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ORIGINAL ARTICLE

Observational Study

Effects of cumulative COVID-19 cases on mental health: Evidence from multi-country survey

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Abstract

BACKGROUND

Depression and anxiety were both ranked among the top 25 leading causes of global burden of diseases in 2019 prior to the coronavirus disease 2019 (COVID-19) pandemic. The pandemic affected, and in many cases threatened, the health and lives of millions of people across the globe and within the first year, global prevalence of anxiety and depression increased by 25% with the greatest influx in places highly affected by COVID-19.

AIM

To explore the psychological impact of the pandemic and resultant restrictions in different countries using an opportunistic sample and online questionnaire in different phases of the pandemic.

METHODS

A repeated, cross-sectional online international survey of adults, 16 years and above, was carried out in 10 countries (United Kingdom, India, Canada, Bangladesh, Ukraine, Hong Kong, Pakistan, Egypt, Bahrain, Saudi Arabia). The online questionnaire was based on published approaches to understand the psychological impact of COVID-19 and the resultant restrictions. Five standardised measures were included to explore levels of depression [patient health questionnaire (PHQ-9)], anxiety [generalized anxiety disorder (GAD) assessment], impact of trauma [the impact of events scale-revised (IES-R)], loneliness (a brief loneliness scale), and social support (The Multi-dimensional Scale of Perceived Social support).

RESULTS

There were two rounds of the online survey in 10 countries with 42866 participants in Round 1 and 92260 in Round 2. The largest number of participants recruited from the United Kingdom (112985 overall). The majority of participants reported receiving no support from mental health services throughout the pandemic. This study found that the daily cumulative COVID-19 cases had a statistically significant effect on PHQ-9, GAD-7, and IES-R scores. These scores significantly increased in the second round of surveys with the ordinary least squares regression results with regression discontinuity design specification (to control lockdown effects) confirming these results. The study findings imply that participants' mental health worsened with high cumulative COVID-19 cases.

CONCLUSION

Whist we are still living through the impact of COVID-19, this paper focuses on its impact on mental health, discusses the possible consequences and future implications. This study revealed that daily cumulative COVID-19 cases have a significant impact on depression, anxiety, and trauma. Increasing cumulative cases influenced and impacted education, employment, socialization and finances, to name but a few. Building a database of global evidence will allow for future planning of pandemics, particularly the impact on mental health of populations considering the cultural differences.

Key Words: COVID-19; Mental health; Global research; International; Pandemic; Impact

Core Tip: This study explores the effect of cumulative coronavirus disease 2019 cases on mental health, more specifically on anxiety, depression, and trauma. Negative impact on mental health was found internationally, with individuals struggling to receive support from mental health services. Results also show that as the pandemic continued, mental health scores got worse.

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INTRODUCTION

Depression and anxiety conditions both ranked among the top 25 leading causes of global burden of diseases in 2019 prior to the coronavirus disease 2019 (COVID-19) pandemic[1]. On January 30, 2020, the World Health Organization (WHO) declared a public health emergency of international concern and governments were urged to prepare for the global spread of COVID-19 from East Asia[2]. The COVID-19 pandemic affected, and in many cases threatened the health and lives of millions of people across the globe[2].

In the first year of the COVID-19 pandemic, global prevalence of anxiety and depression increased by 25%, and overall, the pandemic was estimated to have caused 137.1 (95%UI: 92.5–190.6) additional disability adjusted life years per 100000 population for Major Depressive Disorder and 116.1 per 100000 population (95%UI: 79.3–163.80) for anxiety disorders according to a scientific brief released by the WHO[3]. A number of factors have been implicated including, but not limited to, the stress of social and self-isolation, loneliness, restrictions due to lockdowns[4,5], fear of infection and death of self and near ones, grief and bereavement, worries regarding jobs and finances, as well as impact on education, relationships and on carers[6].

Long COVID described the presence of persistent symptoms following infection from the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus[7]. This can last weeks or months after initial infection[7,8]. Common symptoms of long COVID include breathlessness, fatigue, headaches, and weakness as well as reduced quality of life[7, 9]. The most common mental health problems experienced by individuals with long COVID were anxiety, depression, and post-traumatic stress disorder (PTSD)[9,10]. A scoping review of 239 patients found that 3-mo post-COVID, 37.2% experienced PTSD, 35.6% experienced anxiety, and 46.9% were experiencing depression[11,12]. These effects were maintained at 6-mo[11]. Overall, symptoms were more prevalent in women and hospitalized patients[9]. A number of population groups have been shown to have been more adversely affected, including young people and women[7], individuals with vulnerabilities and pre-existing mental health conditions[9,11]. Evidence on healthcare workers, who were frontline during the pandemic has been equivocal with different studies showing a range of impact in this group[11, 13]. The greatest increases in depression and anxiety were found in places highly affected by COVID-19 as indicated by decreased human mobility and daily COVID-19 infection rates[3].

Each country across the globe has responded to the pandemic guided by their population, resources, number of cases, socio demographics, political landscape, and culture[14]. Given the unique situation we faced, the authors sought to explore the psychological impact of the pandemic and resultant restrictions in different countries, using an opportunistic sample and online questionnaire that was established at the beginning of the pandemic.

