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Awareness, Attitudes and Actions of UK adults at high risk of severe illness from COVID-19

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Key points

What is already known about this topic?

- During the COVID-19 lockdown there was no research evidence published on the impact of the pandemic on people at high risk of severe illness and death from COVID-19 infection.
- Since then, there has been a paucity of evidence published examining this vulnerable population, with no evidence of how this has impacted access to healthcare and use of technology, with little evidence on mental health and lifestyle behaviours.
- To date, there has been no research using Artificial Intelligence to gain greater insights to improve our understanding of how people are responding to the pandemic.

What this study adds

- This original research provides new insights into the impact of the COVID-19 lockdown on awareness, attitudes and actions of people identified as at high risk of severe illness as identified by the UK Government.
- Our novel insights highlight the impact that the COVID-19 lockdown has had on access to healthcare, mental health and lifestyle behaviours.
- We have also used an innovative Artificial Intelligence tool to further our understanding on the impact that COVID-19 lockdown has had on this vulnerable population.

Abstract

Objectives

This study explored the impact of COVID-19 on people identified as at high risk of severe illness by UK Government, and in particular, the impact of lockdown on access to healthcare, medications and use of technological platforms.

Design

Online survey methodology

Setting

UK

Participants

1038 UK adults were recruited who were either identified by UK Government as at high risk of severe illness from COVID-19 or self-identified as at high risk with acute or other chronic health conditions not included in the UK Government list. Participants were recruited through social media advertisements, health charities and patient organisations.

Main outcomes measures

The Awareness, Attitudes and Actions survey which explores the impact of COVID-19, on including access to healthcare, use of technology for health condition management, mental health, depression, wellbeing, and lifestyle behaviours.

Results

Nearly half of the sample reported that their mental health had worsened during the COVID-19 lockdown. Management of health conditions changed including access to medications and delayed surgery, with nearly half of the sample using telephone care. Artificial Intelligence identified that participants in the negative cluster had higher neuroticism, insecurity and negative sentiment. Participants in this cluster reported more negative impacts on lifestyle behaviours, higher depression and lower wellbeing, alongside lower satisfaction with platforms to deliver healthcare.

Conclusions

This study provides novel evidence of the impact of COVID-19 on people identified as at high risk of severe illness. These findings should be considered by policymakers and healthcare professionals to avoid unintended consequences of continued restrictions and future pandemic responses.

Keywords: COVID-19; Lockdown; Attitudes; Behaviours; Artificial Intelligence; High Risk

Article Summary

Strengths and limitations of this study

- This original research provides new insights into the impact of the COVID-19 lockdown on awareness, attitudes and actions of people identified as at high risk of severe illness as identified by the UK Government.
- Our novel insights highlight the impact that the COVID-19 lockdown has had on access to healthcare, mental health and lifestyle behaviours.
- We have also used an innovative Artificial Intelligence tool to further our understanding on the impact that COVID-19 lockdown has had on this vulnerable population.
- The study provides a cross-sectional analysis, and as such informs about the COVID-19 lockdown period. Nevertheless, this study provides much needed insights about a subsection of the population who have been subject to greater restrictions and as the findings demonstrate, have been impacted in terms of access to healthcare, lifestyle behaviours, and mental health.
- Given the reported increased risk for people from black and minority ethnic (BAME) backgrounds, the low recruitment of people from BAME backgrounds means that comparison of the impact on people of different ethnic backgrounds was not possible.

Introduction

On 11th March 2020, the World Health Organization (WHO) announced that coronavirus disease 2019 (COVID-19) was a global pandemic.[1] In response, governments across the world took a range of actions to help reduce its spread including the development of legislation and policies. The majority of countries also imposed a period of a variable degree of "lockdown".

Beyond the population level lockdown, further guidance was issued for people identified as at a higher risk of morbidity and mortality from COVID-19. This 'high risk' grouping was typically comprised of people living with chronic health conditions such as diabetes, heart disease or acquired immunodeficiency syndrome (AIDS), as well as people who are pregnant or aged 60 years or over. For some 2.2 million people, this additional guidance included the need to 'shield' for people identified as the most vulnerable to COVID-19 infection and illness.[2] However, unintended consequences have been noted in emerging evidence, including accentuated feelings of social isolation, self-stigma and loneliness.[3,4] Thus far, the impact of lockdown and associated restrictions have primarily been reported within the general population, however, given the greater restrictions on people identified as at higher risk including a longer duration of lockdown and need to 'shield' or self-isolate, the potential impact of COVID-19 is likely to have been greater on this sub-group of the population. Recently, the Office of National Statistics[2] reported that a high proportion of people identified as being at high risk self-reported that they followed the shielding guidance completely during lockdown.

There is a pressing need to investigate the impact of lockdown and shielding on people identified as at higher risk of severe illness from COVID-19. We defined impact as changes as a consequence of shielding to different aspects of everyday life, including actions and attitudes, healthcare delivery, mental health and wellbeing, lifestyle behaviours, and social interaction. Some of these aspects such as access to healthcare delivery, have not been investigated for this population previously. In terms of attitudes and actions, emerging evidence from the US suggests that despite concerns about infection, there was a lack of critical knowledge and limited changes to the plans or routines for people identified as at high risk of severe illness from COVID-19 infection.[5]

Therefore, to understand the impact, and contribute evidence for healthcare policy and networks to support people effectively and address unmet needs, we have delivered a time-sensitive study of the impact the COVID-19 pandemic and the associated UK Government guidance has had on people identified as at high risk of severe illness from COVID-19.

Methods

Design

Between 15 March and 31 May 2020, the Awareness, Attitudes and Actions (AAA) survey was disseminated via UK charities, healthcare and relevant higher education email distribution lists, social media, and website advertisement. The survey was hosted by Qualtrics LLC; a third-party online survey administration platform. Inclusion criteria was being aged ≥ 18 years with one or more of the factors for high risk of severe illness from COVID-19 identified by the UK Government or self-identified as at high risk due to an acute or chronic health condition not listed.[6]

AAA Survey

An online survey was developed to explore the AAA of UK adults identified as at high risk of severe illness from COVID-19 by the UK Government or self-identified as high risk. The survey comprised of seven sections utilising a combination of closed and open questions:

1) participant demographics,

2) awareness, attitudes and actions relating to COVID-19 including whether participants had been diagnosed with COVID-19, experienced symptoms, and took actions to reduce infection and spread,

3) impact of COVID-19 on management of health conditions and use of technology,

4) impact on mental health and wellbeing, and depression including the Warwick-Edinburgh Mental Well-being Scale (WEMWBS)[7] and Patient Health Questionnaire (PHQ-9)[8]

5) lifestyle related behaviours; diet, alcohol intake, physical activity type and amount, sleep quality and amount, smoking behaviour, e-cigarette use and recreational drug use,

6) interaction with others regarding changes in other people's behaviour towards participants and feeling stigmatised and discriminated,

7) additional comments.

Please see Supplementary Table 1 for an overview of the online survey.

Patient and Public Involvement

Patients and Public were involved from the outset and throughout the study, including the design, conducting, choice, development and piloting of the AAA survey, recruitment and reporting of the study.

Data analysis

Data from this survey produced quantitative and text data from validated questionnaires, and closed and open ended questions.

For the statistical analysis, we fit generalised linear models of the data, and used logistic regression to model 1) actions taken to mitigate the risk of contracting COVID-19, 2) the impact of COVID-19 on the management of health conditions, and 3) the technology platforms used to receive healthcare. Responses regarding the impact of COVID-19 on lifestyle related behaviours were modelled using multinomial and Adjacent Category Logit models assuming proportional odds. Odds ratios and p-values were reported for logistic, multinomial, and Adjacent Category Logit models. All statistical analyses were performed using the tidyverse (version 1.3.0)[9] and VGAM (version 1.1-2)[10] packages in R (version 3.6.2).[11] Statistical significance was defined at p-value <0.05.

Text data was collected across 17 open-ended questions which were distributed throughout the survey sections. The language sample for each participant was processed to derive sentiment scores and personality scores. VADER Sentiment Analysis tool[12] was used to obtain sentiment scores (positive, neutral, negative, and compound sentiment). Personality scores were obtained using proprietary software by Scaled Insights. The software takes as input a language sample and produces 114 personality features. Following this, the 118 features (114 personality, 4 sentiment) were used as input into the multiple machine learning models, which were used in two settings: unsupervised (clustering) and supervised (classification or regression).

For further information the data analysis approach, see supplementary materials.

Results

Descriptive Statistics

The original sample comprised 1038 UK adults. Six participants were removed for either reporting being aged less than 18 years old or an infeasible age. Of the remaining sample, 624 were female, 402 male, 4 reported other and 2 preferred not to say. Due to small numbers, participants who responded 'other' or 'prefer not to say' when asked about their gender were removed. Characteristics of the 1026 participants in the final analysis are presented in Table 1. Six hundred and twenty four (61%) participants were female; 979 (95.4%) identified as White-British, Irish, other; with a mean age of 54.6 ± 14.9 years and mean BMI of 28.8 ± 8.1 kg/m^2. Two hundred and nineteen participants (21.3%) reported having three or more indicators for high risk of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition. The 12 high risk indicators are summarised in Table 1. Notably over half of the sample (n=528; 52.4%) reported that they were living with diabetes (either Type 1 or Type 2). Participants reported high concern about infection, illness and death, spread to others, and access to healthcare across all higher risk groups

(see supplementary materials for statistical analysis of COVID-19 concerns, risk mitigating behaviour and interactions with others).

Table 1. Demographics characteristics of participants in the AAA survey.

Participant Characteristics[1]	
Age[2] mean (SD; years)	54.6 ±14.9
BMI[2] mean (SD; kg/m²; n = 1003)	28.8 ± 8.1
Index of Multiple Deprivation[2] mean (SD, n = 759)	5.33 ± 2.7
Gender n (%)	
Male	402 (39.2%)
Female	624 (60.8%)
Ethnicity n (%)	
White - British, Irish, other	979 (95.4%)
Black/Black British - Caribbean, African, other	8 (0.8%)
Chinese/Chinese British	2 (0.2%)
Middle Eastern/Middle Eastern British - Arab, Turkish, other	2 (0.2%)
Mixed race -other	5 (0.5%)
Mixed race - White and Black/Black British	3 (0.3%)
Other ethnic groups	7 (0.7%)
Health or social care worker (n=1025) n (%)	
Yes	150 (14.6%)
No	875 (85.3%)
Job requires contact with COVID-19 patients (n=144) n (%)	
Yes	39 (3.8%)
No	105 (10.2%)
Diabetes n (%)	
Yes	538 (52.4%)
No	488 (47.6%)
BMI ≥ 40 kg/m² n (%)	
Yes	142 (13.8%)
No	884 (86.2%)
Chronic Respiratory Disease n (%)	
Yes	179 (17.4%)
No	847 (82.6%)
Chronic Heart Disease n (%)	
Yes	132 (12.9%)

No	894 (87.1%)
Chronic Kidney Disease n (%)	
Yes	147 (14.3%)
No	879 (85.7%)
Chronic Liver Disease n (%)	
Yes	49 (4.8%)
No	977 (95.2%)
Chronic Neurological Conditions n (%)	
Yes	35 (3.4%)
No	991 (96.6%)
Spleen problems n (%)	
Yes	16 (1.6%)
No	1010 (98.4%)
Weakened immune system n (%)	
Yes	159 (15.5%)
No	867 (84.5%)
Aged > 70 years n (%)	
Yes	178 (17.3%)
No	848 (82.7%)
Pregnant n (%)	
Yes	21 (2.0%)
No	1005 (98.0%)
Other risk factors* n (%)	
Yes	303 (29.5%)
No	723 (70.5%)
Number of high-risk groups n (%)	
1	471 (45.9%)
2	336 (32.7%)
3+	219 (21.3%)

1.n = 1026 except where otherwise specified; 2. Mean and standard deviation; SD=standard deviation; N=number; %=percentage

** Short or long term health conditions e.g. mental health*

Impact of COVID-19 on Lifestyle Related Behaviours

Supplementary Figures 7-12 display the impact of COVID-19 on lifestyle related behaviours for each high-risk indicator of severe illness from COVID-19. Generally, across all high-risk indicators a high proportion of participants indicated little to moderate change in diet, no change in alcohol consumption, less or much less physical activity, no change in the type of physical activity, and a great deal of change in shopping habits. Change in quality and amount of sleep was variable across risk groups.

Further analysis of lifestyle related behaviours compared to prior to COVID-19 lockdown suggested that women and participants with CKD were more likely to report greater change in their shopping habits (OR 1.18 and 1.62; $p = 0.030$ and 0.047, respectively). Older participants were less likely to report greater changes in their diet (OR 0.99 per additional year of age; $p = 0.013$), whereas participants with higher BMI and women reported greater change in their diet (OR 1.02 per additional kg/m^2 and OR 1.19; $p = 0.008$ and 0.027, respectively). Furthermore, participants with either chronic respiratory disease, CKD, weakened immune systems, or a higher BMI were less likely to report greater change in the amount of physical activity they engaged in (OR 0.70, 0.65, 0.54, and 0.98 per additional kg/m^2; $p = 0.035$, 0.029, 0.001, 0.009 respectively). In addition, though older participants were less likely to report a change in the type of physical activity they engaged in (OR 0.98 per additional year of age; $p = 0.020$), participants with weakened immune systems were more likely to indicate change in type of physical activity (OR 3.17; $p = 0.012$).

Impact of COVID-19 on Mental Health, Wellbeing & Depression

Four hundred and forty-five (49.8%) participants indicated that their self-reported mental health was about the same compared to prior to COVID-19 lockdown (Table 2). Women were more likely to report worsening of their mental health (OR 2.09; $p = 0.044$) whereas participants > 70 years old were less likely to report worsening of their mental health (OR 0.16; $p = 0.032$). Specifically, for each additional year in age, participants were more likely to report that their mental health had been impacted less negatively during COVID-19 lockdown (OR 1.04, $p = 0.008$).

For all participants, mean wellbeing (WEMWBS) was 44.9 ± 11.3 – lower than the population wellbeing norm – and participants on average reported mild depression (PHQ-9) of 7.53 ± 6.11.

Wellbeing

Participants who were older reported statistically higher wellbeing (WEMWBS). For each additional year, wellbeing increased by 0.25 ($p < 0.001$). By contrast, women reported wellbeing that was 1.75 lower than those of men ($p = 0.048$).

Depression

Pregnant women and older participants reported lower depression (PHQ-9), with pregnant women reporting scores 4.41 points lower than women who were not pregnant ($p = 0.013$), whereas for each additional year in age there was a reduction in depression by 0.14 points ($p < 0.001$). In addition, participants' weight impacted depression, with each unit increase in BMI, there was an increase of depression by 0.09; gender impacted depression with women reporting an average depression score that was 1.41 points higher than men; and participants with three or more indicators of high-risk reported greater depression with a mean increase of 4.78 compared to those with only one high-risk indicator ($p < 0.05$ for all factors).

Table 2. Summary of Warwick-Edinburgh Mental Well-being Scale (WEMWBS) and Patient Health Questionnaire (PHQ-9) scores and changes in self-reported mental health compared to pre-COVID-19.

Participant response	
WEMWBS[1] (n = 922)	44.9 ± 11.3
PHQ-9[1] (n = 927)	7.53 ± 6.11
Mental health changes since COVID-19 (n = 893) n (%)	
Worse	397 (44.5%)
About the same	445 (49.8%)
Better	51 (5.7%)

1. Mean and standard deviation

Impact on Management of Health Conditions and Use of Technology

The impact of COVID-19 on the delivery of care for those with high-risk indicators is summarised in Table 3. Six hundred and eighty-two (66.5%) participants indicated changes to their regular healthcare appointments, while 199 (19.4%) participants indicated that there were no changes to regular healthcare support during the COVID-19 lockdown.

Participants with chronic liver disease were more likely to report change to management of health conditions compared to prior to the COVID-19 lockdown (OR 3.15, p = 0.014). Participants with either diabetes, weakened immune systems or liver disease were more likely to report change to appointments (OR 2.40, 2.90, 3.48, ; p = 0.036, 0.028, and 0.036, respectively); whereas participants with spleen problems had a greater likelihood of reporting changes to their medications (OR 7.10; p = 0.026). Older participants were more likely to report changes to elective surgery and their clinician (OR 1.03 and 1.03 for each additional year in age; p = 0.016 and 0.005, respectively). However, participants who were > 70 years old were less likely to report other changes to regular healthcare support beyond those specified in the survey (OR 0.24; p = 0.042).

Four hundred and sixty-seven (45.5%) participants indicated that their care changed to using telephone support, while 321 (31.3%) reported that they did not use any of the platforms specified in the survey (Table 3). Participants > 70 years were less likely to use the telephone to receive care (OR 0.46 and p = 0.048). Participants living with diabetes or with liver disease were more likely to use social media (OR 2.82 and 5.91; p = 0.050 and 0.006, respectively). In addition, participants with liver disease were more likely to report using virtual consultation platforms; as were participants with neurological conditions (OR 4.39 and 3.56; p = 0.009 and 0.031, respectively). By contrast, women were less likely to use virtual consultation platforms compared to men (OR 0.56; p = 0.041). Participants with neurological conditions were more likely to indicate that they used email to receive care, while those >70 years were less likely to use emails (OR 2.88 and 0.98 for each additional year in age; p = 0.048 and 0.030, respectively). When asked whether participants were satisfied with the support platforms and with the information received during the COVID-19 lockdown, the majority reported either being somewhat or extremely satisfied (40.3%, 39.6%, respectively; Table 3).

Four hundred and sixty-six (45.4%) participants indicated that they would welcome continued use of the platforms used during COVID-19 lockdown. When comparing gender, women were less satisfied with the platform they used (OR 0.84; p = 0.034); however, the level of satisfaction with using the information provided through the platform was similar across all groups. Age appeared to impact whether participants wished to continue to use the healthcare platform after COVID-19 lockdown (OR 1.03 for each additional year of age, p = 0.004). While those with greater social deprivation appeared to be unsure about continuing to use the platform (OR 1.10 for each increased in IMD, p = 0.011).

Table 3. Summary of participant changes to clinical management during COVID-19 lockdown.

	Percent Identifying (n = 1026)
Changes to regular healthcare support?* n (%)	
Appointments	682 (66.5%)
Medication	292 (28.5%)
Elective surgery	122 (11.9%)
Communication platform	183 (17.8%)
Clinician	196 (19.1%)
Other	83 (8.1%)
No change	199 (19.4%)
Platforms used to receive care n (%)	
Social media	63 (6.1%)
Mobile phone app	97 (9.5%)
Email	146 (14.2%)
Telephone	467 (45.5%)
Virtual consultation	90 (8.8%)
Other	46 (4.5%)
No platforms	321 (31.3%)
Face to face care	35 (3.4%)
How satisfied are you with the platforms? (n =860) n (%)	
Extremely dissatisfied	51 (5.0%)
Somewhat dissatisfied	92 (9.0%)
Neither satisfied nor dissatisfied	303 (29.5%)
Somewhat satisfied	234 (22.8%)
Extremely satisfied	180 (17.5%)
How satisfied are you with using information received via platforms? (n=867) n (%)	
Extremely dissatisfied	41 (4.0%)
Somewhat dissatisfied	114 (11.1%)
Neither satisfied nor dissatisfied	306 (29.8%)
Somewhat satisfied	255 (24.9%)
Extremely satisfied	151 (14.7%)

Use platforms after COVID-19? (n = 875) n (%)	
No	154 (15.0%)
No, but would welcome other platforms	81 (7.9%)
Not sure, I need more time to use them	174 (17.0%)
Yes	466 (45.4%)

1.n = 1026 except where otherwise specified.

** Changed type or frequency of support*

Exploration and Prediction using Text-Derived Features

Clustering

The personality and sentiment features were used as input to a clustering algorithm (*k*-means) in order to separate survey participants into groups. As the *k*-means algorithm requires to specify the number of clusters, we first experimented with different values of *k* (between 2 and 10). We used two heuristics (sum of squared distance and an elbow plot, and degree of separation between clusters and a silhouette plot) to evaluate which *k* value resulted in most coherent and disparate clusters. According to both heuristics, two clusters resulted in the best differentiation: the first cluster with 335 participants and second with 301 participants (see Figure 3 for a visualisation of the clusters). Table 4 lists the ten most differentiating features and the cluster centroid values. The first cluster had a negative compound sentiment score and higher values for neuroticism, insecurity, 'Type A' personality (i.e. more competitive and ambitious), aggression, stress, and coldness, while the second cluster had a positive compound sentiment score and higher values for dutifulness, cooperation, and social skills. From here on in, the first cluster is referred to as the Negative Cluster, and the second cluster as the Positive Cluster.

Figure 3. Visualisation of clusters using Principal Component Analysis (PCA).

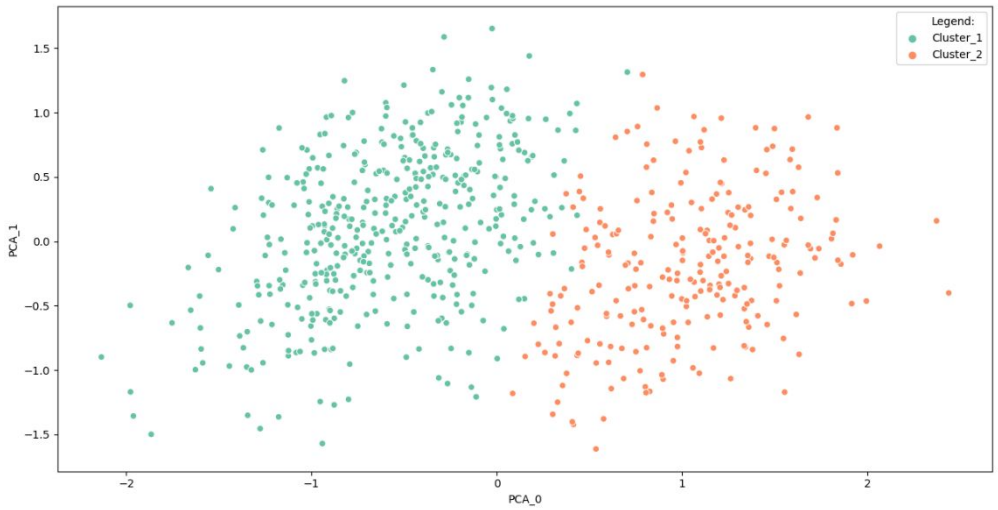

Table 4. Cluster centroids for the ten features with greatest absolute value differences between clusters. All scores are within [0, 1] range with the exception of compound sentiment score which uses [-1, 1] range.

