of stress compared with former and never smokers<sup>22</sup> and are less adherent to medical advice,<sup>45 46</sup> so our findings do not present a substantial deviation from what one might usually expect. However, this apparent contradiction between motivation and behaviour may reflect inequality in the opportunity or ability to adhere to guidelines.<sup>32</sup> For some smokers with post-16 qualifications, increased worry or stress may have translated to their increased efforts to cut down cigarette consumption, but for others with and without post-16 qualifications it was associated with smoking more, possibly in an effort to reduce or cope with stress.<sup>21–23 47</sup> Further evidence on smoking potentially being used as a maladaptive coping mechanism by those

with no post-16 qualifications is apparent in the data linking confirmed/suspected COVID-19 with changes in smoking: while COVID-19 cases had twice the odds of reporting reduced smoking relative to those without suspected COVID-19, those with no post-16 qualifications also had significantly increased odds of reporting smoking more than usual (an association not seen in smokers with post-16 qualifications). Among the current smokers we surveyed, a considerably higher proportion reported a recent increase in smoking (42.0%) than reported smoking less (13.4%). Reduced smoking was more common among those with (16.7%) than without post-16 qualifications (9.8%). These findings emphasise the need for continued investment in tobacco control activity and cessation support during the pandemic. Existing tobacco control measures have been very effective in reducing smoking prevalence in the UK over the last 20 years,<sup>48</sup> and to achieve the government's ambition to be smoke-free by 2030<sup>49</sup> it is important to continue to invest in this approach at a time when there are likely to be severe budget pressures and competing priorities. Our findings also highlight the need for focused effort to target disadvantaged smokers. Correcting the common misperception that smoking is effective in relieving stress could help to combat an exacerbation in smoking inequalities during the COVID-19 pandemic.<sup>47</sup> Tailoring interventions to address needs specific to disadvantaged smokers (eg, financial stress, absence of social support, insufficient self-efficacy or poor understanding of tobacco harms<sup>2</sup>) could also reduce inequalities. Existing research shows that tailored interventions and messages to date have had little success in this area, but there is potential to achieve equity-positive smoking cessation outcomes through improvements in tailored intervention development.<sup>50</sup>

This study had a number of strengths. The sample size was much larger than any other study of smoking and COVID-19 and a broad range of data were collected, permitting the first analysis of smoking and COVID-19 infection in the population with adjustment for important confounding variables. The collection of data in real time while the pandemic is at its (anticipated) peak is also an advantage, minimising recall bias that is likely to be present in future studies that collect data retrospectively. There were also several limitations. First, rates of COVID-19 testing at the time the data were collected were lower in the UK than in many other countries, suppressing numbers of confirmed COVID-19 cases; but this would only affect our results if testing rates differed by smoking status. Second, recency of cessation among former smokers was not assessed, so this group ranges from those who stopped smoking decades previously to those who quit in the days prior to the survey. Future studies should ask former smokers about time since quitting to better evaluate whether abrupt quitting following the onset of COVID-19 symptoms may contribute to lower rates of smoking recorded among hospitalised patients.<sup>4 13 29</sup> Third, the measure of smoking less underestimates those making reductions in their smoking because those who quit altogether in the last week are not included. Fourth, the measure of changes in smoking was not anchored to the pandemic (ie, did not ask about changes since COVID-19 started to affect the respondent's life), so may not be sensitive to detect early changes in smoking in response to the pandemic. We observed associations between the date participants completed the survey and the odds of smoking less (which decreased over time) and smoking more (increased over time), which suggests that changes in smoking behaviour in reaction to the pandemic may be changing as time passes, possibly in response to conflicting messages on smoking and COVID-19 risk.<sup>27 28</sup> Longitudinal data tracking changes over time within individuals would be useful in determining trajectories of

smoking behaviour as the pandemic continues and evaluating the extent to which any initial changes are maintained over time. Fifth, while COVID-19 mortality in the UK is disproportionately high among black and minority ethnic groups,<sup>51</sup> in particular those of South Asian heritage, our analysis did not disaggregate ethnic minority groups. Further research could explore whether associations between smoking and COVID-19 outcomes vary by ethnicity. Sixth, while the recruitment methods used were effective in achieving a large sample, the unweighted sample was not representative of the UK adult population, and the issue of self-selection (ie, certain types of people being more likely than others to respond to a survey of this kind) introduces a systematic bias. However, we applied weights to match our data to key socio-demographic characteristics of the population, which resulted in an estimate of current smoking prevalence closely aligned with official estimates.<sup>52</sup> Finally, while the sample was weighted to be representative of the UK adult population, results cannot be presumed to generalise to other countries with different demographic profiles or healthcare systems.

## CONCLUSIONS

When assessed by self-report in a population sample, current smoking was independently associated with increased odds of confirmed COVID-19 infection. There were socio-economic disparities, with the association only apparent among those without post-16 qualifications. Smokers reported lower adherence to guidelines despite being more worried than non-smokers about catching or becoming seriously ill from COVID-19. Many smokers reported smoking more than usual, and COVID-19-related stress was associated with increased smoking, particularly among those with no post-16 qualifications.

### What this paper adds

- ▶ Former or current smoking can increase the risk of respiratory viral and bacterial infections and is associated with worse outcomes for those infected.
- ▶ However, data from several countries indicate that rates of current smoking are substantially lower among hospitalised COVID-19 patients than would be expected based on population-level smoking prevalence.
- ▶ Data from a large population-based sample of adults in the UK conflict with the hypothesis that smoking is protective against COVID-19 infection; rather, we found that current smoking was independently associated with increased odds of self-reported confirmed COVID-19 infection after adjusting for relevant confounders.
- ▶ Socio-economic disparities were evident, with the association between smoking and confirmed COVID-19 only apparent among those without post-16 qualifications.
- ▶ Smokers reported lower adherence to guidelines despite being more worried than non-smokers about catching or becoming seriously ill from COVID-19.

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**Contributors** SJ, JB, LS, AS and DF conceived and designed the study. AS and DF collected the data. SEJ analysed the data and wrote the first draft. JB, LS, AS and DF provided critical revisions. All authors read and approved the submitted manuscript.

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**Competing interests** JB has received unrestricted research funding from Pfizer who manufacture smoking cessation medications. LS has received honoraria for talks, an unrestricted research grant and travel expenses to attend meetings and workshops from Pfizer, and has acted as paid reviewer for grant awarding bodies and as a paid consultant for healthcare companies. All authors declare no financial links with tobacco companies or e-cigarette manufacturers or their representatives.

**Patient consent for publication** Not required.

**Ethics approval** Ethical approval for the COVID-19 Social Study was granted by the UCL Ethics Committee. All participants provided fully informed consent. The study is GDPR compliant.

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**Data availability statement** No data are available. Anonymous data will be made available following the end of the UK pandemic.

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