MATERIALS AND METHODS

Study design

This international study aimed to investigate and report the psychological impact of cumulative COVID-19 cases in the participant sites. A repeated, cross-sectional online international survey of adults, 16 years and above, was carried out in 10 countries (United Kingdom, India, Canada, Bangladesh, Ukraine, Hong Kong, Pakistan, Egypt, Bahrain, Saudi Arabia). The online questionnaire was based on published approaches, to understand the psychological impact of COVID-19 and the resultant restrictions. Five standardised measures were included to explore levels of depression [patient health questionnaire-9 (PHQ-9)][15], anxiety [generalized anxiety disorder (GAD)-7; Generalised Anxiety Disorder Assessment] [16], impact of trauma [the impact of events scale-revised (IES-R)][17], loneliness (a brief loneliness scale)[18], and social support (The Multi-dimensional Scale of Perceived Social support)[19]. Further details of the methodology are documented in earlier publications by the group[9,13].

Materials

The survey was repeated to capture the dynamic impact of the pandemic. The questionnaire was changed for each round depending on the stage of pandemic, government policies, and circumstances in each country at the time. In order to make the questionnaire relevant to each country, it was available in different languages and various adaptations were made to ensure that local culture and responses to the pandemic were considered. For this reason, each country published the questionnaire at a slightly different time and some of the questions were variable. As an example, the "Keyworker" status did not exist in many countries and was only used where relevant. Another example, in the Ukraine questionnaire version, the question about exceeding the recommended limits of alcohol was excluded because of the absence of such recommended limits.

Study distribution

In the United Kingdom, the survey was conducted thrice with the corresponding two rounds of the survey in the other countries. The dates of the surveys in the participant countries are noted below. The surveys were publicised to the general population including students and healthcare professionals through social media. Most countries collaborated internally to capture a wide population. As an example, the leads in Ukraine collaborated with Ukrainian organizations including Mental health for Ukraine Project, National Psychological Association of Ukraine, Ukrainian Association of Cognitive-Behavioural Therapy, and Zhytomyr State University to help further with dissemination. Due to the unusual circumstances of the time, this was the best way to disseminate the survey.

Southern Health NHS Foundation Trust in the United Kingdom led and co-ordinated the online survey with support from the participant countries. The survey was advertised to staff, patients, and the public with a weblink to the survey platform.

Data analysis

Cumulative COVID-19 case data has been derived from Microsoft Azure Open dataset, which is a population open dataset[20]. Mental health scores are derived from the online survey and is sample data. In both data, time is day. Although cumulative COVID-19 cases data is available daily (for around last two years), mental health scores in the study were not available for each day during that time. The availability of mental health scores on a specific day depended on whether the survey was conducted on that day by a participant.

The study has used regression analyses, using cross section data of all countries that participated in the study. Separate regression analysis was conducted for survey round 1 and 2. In both regressions, we used dummies for all individual characteristics listed in Table 1 as control variables. Vulnerabilities including requiring shielding, experience of coronavirus, pre-existing mental health conditions, and mental health support, had extremely low response rates therefore, we have recoded missing values into no category, to increase sample sizes in regressions.

In both regressions, the main independent variable, daily cumulative COVID-19 cases, is converted into million unit (by dividing COVID-19 case by 1000000). The purpose is to scale up its coefficients.

The relationship between average mental health scores and average cumulative COVID-19 cases maybe be contaminated or biased by lockdown effects. To control for such effects, we added lockdown dummy, trend and their interaction following the specification in regression discontinuity design (RDD).

RESULTS

Demographics

There were two rounds of the online survey in eight country groups as shown in Table 1. Egypt, Saudi Arabia, and Bahrain were analysed as a single group (labelled Arabic speaking countries). Hong Kong did not participate in the second round due to difficulties in recruitment. While there were three rounds in the United Kingdom, we have only used data from the corresponding two rounds with other participant countries. The United Kingdom has the largest number of participants in both rounds (29134 and 83851, respectively).

In the first round of the survey, participants who reported being healthcare professionals are higher in the United Kingdom (43%). In the second round, Arabic speaking countries had the highest number of participants who reported as healthcare professionals (66%), with a sample size of 909.

Age follows a bell shaped or downward distribution. Female participants were higher than male in most countries. In Canada, United Kingdom and Ukraine, most participants were White. Christian religion was reported the dominant religion in the Western countries. In round one in the Arabic speaking countries, most survey participants reported as Christians too. In most countries, survey participants did not report University education. Most survey participants lived in their own homes. Low proportion of participants reported experiencing COVID-19, but a high percent of participants followed social distancing guidelines. Most of the participants did not report any pre-existing physical health conditions. Alcohol consumption was reported by participants in Canada, United Kingdom, and Ukraine. Most participants did not report taking drugs. Majority participants did not report receiving support from mental health services. Where received, mental health support was reported through general practitioners and many participants did not respond to this question as it was only relevant if they reported experiencing mental health problems.

Mental health scales

Table 2 shows means and SD of PHQ-9, GAD-7 and IES-R by country and survey rounds, with number of respondents (*n*), missing observations and nonrespondents. In both rounds in each country, there were fewer respondents of PHQ-9 compared to nonrespondents. For the other two mental health scales, the gap between respondents and nonrespondents is not that large, with respondents being higher than nonrespondents in some cases. PHQ-9 can vary from 0 to 27, GAD-7 from 0 to 21, and IES-R from 0-88; however, average figures of PHQ-9 are lower than those of other two. IES-R has higher mean scores than others. Hong Kong, Indian, and Ukrainian participants have reported lower scores on the three scales compared with other countries. Bangladesh has highest mean scores on PHQ9, GAD7 and IES -R. All scores increased in round 2 of the surveys.