Feature	Negative Cluster	Positive Cluster
Sentiment (compound score)	-0.75	0.62
Neurotic	0.85	0.61
Insecure	0.73	0.50
'Type A'	0.34	0.15
Aggressive	0.53	0.34
Dutiful	0.50	0.69
Cooperative	0.58	0.75
Stressed	0.81	0.64
Cold	0.62	0.46
Social skills	0.13	0.29

The study investigated whether the two clusters had differed in their responses (Table 5). There were no significant differences in how the two clusters took mitigating actions to avoid infection from COVID-19. However, participants in the Negative Cluster rated their concerns significantly higher than the Positive Cluster in five out of six cases; with the only concern showing no difference was about spreading COVID-19 to others. In terms of lifestyle behaviours, Negative Cluster reported greater impact on diet and sleep, and less physical activity than before COVID-19 lockdown. Negative Cluster also scored significantly worse for depression and psychological wellbeing. In terms of changes to healthcare support, Negative Cluster reported more often change to their appointments and using telephone appointments, while Positive Cluster reported no change to healthcare support, and lower satisfaction with platforms used to receive care and with the information and resources presented within them.

Table 5. Comparison between clusters of actions, concerns, lifestyle behaviours, depression and wellbeing scores, impact on health management, and use of platforms for health management. Numeric variables were compared using *t*-test, binary variables were compared using proportions *z*-test. Test results and p-values were rounded to two decimal places.

		Negative Cluster	Positive Cluster	Test result	*p*-value
Actions	Social distancing	303	188	0.83	0.41
	Self-isolation	202	104	-1.72	0.09
	Wearing protective apparel	127	81	0.55	0.58
	Online shopping	187	117	0.53	0.60
	Shielding	109	64	-0.14	0.89
	All above	51	26	-0.71	0.48
Concerns	Becoming infected	7.72	7.05	-3.29	0
	Severe illness or death	7.88	7.25	-2.82	0.01
	Spreading COVID-19 to others	7.12	6.76	-1.44	0.15
	Access to healthcare	6.06	4.97	-4.28	0
	Appropriate care if infected	6.88	5.76	-4.22	0
	Worse care compared to low-risk individuals	6.02	5.05	-3.23	0
Lifestyle	Shopping	3.31	3.22	-1.16	0.25
	Diet	1.75	1.41	-3.72	0
	Alcohol consumption	0.05	0.09	0.62	0.53

	Physical activity (amount)	-0.78	-0.28	5.25	0
	Physical activity(type)	0.75	0.78	0.8	0.43
	Sleep	1.93	1.37	-5.15	0
	Smoking (indicated yes)	0.05	0.01	-2.81	0.01
	Smoking (impact)	0.15	0	-0.16	0.87
	E-cigarettes (indicated yes)	0.04	0.03	-1.14	0.25
	E-cigarettes (impact)	0.53	0.33	-0.48	0.64
	Recreational drugs (indicated yes)	0.02	0.02	-0.07	0.94
	Recreational drugs (impact)	0.29	0	-0.37	0.72
Depression	PHQ-9 score	9.16	5.49	-7.63	0
Wellbeing	WEMWBS score	42.23	49.36	8.29	0
Change to healthcare support	General management	398	237	-1.29	0.2
	Appointments	311	161	-2.93	0
	Medication	146	75	-1.33	0.19
	Elective surgery	50	36	0.91	0.36
	Communications platform	84	44	-0.8	0.43
	Clinician	91	50	-0.55	0.59
	Other	50	21	-1.45	0.15
	No change	55	60	3.61	0
Platforms used to receive care	Social media	23	19	1.08	0.28
	Mobile phone app	34	34	2.27	0.02
	Email	60	35	-0.13	0.90
	Telephone	219	111	-2.05	0.04
	Virtual consultation	43	23	-0.46	0.65
	Other	18	18	1.61	0.11
	No new platforms	118	79	0.94	0.35
	Still face-to-face	18	9	-0.45	0.65
	Satisfied with platforms	0.39	0.7	3.32	0
	Satisfied with information	0.33	0.64	3.46	0
	Continue using in the future	186	124	1.31	0.19

Discussion

This study provides the essential evidence to start addressing the dearth of detailed information regarding the impact of COVID-19 on the 2.2 million people identified at higher risk of severe illness from COVID-19 and advised to shield during lockdown.

During the COVID-19 lockdown, the management of health conditions amongst people identified as at high risk of severe illness changed. Nearly half of the sample reported using telephone care, with people aged 70 years or over less likely to use telephone care. People living with diabetes and liver disease reported the greatest use of social media, while people living with chronic liver disease and neurological conditions were most likely to use virtual consultations. The majority of participants reported that they were satisfied with the new platforms and the information provided to manage their health conditions, and importantly would welcome continued use. Notably, people living in higher deprivation reported greater uncertainty about continued use which may identify concerns regarding internet poverty and inability to access digital care within this community. It is imperative that new technologies for supporting people living with health conditions are accessible for all, and does not disproportionately impact subgroups of the population and potentially widen health inequalities. Indeed, the higher prevalence of chronic health conditions amongst people living in more deprived communities, and the disproportionate impact of COVID-19 infection on people living in poorer communities, highlights the

need to address these concerns or uncertainty, given the likelihood of continued short- and long-term use of new technologies to support patient care.

Emerging evidence has demonstrated that the COVID-19 lockdown and restrictions have impacted lifestyle behaviours such as decrease in physical activity and sleep deprivation, although this has predominantly focussed on the general population.[13,14] Current study findings provide novel evidence about the impact on people identified as at high risk of severe illness from COVID-19 infection, and thus, people who have needed to follow greater restrictions. The study findings demonstrated that whilst the type of physical activity typically did not change across the groups, the amount of physical activity decreased substantially. People with a higher BMI reported reductions in physical activity amount, as well as increased changes to their diet, which may have placed this group at greater risk of weight gain and worsening health. Reductions in physical activity were also observed for people with chronic respiratory disease, CKD and weakened immune system, which would be consistent with those who may have avoided venturing outside due to risk of COVID-19 infection. Across all groups, people reported that their sleep quality and amount was impacted.

As the pandemic has progressed, a greater emphasis has been placed on the impact that lockdown, restrictions on daily life including meeting with significant others, the loss of loved ones, the loss of work and others have had on mental health. This study demonstrates that for the majority of the sample, the pandemic has led to worse mental health, with only 6% reporting an improvement. This was greater than the 35% of vulnerable people reporting worse mental health from the Office of National Statistics.[2] This may have been due to population differences but overall represents a consistent message that lockdown had a negative impact on people's self-reported mental health. In alignment, mean wellbeing was lower than the national average,[15] and depression was higher than that found in a general population sample from the COVID-19 Social Study.[16] The statistical analysis demonstrates that young women who are at risk of severe illness from COVID-19 report that their mental health has been most negatively impacted, have lower wellbeing and higher depression. This is consistent with other data showing that depression was higher in young people,[16] suggesting that the lockdown restrictions has more negatively impacted younger people and requires greater consideration. Moreover, people with a higher BMI or with multiple risk factors reported the highest depression, which may well be expected given the link between obesity and depression.[17] Given that this study highlights the impact of the COVID-19 pandemic on the mental health of people identified as at high risk of severe illness, policymakers, community groups, and health charities should consider how and in what ways they can best support or refer people whose mental health may have been compromised – which for many may go above and beyond their usual activities. This may involve policymakers considering how and in what ways to support in particular health charities to provide this care given economic challenges facing many during the pandemic and the reduction in access to clinical services.

Artificial Intelligence methods were applied to the data to consider how intrinsic factors, specifically personality and sentiment, derived from language samples could provide additional insights into people's actions and attitudes relating to COVID-19. Based on those intrinsic factors, the participants clustered into two groups. Crucially, the two groups differed significantly in their responses. Compared to the Positive Cluster (with higher dutifulness and cooperation scores and positive sentiment), the Negative Cluster had higher neuroticism, insecurity score and negative sentiment and reported higher levels of concern, greater negative impact on lifestyle behaviours, higher depression and lower wellbeing, alongside lower satisfaction with platforms used to deliver their healthcare during COVID-19. Furthermore, when predicting actions or attitudes for individuals, word vectors (features derived from language samples) achieved fairly good to good prediction performance (between 0.7 and 0.8 AUROC). On the other hand, personality and sentiment features were better predictors of depression and wellbeing than word vectors. Overall, current study data suggests that analysing language samples using Artificial Intelligence could yield useful insights into people's attitudes and actions relating to COVID-19 and effectively identify individuals at higher risk. Future work can explore the feasibility of using these methods as a preventative support measure, by using them within a digital environment to identify whether someone is likely to be more significantly impacted and offer them appropriate support.

This study is not without limitations. First, it provides a cross-sectional analysis, and as such informs about the COVID-19 lockdown period. Nevertheless, this study provides much needed insights about a subsection of the population who have been subject to greater restrictions and as the findings demonstrate, have been impacted in terms of access to healthcare, lifestyle behaviours, and mental health. Second, due to the recruitment methods, the sample was not totally representative, and would not have recruited people experiencing digital poverty. Finally, given the reported increased risk for people from black and minority ethnic (BAME) backgrounds, the low recruitment of people from BAME backgrounds means that comparison of the impact on people of different ethnic backgrounds was not possible.

Further research to assess the longer term impact of COVID-19 on people identified at high risk is needed. This research should provide insights into the longer term changes to healthcare access, provision and support, and where relevant, how technological platforms have facilitated continued care. This study demonstrated the adults identified as at high risk of severe illness from COVID-19 reported lower wellbeing, that their mental health had worsened and varied levels of depression. Given the continued restrictions for many people within this population subgroup, and thus the associated impact on other areas of life including employment, future research should assess the longer term impact on mental health. Indeed, it might be argued that people with mental health concerns may also be at high risk from the impact of COVID-19 and as such, appropriate measures and support made available. Finally, research is also needed to understand the impact of delayed healthcare support such as elective surgery.

Conclusions

This study provides novel insights into the awareness, attitudes and actions of UK adults identified as at high risk of severe illness from COVID-19. In particular, this study demonstrates that the pandemic has impacted people's access to healthcare support, lifestyle behaviours and mental health. Furthermore, the use of an innovative Artificial Intelligence tool has demonstrated the advanced insights that can be gleaned from patient language samples to predict behaviours and health outcomes in response to the COVID-19 pandemic. This has the potential to enable clinicians to identify people at greater risk and highlights the value of using Artificial Intelligence within healthcare, particularly during the COVID-19 pandemic.

As such, there are important implications for policy makers, healthcare and clinical practice as well as healthcare technology companies. Working with adults identified as at high risk of severe illness from COVID-19, action is needed that aims to address issues relating to access to healthcare, attitudes towards use of technological platforms and to support people's mental health. The findings demonstrate that healthcare access and support has been significantly impacted, that their lifestyle related behaviours have changed and that mental health has worsened. It is paramount to not only understand but take actions to reduce any potential unintended consequences of the restrictions placed on daily life, which may avoid exacerbating physical and mental health concerns.

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Hepatitis C Trust
Kidney Care UK
JDRF
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LIVErNORTH
Melanoma UK
MS Society
Nexus Leeds
Norfolk & Norwich Liver Group
Obesity UK
Parkinson's Society
PBC Foundation
Public Health Scotland
Research for the Future
Salford Sickle Cell Society
Terrance Higgins Trust
The Somerville Foundation
Yorkshire Cancer Community

Contributorship Statement
SWF conceived the study. SWF, AB and AT contributed to the study design and methodology. SWF was responsible for the oversight of the study. SWF, AB & AT contributed to the recruitment of participants. AP & ACJ were responsible for data analysis. All authors contributed to data interpretation, and the writing of the manuscript. All authors contributed to critical revision of the manuscript for important intellectual content and gave final approval.

Declaration of Interest
SWF & AP are employed by Scaled Insights.

Data sharing statement

De-identified participant data that underlie the results reported in this manuscript will be made available on publication and ending 5 years after publication. Proposals should be made to the corresponding author and will require a data access agreement.

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Ethical Approval

The study was granted ethical approval by the School of Psychology Research Ethics Committee at University of Leeds (REC number PSYC-28).

Patient and Public Involvement

Patients and Public were involved from the outset and throughout the study, including the design, conducting, choice, development and piloting of the AAA survey, recruitment and reporting of the study. We are very grateful for the organisations and individuals as listed in our acknowledgements section who have and continue to support this study.

A public facing report of the study will be provided to the organisations that have supported our study once the manuscript has been published, and all study participants are able to request a copy of the final report and manuscript once published.

Supplementary materials

1. Awareness, Attitudes and Actions (AAA) survey
2. Supplementary data analysis
3. Stats tables and figures
4. AI prediction models

Awareness, Attitudes and Actions (AAA) survey

Survey questions	Response categories/instruction
Section A: demographics	
Does any of the following apply to you? (select all that apply)	Diabetes (Type 1 or 2) A body mass index (BMI) of 40 or above Chronic (long-term) respiratory diseases, such as asthma, chronic obstructive pulmonary disease (COPD), emphysema or bronchitis Chronic heart disease, such as heart failure Chronic kidney disease Chronic liver disease, such as hepatitis Chronic neurological conditions, such as Parkinson's disease, motor neurone disease, multiple sclerosis (MS), a learning disability or cerebral palsy Problems with your spleen – for example, sickle cell disease or if you have had your spleen removed A weakened immune system as the result of conditions such as HIV and AIDS, or medicines such as steroid tablets or chemotherapy None of these apply to me I have a different long term health condition not listed above (please specify in the text box provided)
Please state your age	Textbox
Gender	Male Female Other (textbox) Prefer not to say
What is your ethnicity?	White – British, Irish, other Asian/Asian British – Indian, Pakistani, Bangladeshi, other Chinese/Chinese British Black/Black British – Caribbean, African, other Middle Eastern/Middle Eastern British – Arab, Turkish, other Mixed race – White and Black/Black British Mixed race – other Other ethnic groups (please specify in the text box provided) Prefer not to say
What is your height in feet and inches, or centimetres?	Text box provided for each
What is your weight in pounds or kilograms?	Text box provided for each

Do you work in health or social care?	Yes (please provide your job title in the text box) No
Does your job require you to be in direct contact with coronavirus (COVID-19) patients?	Yes No
Please provide the first half of your postcode (e.g. NG1)	Textbox provided
Please provide your email address	Textbox provided
Section B: awareness, attitudes and actions relating to COVID-19	
Have you had coronavirus?	Yes – I have been diagnosed and am still ill Yes – I have and I have recovered Yes - I have been diagnosed, but had no symptoms No
Have you experienced coronavirus symptoms?	Yes - and I was diagnosed Yes – but I have not been diagnosed No I don't know what the symptoms
Which of the below are symptoms of coronavirus? (Select all that is relevant)	Persistent cough Feeling confused Loss of appetite Loss of smell Loss of taste Tightness in chest Diarrhoea Fatigue Shortness of breath Fever Sore throat None of the above
Have you taken any of the actions below in response to the coronavirus (COVID-19) outbreak? (select all that apply)	Social distancing Self-isolation Worn protective apparel (e.g. gloves, mask etc.) Used online shopping or food delivery service Shielding due as my health status means I am defined as 'extremely vulnerable' All of the above Other (Textbox)
Do you believe you are at higher risk of severe illness from coronavirus (COVID-19)?	Yes No
Why do you believe you are at a higher risk of severe illness from coronavirus (COVID-19)? (only for those who answered yes)	Textbox
Why do you believe you are not at a higher risk of severe illness from coronavirus (COVID-19)? (only for those who answered no)	Textbox

Describe how being identified as being at a higher risk of severe illness from coronavirus (COVID-19) by the UK Government, has made you feel?	Textbox
What sources have informed you that you are at a higher risk from coronavirus (COVID-19)? (select all that apply)	Traditional media (TV, Newspapers, Radio) Social media (Twitter, Facebook, Instagram, Snapchat) National or Local Government Employer Healthcare organisations Community groups Charity Friends and Family Schools and education centres Other (please specify in the text box provided)
Do you feel like you have enough information specific to your higher risk of severe illness from coronavirus (COVID-19)?	Yes No
Why do you believe you have received enough information specific to your higher risk of severe illness from coronavirus (COVID-19), and what more do you want to know? (only for those who answered yes)	Textbox
Why do you believe you have not received enough information specific to your higher risk of severe illness from coronavirus (COVID-19), and what else do you want to know? (only for those who answered no)	Textbox
Have you used other forms of information (i.e. nonprofessional/social media "experts"/other people/patients) since the COVID-19 outbreak?	Yes No
Please specify what information you have used relating to your higher risk status since the coronavirus (COVID19) outbreak	Textbox
How concerned are you about each of the statements below • Becoming infected with coronavirus (COVID-19) • Severe illness and possibly death from coronavirus (COVID-19) • Spreading coronavirus (COVID-19) to others including family and friends • Access to healthcare support (e.g. advice, medication) • If you become infected, that you would receive appropriate care/support • That your higher risk of severe illness from coronavirus (COVID-19) means you may not	Likert scale from 0 (Not concerned at all) to 10 (Very concerned)

receive healthcare support compared with people who do not have a higher risk status	
Section C: impact of COVID-19 on management of health conditions and use of technology	
Has your management of your health condition changed compared to before the coronavirus (COVID-19) outbreak?	Yes No Not applicable (70 years or over or pregnant without a health condition)
How and why has it changed?	Textbox
How do you feel about changing your management of your health condition due to the coronavirus (COVID-19) outbreak?	Textbox
Has COVID-19 changed your regular healthcare support? (this could type or frequency of support e.g. appointments, service, medications, communication consultant)	Appointments (please specify in the text box) Medication (please specify in the text box) Elective surgery (please specify in the text box) Communication platform (please specify in the text box) Clinician caring for me (please specify in the text box) Other (please specify in the text box) There has been no change
Have you received care through any of the following platforms?	Social media (please specify in the text box) Mobile phone app (please specify in the text box) Email Telephone Virtual consultation e.g. Zoom, Microsoft Teams (please specify in the text box) Other (please specify in the text box) No platforms have been used I am still receiving face to face care
How satisfied are you with using the platforms that you are receiving care through?	Extremely dissatisfied Somewhat dissatisfied Neither satisfied nor dissatisfied Somewhat satisfied Extremely satisfied
How satisfied are you with using the information/resources provided through the platforms that you are receiving care through?	Extremely dissatisfied Somewhat dissatisfied Neither satisfied nor dissatisfied Somewhat satisfied Extremely satisfied
Would you welcome the continued use of these platforms in the future, after the coronavirus (COVID-19) outbreak?	Yes No, but would welcome other platforms (please specify in the text box) No Not sure, I need more time to use them

You indicated that you have more than one of the high risk indicator for severe illness from coronavirus (COVID19). Please describe how this makes you feel, and why?	Textbox
Section D: Mental Health and Wellbeing	
Since the coronavirus (COVID-19) outbreak, my mental health is	Yes No
Warwick-Edinburgh Mental Well-being Scale (WEMWBS) During the past two weeks... • I've been feeling optimistic about the future • I've been feeling useful • I've been feeling relaxed • I've been feeling interested in other people • I've had energy to spare • I've been dealing with problems well • I've been thinking clearly • I've been feeling good about myself • I've been feeling close to other people • I've been feeling confident • I've been able to make up my own mind about things • I've been feeling loved • I've been interested in new things • I've been feeling cheerful	Not at all Rarely Some of the time Often All of the time
Patient Health Questionnaire (PHQ-9) Over the last two weeks, how often have you been bothered by any of the following problems • Little interest or pleasure in doing things? • Feeling down, depressed, or hopeless? • Trouble falling or staying asleep, or sleeping too much? • Feeling tired or having little energy? • Poor appetite or overeating? • Feeling bad about yourself - or that you are a failure or have let yourself or your family down? • Trouble concentrating on things, such as reading the newspaper or watching television? • Moving or speaking so slowly that other people could have noticed? Or the opposite - being so fidgety or restless that you have been moving around a lot more than usual? • Thoughts that you would be better off dead, or of hurting yourself in some way?	Not at all Several days More than half the days Nearly every day
Section D: lifestyle related behaviours	

Has your shopping changed since the coronavirus (COVID-19) outbreak?	A great deal A lot A moderate amount A little Not at all
Describe how your shopping has changed since the coronavirus (COVID-19) outbreak	Textbox
Has your diet changed since the coronavirus (COVID19) outbreak?	A great deal A lot A moderate amount A little Not at all
Describe how your diet has changed since the coronavirus (COVID-19) outbreak	Textbox
Has your alcohol consumption changed since the coronavirus outbreak?	I have consumed much less alcohol than usual I have consumed less alcohol than usual It hasn't changed I have consumed more alcohol than usual I have consumed much more alcohol than usual
Why has your alcohol consumption changed since the coronavirus (COVID-19) outbreak?	Textbox
Has the amount of physical activity you usually engage in changed since the coronavirus outbreak?	I am much less active I am less active It hasn't changed I am more active I am much more active
Has the type of physical activity you usually engage in changed since the coronavirus outbreak?	Yes No
Describe how and why your physical activity has changed since the coronavirus outbreak	Textbox
Has the amount or quality of your sleep changed since the coronavirus outbreak?	A great deal A lot A moderate amount A little Not at all
Describe how and why the amount or quality of your sleep has changed since the coronavirus outbreak	Textbox
Do you smoke tobacco?	Yes No
Has the amount of tobacco you smoke changed compared to before the coronavirus (COVID-19) outbreak?	Much more Somewhat more About the same Somewhat less Much less
Do you use e-cigarettes?	Yes No

Has the amount of e-cigarettes you use changed compared to before the coronavirus (COVID19) outbreak?	Much more Somewhat more About the same Somewhat less Much less
Other than alcohol or tobacco, do you use any recreational drugs?	Yes No
Has the amount of recreational drugs you use changed compared to before the coronavirus (COVID19) outbreak?	Much more Somewhat more About the same Somewhat less Much less
Section E: Interaction with others	
For the following questions, please respond with your health condition or higher risk status (70 years old or over or pregnant regardless of medical conditions) in mind. Since the coronavirus (COVID-19) outbreak...	
Other people have behaved differently towards you?	Yes No
Describe how and why people have behaved differently towards you since the COVID-19 outbreak?	Textbox
You felt stigmatised or discriminated against?	Yes No
Describe the stigmatising and/or discriminatory experience(s) you have had since the COVID-19 outbreak, and how this has made you feel?	Textbox
Final section	
Is there anything that you haven't had chance to say about the coronavirus outbreak that you would like to share?	Textbox

Supplementary Data analysis

Statistical analysis

We fit generalised linear models to the data. Participant responses were used to calculate the WEMWBS and PHQ-9 scores for well-being and depression, respectively. We imputed missing values for participants who did not respond to all items needed to calculate WEMWBS and PHQ-9 scores. If a participant responded to at least 11 of the 14 WEMWBS items or at least 7 of the 9 PHQ-9 items, we used the mean value of the participant's responses in place of missing values. WEMWBS, PHQ-9, and concerns regarding COVID-19 were treated as continuous outcomes. Logistic regression models were used to model 1) actions taken to mitigate the risk of contracting COVID-19, 2) the impact of COVID-19 on the management of health conditions, and 3) the technology platforms used to receive health care. Responses regarding the impact of COVID-19 on lifestyle related behaviours were modelled using multinomial and Adjacent Category Logit models assuming proportional odds. Odds ratios and p-values were reported for logistic, multinomial, and Adjacent Category Logit models.

Each response was modelled as a function of the indicators for high risk of severe illness from COVID-19 (12 separate binary variables) which included: diabetes; Body Mass Index (BMI) $\geq$ 40kg/m^2; chronic respiratory disease; chronic heart disease; chronic kidney disease (CKD); chronic liver disease; chronic neurological conditions; spleen problems; weakened immune system; aged over 70 years; pregnant; and other, which included short or long-term health conditions. Other covariates in the models were the participant's gender (male or female), age (in years), BMI (numeric), Index of Multiple Deprivation (IMD; numeric: 1-10 as identified using the English Indices of Deprivation 2019), and whether the participant had multiple indicators for high risk (categorical: one, two, three or more conditions). Descriptive data were summarised with mean (standard deviations [SD]) or median (interquartile range [IQR]) for continuous data depending on data distribution, with categorical data summarised as counts (percentage, %). All statistical analyses were performed using the tidyverse (version 1.3.0; Wickham et al., 2019) and VGAM (version 1.1-2; Yee, 2020) packages in R (version 3.6.2.; R Core Team, 2019). Statistical significance defined was a p-value <0.05.

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Text Data

Text data was collected across 17 open-ended questions which were distributed throughout the survey sections. All responses to open-ended questions were concatenated, yielding a language sample for each survey participant, which was then tokenised using spaCy's large English web model[1]. The length of the concatenated responses (i.e. the number of tokens, including words, digits, and punctuation) varied from 1 to 2125 tokens (mean=184, median=135). The language sample for each participant was further processed to derive sentiment scores and personality scores. VADER Sentiment Analysis tool (Hutto & Gilbert, 2014) was used to obtain sentiment scores (positive, neutral, negative, and compound sentiment). Personality scores were obtained using proprietary software by Scaled Insights. The software takes as input a language sample and produces 114 personality features. Following this, the 118 features (114 personality, 4 sentiment) were used as input into the multiple machine learning models described below. As the reliability of the personality modelling software depends on the number of words provided in the language sample, the following analysis was restricted to participants (N=636) whose combined text response consisted of at least 100 tokens. The machine learning was used in two settings: unsupervised (clustering) and supervised (classification or regression).

In addition to the clustering, we investigated to what extent features obtained from a language sample could be used for predicting concerns, mitigating actions, impact on lifestyle behaviours, and wellbeing and depression scores in the context of COVID-19. A model which predicts these attitudes and behaviours and requires only a language sample could potentially be used within a digital environment to better identify people who might be more likely to be negatively impacted and offer them preventative support.

For each attitude or behaviour we trained a separate binary or multi-class classifier. We first explored a range of different classifiers (logistic regression, support vector machine, stochastic gradient descent classifier, and Random Forest). Across all classifiers we found that Random Forest achieved the best results, and we tuned the parameters for each classifier separately. The tuned parameters were then used to train the final classifiers using 10-fold cross-validation. As there were only sufficient language samples for 636 participants, we also trained classifiers using GloVe word vectors obtained from the same language model as the tokens. By using word vectors, we were able to train prediction models using all participants' data.

All classification problems were evaluated using the Area Under the Receiver Operating Characteristics (AUROC) metric, while regression problems were evaluated using Mean Absolute Error (MAE) and explained variance.

Concerns about COVID-19

A large proportion of participants in each high-risk group reported that they were 'very concerned' to statements about infection, spread and potential impact of COVID-19; see Supplementary Figure 1-6.

Participants with either chronic respiratory disease, chronic heart disease, CKD, other acute/chronic diseases, diabetes, or weakened immune systems were more concerned about becoming infected compared to those who did not belong to any of these high-risk groups ($p < 0.05$). The coefficients for these covariates suggest that participants in either of these high-risk groups selected the next highest response compared to individuals who believed they were not at high risk. Additionally, concerns about being infected were significantly higher for women than in men (difference 0.59; $p = 0.003$), and for older participants (difference 0.02; $p=0.032$), although the differences were relatively small. Participants with either chronic

[1] https://spacy.io/models/en#en_core_web_lg

respiratory disease, chronic heart disease, CKD, BMI ≥ 40, or weakened immune systems were more concerned about experiencing severe illness or death (next highest response) compared to those who did not belong to these high-risk groups ($p < 0.05$); whereas pregnant women were less concerned (2.10 points lower) than women who were not pregnant ($p = 0.012$).

Participants with chronic respiratory disease were significantly more concerned (next highest response) about access to healthcare support ($p = 0.020$).

There were no statistically significant factors for the models with the following concerns: spreading COVID-19 to others; receiving appropriate care/support; and potentially receiving disparate healthcare support due to higher risk status. This suggests that high concern was similar across all high-risk groups.

Mitigating COVID-19

More than 50% of participants in each high-risk group practiced social distancing with the exception of those with weakened immune systems (n=71; 44.7%); see Supplementary Table 1. Twenty-one (60%) participants with chronic neurological diseases and 102 (57.3%) aged 70 years or older self-isolated. Twenty-eight (57.1%) participants with chronic liver disease, 18 with chronic neurological disease, and 96 (53.9%) aged 70 years or older used online shopping or food delivery. Eighty-five (53.5%) participants with weakened immune systems and 11 (68.8%) with spleen problems used shielding. Less than 50% of participants in each high-risk group wore protective apparel or took all of the actions specified in the survey.

Participants living with diabetes were more likely to practice social distancing (odds ratio (OR) 2.44; $p = 0.010$), whereas participants with weakened immune systems were less likely to practice social distancing (OR 0.34; $p = 0.005$). Participants living with diabetes were also more likely to wear protective apparel (OR 2.17; $p = 0.019$); while participants with people > 70 years and chronic liver disease were more likely to shop online (OR 2.66 and 3.34; $p = 0.013$ and 0.007, respectively). Participants with either CKD, weakened immune systems or spleen problems were more likely to practice shielding (OR 2.76, 3.33, and 5.33; $p = 0.016$, 0.002, and 0.035, respectively). Finally, participants with weakened immune systems were more likely to take all mitigating risk actions identified compared with the other at-risk groups (OR 2.61; $p = 0.039$). There were no statistically significant differences between high risk groups with regards to self-isolation.

Interactions with Others and Stigma

Three hundred and seventy-seven (41.0%) participants indicated that people behaved differently toward them compared to prior to COVID-19 lockdown. When asked if during the COVID-19 lockdown they felt more stigmatised or discriminated against 119 (13.0%) reported they had compared to prior to COVID-19 lockdown. Of these participants, 65 (54.6%) were living with diabetes, 25 (21.0%) had a BMI of ≥ 40 kg/m^2, 21 (17.6%) had chronic respiratory disease, 24 (20.2%) had a weakened immune system, and 44 (37%) had other chronic short- or long-term risk factors. In all other high-risk groups fewer than 20 participants said that they felt stigmatised or discriminated against.

Participants with two high risk indicators and participants with three or more high risk indicators were more likely to report that people behaved differently towards them (OR 2.38 and 6.17; $p = 0.015$ and 0.013, respectively). There were no discernible differences between the high-risk groups with regards to feelings of stigma and discrimination compared to prior to COVID-19 lockdown.

Prediction models

Concerns about COVID-19

The responses relating to concerns were all expressed on a [1,10] scale. To form classes, the values were split into 'slight' (1-3), 'some' (4-7) and 'great' (8-10). Word vectors achieved the best performance with AUROC ranging from 0.71 to 0.78; see Supplementary Table 3.

Mitigating COVID-19

The mitigating actions each formed a binary class (i.e. someone either used particular mitigation action or not). Best performance was achieved by word vectors with AUROC ranging between 0.67 and 0.82. In the case of a more unbalanced class (predicting someone taking all possible mitigating actions), the best AUROC score (0.68) was achieved by personality and sentiment features; see Supplementary Table 2.

Impact of COVID-19 on Health and Lifestyle Related Behaviours

The responses on the impact of COVID-19 on lifestyle behaviours, used scales which were converted to classes as follows. Scale [-2,2] (used for alcohol consumption, physical activity, smoking, e-cigarettes, and recreational drug use) was converted to 'Decrease' [-2,-1], 'No Change' [0], 'Increase' [1,2]. Scale [0,4] (used for shopping, diet and sleep) was converted to 'No or little impact' [0,1], 'Some impact' [2], 'Great impact' [3,4]. For the lifestyle behaviours which were not well represented in the survey cohort (smoking, e-cigarettes, and recreational drug use) the results are very low (AUROC slightly better than random at 0.53 for recreational drug use). The best classifiers for other lifestyle behaviours had AUROC scores between 0.72 and 0.81; see Supplementary Table 4.

Impact of COVID-19 on Wellbeing

The scores for WEMWBS and PHQ-9 for both measures were used directly as target variables in the regression models. Unlike the prediction models reported previously, for both wellbeing and depression scores the best performing models used personality and sentiment scores. The model for depression achieved MAE = 4.25 and explained variance of 0.15, while the wellbeing model achieved MAE=7.97 and explained variance of 0.17; see Supplementary Table 5.

Supplementary Table 1. Mitigating actions taken in response to the coronavirus outbreak.

	Diabetes (N=538)	BMI ≥ 40 kg/m² (N=142)	Chronic Respiratory Disease (N=179)	Chronic Heart Disease (N=132)	Chronic Kidney Disease (N=147)	Chronic Liver Disease (N=49)	Chronic Neurological Disease (N=35)	Spleen Problems (N=16)	Weakened Immune System (N=159)	Aged > 70 years (N=178)	Pregnant (N=21)	Other Risk Factors (N=303)
Social distancing n (%)												
Yes	446 (82.9%)	105 (73.9%)	125 (69.8%)	90 (68.2%)	82 (55.8%)	32 (65.3%)	26 (74.3%)	9 (56.2%)	71 (44.7%)	135 (75.8%)	18 (85.7%)	212 (70.0%)
No	92 (17.1%)	37 (26.1%)	54 (30.2%)	42 (31.8%)	65 (44.2%)	17 (34.7%)	9 (25.7%)	7 (43.8%)	88 (55.3%)	43 (24.2%)	3 (14.3%)	91 (30.0%)
Self-isolation n (%)												
Yes	263 (48.9%)	68 (47.9%)	83 (46.4%)	58 (43.9%)	66 (44.9%)	19 (38.8%)	21 (60.0%)	7 (43.8%)	61 (38.4%)	102 (57.3%)	10 (47.6%)	148 (48.8%)
No	275 (51.1%)	74 (52.1%)	96 (53.6%)	74 (56.1%)	81 (55.1%)	30 (61.2%)	14 (40.0%)	9 (56.2%)	98 (61.6%)	76 (42.7%)	11 (52.4%)	155 (51.2%)
Worn protective apparel n (%)												
Yes	201 (37.4%)	47 (33.1%)	59 (33.0%)	44 (33.3%)	30 (20.4%)	17 (34.7%)	13 (37.1%)	1 (6.2%)	22 (13.8%)	57 (32.0%)	6 (28.6%)	106 (35.0%)
No	337 (62.6%)	95 (66.9%)	120 (67.0%)	88 (66.7%)	117 (79.6%)	32 (65.3%)	22 (62.9%)	15 (93.8%)	137 (86.2%)	121 (68.0%)	15 (71.4%)	197 (65.0%)
Used online shopping or food delivery n (%)												
Yes	258 (48.0%)	67 (47.2%)	77 (43.0%)	66 (50.0%)	60 (40.8%)	28 (57.1%)	18 (51.4%)	7 (43.8%)	55 (34.6%)	96 (53.9%)	10 (47.6%)	125 (41.3%)
No	280 (52.0%)	75 (52.8%)	102 (57.0%)	66 (50.0%)	87 (59.2%)	21 (42.9%)	17 (48.6%)	9 (56.2%)	104 (65.4%)	82 (46.1%)	11 (52.4%)	178 (58.7%)
Shielding n (%)												
Yes	100 (18.6%)	33 (23.2%)	65 (36.3%)	38 (28.8%)	68 (46.3%)	22 (44.9%)	6 (17.1%)	11 (68.8%)	85 (53.5%)	38 (21.3%)	2 (9.5%)	80 (26.4%)
No	438 (81.4%)	109 (76.8%)	114 (63.7%)	94 (71.2%)	79 (53.7%)	27 (55.1%)	29 (82.9%)	5 (31.2%)	74 (46.5%)	140 (78.7%)	19 (90.5%)	223 (73.6%)
All of the above n (%)												
Yes	55 (10.2%)	19 (13.4%)	22 (12.3%)	23 (17.4%)	31 (21.1%)	7 (14.3%)	4 (11.4%)	2 (12.5%)	40 (25.2%)	29 (16.3%)	2 (9.5%)	46 (15.2%)
No	483 (89.8%)	123 (86.6%)	157 (87.7%)	109 (82.6%)	116 (78.9%)	42 (85.7%)	31 (88.6%)	14 (87.5%)	119 (74.8%)	149 (83.7%)	19 (90.5%)	257 (84.8%)

Supplementary Table 2. Prediction results for mitigating actions using three feature groups and evaluated using AUROC. The best performing feature group is in bold.

	Social distancing	Self-isolation	PPE	Online shopping	Shielding	All above
# positive class	491	306	208	304	173	77
# negative class	145	330	428	332	463	559
Personality and sentiment features	0.66	0.55	0.51	0.49	0.62	**0.68**
Word vectors	**0.82**	**0.7**	**0.67**	**0.68**	**0.73**	0.54
All features	0.71	0.58	0.51	0.52	0.69	0.67

Supplementary Table 3. Prediction results for concerns using three feature groups and evaluated using AUROC. The best performing feature group is in bold.

	Becoming infected	Severe illness or death	Spreading to others	Access to healthcare	Enough support	Less care compared to low risk
# Slight concern	60	71	114	197	156	236
# Some concern	214	164	190	229	185	160
# Great concern	362	401	332	210	295	240
Personality and sentiment features	0.63	0.6	0.54	0.58	0.58	0.58
Word vectors	**0.78**	**0.78**	**0.73**	**0.71**	**0.71**	**0.71**
All features	0.64	0.62	0.52	0.58	0.58	0.58

Supplementary Table 4. Prediction results for lifestyle behaviours using three feature groups and evaluated using AUROC. The best performing feature group is in bold.

	Shopping	Diet	Alcohol	Amount of physical activity	Sleep	Smoking	E-cigarettes	Recreational drugs
# Decrease / Little impact	47	302	96	385	293	5	2	3
# No change / Some impact	90	205	372	99	157	623	624	628
# Increase / Great impact	499	129	168	152	186	8	10	5
Personality and sentiment features	0.56	0.62	0.61	0.65	0.65	0.44	0.55	0.36
Word vectors	**0.81**	**0.74**	**0.72**	**0.8**	**0.75**	**0.6**	**0.67**	0.45
All features	0.55	0.6	0.56	0.61	0.65	0.58	0.58	**0.53**

Supplementary Table 5. Prediction results for depression (Patient Health Questionnaire, PHQ-9) and wellbeing score (Warwick-Edinburgh Mental Well-being Scale, WEMWBS) using three feature groups and evaluated using mean absolute error and explained variance. The best performing feature group is in bold.

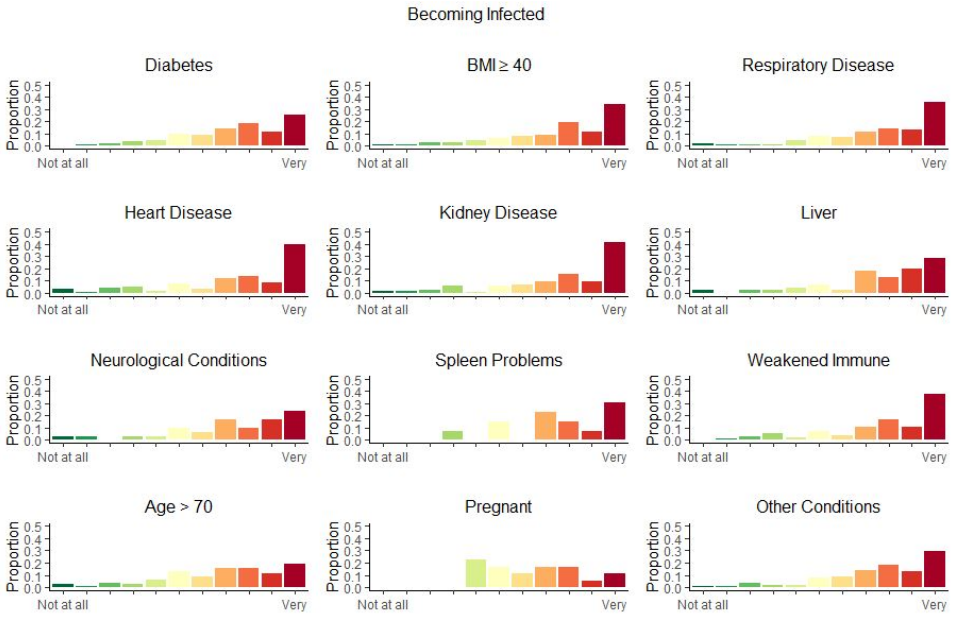
	Depression score (PHQ-9)	Wellbeing score (WEMWBS)
# participants	584	636
Personality and sentiment features, MAE	**4.25**	**7.97**
Personality and sentiment features, Exp. Var.	**0.15**	**0.17**
Word vectors, MAE	4.52	8.6
Word vectors, Exp. Var.	0.07	0.1
All features, MAE	4.33	8.15
All features, Exp. Var.	0.12	0.13

Supplementary Table 6 Median wellbeing (Warwick-Edinburgh Mental Well-being Scale, WEMWBS) and depression (Patient Health Questionnaire, PHQ-9) scores based on high risk group.