Cumulative COVID-19 cases

For each country, cumulative COVID-19 cases (the cumulative number of people who suffered coronavirus in official records) varied over time. Mental health scores (on the 3 scales: PHQ-9, GAD-7 and IES-R) in each country varied over time and by individuals' responses during the survey period.

Figure 1 shows a histogram of day/time by country. Two long bars in Bangladesh indicate that survey responses in both rounds were received during short windows, although the survey was open for three months each time in each site. The same pattern is seen in Canada and Hong Kong. Survey periods in Arabic speaking sites and Ukraine seem longer but scattered, meaning that for several days, survey data including mental health scores were not available during the three month period. India and Pakistan showed good density for moderately wider periods in round 1. United Kingdom showed the longest periods of survey responses in both rounds, which indicates that survey data including mental health

Table 1 Percent of categories in individual characteristics by country and survey rounds (1 and 2)

	Arabic		Bangladesh		Canada		China	India		Pakistan		United Kingdom		Ukraine	
	1	2	1	2	1	2	1	1	2	1	2	1	2	1	2
Observations	1121	909	299	746	8648	5920	178	1427	68	803	160	29134	83851	1256	606
	Percent of above observations														
Healthcare professional															
No	40	9	67	69	88	91	65	65	40	44	41	47	66	79	74
Yes	38	66	4	5	7	9	19	19	44	0	34	43	22	9	10
Missing	22	25	29	26	5	0	16	16	16	56	25	10	12	12	16
Age category															
Under 25	10	4	69	68	8	16	2	20	7	20	51	6	6	35	15
25-44	44	61	14	14	36	36	43	44	44	35	26	36	31	43	54
45-54	16	9	2	1	15	16	12	11	16	3	4	23	19	9	13
55 and over	7	3	1	1	37	32	26	13	21	2	1	26	34	2	3
Missing	22	22	14	17	5	0	17	13	12	40	18	10	11	11	15
White ethnicity															
No	77	21	92	89	20	21	9	88	88	81	73	9	15	3	3
Yes	1	57	0	0	76	78	79	0	0	0	0	82	74	88	82
Missing	22	22	8	11	4	0	12	12	12	19	27	10	11	9	15
Christian religion															
No	8	73	92	87	48	52	8	80	78	81	75	48	46	21	22
Yes	70	4	0	0	47	47	32	7	9	0	0	41	39	69	62
Missing	22	22	8	13	5	1	60	13	13	19	25	11	15	11	16
Gender															
Female	50	27	22	23	56	54	61	60	56	49	61	74	61	77	74
Male	28	51	68	63	39	45	24	27	31	31	18	15	26	13	9
Missing	22	22	10	14	5	1	15	13	13	20	21	11	13	11	16
Attended university															
No	78	79	91	88	51	53	85	38	79	80	83	90	89	90	85
Yes	0	0	0	0	43	47	0	50	9	0	0	0	0	0	0
Missing	22	21	9	12	6	0	15	13	12	20	18	10	11	10	15
Living at own home															
No	43	52	64	53	35	41	37	49	0	43	41	25	29	54	41
Yes	35	26	26	35	61	59	51	39	0	38	40	66	61	36	44
Missing	22	22	10	12	5	0	13	12	100	19	19	10	11	10	15
Vulnerable according to government category															
No	63	34	74	52	63	66	71	68	0	68	46	70	67	76	54
Age ≥ 70	1	40	9	36	15	34	5	7	0	2	31	4	21	1	29
Chronic disease	2	0	1	0	6	0	2	1	0	2	0	6	0	4	0
Diabetes	2	0	0	0	3	0	4	1	0	0	0	2	0	0	0
Other	3	0	3	0	7	0	1	2	0	3	0	5	0	3	0
Missing	28	26	13	12	6	0	16	19	100	25	23	13	12	16	17
Vulnerable according to government category and require shielding															

No	64	0	85	0	75	0	77	72	0	67	0	77	0	72	0
Yes	6	0	2	0	13	0	5	6	0	6	0	7	0	11	0
Missing	30	100	14	100	12	100	18	22	100	26	100	16	100	17	100
Whether experienced coronavirus															
No	23	0	42	0	28	0	58	35	0	28	0	22	0	31	0
Yes	49	29	40	23	63	12	26	43	25	43	48	64	25	52	47
Missing	28	71	17	77	8	88	16	22	75	29	53	14	75	17	53
Pre-existing mental health condition															
No	42	0	46	1	62	1	74	67	3	40	0	53	0	60	0
Yes	28	3	41	5	31	21	8	11	4	35	11	31	18	23	9
Missing	30	97	13	95	7	79	18	22	93	25	89	16	82	17	91
Drinking alcohol															
No	68	64	76	77	20	54	28	57	47	0	0	13	75	17	0
Yes	5	1	12	6	74	22	56	24	35	0	5	75	11	69	1
Missing	27	35	13	17	5	24	16	19	18	100	95	12	14	14	99
Whether taking drug															
No	71	65	81	73	83	86	79	78	82	71	69	85	83	83	77
Yes	0	4	8	11	12	14	6	2	1	3	6	2	3	3	2
Missing	28	31	11	15	5	0	15	20	16	26	25	13	13	14	21
Ever experienced suicidal thoughts															
No	9	61	70	69	67	77	74	68	66	55	55	59	60	60	53
Yes	62	7	18	16	27	23	10	12	16	19	18	27	26	24	28
Missing	29	32	13	15	6	1	16	21	18	26	27	13	14	16	19
Having mental health support from															
No support	18	1	27	3	13	4	6	5	3	30	4	14	5	13	2
Health service provider	6	1	5	1	11	6	2	3	1	8	3	12	8	6	5
Other	3	1	7	1	7	10	2	2	1	4	3	5	4	7	1
Missing	73	97	61	95	69	80	90	89	94	58	90	69	83	75	91