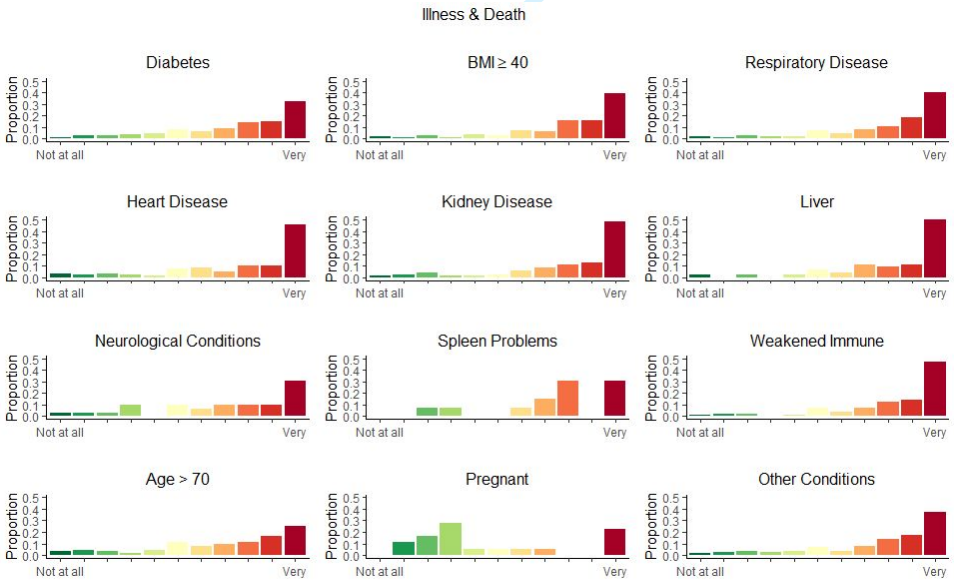
	Wellbeing Median [Min, Max]	Depression Median [Min, Max]
Diabetes		
Yes	45.0 [14.0, 70.0]	6.00 [0, 26.0]
No	46.0 [14.0, 70.0]	7.00 [0, 26.0]
BMI ≥ 40 kg/m²		
Yes	40.6 [15.0, 70.0]	10.00 [0, 26.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]]
Chronic Respiratory Disease		
Yes	43.5 [14.0, 70.0]	9.00 [0, 26.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]
Chronic Heart Disease		
Yes	47.4 [14.0, 70.0]	7.00 [0, 26.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]
Chronic Kidney Disease		
Yes	47.0 [14.0, 70.0]	6.00 [0, 26.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]
Chronic Liver Disease		
Yes	43.0 [15.0, 62.0]	7.00 [0, 22.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]
Chronic Neurological Conditions		
Yes	46.2 [19.0, 66.0]	8.00 [0, 22.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]
Spleen problems		
Yes	46.0 [26.0, 66.0]	5.00 [2.0, 13.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]
Weakened immune system		
Yes	46.0 [14.0, 68.0]	6.00 [0, 26.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]

Aged > 70 years		
Yes	51.0 [14.0, 70.0]	3.00 [0, 26.0]
No	44.0 [14.0, 70.0]	7.00 [0, 26.0]
Pregnant		
Yes	42.0 [29.0, 61.0]	6.00 [0, 17.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]
Other risk factors *		
Yes	44.0 [14.0, 70.0]	8.00 [0, 26.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]

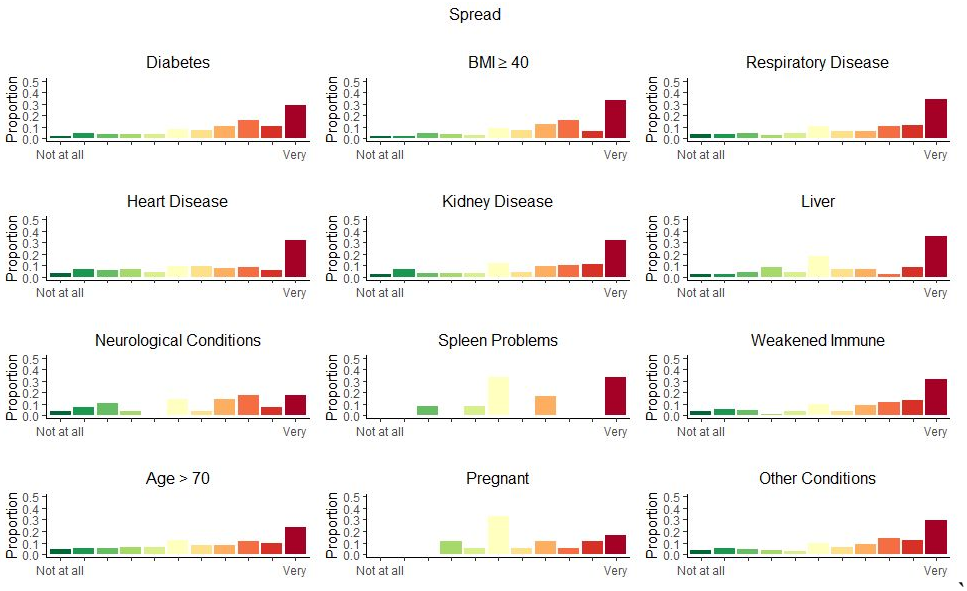
** Changed type or frequency of support*



Supplementary Figure 1: Concern about becoming infected with COVID-19 for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.

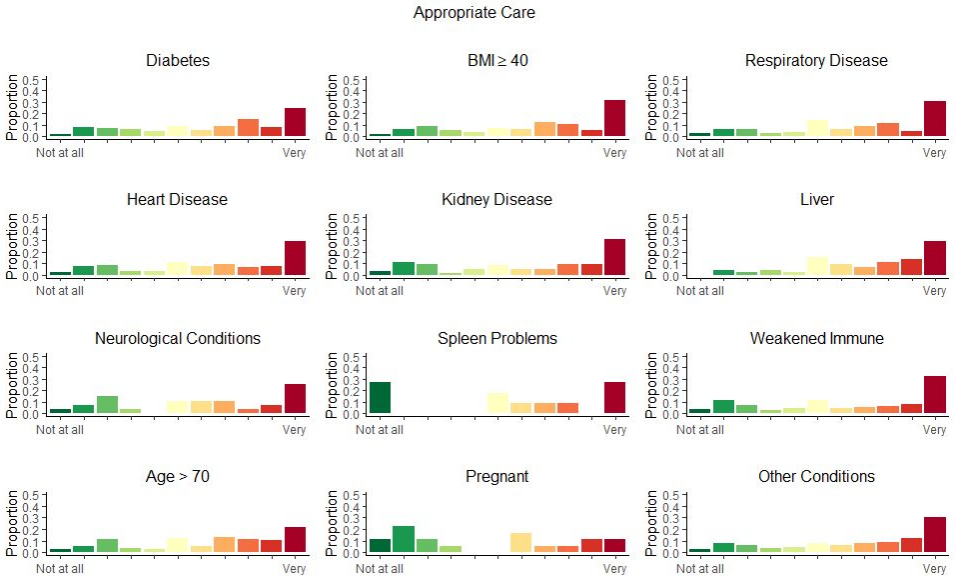


Supplementary Figure 2: Concern about severe illness and possible death from COVID-19 for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.

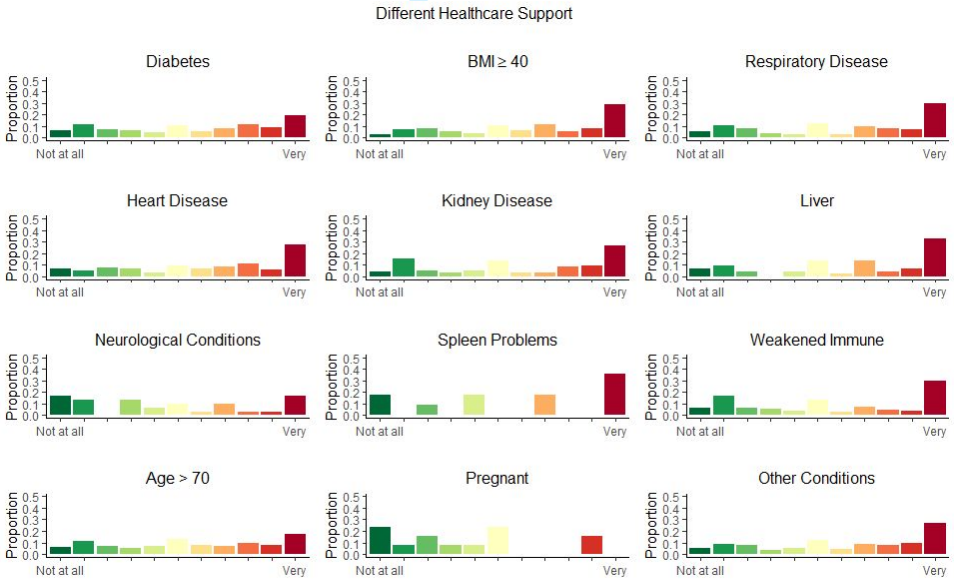


Supplementary Figure 3: Concern about spreading COVID-19 to others including family and friends for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.

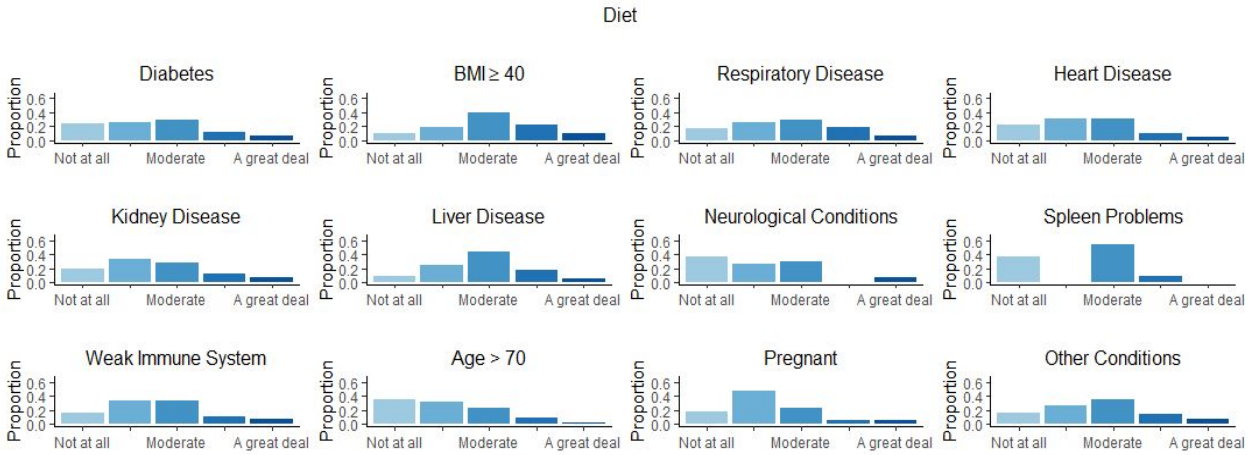
Supplementary Figure 4: Concern about access to healthcare support for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



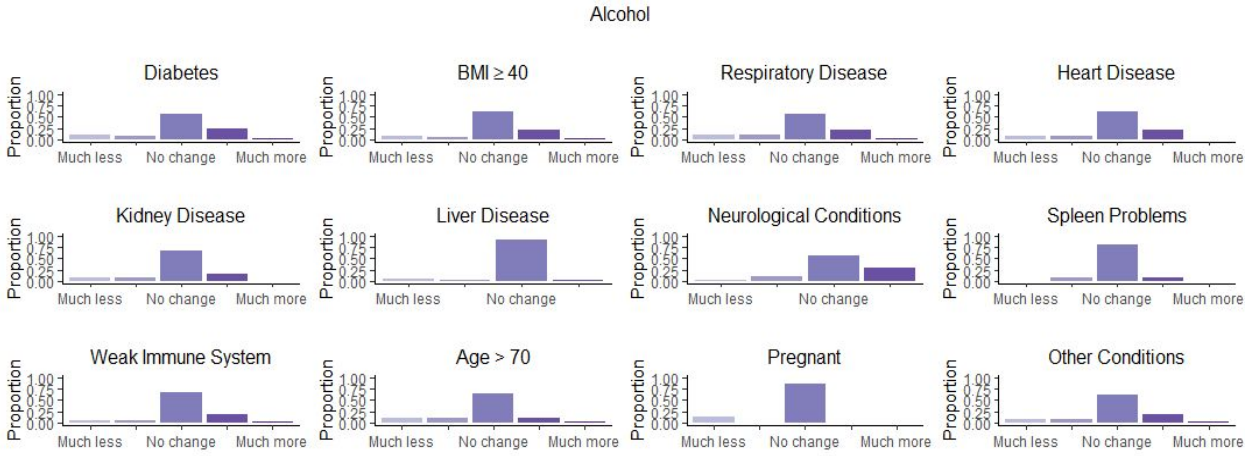
Supplementary Figure 5: Concern about access to appropriate care if infected with COVID-19 for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



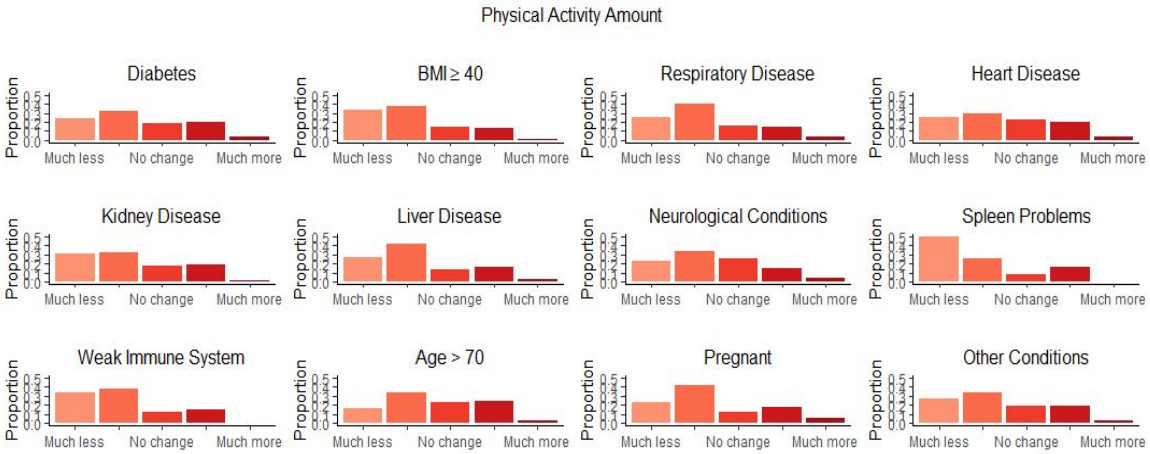
Supplementary Figure 6: Concern about disparate care as a result of high-risk status for each indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



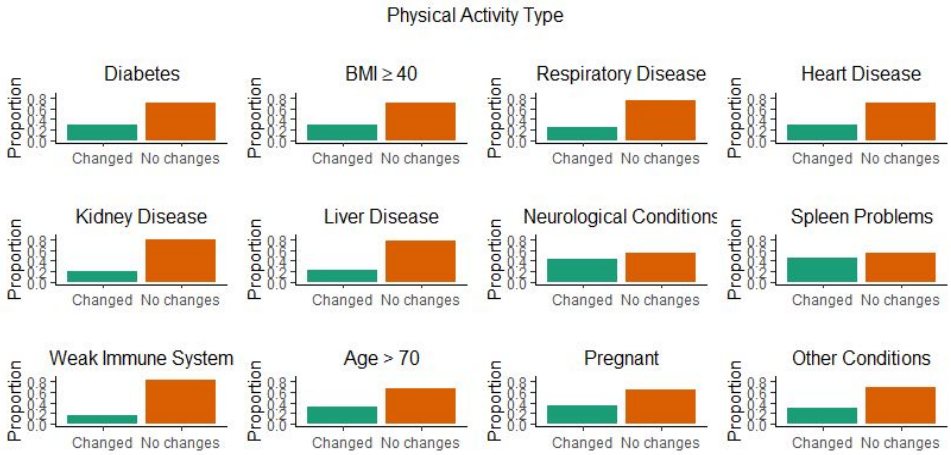
Supplementary Figure 7. Change in diet compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



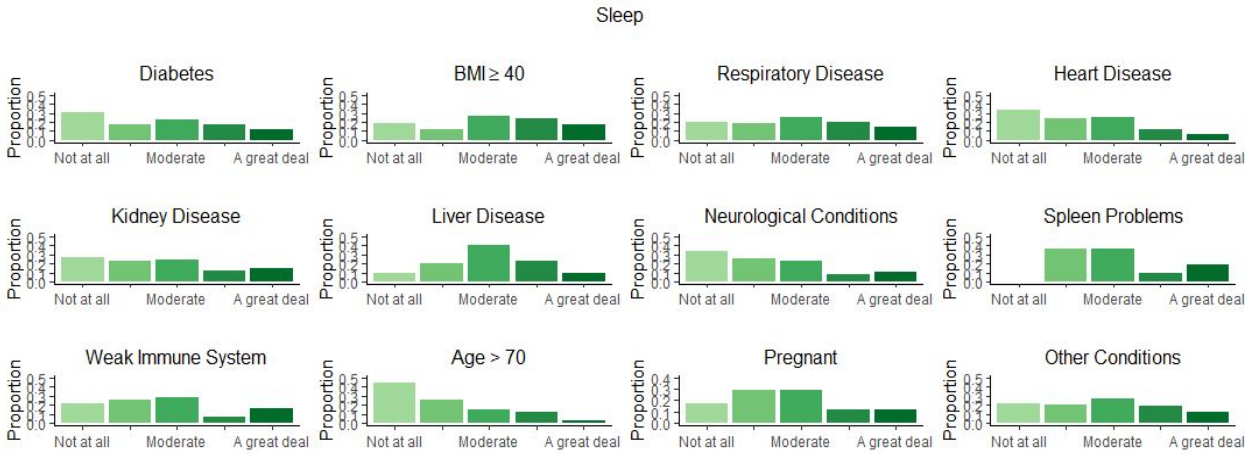
Supplementary Figure 8. Change in alcohol consumption compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



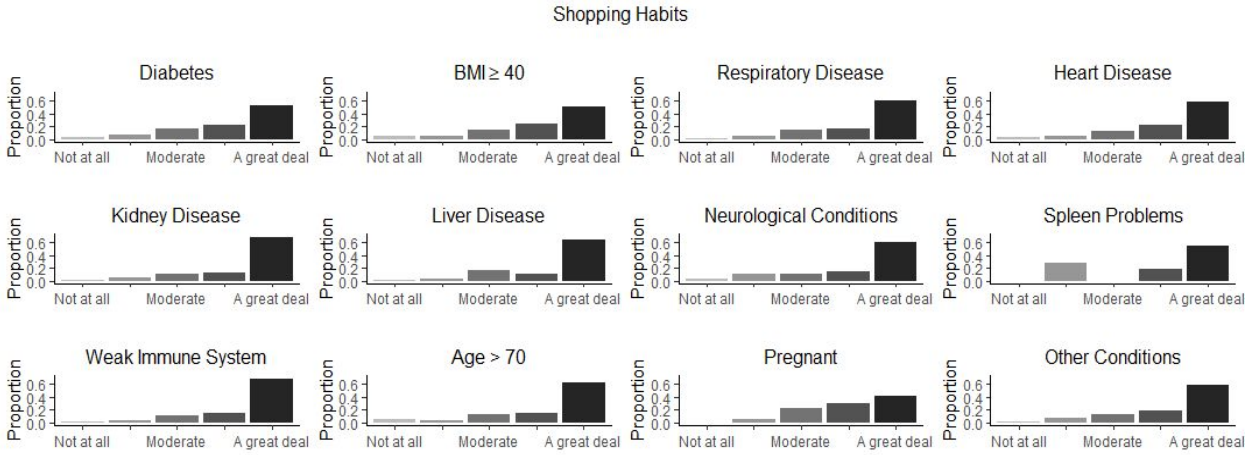
Supplementary Figure 9. Change in amount of physical activity compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



Supplementary Figure 10. Change in type of physical activity compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



Supplementary Figure 11. Change in amount or quality of sleep compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



Supplementary Figure 12. Change in shopping compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.

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A cross-sectional analysis to explore the Awareness, Attitudes and Actions of UK adults at high risk of severe illness from COVID-19

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A cross-sectional analysis to explore the Awareness, Attitudes and Actions of UK adults at high risk of severe illness from COVID-19

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Abstract

Objectives
This study explored the impact of COVID-19 on people identified as at high risk of severe illness by UK Government, and in particular, the impact of lockdown on access to healthcare, medications and use of technological platforms.

Design
Online survey methodology

Setting
UK

Participants
1038 UK adults were recruited who were either identified by UK Government as at high risk of severe illness from COVID-19 or self-identified as at high risk with acute or other chronic health conditions not included in the UK Government list. Participants were recruited through social media advertisements, health charities and patient organisations.

Main outcomes measures
The Awareness, Attitudes and Actions survey which explores the impact of COVID-19, on including access to healthcare, use of technology for health condition management, mental health, depression, wellbeing, and lifestyle behaviours.

Results
Nearly half of the sample (44.5%) reported that their mental health had worsened during the COVID-19 lockdown. Management of health conditions changed including access to medications (28.5%) and delayed surgery (11.9%), with nearly half of the sample using telephone care (45.5%). Artificial Intelligence identified that participants in the negative cluster had higher neuroticism, insecurity and negative sentiment. Participants in this cluster reported more negative impacts on lifestyle behaviours, higher depression and lower wellbeing, alongside lower satisfaction with platforms to deliver healthcare.

Conclusions
This study provides novel evidence of the impact of COVID-19 on people identified as at high risk of severe illness. These findings should be considered by policymakers and healthcare professionals to avoid unintended consequences of continued restrictions and future pandemic responses.

Keywords: COVID-19; Lockdown; Attitudes; Behaviours; Artificial Intelligence; High Risk

Article Summary

Strengths and limitations of this study

- This study collected data during the COVID-19 lockdown, exploring the impact on a high-risk subsection of the population who have been subject to greater restrictions.
- The study collected novel data on the impact of the UK national lockdown on access to healthcare, lifestyle behaviours, and mental health.
- An innovative Artificial Intelligence tool was used to provide further insights about the impact of COVID-19 lockdown on this vulnerable population.
- The study used an online survey methodology and as such may have excluded recruitment of people experiencing digital poverty.
- Given the reported increased risk for people from black and minority ethnic (BAME) backgrounds, the low recruitment of people from BAME backgrounds means that comparison of the impact on people of different ethnic backgrounds was not possible.

Introduction

On 11th March 2020, the World Health Organization (WHO) announced that coronavirus disease 2019 (COVID-19) was a global pandemic.[1] In response, governments across the world took a range of actions to help reduce its spread including the development of legislation and policies. The majority of countries also imposed a period of a variable degree of "lockdown".

Beyond the population level lockdown, further guidance was issued for people identified as at a higher risk of morbidity and mortality from COVID-19. This 'high risk' grouping was typically comprised of people living with chronic health conditions such as diabetes, heart disease or acquired immunodeficiency syndrome (AIDS), as well as people who are pregnant or aged 60 years or over. For some 2.2 million people, this additional guidance included the need to 'shield' for people identified as the most vulnerable to COVID-19 infection and illness.[2] However, unintended consequences have been noted in emerging evidence, including accentuated feelings of social isolation, self-stigma and loneliness.[3,4] Thus far, the impact of lockdown and associated restrictions have primarily been reported within the general population, however, given the greater restrictions on people identified as at higher risk including a longer duration of lockdown and need to 'shield' or self-isolate, the potential impact of COVID-19 is likely to have been greater on this sub-group of the population. Recently, the Office of National Statistics[2] reported that a high proportion of people identified as being at high risk self-reported that they followed the shielding guidance completely during lockdown.

There is a pressing need to investigate the impact of lockdown and shielding on people identified as at higher risk of severe illness from COVID-19. We defined impact as changes as a consequence of shielding to different aspects of everyday life, including actions and attitudes, healthcare delivery, mental health and wellbeing, lifestyle behaviours, and social interaction. Some of these aspects such as access to healthcare delivery, have not been investigated for this population previously. In terms of attitudes and actions, emerging evidence from the US suggests that despite concerns about infection, there was a lack of critical knowledge and limited changes to the plans or routines for people identified as at high risk of severe illness from COVID-19 infection.[5]

Therefore, to understand the impact, and contribute evidence for healthcare policy and networks to support people effectively and address unmet needs, we have delivered a time-sensitive study of the impact the COVID-19 pandemic and the associated UK Government guidance has had on people identified as at high risk of severe illness from COVID-19. Specifically, we explored the impact of the COVID-19 lockdown on access to healthcare, health and lifestyle behaviours, and mental health amongst UK adults identified as at high risk of severe illness from COVID-19.

Methods

Design

Between 15 March and 31 May 2020, the Awareness, Attitudes and Actions (AAA) survey was disseminated via UK charities, healthcare and relevant higher education email distribution lists, social media, and website advertisement. The survey was hosted by Qualtrics LLC; a third-party online survey administration platform. Inclusion criteria was being aged ≥ 18 years with one or more of the factors for high risk of severe illness from COVID-19 identified by the UK Government or self-identified as at high risk due to an acute or chronic health condition not listed.[6]

AAA Survey

An online survey was developed to explore the AAA of UK adults identified as at high risk of severe illness from COVID-19 by the UK Government or self-identified as high risk. The survey comprised of seven sections utilising a combination of closed and open questions:

1) participant demographics,

2) awareness, attitudes and actions relating to COVID-19 including whether participants had been diagnosed with COVID-19, experienced symptoms, and took actions to reduce infection and spread,

3) impact of COVID-19 on management of health conditions and use of technology,

4) impact on mental health and wellbeing, and depression including the Warwick-Edinburgh Mental Well-being Scale (WEMWBS)[7] and Patient Health Questionnaire (PHQ-9)[8]

5) lifestyle related behaviours; diet, alcohol intake, physical activity type and amount, sleep quality and amount, smoking behaviour, e-cigarette use and recreational drug use,

6) interaction with others regarding changes in other people's behaviour towards participants and feeling stigmatised and discriminated,

7) additional comments.

Please see Supplementary Materials for an overview of the online survey.

Patient and Public Involvement

Patients and Public were involved from the outset and throughout the study, including the design, conducting, choice, development and piloting of the AAA survey, recruitment and reporting of the study.

Data analysis

Data from this survey produced quantitative and text data from validated questionnaires, and closed and open-ended questions.

For the statistical analysis, we fit generalised linear models to the data. Participant responses were used to calculate the WEMWBS and PHQ-9 scores for well-being and depression, respectively. We imputed missing values for participants who did not respond to all items needed to calculate WEMWBS and PHQ-9 scores. If a participant responded to at least 11 of the 14 WEMWBS items or at least 7 of the 9 PHQ-9 items, we used the mean value of the participant's responses in place of missing values. WEMWBS, PHQ-9, and concerns regarding COVID-19 were treated as continuous outcomes. Logistic regression models were used to model 1) actions taken to mitigate the risk of contracting COVID-19, 2) the impact of COVID-19 on the management of health conditions, and 3) the technology platforms used to receive health care. Responses regarding the impact of COVID-19 on lifestyle related behaviours were modelled using multinomial and Adjacent Category Logit models assuming proportional odds. Odds ratios (OR) and 95% confidence intervals (CI) were reported for logistic, multinomial, and Adjacent Category Logit models.

Each response was modelled as a function of the indicators for high risk of severe illness from COVID-19 (12 separate binary variables) which included: diabetes; Body Mass Index (BMI) $\geq 40 kg/m^2$; chronic respiratory disease; chronic heart disease; chronic kidney disease (CKD); chronic liver disease; chronic neurological conditions; spleen problems; weakened immune system; aged over 70 years; pregnant; and other, which included short or long-term health conditions. Other covariates in the models were the participant's gender (male or female), age (in years), BMI (numeric), Index of Multiple Deprivation (IMD; numeric: 1-10 as identified using the English Indices of Deprivation 2019), and whether the participant had multiple indicators for high risk (categorical: one, two, three or more conditions). Descriptive data were summarised with mean (standard deviations [SD]) or median (interquartile range [IQR]) for continuous data depending on data distribution, with categorical data summarised as counts (percentage, %). In each scenario, the reference group consisted of participants who do not belong to the specified high risk group. All statistical analyses were performed using the tidyverse (version 1.3.0)[9] and VGAM (version 1.1-2)[10] packages in R (version 3.6.2).[11] Statistical significance was defined at p-value <0.05.

Text data was collected across 17 open-ended questions which were distributed throughout the survey sections. The language sample for each participant was processed to derive sentiment scores and personality scores. VADER Sentiment Analysis tool[12] was used to obtain sentiment scores (positive, neutral, negative, and compound sentiment). Personality scores were obtained using proprietary software by Scaled Insights. The software takes as input a language sample and produces 114 personality features. Following this, the 118 features (114 personality, 4 sentiment) were used as input into the multiple machine learning models, which were used in two settings:

unsupervised (clustering) and supervised (classification or regression). We also investigated to what extent features obtained from a language sample are predictive of concerns, mitigating actions, impact on lifestyle behaviours, and wellbeing and depression scores in the context of COVID-19. For further details and an overview of the prediction models see the supplementary materials and supplementary tables 1-4 for the outcomes of the models.

Patient and Public Involvement

Patients and Public were involved from the outset and throughout the study, including the design, conducting, choice, development and piloting of the AAA survey, recruitment and reporting of the study. We are very grateful for the organisations and individuals as listed in our acknowledgements section who have and continue to support this study.

A public facing report of the study will be provided to the organisations that have supported our study once the manuscript has been published, and all study participants are able to request a copy of the final report and manuscript once published.

Results

Descriptive Statistics

The original sample comprised 1038 UK adults. Six participants were removed for either reporting being aged less than 18 years old or an infeasible age. Of the remaining sample, 624 were female, 402 male, 4 reported other and 2 preferred not to say. Due to small numbers, participants who responded 'other' or 'prefer not to say' when asked about their gender were removed. Characteristics of the 1026 participants in the final analysis are presented in Table 1. Six hundred and twenty-four (61%) participants were female; 979 (95.4%) identified as White-British, Irish, other; with a mean age of 54.6 ± 14.9 years and mean BMI of 28.8 ± 8.1 kg/m^2. Two hundred and nineteen participants (21.3%) reported having three or more indicators for high risk of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition. The 12 high risk indicators are summarised in Table 1. Notably over half of the sample (n=528; 52.4%) reported that they were living with diabetes (either Type 1 or Type 2). Participants reported high concern about infection, illness and death, spread to others, and access to healthcare across all higher risk groups (see supplementary materials for statistical analysis of COVID-19 concerns, risk mitigating behaviour and interactions with others).

Impact of COVID-19 on Lifestyle Related Behaviours

Supplementary Figures 1-6 display the impact of COVID-19 on lifestyle related behaviours for each high-risk indicator of severe illness from COVID-19. Generally, across all high-risk indicators a high proportion of participants indicated little to moderate change in diet, no change in alcohol consumption, less or much less physical activity, no change in the type of physical activity, and a great deal of change in shopping habits. Change in quality and amount of sleep was variable across risk groups.

Further analysis of lifestyle related behaviours compared to prior to COVID-19 lockdown suggested that women and participants with CKD were more likely to report greater change in their shopping habits compared to those without CKD (OR 1.18, CI (1.02, 1.38) and1.62, CI (1.01, 2.60) respectively); see Supplementary Table 5. Participants were less likely to report greater changes in their diet for each additional year of age [OR 0.99 , CI (0.98, 1.00)), whereas participants with higher BMI and women reported greater change in their diet (OR 1.02 per additional kg/m^2, CI (1.00, 1.03) and OR 1.19, CI (1.02, 1.39) respectively). Furthermore, participants with either chronic respiratory disease, CKD, weakened immune systems, or a higher BMI were less likely to report greater change in the amount of physical activity they engaged in compared to those who did not belong to any of these high-risk groups (OR 0.70, CI (0.50, 0.97); OR 0.65, CI (0.44, 0.96); OR 0.54, CI (0.37, 0.78); and OR 0.98 per additional

kg/m^2, CI (0.97, 1.00), respectively). In addition, individuals with chronic neurological conditions were less likely to report a change in the type of physical activity they engaged in (OR 0.23, CI (0.06, 1.00)).

Impact of COVID-19 on Mental Health, Wellbeing & Depression

Four hundred and forty-five (49.8%) participants indicated that their self-reported mental health was about the same compared to prior to COVID-19 lockdown (Table 2). Women were more likely to report worsening of their mental health (OR 2.09, CI (1.02, 4.29)) whereas participants > 70 years old were less likely to report worsening of their mental health (OR 0.16, CI (0.03, 0.86)). Specifically, for each additional year of age, participants were more likely to report that their mental health had been impacted less negatively during COVID-19 lockdown (OR 1.04, CI (1.01, 1.08))

For all participants, mean wellbeing (WEMWBS) was 44.9 ± 11.3 – lower than the population wellbeing norm – and participants on average reported mild depression (PHQ-9) of 7.53 ± 6.11. For median wellbeing and depression scores based on high risk group, see Supplementary Table 6.

Wellbeing

Participants who were older reported statistically higher wellbeing (WEMWBS). For each additional year, wellbeing increased by 0.25 ($p < 0.001$). By contrast, women reported wellbeing that was 1.75 lower than those of men ($p = 0.048$).

Depression

Pregnant women and older participants reported lower depression (PHQ-9), with pregnant women reporting scores 4.41 points lower than women who were not pregnant ($p = 0.013$), whereas for each additional year of age there was a reduction in depression by 0.14 points ($p < 0.001$). In addition, participants' weight impacted depression, with each unit increase in BMI, there was an increase of depression by 0.09; gender impacted depression with women reporting an average depression score that was 1.41 points higher than men; and participants with three or more indicators of high-risk reported greater depression with a mean increase of 4.78 compared to those with only one high-risk indicator ($p < 0.05$ for all factors).

Table 1. Demographics characteristics of participants in the AAA survey.

Participant Characteristics[1]	
Age[2] mean (SD; years)	54.6 ±14.9
BMI[2] mean (SD; kg/m^2; n = 1003)	28.8 ± 8.1
Index of Multiple Deprivation[2] mean (SD, n = 759)	5.33 ± 2.7
Gender n (%)	
Male	402 (39.2%)
Female	624 (60.8%)
Ethnicity n (%)	
White - British, Irish, other	979 (95.4%)
Black/Black British - Caribbean, African, other	8 (0.8%)
Chinese/Chinese British	2 (0.2%)

Middle Eastern/Middle Eastern British - Arab, Turkish, other	2 (0.2%)
Mixed race -other	5 (0.5%)
Mixed race - White and Black/Black British	3 (0.3%)
Other ethnic groups	7 (0.7%)
Health or social care worker (n=1025) n (%)	
Yes	150 (14.6%)
No	875 (85.3%)
Job requires contact with COVID-19 patients (n=144) n (%)	
Yes	39 (3.8%)
No	105 (10.2%)
Diabetes n (%)	
Yes	538 (52.4%)
No	488 (47.6%)
BMI ≥ 40 kg/m^2 n (%)	
Yes	142 (13.8%)
No	884 (86.2%)
Chronic Respiratory Disease n (%)	
Yes	179 (17.4%)
No	847 (82.6%)
Chronic Heart Disease n (%)	
Yes	132 (12.9%)
No	894 (87.1%)
Chronic Kidney Disease n (%)	
Yes	147 (14.3%)
No	879 (85.7%)
Chronic Liver Disease n (%)	
Yes	49 (4.8%)
No	977 (95.2%)
Chronic Neurological Conditions n (%)	
Yes	35 (3.4%)
No	991 (96.6%)
Spleen problems n (%)	
Yes	16 (1.6%)

No	1010 (98.4%)
Weakened immune system n (%)	
Yes	159 (15.5%)
No	867 (84.5%)
Aged > 70 years n (%)	
Yes	178 (17.3%)
No	848 (82.7%)
Pregnant n (%)	
Yes	21 (2.0%)
No	1005 (98.0%)
Other risk factors* n (%)	
Yes	303 (29.5%)
No	723 (70.5%)
Number of high-risk groups n (%)	
1	471 (45.9%)
2	336 (32.7%)
3+	219 (21.3%)

1.n = 1026 except where otherwise specified; 2. Mean and standard deviation; SD=standard deviation; N=number; %=percentage

** Short- or long-term health conditions e.g. mental health*

Table 2. Summary of Warwick-Edinburgh Mental Well-being Scale (WEMWBS) and Patient Health Questionnaire (PHQ-9) scores and changes in self-reported mental health compared to pre-COVID-19.

Participant response	
WEMWBS[1] (n = 922)	44.9 ± 11.3
PHQ-9[1] (n = 927)	7.53 ± 6.11
Mental health changes since COVID-19 (n = 893) n (%)	
Worse	397 (44.5%)
About the same	445 (49.8%)
Better	51 (5.7%)

1. Mean and standard deviation

Impact on Management of Health Conditions and Use of Technology

The impact of COVID-19 on the delivery of care for those with high-risk indicators is summarised in Table 3. Six hundred and eighty-two (66.5%) participants indicated changes to their regular healthcare appointments, while 199 (19.4%) participants indicated that there were no changes to regular healthcare support during the COVID-19 lockdown.

Participants with chronic liver disease were more likely to report change to management of health conditions compared to prior to the COVID-19 lockdown (OR 3.15, CI (1.29, 8.01)); see Supplementary Table 7. Participants with either diabetes, weakened immune systems or liver disease were more likely to report change to appointments (OR 2.40, CI (1.11, 5.75); OR 2.90, CI (1.18, 7.93); and OR 3.48, CI (1.16, 12.16), respectively); whereas participants with spleen problems had a greater likelihood of reporting changes to their medications (OR 7.10, CI (1.45, 53.03)). For each additional year of age, participants were more likely to report changes to elective surgery and their clinician (OR 1.03, CI (1.01, 1.06) and OR 1.03, CI (1.01, 1.05), respectively). However, participants who were > 70 years old were less likely to report other changes to regular healthcare support beyond those specified in the survey (OR 0.24, CI (0.05, 0.88)).

Four hundred and sixty-seven (45.5%) participants indicated that their care changed to using telephone support, while 321 (31.3%) reported that they did not use any of the platforms specified in the survey (Table 3). Participants > 70 years were less likely to use the telephone to receive care (OR 0.46, CI (0.21,0.99). Participants living with liver disease were more likely to use social media (OR 5.91, CI (1.62, 20.84)). In addition, participants with liver disease were more likely to report using virtual consultation platforms; as were participants with neurological conditions (OR 4.39, CI (1.41, 13.20) and OR 3.56, CI (1.06, 10.98), respectively). By contrast, women were less likely to use virtual consultation platforms compared to men (OR 0.56, CI (0.32, 0.98)). For each additional year in age, participants were less likely to use emails (OR 0.98, CI (0.96, 1.00)). When asked whether participants were satisfied with the support platforms and with the information received during the COVID-19 lockdown, the majority reported either being somewhat or extremely satisfied (40.3%, 39.6%, respectively; Table 3).

Four hundred and sixty-six (45.4%) participants indicated that they would welcome continued use of the platforms used during COVID-19 lockdown. When comparing gender, women were less satisfied with the platform they used (OR 0.84, CI (0.72, 0.99)); however, the level of satisfaction with using the information provided through the platform was similar across all groups. Age appeared to impact whether participants wished to continue to use the healthcare platform after COVID-19 lockdown (OR 1.03 for each additional year of age, CI (1.01, 1.06)). While those with greater social deprivation appeared to be unsure about continuing to use the platform (OR 1.10 for each increased in IMD, CI (1.02, 1.19)).

Table 3. Summary of participant changes to clinical management during COVID-19 lockdown.

	Percent Identifying (n = 1026)
Changes to regular healthcare support?* n (%)	
Appointments	682 (66.5%)
Medication	292 (28.5%)
Elective surgery	122 (11.9%)
Communication platform	183 (17.8%)

Clinician	196 (19.1%)
Other	83 (8.1%)
No change	199 (19.4%)
Platforms used to receive care n (%)	
Social media	63 (6.1%)
Mobile phone app	97 (9.5%)
Email	146 (14.2%)
Telephone	467 (45.5%)
Virtual consultation	90 (8.8%)
Other	46 (4.5%)
No platforms	321 (31.3%)
Face to face care	35 (3.4%)
How satisfied are you with the platforms? (n =860) n (%)	
Extremely dissatisfied	51 (5.0%)
Somewhat dissatisfied	92 (9.0%)
Neither satisfied nor dissatisfied	303 (29.5%)
Somewhat satisfied	234 (22.8%)
Extremely satisfied	180 (17.5%)
How satisfied are you with using information received via platforms? (n=867) n (%)	
Extremely dissatisfied	41 (4.0%)
Somewhat dissatisfied	114 (11.1%)
Neither satisfied nor dissatisfied	306 (29.8%)
Somewhat satisfied	255 (24.9%)
Extremely satisfied	151 (14.7%)
Use platforms after COVID-19? (n = 875) n (%)	
No	154 (15.0%)
No, but would welcome other platforms	81 (7.9%)
Not sure, I need more time to use them	174 (17.0%)
Yes	466 (45.4%)

1.n = 1026 except where otherwise specified.

** Changed type or frequency of support*

Concerns about COVID-19

A large proportion of participants in each high-risk group reported that they were 'very concerned' to statements about infection, spread and potential impact of COVID-19; see Supplementary Figure 7-12.

Participants with either chronic respiratory disease, chronic heart disease, CKD, other acute/chronic diseases, diabetes, or weakened immune systems were more concerned about becoming infected compared to those who did not belong to any of these high-risk groups ($p < 0.05$). The coefficients for these covariates suggest that participants in either of these high-risk groups selected the next highest response compared to individuals who believed they were not at high risk. Additionally, concerns about being infected were significantly higher for women than in men (difference 0.59; $p = 0.003$), and for older participants (difference 0.02; $p=0.032$), although the differences were relatively small. Participants with either chronic respiratory disease, chronic heart disease, CKD, BMI ≥ 40, or weakened immune systems were more concerned about experiencing severe illness or death (next highest response) compared to those who did not belong to these high-risk groups ($p < 0.05$); whereas pregnant women were less concerned (2.10 points lower) than women who were not pregnant ($p = 0.012$).

Participants with chronic respiratory disease were significantly more concerned (next highest response) about access to healthcare support ($p = 0.020$).

There were no statistically significant factors for the models with the following concerns: spreading COVID-19 to others; receiving appropriate care/support; and potentially receiving disparate healthcare support due to higher risk status. This suggests that high concern was similar across all high-risk groups.

Mitigating COVID-19

More than 50% of participants in each high-risk group practiced social distancing with the exception of those with weakened immune systems (n=71; 44.7%); see Supplementary Table 8. Twenty-one (60%) participants with chronic neurological diseases and 102 (57.3%) aged 70 years or older self-isolated. Twenty-eight (57.1%) participants with chronic liver disease, 18 with chronic neurological disease, and 96 (53.9%) aged 70 years or older used online shopping or food delivery. Eighty-five (53.5%) participants with weakened immune systems and 11 (68.8%) with spleen problems used shielding. Less than 50% of participants in each high-risk group wore protective apparel or took all of the actions specified in the survey.

Participants living with diabetes were more likely to practice social distancing (OR 2.44, CI (1.25, 4.90)), whereas participants with weakened immune systems were less likely to practice social distancing (OR 0.34, CI (0.16, 0.73)); see Supplementary Table 9. Participants living with diabetes were also more likely to wear protective apparel (OR 2.17, CI (1.13, 4.14)); while participants with people > 70 years and chronic liver disease were more likely to shop online (OR 2.66, CI (1.24, 5.88) and OR 3.34, CI (1.42, 8.14), respectively). Participants with either CKD, weakened immune systems or spleen problems were more likely to practice shielding (OR 2.76, CI (1.21, 6.31); OR 3.33, CI (1.55, 7.22); and OR 5.33, CI (1.15, 28.78), respectively). Finally, participants with weakened immune systems were more likely to take all mitigating risk actions identified (OR 2.61, CI (1.01, 6.41)). There were no statistically significant differences between high-risk groups with regards to self-isolation.

Interactions with Others and Stigma

Three hundred and seventy-seven (41.0%) participants indicated that people behaved differently toward them compared to prior to COVID-19 lockdown. When asked if during the COVID-19 lockdown they felt more stigmatised or discriminated against 119 (13.0%) reported they had compared to prior to COVID-19 lockdown. Of these participants, 65 (54.6%) were living with diabetes, 25 (21.0%) had a BMI of ≥ 40 kg/m^2, 21 (17.6%) had chronic respiratory disease, 24 (20.2%) had a weakened immune system, and 44 (37%) had other chronic short- or long-term risk factors. In all other high-risk groups fewer than 20 participants said that they felt stigmatised or discriminated against.

Participants with chronic neurological diseases were less likely to report that people behaved differently towards them (OR 0.23, CI (0.06, 1.00)) There were no discernible differences between the high-risk groups with regards to feelings of stigma and discrimination compared to prior to COVID-19 lockdown.