Each panel in a column shows percentages of categories/responses of a characteristic/question. Total respondents in each category were divided by observations shown at the beginning of the table and then multiplied by 100, to get the percentage.

scores were available for relatively more days in United Kingdom despite the fact that the survey was available for the same number of months at each site.

Daily cumulative COVID-19 cases (in million) have been plotted for each country, from April 1, 2020 to April 1, 2021 (Figure 2). As India had high COVID-19 cases, we have scaled down the COVID-19 cases by converting its unit into million, to raise the coefficients of cumulative COVID-19 case in regressions. United Kingdom also had high figures (reached nearly 10 million in March 2021). Ukraine and Canada reached relatively high figures. Other countries including Hong Kong had lower figures for cumulative COVID-19 cases. Therefore, the lines are relatively flat (near zero). Hong Kong had low figures at those periods as different countries had their spikes at different times. The figure shows downward movement of lines in India and United Kingdom, because COVID-19 cases were revised.

In survey data of the countries, scores of three mental health scales were available for several individuals in a day. They are reported as averages in a day. Country averages of those averages are taken to get single values in each day. Country average of cumulative COVID-19 cases are also taken. In Figure 3, scatter plots of average values of PHQ-9, GAD-7 and IES-R are shown in three different subplots. Average cumulative COVID-19 cases are plotted in line with three subplots. While left vertical axes measure the average cumulative COVID-19 cases, the right vertical axes measure three average values of mental health scores/indices. As mental health is an individual characteristic, average mental health scores fluctuated over time, and were not uniform like average cumulative COVID-19 cases. However, average mental health scores had less fluctuation/scatter at the beginning of each round (especially at the beginning of the second round). At that time, average mental health scores showed upward movement with average cumulative COVID-19 cases.

Table 2 Summary statistics of mental health scores by country and survey rounds

		PHQ-9		GAD-7		IES-R	
		Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Arabic	Mean	7.85	6.27	5.28	4.56	20.81	17.14
	SD	6.97	6.88	5.78	5.56	18.79	19.12
	n	596	481	596	486	539	430
	Missing	525	428	525	423	582	479
Bangladesh	Mean	8.07	7.45	5.76	5.45	23.28	21.86
	SD	5.79	6.91	5.38	5.69	18.08	20.35
	n	205	462	205	485	179	419
	Missing	94	284	94	261	120	327
Canada	Mean	6.11	6.97	4.40	4.94	15.10	16.96
	SD	6.44	6.70	5.32	5.46	17.87	18.24
	n	7653	5721	7684	5770	7329	5554
	Missing	995	199	964	150	1319	366
China	Mean	4.38		3.25		11.61	
	SD	4.91		4.20		13.63	
	n	127		124		117	
	Missing	51		54		61	
India	Mean	4.99	4.07	3.46	2.43	14.65	10.24
	SD	5.56	5.34	4.38	3.31	16.49	12.00
	n	820	41	823	42	741	38
	Missing	607	27	604	26	686	30
Pakistan	Mean	8.55	8.64	5.10	5.37	19.02	19.59
	SD	7.34	7.51	5.56	5.42	17.26	19.18
	n	412	85	413	90	376	75
	Missing	391	75	390	70	427	85
United Kingdom	Mean	7.70	8.21	5.46	6.04	17.01	19.19
	SD	6.47	7.03	5.51	5.92	17.51	18.93
	n	22166	64382	22343	65056	20780	59966
	Missing	6968	19469	6791	18795	8354	23885
Ukraine	Mean	6.63	7.81	4.17	5.02	14.93	15.55
	SD	6.10	6.51	4.65	5.20	15.34	15.41
	n	860	421	863	426	782	382
	Missing	396	185	393	180	474	224
Total	Mean	7.24	8.09	5.11	5.93	16.55	18.98
	SD	6.49	7.01	5.45	5.88	17.57	18.88
	n	32839	71593	33051	72355	30843	66864
	Missing	10027	20667	9815	19905	12023	25396

PHQ-9: Patient health questionnaire-9; IES-R: Impact of Events Scale-Revised; GAD-7: Generalized anxiety disorder-7.

In more scatter areas, such positive relation between average cumulative COVID-19 cases and average mental health scores is not seen. As less scatter zones showed a positive relation, we can expect an overall positive relation between them. To control for bias or contamination effect of lockdown, we added lockdown dummy, trend and their interaction

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Figure 1 Distribution of survey respondents over time, by country.

following the specification in RDD.