Exploration and Prediction using Text-Derived Features

Clustering

The personality and sentiment features were used as input to a clustering algorithm (*k*-means) in order to separate survey participants into groups. As the *k*-means algorithm requires to specify the number of clusters, we first experimented with different values of *k* (between 2 and 10). We used two heuristics (sum of squared distance and an elbow plot, and degree of separation between clusters and a silhouette plot) to evaluate which *k* value resulted in most coherent and disparate clusters. According to both heuristics, two clusters resulted in the best differentiation: the first cluster with 335 participants and second with 301 participants (see Figure 1 for a visualisation of the clusters). Table 4 lists the ten most differentiating features and the cluster centroid values. The first cluster had a negative compound sentiment score and higher values for neuroticism, insecurity, 'Type A' personality (i.e., more competitive and ambitious), aggression, stress, and coldness, while the second cluster had a positive compound sentiment score and higher values for dutifulness, cooperation, and social skills. From here on in, the first cluster is referred to as the Negative Cluster, and the second cluster as the Positive Cluster.

Figure 1. Visualisation of clusters using Principal Component Analysis (PCA).

Table 4. *Cluster centroids for the ten features with greatest absolute value differences between clusters. All scores are within [0, 1] range with the exception of compound sentiment score which uses [-1, 1] range.*

Feature	Negative Cluster	Positive Cluster
Sentiment (compound score)	-0.75	0.62
Neurotic	0.85	0.61
Insecure	0.73	0.50
'Type A'	0.34	0.15
Aggressive	0.53	0.34
Dutiful	0.50	0.69
Cooperative	0.58	0.75
Stressed	0.81	0.64
Cold	0.62	0.46
Social skills	0.13	0.29

The study investigated whether the two clusters had differed in their responses (Table 5). There were no significant differences in how the two clusters took mitigating actions to avoid infection from COVID-19. However, participants in the Negative Cluster rated their concerns significantly higher than the Positive Cluster in five out of six cases; with the only concern showing no difference was about spreading COVID-19 to others. In terms of lifestyle behaviours, Negative Cluster reported greater impact on diet and sleep, and less physical activity than before COVID-19 lockdown. Negative Cluster also scored significantly worse for depression and psychological wellbeing. In terms of changes to healthcare support, Negative Cluster reported more often change to their appointments and using telephone appointments, while Positive Cluster reported no change to healthcare support, and lower satisfaction with platforms used to receive care and with the information and resources presented within them.

Table 5. Comparison between clusters of actions, concerns, lifestyle behaviours, depression and wellbeing scores, impact on health management, and use of platforms for health management. Numeric variables were compared using *t*-test, binary variables were compared using proportions *z*-test. Test results and p-values were rounded to two decimal places.

		Negative Cluster	Positive Cluster	Test result	*p*-value
Actions	Social distancing	303	188	0.83	0.41
	Self-isolation	202	104	-1.72	0.09
	Wearing protective apparel	127	81	0.55	0.58
	Online shopping	187	117	0.53	0.60
	Shielding	109	64	-0.14	0.89
	All above	51	26	-0.71	0.48
Concerns	Becoming infected	7.72	7.05	-3.29	<0.01
	Severe illness or death	7.88	7.25	-2.82	0.01
	Spreading COVID-19 to others	7.12	6.76	-1.44	0.15
	Access to healthcare	6.06	4.97	-4.28	<0.01
	Appropriate care if infected	6.88	5.76	-4.22	<0.01
	Worse care compared to low-risk individuals	6.02	5.05	-3.23	<0.01
Lifestyle	Shopping	3.31	3.22	-1.16	0.25
	Diet	1.75	1.41	-3.72	<0.01
	Alcohol consumption	0.05	0.09	0.62	0.53
	Physical activity (amount)	-0.78	-0.28	5.25	<0.01
	Physical activity(type)	0.75	0.78	0.8	0.43
	Sleep	1.93	1.37	-5.15	<0.01
	Smoking (indicated yes)	0.05	0.01	-2.81	0.01
	Smoking (impact)	0.15	0	-0.16	0.87
	E-cigarettes (indicated yes)	0.04	0.03	-1.14	0.25
	E-cigarettes (impact)	0.53	0.33	-0.48	0.64
	Recreational drugs (indicated yes)	0.02	0.02	-0.07	0.94
	Recreational drugs (impact)	0.29	0	-0.37	0.72
Depression	PHQ-9 score	9.16	5.49	-7.63	<0.01
Wellbeing	WEMWBS score	42.23	49.36	8.29	<0.01
Change to healthcare support	General management	398	237	-1.29	0.2
	Appointments	311	161	-2.93	<0.01
	Medication	146	75	-1.33	0.19
	Elective surgery	50	36	0.91	0.36
	Communications platform	84	44	-0.8	0.43
	Clinician	91	50	-0.55	0.59
	Other	50	21	-1.45	0.15
	No change	55	60	3.61	<0.01
Platforms used to receive care	Social media	23	19	1.08	0.28
	Mobile phone app	34	34	2.27	0.02
	Email	60	35	-0.13	0.90
	Telephone	219	111	-2.05	0.04
	Virtual consultation	43	23	-0.46	0.65
	Other	18	18	1.61	0.11
	No new platforms	118	79	0.94	0.35
	Still face-to-face	18	9	-0.45	0.65

	Satisfied with platforms	0.39	0.7	3.32	<0.01
	Satisfied with information	0.33	0.64	3.46	<0.01
	Continue using in the future	186	124	1.31	0.19

Discussion

This study provides the essential evidence to start addressing the dearth of detailed information regarding the impact of COVID-19 on the 2.2 million people identified at higher risk of severe illness from COVID-19 and advised to shield during lockdown.

During the COVID-19 lockdown, the management of health conditions amongst people identified as at high risk of severe illness changed. Nearly half of the sample reported using telephone care, with people aged 70 years or over less likely to use telephone care. People living with diabetes and liver disease reported the greatest use of social media, while people living with chronic liver disease and neurological conditions were most likely to use virtual consultations. The majority of participants reported that they were satisfied with the new platforms and the information provided to manage their health conditions, and importantly would welcome continued use. Notably, people living in higher deprivation reported greater uncertainty about continued use which may identify concerns regarding internet poverty and inability to access digital care within this community. It is imperative that new technologies for supporting people living with health conditions are accessible for all, and does not disproportionately impact subgroups of the population and potentially widen health inequalities. Indeed, the higher prevalence of chronic health conditions amongst people living in more deprived communities, and the disproportionate impact of COVID-19 infection on people living in poorer communities, highlights the need to address these concerns or uncertainty, given the likelihood of continued short- and long-term use of new technologies to support patient care.

Emerging evidence has demonstrated that the COVID-19 lockdown and restrictions have impacted lifestyle behaviours such as decrease in physical activity and sleep deprivation, although this has predominantly focussed on the general population.[13,14] Current study findings provide novel evidence about the impact on people identified as at high risk of severe illness from COVID-19 infection, and thus, people who have needed to follow greater restrictions. Reductions in physical activity were also observed for people with chronic respiratory disease, CKD and weakened immune system, which would be consistent with those who may have avoided venturing outside due to risk of COVID-19 infection. Across all groups, people reported that their sleep quality and amount was impacted.

As the pandemic has progressed, a greater emphasis has been placed on the impact that lockdown, restrictions on daily life including meeting with significant others, the loss of loved ones, the loss of work and others have had on mental health. This study demonstrates that for the majority of the sample, the pandemic has led to worse mental health, with only 6% reporting an improvement. This was greater than the 35% of vulnerable people reporting worse mental health from the Office of National Statistics.[2] This may have been due to population differences but overall represents a consistent message that lockdown had a negative impact on people's self-reported mental health. In alignment, mean wellbeing was lower than the national average,[15] and depression was higher than that found in a general population sample from the COVID-19 Social Study.[16] The statistical analysis demonstrates that young women who are at risk of severe illness from COVID-19 report that their mental health has been most negatively impacted, have lower wellbeing and higher depression. This is consistent with other data showing that depression was higher in young people,[16] suggesting that the lockdown restrictions has more negatively impacted younger people and requires greater consideration. Moreover, people with a higher BMI or with multiple risk factors reported the highest depression, which may well be expected given the link between obesity and depression.[17] Given that this study highlights the impact of the COVID-19 pandemic on the mental health of people identified as at high risk of severe illness, policymakers, community groups, and health charities should consider how and in what ways they can best support or refer people whose mental health may have been compromised – which for many may go above and beyond their usual activities. This may involve policymakers considering how and in what ways to support in particular health charities to provide this care given economic challenges facing many during the pandemic and the reduction in access to clinical services.

Artificial Intelligence methods were applied to the data to consider how intrinsic factors, specifically personality and sentiment, derived from language samples could provide additional insights into people's actions and attitudes relating to COVID-19. Based on those intrinsic factors, the participants clustered into two groups. Crucially, the two groups differed significantly in their responses. Compared to the Positive Cluster (with higher dutifulness and cooperation scores and positive sentiment), the Negative Cluster had higher neuroticism, insecurity score and negative sentiment and reported higher levels of concern, greater negative impact on lifestyle behaviours, higher depression and lower wellbeing, alongside lower satisfaction with platforms used to deliver their healthcare during COVID-19. Furthermore, when predicting actions or attitudes for individuals, word vectors (features derived from language samples) achieved fairly good to good prediction performance (between 0.7 and 0.8 AUROC). On the other hand, personality and sentiment features were better predictors of depression and wellbeing than word vectors. Overall, current study data suggests that analysing language samples using Artificial Intelligence could yield useful insights into people's attitudes and actions relating to COVID-19 and effectively identify individuals at higher risk. Future work can explore the feasibility of using these methods as a preventative support measure, by using them within a digital environment to identify whether someone is likely to be more significantly impacted and offer them appropriate support.

This study is not without limitations. First, it provides a cross-sectional analysis, and as such informs about the COVID-19 lockdown period. Nevertheless, this study provides much needed insights about a subsection of the population who have been subject to greater restrictions and as the findings demonstrate, have been impacted in terms of access to healthcare, lifestyle behaviours, and mental health. Second, due to the recruitment methods, the sample was not totally representative, has used a self-recruitment methods which may have led to a more motivated sample and would not have recruited people experiencing digital poverty. Finally, given the reported increased risk for people from black and minority ethnic (BAME) backgrounds, the low recruitment of people from BAME backgrounds means that comparison of the impact on people of different ethnic backgrounds was not possible.

Further research to assess the longer term impact of COVID-19 on people identified at high risk is needed. This research should provide insights into the longer term changes to healthcare access, provision and support, and where relevant, how technological platforms have facilitated continued care. This study demonstrated the adults identified as at high risk of severe illness from COVID-19 reported lower wellbeing, that their mental health had worsened and varied levels of depression. Given the continued restrictions for many people within this population subgroup, and thus the associated impact on other areas of life including employment, future research should assess the longer term impact on mental health. Indeed, it might be argued that people with mental health concerns may also be at high risk from the impact of COVID-19 and as such, appropriate measures and support made available. Finally, research is also needed to understand the impact of delayed healthcare support such as elective surgery.

Conclusions

This study provides novel insights into the awareness, attitudes and actions of UK adults identified as at high risk of severe illness from COVID-19. In particular, this study demonstrates that the pandemic has impacted people's access to healthcare support, lifestyle behaviours and mental health. Furthermore, the use of an innovative Artificial Intelligence tool has demonstrated the advanced insights that can be gleaned from patient language samples to predict behaviours and health outcomes in response to the COVID-19 pandemic. This has the potential to enable clinicians to identify people at greater risk and highlights the value of using Artificial Intelligence within healthcare, particularly during the COVID-19 pandemic.

As such, there are important implications for policy makers, healthcare and clinical practice as well as healthcare technology companies. Working with adults identified as at high risk of severe illness from COVID-19, action is needed that aims to address issues relating to access to healthcare, attitudes towards use of technological platforms and to support people's mental health. The findings demonstrate that healthcare access and support has been significantly impacted, that their lifestyle related behaviours

have changed and that mental health has worsened. It is paramount to not only understand but take actions to reduce any potential unintended consequences of the restrictions placed on daily life, which may avoid exacerbating physical and mental health concerns.

Contributorship Statement

SWF conceived the study. SWF, AB and AT contributed to the study design and methodology. SWF was responsible for the oversight of the study. SWF, AB & AT contributed to the recruitment of participants. AP & ACJ were responsible for data analysis. All authors contributed to data interpretation, and the writing of the manuscript. All authors contributed to critical revision of the manuscript for important intellectual content and gave final approval.

Competing Interest

SWF & AP are employed by Scaled Insights.

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Data sharing statement

De-identified participant data that underlie the results reported in this manuscript will be made available on publication and ending 5 years after publication. Proposals should be made to the corresponding author and will require a data access agreement.

Ethical Approval

The study was granted ethical approval by the School of Psychology Research Ethics Committee at University of Leeds (REC number PSYC-28).

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British Liver Trust
British Lung Foundation
Diabetes UK
Elton John AIDS Foundation

European Association for the Study of Obesity
Hepatitis C Trust
Kidney Care UK
JDRF
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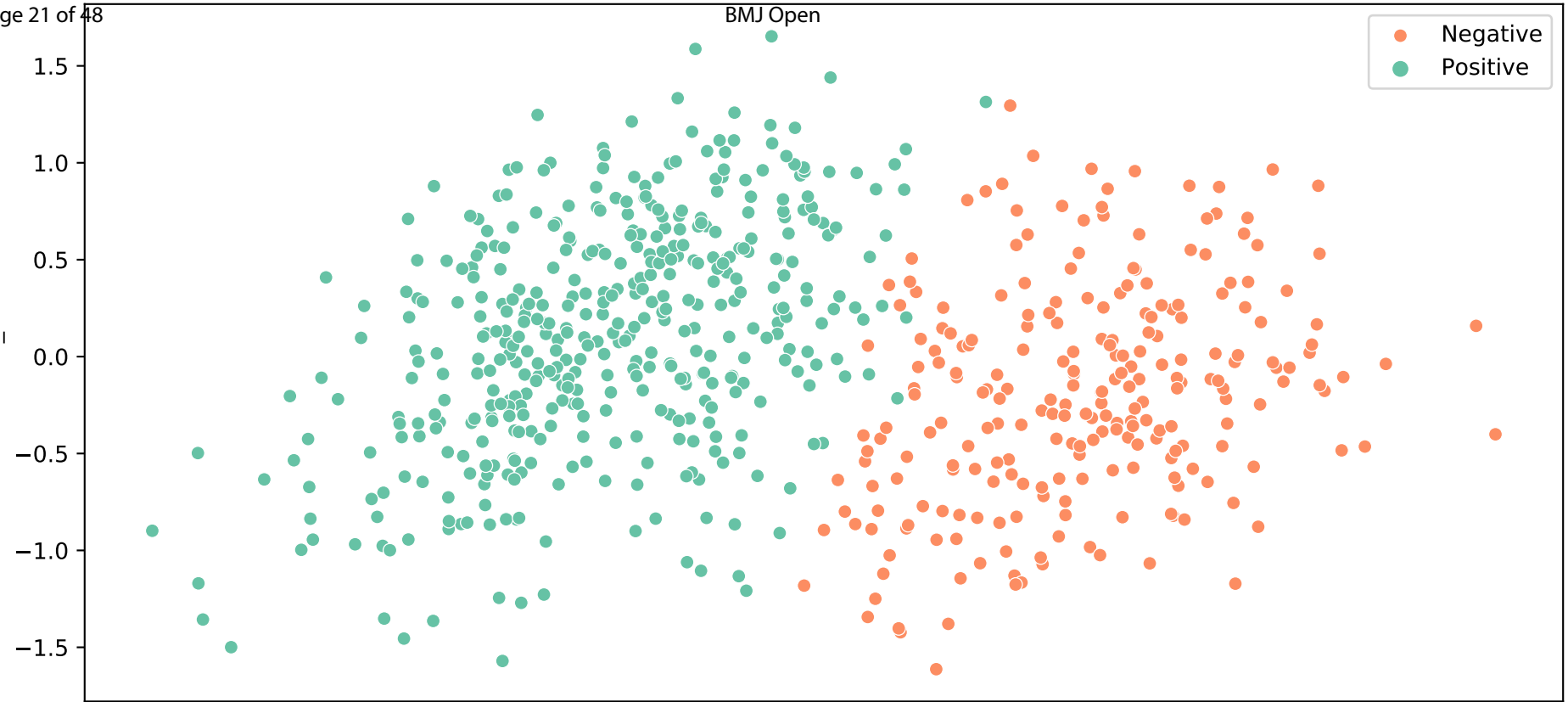
LIVErNORTH
Melanoma UK
MS Society
Nexus Leeds
Norfolk & Norwich Liver Group
Obesity UK
Parkinson's Society
PBC Foundation
Public Health Scotland
Research for the Future
Salford Sickle Cell Society
Terrance Higgins Trust
The Somerville Foundation
Yorkshire Cancer Community



Supplementary materials

1. Awareness, Attitudes and Actions (AAA) survey
2. Supplementary data analysis
3. Statistics tables and figures
4. AI prediction models

Awareness, Attitudes and Actions (AAA) survey

Survey questions	Response categories/instruction
Section A: demographics	
Does any of the following apply to you? (select all that apply)	Diabetes (Type 1 or 2) A body mass index (BMI) of 40 or above Chronic (long-term) respiratory diseases, such as asthma, chronic obstructive pulmonary disease (COPD), emphysema or bronchitis Chronic heart disease, such as heart failure Chronic kidney disease Chronic liver disease, such as hepatitis Chronic neurological conditions, such as Parkinson's disease, motor neurone disease, multiple sclerosis (MS), a learning disability or cerebral palsy Problems with your spleen – for example, sickle cell disease or if you have had your spleen removed A weakened immune system as the result of conditions such as HIV and AIDS, or medicines such as steroid tablets or chemotherapy None of these apply to me I have a different long term health condition not listed above (please specify in the text box provided)
Please state your age	Textbox
Gender	Male Female Other (textbox) Prefer not to say
What is your ethnicity?	White – British, Irish, other Asian/Asian British – Indian, Pakistani, Bangladeshi, other Chinese/Chinese British Black/Black British – Caribbean, African, other Middle Eastern/Middle Eastern British – Arab, Turkish, other Mixed race – White and Black/Black British Mixed race – other Other ethnic groups (please specify in the text box provided) Prefer not to say
What is your height in feet and inches, or centimetres?	Text box provided for each
What is your weight in pounds or kilograms?	Text box provided for each

Do you work in health or social care?	Yes (please provide your job title in the text box) No
Does your job require you to be in direct contact with coronavirus (COVID-19) patients?	Yes No
Please provide the first half of your postcode (e.g. NG1)	Textbox provided
Please provide your email address	Textbox provided
Section B: awareness, attitudes and actions relating to COVID-19	
Have you had coronavirus?	Yes – I have been diagnosed and am still ill Yes – I have and I have recovered Yes - I have been diagnosed, but had no symptoms No
Have you experienced coronavirus symptoms?	Yes - and I was diagnosed Yes – but I have not been diagnosed No I don't know what the symptoms
Which of the below are symptoms of coronavirus? (Select all that is relevant)	Persistent cough Feeling confused Loss of appetite Loss of smell Loss of taste Tightness in chest Diarrhoea Fatigue Shortness of breath Fever Sore throat None of the above
Have you taken any of the actions below in response to the coronavirus (COVID-19) outbreak? (select all that apply)	Social distancing Self-isolation Worn protective apparel (e.g. gloves, mask etc.) Used online shopping or food delivery service Shielding due as my health status means I am defined as 'extremely vulnerable' All of the above Other (Textbox)
Do you believe you are at higher risk of severe illness from coronavirus (COVID-19)?	Yes No
Why do you believe you are at a higher risk of severe illness from coronavirus (COVID-19)? (only for those who answered yes)	Textbox
Why do you believe you are not at a higher risk of severe illness from coronavirus (COVID-19)? (only for those who answered no)	Textbox

Describe how being identified as being at a higher risk of severe illness from coronavirus (COVID-19) by the UK Government, has made you feel?	Textbox
What sources have informed you that you are at a higher risk from coronavirus (COVID-19)? (select all that apply)	Traditional media (TV, Newspapers, Radio) Social media (Twitter, Facebook, Instagram, Snapchat) National or Local Government Employer Healthcare organisations Community groups Charity Friends and Family Schools and education centres Other (please specify in the text box provided)
Do you feel like you have enough information specific to your higher risk of severe illness from coronavirus (COVID-19)?	Yes No
Why do you believe you have received enough information specific to your higher risk of severe illness from coronavirus (COVID-19), and what more do you want to know? (only for those who answered yes)	Textbox
Why do you believe you have not received enough information specific to your higher risk of severe illness from coronavirus (COVID-19), and what else do you want to know? (only for those who answered no)	Textbox
Have you used other forms of information (i.e. nonprofessional/social media "experts"/other people/patients) since the COVID-19 outbreak?	Yes No
Please specify what information you have used relating to your higher risk status since the coronavirus (COVID19) outbreak	Textbox
How concerned are you about each of the statements below • Becoming infected with coronavirus (COVID-19) • Severe illness and possibly death from coronavirus (COVID-19) • Spreading coronavirus (COVID-19) to others including family and friends • Access to healthcare support (e.g. advice, medication) • If you become infected, that you would receive appropriate care/support • That your higher risk of severe illness from coronavirus (COVID-19) means you may not	Likert scale from 0 (Not concerned at all) to 10 (Very concerned)

receive healthcare support compared with people who do not have a higher risk status	
Section C: impact of COVID-19 on management of health conditions and use of technology	
Has your management of your health condition changed compared to before the coronavirus (COVID-19) outbreak?	Yes No Not applicable (70 years or over or pregnant without a health condition)
How and why has it changed?	Textbox
How do you feel about changing your management of your health condition due to the coronavirus (COVID-19) outbreak?	Textbox
Has COVID-19 changed your regular healthcare support? (this could type or frequency of support e.g. appointments, service, medications, communication consultant)	Appointments (please specify in the text box) Medication (please specify in the text box) Elective surgery (please specify in the text box) Communication platform (please specify in the text box) Clinician caring for me (please specify in the text box) Other (please specify in the text box) There has been no change
Have you received care through any of the following platforms?	Social media (please specify in the text box) Mobile phone app (please specify in the text box) Email Telephone Virtual consultation e.g. Zoom, Microsoft Teams (please specify in the text box) Other (please specify in the text box) No platforms have been used I am still receiving face to face care
How satisfied are you with using the platforms that you are receiving care through?	Extremely dissatisfied Somewhat dissatisfied Neither satisfied nor dissatisfied Somewhat satisfied Extremely satisfied
How satisfied are you with using the information/resources provided through the platforms that you are receiving care through?	Extremely dissatisfied Somewhat dissatisfied Neither satisfied nor dissatisfied Somewhat satisfied Extremely satisfied
Would you welcome the continued use of these platforms in the future, after the coronavirus (COVID-19) outbreak?	Yes No, but would welcome other platforms (please specify in the text box) No Not sure, I need more time to use them

You indicated that you have more than one of the high risk indicator for severe illness from coronavirus (COVID19). Please describe how this makes you feel, and why?	Textbox
Section D: Mental Health and Wellbeing	
Since the coronavirus (COVID-19) outbreak, my mental health is	Yes No
Warwick-Edinburgh Mental Well-being Scale (WEMWBS) During the past two weeks... • I've been feeling optimistic about the future • I've been feeling useful • I've been feeling relaxed • I've been feeling interested in other people • I've had energy to spare • I've been dealing with problems well • I've been thinking clearly • I've been feeling good about myself • I've been feeling close to other people • I've been feeling confident • I've been able to make up my own mind about things • I've been feeling loved • I've been interested in new things • I've been feeling cheerful	Not at all Rarely Some of the time Often All of the time
Patient Health Questionnaire (PHQ-9) Over the last two weeks, how often have you been bothered by any of the following problems • Little interest or pleasure in doing things? • Feeling down, depressed, or hopeless? • Trouble falling or staying asleep, or sleeping too much? • Feeling tired or having little energy? • Poor appetite or overeating? • Feeling bad about yourself - or that you are a failure or have let yourself or your family down? • Trouble concentrating on things, such as reading the newspaper or watching television? • Moving or speaking so slowly that other people could have noticed? Or the opposite - being so fidgety or restless that you have been moving around a lot more than usual? • Thoughts that you would be better off dead, or of hurting yourself in some way?	Not at all Several days More than half the days Nearly every day
Section D: lifestyle related behaviours	

Has your shopping changed since the coronavirus (COVID-19) outbreak?	A great deal A lot A moderate amount A little Not at all
Describe how your shopping has changed since the coronavirus (COVID-19) outbreak	Textbox
Has your diet changed since the coronavirus (COVID19) outbreak?	A great deal A lot A moderate amount A little Not at all
Describe how your diet has changed since the coronavirus (COVID-19) outbreak	Textbox
Has your alcohol consumption changed since the coronavirus outbreak?	I have consumed much less alcohol than usual I have consumed less alcohol than usual It hasn't changed I have consumed more alcohol than usual I have consumed much more alcohol than usual
Why has your alcohol consumption changed since the coronavirus (COVID-19) outbreak?	Textbox
Has the amount of physical activity you usually engage in changed since the coronavirus outbreak?	I am much less active I am less active It hasn't changed I am more active I am much more active
Has the type of physical activity you usually engage in changed since the coronavirus outbreak?	Yes No
Describe how and why your physical activity has changed since the coronavirus outbreak	Textbox
Has the amount or quality of your sleep changed since the coronavirus outbreak?	A great deal A lot A moderate amount A little Not at all
Describe how and why the amount or quality of your sleep has changed since the coronavirus outbreak	Textbox
Do you smoke tobacco?	Yes No
Has the amount of tobacco you smoke changed compared to before the coronavirus (COVID-19) outbreak?	Much more Somewhat more About the same Somewhat less Much less
Do you use e-cigarettes?	Yes No

Has the amount of e-cigarettes you use changed compared to before the coronavirus (COVID19) outbreak?	Much more Somewhat more About the same Somewhat less Much less
Other than alcohol or tobacco, do you use any recreational drugs?	Yes No
Has the amount of recreational drugs you use changed compared to before the coronavirus (COVID19) outbreak?	Much more Somewhat more About the same Somewhat less Much less
Section E: Interaction with others	
For the following questions, please respond with your health condition or higher risk status (70 years old or over or pregnant regardless of medical conditions) in mind. Since the coronavirus (COVID-19) outbreak...	
Other people have behaved differently towards you?	Yes No
Describe how and why people have behaved differently towards you since the COVID-19 outbreak?	Textbox
You felt stigmatised or discriminated against?	Yes No
Describe the stigmatising and/or discriminatory experience(s) you have had since the COVID-19 outbreak, and how this has made you feel?	Textbox
Final section	
Is there anything that you haven't had chance to say about the coronavirus outbreak that you would like to share?	Textbox

Supplementary Data analysis

Text Data

Text data was collected across 17 open-ended questions which were distributed throughout the survey sections. All responses to open-ended questions were concatenated, yielding a language sample for each survey participant, which was then tokenised using spaCy's large English web model[1]. The length of the concatenated responses (i.e. the number of tokens, including words, digits, and punctuation) varied from 1 to 2125 tokens (mean=184, median=135). The language sample for each participant was further processed to derive sentiment scores and personality scores. VADER Sentiment Analysis tool (Hutto & Gilbert, 2014) was used to obtain sentiment scores (positive, neutral, negative, and compound sentiment). Personality scores were obtained using proprietary software by Scaled Insights. The software takes as input a language sample and produces 114 personality features. Following this, the 118 features (114 personality, 4 sentiment) were used as input into the multiple machine learning models described below. As the reliability of the personality modelling software depends on the number of words provided in the language sample, the following analysis was restricted to participants (N=636) whose combined text response consisted of at least 100 tokens. The machine learning was used in two settings: unsupervised (clustering) and supervised (classification or regression).

In addition to the clustering, we investigated to what extent features obtained from a language sample could be used for predicting concerns, mitigating actions, impact on lifestyle behaviours, and wellbeing and depression scores in the context of COVID-19. A model which predicts these attitudes and behaviours and requires only a language sample could potentially be used within a digital environment to better identify people who might be more likely to be negatively impacted and offer them preventative support.

For each attitude or behaviour we trained a separate binary or multi-class classifier. We first explored a range of different classifiers (logistic regression, support vector machine, stochastic gradient descent classifier, and Random Forest). Across all classifiers we found that Random Forest achieved the best results, and we tuned the parameters for each classifier separately. The tuned parameters were then used to train the final classifiers using 10-fold cross-validation. As there were only sufficient language samples for 636 participants, we also trained classifiers using GloVe word vectors obtained from the same language model as the tokens. By using word vectors, we were able to train prediction models using all participants' data.

All classification problems were evaluated using the Area Under the Receiver Operating Characteristics (AUROC) metric, while regression problems were evaluated using Mean Absolute Error (MAE) and explained variance.

[1] https://spacy.io/models/en#en_core_web_lg

Prediction models

Concerns about COVID-19

The responses relating to concerns were all expressed on a [1,10] scale. To form classes, the values were split into 'slight' (1-3), 'some' (4-7) and 'great' (8-10). Word vectors achieved the best performance with AUROC ranging from 0.71 to 0.78; see Supplementary Table 3.

Mitigating COVID-19

The mitigating actions each formed a binary class (i.e. someone either used particular mitigation action or not). Best performance was achieved by word vectors with AUROC ranging between 0.67 and 0.82. In the case of a more unbalanced class (predicting someone taking all possible mitigating actions), the best AUROC score (0.68) was achieved by personality and sentiment features; see Supplementary Table 2.

Impact of COVID-19 on Health and Lifestyle Related Behaviours

The responses on the impact of COVID-19 on lifestyle behaviours, used scales which were converted to classes as follows. Scale [-2,2] (used for alcohol consumption, physical activity, smoking, e-cigarettes, and recreational drug use) was converted to 'Decrease' [-2,-1], 'No Change' [0], 'Increase' [1,2]. Scale [0,4] (used for shopping, diet and sleep) was converted to 'No or little impact' [0,1], 'Some impact' [2], 'Great impact' [3,4]. For the lifestyle behaviours which were not well represented in the survey cohort (smoking, e-cigarettes, and recreational drug use) the results are very low (AUROC slightly better than random at 0.53 for recreational drug use). The best classifiers for other lifestyle behaviours had AUROC scores between 0.72 and 0.81; see Supplementary Table 4.

Impact of COVID-19 on Wellbeing

The scores for WEMWBS and PHQ-9 for both measures were used directly as target variables in the regression models. Unlike the prediction models reported previously, for both wellbeing and depression scores the best performing models used personality and sentiment scores. The model for depression achieved MAE = 4.25 and explained variance of 0.15, while the wellbeing model achieved MAE=7.97 and explained variance of 0.17; see Supplementary Table 5.

Supplementary Table 1. Prediction results for mitigating actions using three feature groups and evaluated using AUROC. The best performing feature group is in bold.

	Social distancing	Self-isolation	PPE	Online shopping	Shielding	All above
# positive class	491	306	208	304	173	77
# negative class	145	330	428	332	463	559
Personality and sentiment features	0.66	0.55	0.51	0.49	0.62	**0.68**
Word vectors	**0.82**	**0.7**	**0.67**	**0.68**	**0.73**	0.54
All features	0.71	0.58	0.51	0.52	0.69	0.67

Supplementary Table 2. Prediction results for concerns using three feature groups and evaluated using AUROC. The best performing feature group is in bold.

	Becoming infected	Severe illness or death	Spreading to others	Access to healthcare	Enough support	Less care compared to low risk
# Slight concern	60	71	114	197	156	236
# Some concern	214	164	190	229	185	160
# Great concern	362	401	332	210	295	240
Personality and sentiment features	0.63	0.6	0.54	0.58	0.58	0.58
Word vectors	**0.78**	**0.78**	**0.73**	**0.71**	**0.71**	**0.71**
All features	0.64	0.62	0.52	0.58	0.58	0.58

Supplementary Table 3. Prediction results for lifestyle behaviours using three feature groups and evaluated using AUROC. The best performing feature group is in bold.

	Shopping	Diet	Alcohol	Amount of physical activity	Sleep	Smoking	E-cigarettes	Recreational drugs
# Decrease / Little impact	47	302	96	385	293	5	2	3
# No change / Some impact	90	205	372	99	157	623	624	628
# Increase / Great impact	499	129	168	152	186	8	10	5
Personality and sentiment features	0.56	0.62	0.61	0.65	0.65	0.44	0.55	0.36
Word vectors	**0.81**	**0.74**	**0.72**	**0.8**	**0.75**	**0.6**	**0.67**	0.45
All features	0.55	0.6	0.56	0.61	0.65	0.58	0.58	**0.53**

Supplementary Table 4. Prediction results for depression (Patient Health Questionnaire, PHQ-9) and wellbeing score (Warwick-Edinburgh Mental Well-being Scale, WEMWBS) using three feature groups and evaluated using mean absolute error and explained variance. The best performing feature group is in bold.

	Depression score (PHQ-9)	Wellbeing score (WEMWBS)
# participants	584	636
Personality and sentiment features, MAE	**4.25**	**7.97**
Personality and sentiment features, Exp. Var.	**0.15**	**0.17**
Word vectors, MAE	4.52	8.6
Word vectors, Exp. Var.	0.07	0.1
All features, MAE	4.33	8.15
All features, Exp. Var.	0.12	0.13

Supplementary Table 5. Impact of COVID-19 on Lifestyle Related Behaviours

			OR (95% CI)
Changes to shopping behaviour			
	Chronic kidney disease	Yes	1.62 (1.01, 2.60)
		No	1.00
	Gender	Female	1.18 (1.02, 1.38)
		Male	1.00
Changes to diet			
	Gender	Female	1.19 (1.02, 1.39)
		Male	1.00
	Age		0.99 (0.98, 1.00)
	BMI		1.02 (1.00, 1.03)
Change to activity amount			
	Chronic respiratory disease	Yes	0.70 (0.50, 0.97)
		No	1.00
	Chronic kidney disease	Yes	0.65 (0.44, 0.96)
		No	1.00
	Weakened immune system	Yes	0.54 (0.37, 0.78)
		No	1.00
	BMI		0.98 (0.97, 1.00)
Changes to activity type			
	Chronic neurological conditions	Yes	0.23 (0.06, 1.00)
		No	1.00

Supplementary Table 6 Median wellbeing (Warwick-Edinburgh Mental Well-being Scale, WEMWBS) and depression (Patient Health Questionnaire, PHQ-9) scores based on high risk group.

	Wellbeing Median [Min, Max]	Depression Median [Min, Max]
Diabetes		
Yes	45.0 [14.0, 70.0]	6.00 [0, 26.0]
No	46.0 [14.0, 70.0]	7.00 [0, 26.0]
BMI ≥ 40 kg/m^2		
Yes	40.6 [15.0, 70.0]	10.00 [0, 26.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]]
Chronic Respiratory Disease		
Yes	43.5 [14.0, 70.0]	9.00 [0, 26.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]
Chronic Heart Disease		
Yes	47.4 [14.0, 70.0]	7.00 [0, 26.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]
Chronic Kidney Disease		
Yes	47.0 [14.0, 70.0]	6.00 [0, 26.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]
Chronic Liver Disease		
Yes	43.0 [15.0, 62.0]	7.00 [0, 22.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]
Chronic Neurological Conditions		
Yes	46.2 [19.0, 66.0]	8.00 [0, 22.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]
Spleen problems		
Yes	46.0 [26.0, 66.0]	5.00 [2.0, 13.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]
Weakened immune system		
Yes	46.0 [14.0, 68.0]	6.00 [0, 26.0]
No	45.0 [14.0, 70.0]	6.00 [0, 26.0]

Aged > 70 years		
Yes	51.0 [14.0, 70.0]	3.00 [0, 26.0]
No	44.0 [14.0, 70.0]	7.00 [0, 26.0]
Pregnant		
Yes	42.0 [29.0, 61.0]	6.00 [0, 17.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]
Other risk factors *		
Yes	44.0 [14.0, 70.0]	8.00 [0, 26.0]
No	46.0 [14.0, 70.0]	6.00 [0, 26.0]

** Changed type or frequency of support*

Supplementary Table 7. Impact on Management of Health Conditions and Use of Technology

			OR (95% CI)
Changes to management of health conditions			
	Chronic liver disease	Yes	3.15 (1.29, 8.01)
		No	1.00
Changes to appointments			
	Diabetes	Yes	2.40 (1.11, 5.75)
		No	1.00
	Chronic liver disease	Yes	3.48 (1.16, 12.16)
		No	1.00
	Weakened immune system	Yes	2.90 (1.18, 7.93)
		No	1.00
Changes to medication			
	Spleen problems	Yes	7.10 (1.45, 53.03)
		No	1.00
Changes to elective surgery			
	Age		1.03 (1.01, 1.06)
Clinician			
	Age		1.03 (1.01, 1.05)
Other changes			
	Aged > 70 years	Yes	0.24 (0.05, 0.88)
		No	1.00
Platforms used to receive care			
Social media			
	Chronic liver disease	Yes	5.91 (1.62, 20.84)
		No	1.00
Email			
	Age		0.98 (0.96, 1.00)
Telephone			
	Aged > 70 years	Yes	0.46 (0.21, 0.99)
		No	1.00
Virtual consultation			
	Chronic liver disease	Yes	4.39 (1.41, 13.20)

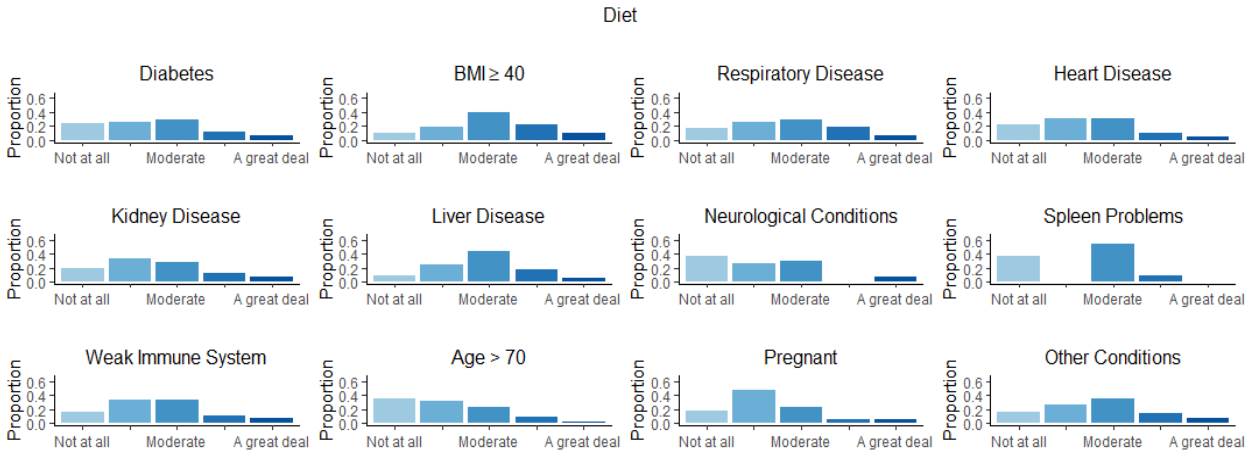
		No	1.00
	Chronic neurological conditions	Yes	3.56 (1.06, 10.98)
		No	1.00
	Gender	Yes	0.56 (0.32, 0.98)
		No	1.00

Supplementary Table 8. Mitigating actions taken in response to the coronavirus outbreak.

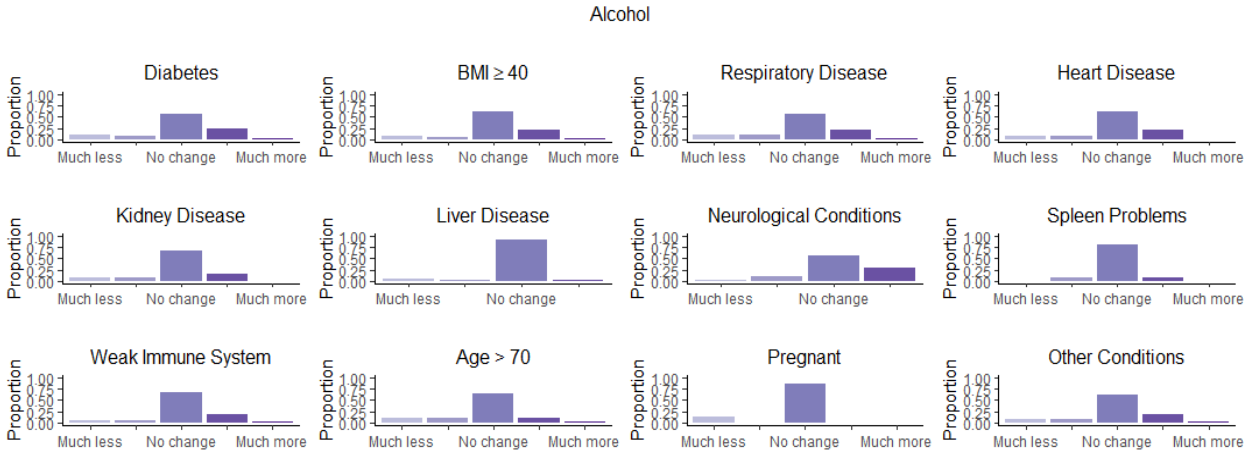
	Diabetes (N=538)	BMI ≥ 40 kg/m² (N=142)	Chronic Respiratory Disease (N=179)	Chronic Heart Disease (N=132)	Chronic Kidney Disease (N=147)	Chronic Liver Disease (N=49)	Chronic Neurological Disease (N=35)	Spleen Problems (N=16)	Weakened Immune System (N=159)	Aged > 70 years (N=178)	Pregnant (N=21)	Other Risk Factors (N=303)
Social distancing n (%)												
Yes	446 (82.9%)	105 (73.9%)	125 (69.8%)	90 (68.2%)	82 (55.8%)	32 (65.3%)	26 (74.3%)	9 (56.2%)	71 (44.7%)	135 (75.8%)	18 (85.7%)	212 (70.0%)
No	92 (17.1%)	37 (26.1%)	54 (30.2%)	42 (31.8%)	65 (44.2%)	17 (34.7%)	9 (25.7%)	7 (43.8%)	88 (55.3%)	43 (24.2%)	3 (14.3%)	91 (30.0%)
Self-isolation n (%)												
Yes	263 (48.9%)	68 (47.9%)	83 (46.4%)	58 (43.9%)	66 (44.9%)	19 (38.8%)	21 (60.0%)	7 (43.8%)	61 (38.4%)	102 (57.3%)	10 (47.6%)	148 (48.8%)
No	275 (51.1%)	74 (52.1%)	96 (53.6%)	74 (56.1%)	81 (55.1%)	30 (61.2%)	14 (40.0%)	9 (56.2%)	98 (61.6%)	76 (42.7%)	11 (52.4%)	155 (51.2%)
Worn protective apparel n (%)												
Yes	201 (37.4%)	47 (33.1%)	59 (33.0%)	44 (33.3%)	30 (20.4%)	17 (34.7%)	13 (37.1%)	1 (6.2%)	22 (13.8%)	57 (32.0%)	6 (28.6%)	106 (35.0%)
No	337 (62.6%)	95 (66.9%)	120 (67.0%)	88 (66.7%)	117 (79.6%)	32 (65.3%)	22 (62.9%)	15 (93.8%)	137 (86.2%)	121 (68.0%)	15 (71.4%)	197 (65.0%)
Used online shopping or food delivery n (%)												
Yes	258 (48.0%)	67 (47.2%)	77 (43.0%)	66 (50.0%)	60 (40.8%)	28 (57.1%)	18 (51.4%)	7 (43.8%)	55 (34.6%)	96 (53.9%)	10 (47.6%)	125 (41.3%)
No	280 (52.0%)	75 (52.8%)	102 (57.0%)	66 (50.0%)	87 (59.2%)	21 (42.9%)	17 (48.6%)	9 (56.2%)	104 (65.4%)	82 (46.1%)	11 (52.4%)	178 (58.7%)
Shielding n (%)												
Yes	100 (18.6%)	33 (23.2%)	65 (36.3%)	38 (28.8%)	68 (46.3%)	22 (44.9%)	6 (17.1%)	11 (68.8%)	85 (53.5%)	38 (21.3%)	2 (9.5%)	80 (26.4%)
No	438 (81.4%)	109 (76.8%)	114 (63.7%)	94 (71.2%)	79 (53.7%)	27 (55.1%)	29 (82.9%)	5 (31.2%)	74 (46.5%)	140 (78.7%)	19 (90.5%)	223 (73.6%)
All of the above n (%)												
Yes	55 (10.2%)	19 (13.4%)	22 (12.3%)	23 (17.4%)	31 (21.1%)	7 (14.3%)	4 (11.4%)	2 (12.5%)	40 (25.2%)	29 (16.3%)	2 (9.5%)	46 (15.2%)
No	483 (89.8%)	123 (86.6%)	157 (87.7%)	109 (82.6%)	116 (78.9%)	42 (85.7%)	31 (88.6%)	14 (87.5%)	119 (74.8%)	149 (83.7%)	19 (90.5%)	257 (84.8%)