Table 3 shows lockdown and survey periods of participant countries in the study. In each round, we have made normalized trend by subtracting lockdown easing/withdraw dates of countries (as lockdown start dates do not fall in survey periods) from trend. Zero is a common cut-off date; based on that we made a discontinuity dummy (1 = above cut-off, 0 = below cut-off), that captured negative effects of lockdown or withdraw on mental health. To capture different slopes on either side of the cut-off, we took interaction of normalized trends and the discontinuity dummy.

Regression results

Table 4 shows regression results for round 1 and Table 5 for round 2. Both tables show two regression results for each mental health score/index, the dependent variable. The first one does not include RDD specification, while the second one does. When RDD specification is included, the results are for United Kingdom only.

In round 1, the cumulative COVID cases had statistically significant effect on all three mental health scores with RDD specification. For example, as United Kingdom had 7.70 average GAD-7, the increase size 1.75 in regression was nearly 23% (1.75 × 100/7.70). So, for a one million increase in cumulative daily COVID cases, GAD-7 increased by 23 percent.

In round 2 (Table 5), all three mental health indices increased statistically and significantly due to increase in cumulative COVID cases, with and without RDD specification. Without RDD specification, for a one million increase in cumulative COVID cases, the increase in PHQ-9 was 0.195 (2.38%), GAD-7 0.129 (2.14%), and IES-R 0.454 (2.37%). With RDD specification, for a one million increase in cumulative COVID cases, the increase in PHQ-9 was 0.433 (5.27%), GAD-7 0.577 (9.55%), and IES-R 1.265 (6.59%). Results with RDD specification implied that United Kingdom had higher effects than other countries.

Table 3 Lockdown and survey dates by country

Country	First lockdown		Second lockdown		Survey period		Can we capture lockdown effects?
	Start	End	Start	End	Round 1	Round 2	
Bangladesh	March 26, 2020	May 16, 2020	April 5, 2021	July 14, 2021	July 1, 2020-July 25, 2020	January 19, 2021-March 18, 2021	No
Canada	March 18, 2020	May 18, 2020	November 7, 2020	January 8, 2021	August 18, 2020-October 2, 2020	December 21, 2020-March 30, 2021	No
China	January 23, 2020	April 8, 2020			June 24, 2020-August 7, 2020		No
India	March 25, 2020	June 7, 2020	April 19, 2021	May 31, 2021	July 1, 2020-September 20, 2020	January 22, 2021-April 1, 2021	No
Pakistan	March 24, 2020	May 9, 2020	May 8, 2021	May 18, 2021	June 10, 2020-September 24, 2020	February 2, 2021-March 29, 2021	No
Saudi Arabia	March 29, 2020	June 21, 2020			June 3, 2020-October 7, 2020	January 16, 2021-April 1, 2021	Yes, in round 1
Ukraine	March 17, 2020	April 24, 2020			June 11, 2020-September 30, 2020	January 7, 2021-March 25, 2021	No
United Kingdom	March 23, 2020	July 4, 2020	November 5, 2020	December 2, 2020	April 28, 2020-August 6, 2020	November 12, 2020-February 18, 2021	Yes, in both rounds

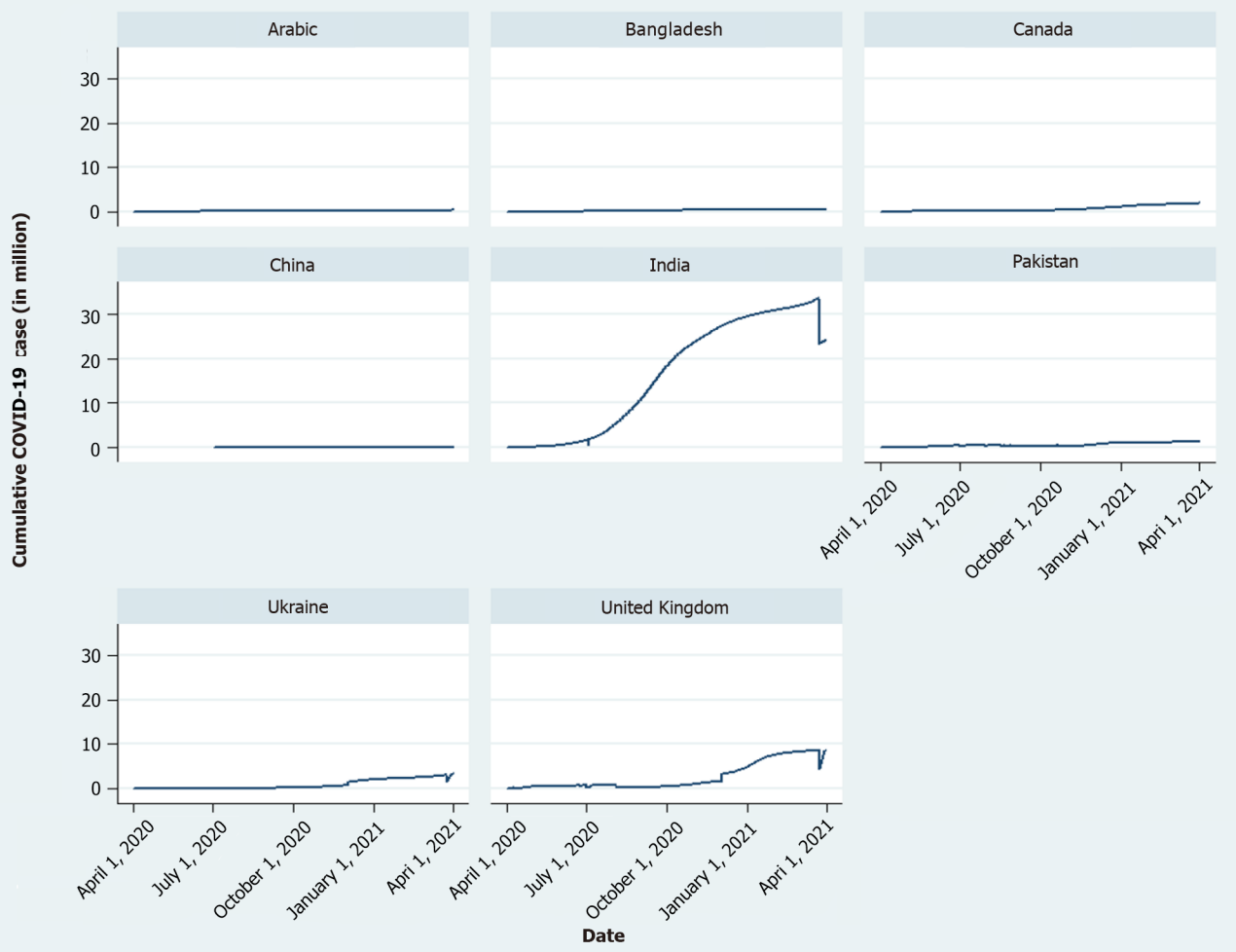

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Figure 2 Cumulative coronavirus disease 2019 case (in million) over time, by country. COVID-19: Coronavirus disease 2019.

Table 4 Ordinary least squares regression of mental health scores on cumulative coronavirus disease 2019 case, lockdown, and individual characteristics (survey round 1)

	PHQ-9		GAD-7		IES-R	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Daily cumulative COVID-19 case/1000000	0.075[a]	2.121[c]	0.041	1.750[c]	0.225[a]	1.543[a]
	[-0.01, 0.16]	[1.58, 2.66]	[-0.03, 0.11]	[1.28, 2.22]	[-0.02, 0.47]	[-0.05, 3.14]
Dummy for first lockdown withdraw		-0.658[c]		-0.450[c]		-1.224[b]
		[-0.97, -0.34]		[-0.73, -0.17]		[-2.16, -0.29]
Dummy for first lockdown withdraw[1] (date-first lockdown withdraw date)		-0.018[c]		-0.014[c]		-0.043[c]
		[-0.03, -0.01]		[-0.02, -0.01]		[-0.07, -0.02]
Date-first lockdown withdraw date		0.006[b]		0.000		0.004
		[0.00, 0.01]		[-0.00, 0.01]		[-0.01, 0.02]
Healthcare professional (1 = yes, 0 = no)	-0.402[c]	-0.737[c]	-0.328[c]	-0.631[c]	-1.394[c]	-2.185[c]
	[-0.54, -0.26]	[-0.89, -0.58]	[-0.45, -0.21]	[-0.77, -0.49]	[-1.81, -0.98]	[-2.65, -1.72]
Age (base: Below 25)	0.000	0.000	0.000	0.000	0.000	0.000
25-44	-1.084[c]	-1.428[c]	-0.482[c]	-0.713[c]	-2.350[c]	-2.091[c]
	[-1.34, -0.83]	[-1.75, -1.11]	[-0.71, -0.26]	[-0.99, -0.43]	[-3.10, -1.60]	[-3.02, -1.16]
45-54	-1.958[c]	-2.345[c]	-1.456[c]	-1.737[c]	-3.992[c]	-3.366[c]
	[-2.24, -1.68]	[-2.69, -1.99]	[-1.70, -1.21]	[-2.05, -1.43]	[-4.83, -3.15]	[-4.39, -2.34]
55 and over	-2.956[c]	-3.108[c]	-2.179[c]	-2.284[c]	-5.568[c]	-4.085[c]
	[-3.24, -2.67]	[-3.47, -2.75]	[-2.43, -1.93]	[-2.60, -1.97]	[-6.42, -4.72]	[-5.15, -3.02]
White (1 = yes, 0 = no)	0.360[c]	0.482[c]	0.299[c]	0.413[c]	-1.120[c]	-0.054
	[0.17, 0.55]	[0.23, 0.74]	[0.13, 0.47]	[0.19, 0.64]	[-1.69, -0.55]	[-0.80, 0.69]
Christian (1 = yes, 0 = no)	-0.206[c]	-0.036	0.018	0.222[c]	0.522[c]	0.829[c]
	[-0.34, -0.07]	[-0.19, 0.12]	[-0.10, 0.13]	[0.08, 0.36]	[0.13, 0.91]	[0.37, 1.29]
Male (1 = yes, 0 = no)	-1.189[c]	-1.231[c]	-1.039[c]	-1.042[c]	-2.997[c]	-3.719[c]
	[-1.34, -1.03]	[-1.43, -1.03]	[-1.18, -0.90]	[-1.22, -0.86]	[-3.46, -2.53]	[-4.31, -3.13]
Attended university (1 = yes, 0 = no)	-1.141[c]	0.000	-0.545[c]	0.000	-1.254[c]	0.000
	[-1.34, -0.94]	[0.00, 0.00]	[-0.72, -0.37]	[0.00, 0.00]	[-1.85, -0.65]	[0.00, 0.00]
Living at own home (1 = yes, 0 = no)	-0.885[c]	-1.105[c]	-0.489[c]	-0.692[c]	-1.432[c]	-2.270[c]
	[-1.04, -0.73]	[-1.30, -0.91]	[-0.63, -0.35]	[-0.86, -0.52]	[-1.89, -0.97]	[-2.83, -1.71]
Vulnerable according to government category (base: Not vulnerable)	0.000	0.000	0.000	0.000	0.000	0.000
Aged 70 or above	-0.898[c]	-1.105[c]	-0.764[c]	-0.985[c]	-1.954[c]	-2.909[c]
	[-1.18, -0.62]	[-1.52, -0.69]	[-1.01, -0.52]	[-1.35, -0.62]	[-2.81, -1.10]	[-4.19, -1.63]
Chronic disease	0.361[b]	0.345[b]	0.533[c]	0.543[c]	1.245[c]	1.644[c]
	[0.08, 0.64]	[0.03, 0.66]	[0.29, 0.78]	[0.26, 0.83]	[0.41, 2.08]	[0.70, 2.59]
Diabetes	0.034	-0.064	0.102	0.139	0.867	1.185
	[-0.43, 0.49]	[-0.63, 0.50]	[-0.30, 0.50]	[-0.36, 0.64]	[-0.50, 2.23]	[-0.49, 2.86]
Other	0.915[c]	0.846[c]	0.390[c]	0.355[b]	0.811[a]	1.208[b]
	[0.62, 1.21]	[0.49, 1.20]	[0.13, 0.65]	[0.04, 0.67]	[-0.07, 1.70]	[0.15, 2.27]
Vulnerable according to government category and require shielding (1 = yes, 0 = no)	1.087[c]	1.096[c]	0.909[c]	0.945[c]	4.281[c]	3.513[c]