Supplementary Table 9. Mitigating COVID-19

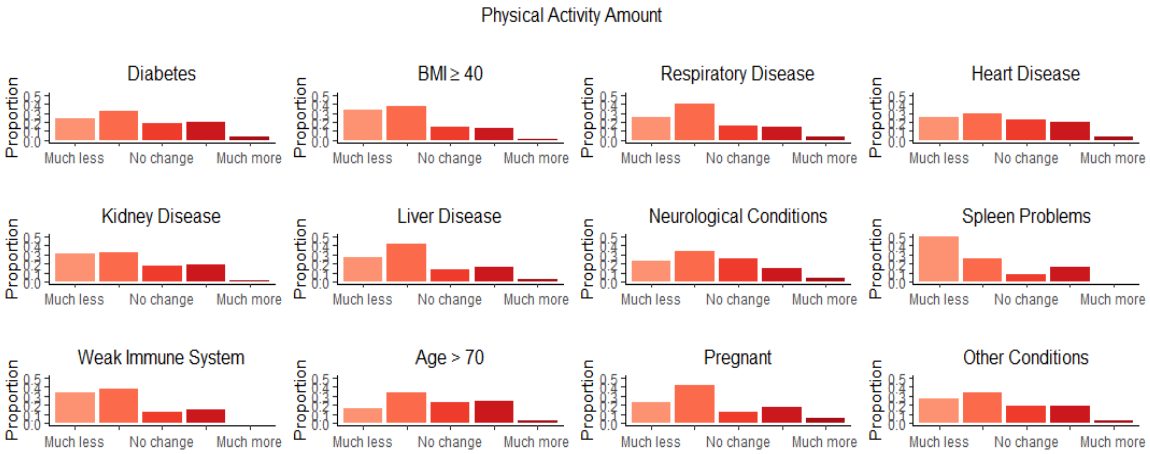
			OR (95% CI)
Social distancing			
	Weakened immune system	Yes	0.34 (0.16, 0.73)
		No	1.00
	Diabetes	Yes	2.44 (1.25, 4.90)
		No	1.00
Protective apparel			
	Diabetes	Yes	2.17 (1.13, 4.14)
		No	1.00
Shop online			
	Aged > 70 years	Yes	2.66 (1.24, 5.88)
		No	1.00
	Chronic liver disease	Yes	3.34 (1.42, 8.14)
		No	1.00
Shielding			
	Chronic kidney disease	Yes	2.76 (1.21, 6.31)
		No	1.00
	Weakened immune system	Yes	3.33 (1.55, 7.22)
		No	1.00
	Spleen problems	Yes	5.33 (1.15, 28.78)
		No	1.00
All mitigating risk actions			
	Weakened immune system	Yes	2.61 (1.01, 6.41)
		No	1.00



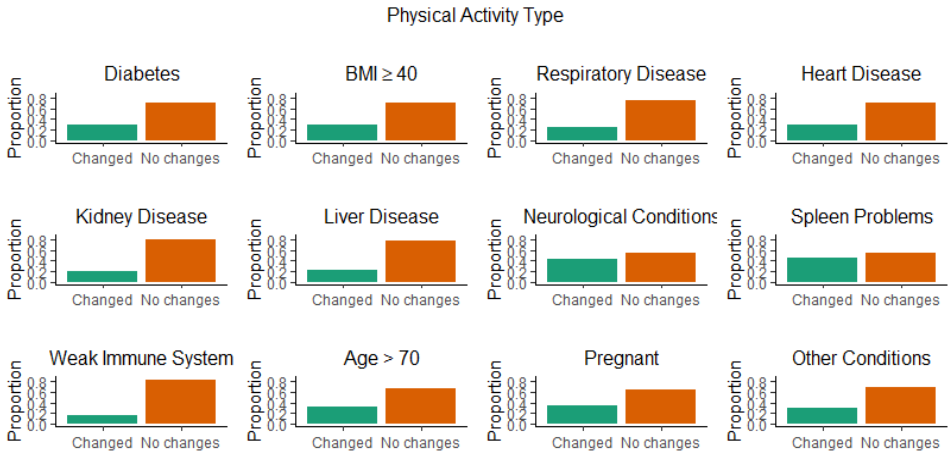
Supplementary Figure 1. Change in diet compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



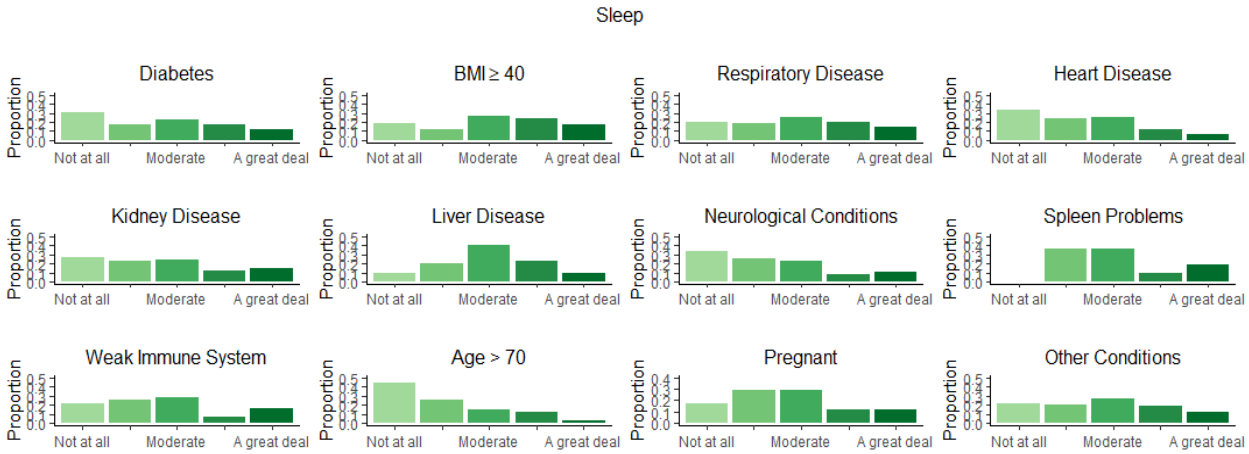
Supplementary Figure 2. Change in alcohol consumption compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



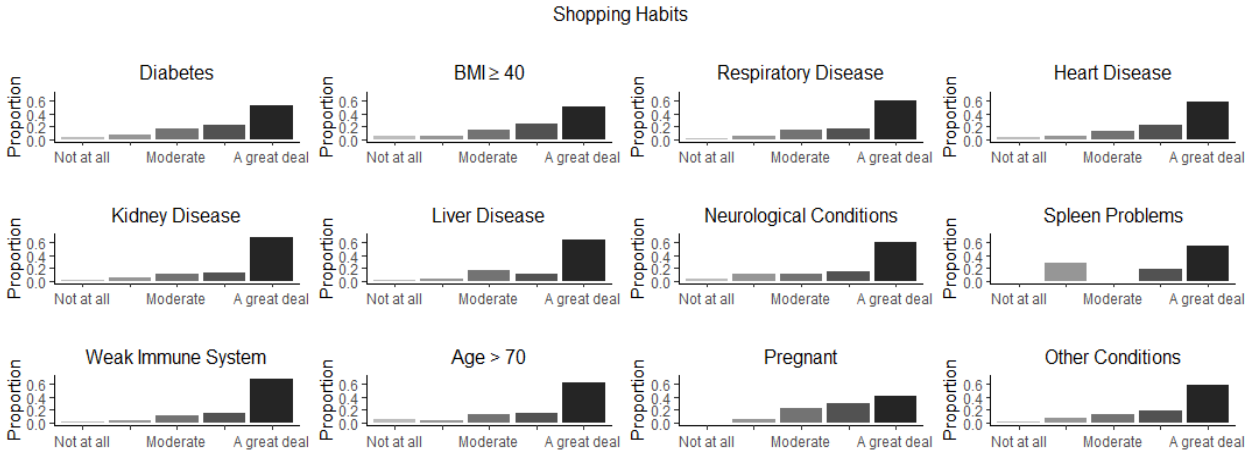
Supplementary Figure 3. Change in amount of physical activity compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



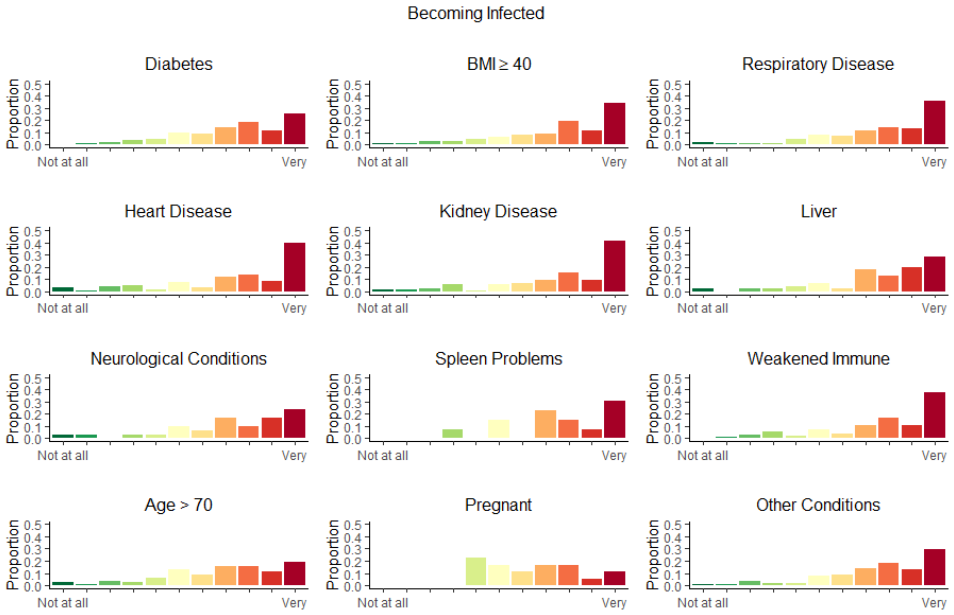
Supplementary Figure 4. Change in type of physical activity compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



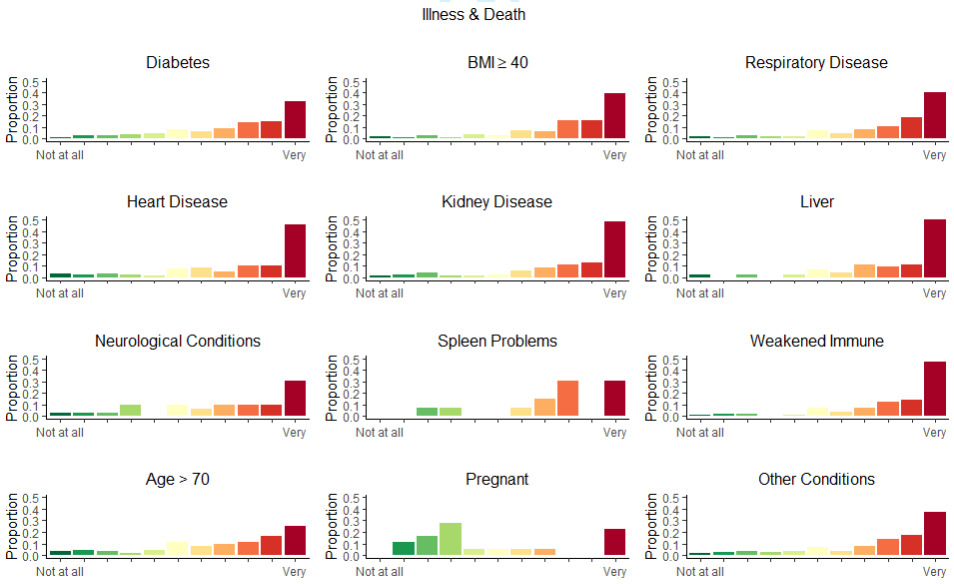
Supplementary Figure 5. Change in amount or quality of sleep compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



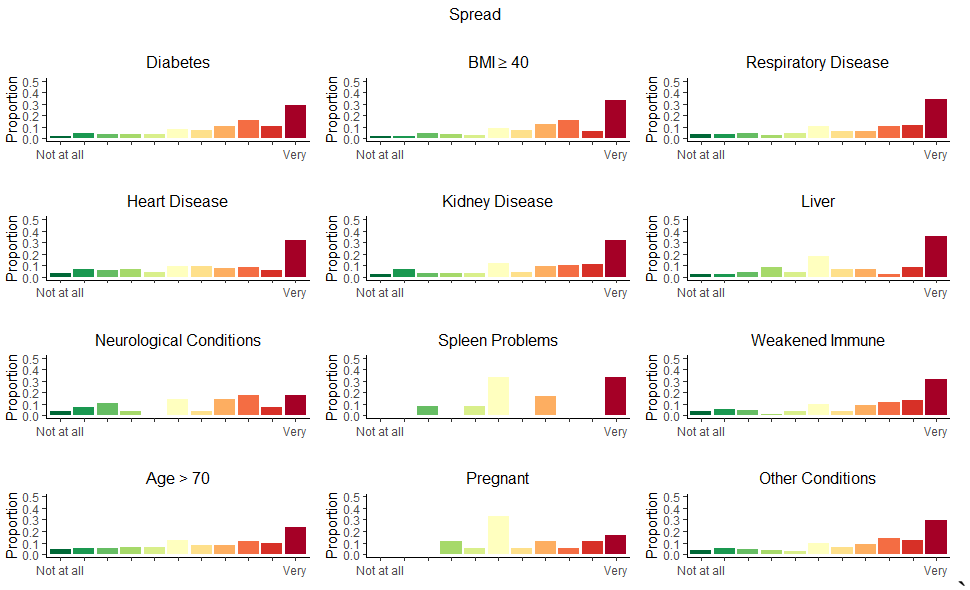
Supplementary Figure 6. Change in shopping compared to pre-COVID-19 for each high-risk indicator of severe illness from COVID-19 as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



Supplementary Figure 7: Concern about becoming infected with COVID-19 for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.

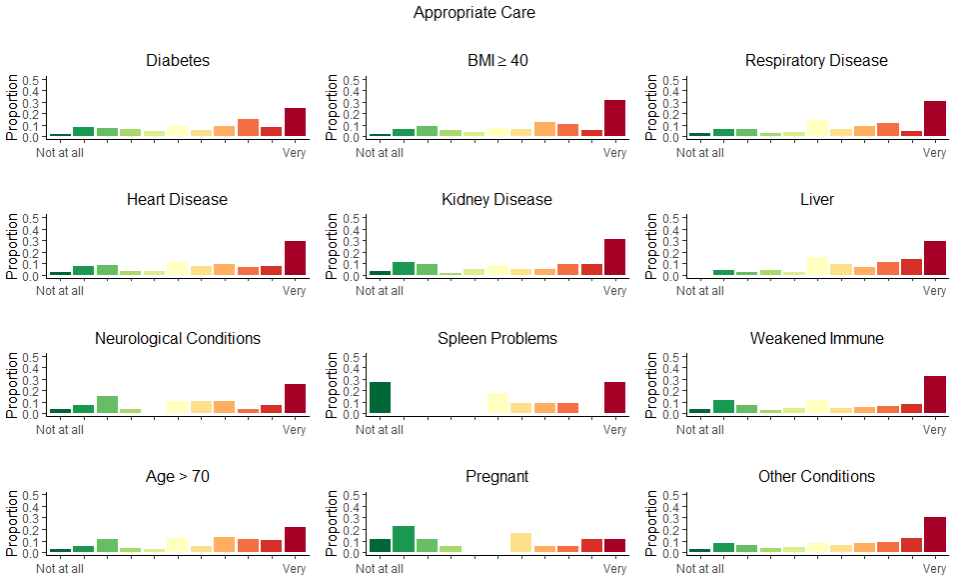


Supplementary Figure 8: Concern about severe illness and possible death from COVID-19 for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.

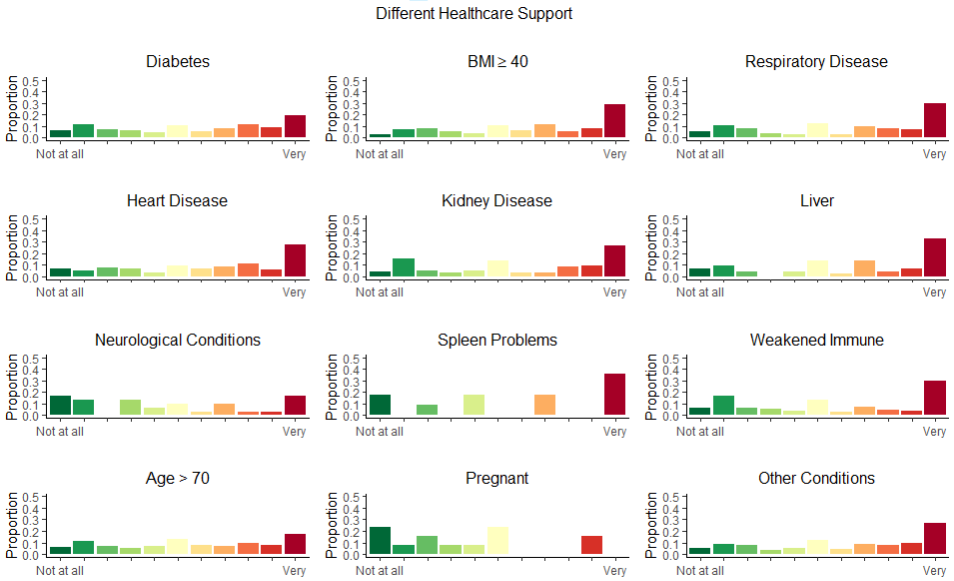


Supplementary Figure 9: Concern about spreading COVID-19 to others including family and friends for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.

Supplementary Figure 10: Concern about access to healthcare support for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



Supplementary Figure 11: Concern about access to appropriate care if infected with COVID-19 for each high-risk indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.



Supplementary Figure 12: Concern about disparate care as a result of high-risk status for each indicator as identified by the UK Government, or based on individual perception due to an acute or chronic health condition.

BMJ Checklist: A cross-sectional analysis to explore the Awareness, Attitudes and Actions of UK adults at high risk of severe illness from COVID-19

Criteria	Response
Author information: Have you provided up-to-date details of all of your co-authors? In the final published article author names, institutions and addresses will be taken from these completed fields and not from the submitted Word document. Have you got an ORCID iD? All BMJ journals publishing primarily original research now mandate ORCID iDs for all submitting authors at the time of article submission.	Yes
Manuscript length and formatting: Have you provided your abstract in the correct format? Have you supplied any required additional information for your article type, such as key messages? Have you checked that your manuscript doesn't exceed the requirements for word count, number of tables and/or figures, and number of references?	Yes
Tables: Are your tables in an editable format? Have you embedded them into the main word document? Have they been cited in the text? Have you provided appropriate table legends? Have you uploaded any lengthy tables as supplementary files for online publication?	Yes
Figures: Have you uploaded figures separately from the text? Have they been supplied in an acceptable format and are they of sufficient quality? Are they suitable for black and white reproduction (unless you intend to pay any required fees for colour printing)? Have the files been labelled appropriately? Have the figures been cited in the text? Have you provided appropriate figure legends?	Yes
References: Have all of the references been cited in the text?	Yes
Supplementary files: Have you supplied these in an acceptable format? Have they been cited in the main text?	Yes
Statements: Have you included the necessary statements relating to author contributorship, competing interests and funding, data sharing, patient consent and ethical approval?	Yes
Acknowledgements: Have you acknowledged all contributors who do not meet the criteria for authorship? Have you acknowledged if your work has been previously presented at a conference/published as a conference abstract?	Yes
Suggested reviewers: Have you suggested reviewers for your paper (if required by the journal)?	Yes
Research reporting checklists: Have you either provided the appropriate reporting guideline for your study type, or explained why a checklist isn't required?	Yes
Reproducing figures: Have you obtained permission from the copyright holder to re-use any previously published material? Has the source been acknowledged?	Yes

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 3
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 3
Methods			
Study design	4	Present key elements of study design early in the paper	Page 3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 3
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	Page 3
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 3-4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Page 3-4
Bias	9	Describe any efforts to address potential sources of bias	-
Study size	10	Explain how the study size was arrived at	-
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 4
		(*b*) Describe any methods used to examine subgroups and interactions	Page 4
		(*c*) Explain how missing data were addressed	Page 4
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Page 4
		(*e*) Describe any sensitivity analyses	-
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 4-5
		(b) Give reasons for non-participation at each stage	Page 5
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 4
		(b) Indicate number of participants with missing data for each variable of interest	Page 4
Outcome data	15*	Report numbers of outcome events or summary measures	-
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 5-8
		(*b*) Report category boundaries when continuous variables were categorized	-
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Page 4
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 16
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.