	[0.83, 1.34]	[0.76, 1.43]	[0.68, 1.13]	[0.65, 1.24]	[3.51, 5.05]	[2.52, 4.50]
Experienced coronavirus (1 = yes, 0 = no)	0.324[c]	0.220[b]	0.237[c]	0.181[b]	0.410[a]	0.547[b]
	[0.18, 0.47]	[0.05, 0.39]	[0.11, 0.36]	[0.03, 0.33]	[-0.01, 0.83]	[0.05, 1.05]
Pre-existing mental health condition (1 = yes, 0 = no)	3.447[c]	3.256[c]	3.158[c]	3.091[c]	8.608[c]	8.227[c]
	[3.26, 3.63]	[3.04, 3.47]	[3.00, 3.32]	[2.90, 3.28]	[8.06, 9.16]	[7.60, 8.86]
Drinking alcohol (1 = yes, 0 = no)	0.251[c]	-0.082	0.234[c]	-0.101	0.410	-0.277
	[0.08, 0.42]	[-0.30, 0.13]	[0.08, 0.38]	[-0.29, 0.09]	[-0.10, 0.92]	[-0.91, 0.36]
Taking drug (1 = yes, 0 = no)	0.794[c]	1.303[c]	0.725[c]	0.729[c]	2.262[c]	2.527[c]
	[0.48, 1.11]	[0.76, 1.84]	[0.45, 1.00]	[0.25, 1.21]	[1.33, 3.19]	[0.95, 4.11]
Ever experienced suicidal thoughts (1 = yes, 0 = no)	3.101[c]	2.976[c]	1.623[c]	1.503[c]	6.054[c]	5.812[c]
	[2.95, 3.25]	[2.80, 3.15]	[1.49, 1.75]	[1.35, 1.66]	[5.61, 6.50]	[5.30, 6.32]
Mental health support from (base: No support)	0.000	0.000	0.000	0.000	0.000	0.000
Health service provider	0.134	0.245[a]	-0.052	-0.021	0.008	-0.030
	[-0.11, 0.37]	[-0.03, 0.52]	[-0.26, 0.16]	[-0.26, 0.22]	[-0.71, 0.72]	[-0.85, 0.79]
Other	1.072[c]	1.269[c]	0.521[c]	0.666[c]	3.042[c]	3.542[c]
	[0.77, 1.38]	[0.91, 1.63]	[0.25, 0.79]	[0.35, 0.98]	[2.14, 3.95]	[2.49, 4.59]
Constant	7.050[c]	7.213[c]	4.651[c]	4.590[c]	16.577[c]	16.791[c]
	[6.73, 7.37]	[6.69, 7.73]	[4.37, 4.93]	[4.13, 5.05]	[15.62, 17.54]	[15.26, 18.32]
Observations	28560	21077	28710	21202	26913	19785
Adjusted R^2	0.279	0.261	0.214	0.203	0.180	0.172

[a]$P < 0.10$.
[b]$P < 0.05$.
[c]$P < 0.01$.
[1]See Table 3 for dates of first lock down period.
95% confidence intervals are in brackets. PHQ-9: Patient health questionnaire-9; IES-R: Impact of Events Scale-Revised; GAD-7: Generalized anxiety disorder-7; COVID-19: Coronavirus disease 2019.

In both regression tables, lockdown withdraw dummy in RDD specification showed that lockdown withdraw had statistical and significant effects on mental health indices, which supported the findings of our previous paper that showed that lockdown increased participants mental health scores, or worsened participant's mental health[8].

In both regression tables, compared to the youngest age group (under 25), other age groups had lower scores on the mental health scales, meaning better mental health. Non-White participants reported better mental health than White participants, in most cases. Non-Christians reported better mental health than Christians in both rounds. In both rounds, higher educated participants had better mental health than the lowest educated group.

Heterogenous effects

To demonstrate heterogeneous effects of cumulative COVID cases on mental health scores for different countries, we ran regressions without RDD specification for each country separately, but we included all characteristics used in previous regressions. RDD specification was only applicable to United Kingdom data.

For China (Hong Kong), cumulative COVID cases was extremely low, and therefore, the coefficients of daily cumulative COVID cases were extremely high. Similarly high and low coefficients in different countries depended on scales of cumulative COVID cases in the relevant countries.

Most countries did not show any significant effects. United Kingdom had very good distribution of survey respondents over a long period of time. Therefore, regression results for United Kingdom are more reliable than others. The results are statistically positive in both rounds in the United Kingdom. The first round in the United Kingdom showed statistically and significantly higher positive results. As we have seen in Table 4, such significance vanishes with the inclusion of RDD specification.

DISCUSSION

Using repeated cross sectional survey data of eight country groups and cumulative COVID-19 cases of same countries from Microsoft AZURE, this study found that the daily cumulative COVID-19 cases had a statistically significant effect on

Table 5 Ordinary least squares regression of mental health scores on cumulative coronavirus disease 2019 case, lockdown, and individual characteristics (survey round 2)

	PHQ-9		GAD-7		IES-R	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Daily cumulative COVID-19 case/1000000	0.195[c]	0.433[c]	0.129[c]	0.557[c]	0.454[c]	1.265[c]
	[0.18, 0.21]	[0.23, 0.63]	[0.11, 0.15]	[0.38, 0.74]	[0.40, 0.51]	[0.67, 1.86]
Dummy for second lockdown withdraw		-0.507[c]		-0.343[b]		-1.077[b]
		[-0.83, -0.18]		[-0.63, -0.05]		[-2.04, -0.11]
Dummy for second lockdown withdraw[1] (date-second lockdown withdraw date)		-0.034[c]		-0.038[c]		-0.104[c]
		[-0.06, -0.01]		[-0.06, -0.02]		[-0.18, -0.03]
Date-second lockdown withdraw date		0.013		-0.002		0.034
		[-0.01, 0.03]		[-0.02, 0.02]		[-0.03, 0.10]
Healthcare professional (1 = yes, 0 = no)	-0.693[c]	-0.747[c]	-0.540[c]	-0.587[c]	-2.325[c]	-2.551[c]
	[-0.80, -0.58]	[-0.86, -0.63]	[-0.64, -0.44]	[-0.69, -0.48]	[-2.65, -2.00]	[-2.89, -2.21]
Age (base: Below 25)						
25-44	-1.147[c]	-1.339[c]	-0.333[c]	-0.445[c]	-1.043[c]	-0.715[b]
	[-1.34, -0.96]	[-1.55, -1.13]	[-0.50, -0.16]	[-0.63, -0.26]	[-1.60, -0.49]	[-1.33, -0.10]
45-54	-2.059[c]	-2.245[c]	-1.310[c]	-1.421[c]	-2.263[c]	-1.750[c]
	[-2.27, -1.85]	[-2.47, -2.02]	[-1.50, -1.12]	[-1.63, -1.22]	[-2.88, -1.65]	[-2.42, -1.08]
55 and over	-3.455[c]	-3.639[c]	-2.424[c]	-2.521[c]	-4.792[c]	-4.223[c]
	[-3.66, -3.25]	[-3.87, -3.41]	[-2.61, -2.24]	[-2.72, -2.32]	[-5.40, -4.18]	[-4.89, -3.55]
White (1 = yes, 0 = no)	-0.291[c]	-0.243[c]	-0.326[c]	-0.249[c]	-2.114[c]	-1.667[c]
	[-0.42, -0.16]	[-0.38, -0.11]	[-0.44, -0.21]	[-0.37, -0.13]	[-2.49, -1.74]	[-2.07, -1.27]
Christian (1 = yes, 0 = no)	-0.017	0.018	0.174[c]	0.183[c]	0.752[c]	0.795[c]
	[-0.11, 0.08]	[-0.08, 0.12]	[0.09, 0.26]	[0.10, 0.27]	[0.47, 1.03]	[0.50, 1.09]
Male (1 = yes, 0 = no)	-1.470[c]	-1.476[c]	-1.491[c]	-1.523[c]	-4.418[c]	-4.798[c]
	[-1.57, -1.37]	[-1.58, -1.37]	[-1.58, -1.40]	[-1.62, -1.43]	[-4.72, -4.12]	[-5.12, -4.48]
Attended university (1 = yes, 0 = no)	-0.699[c]	0.000	-0.543[c]	0.000	-0.174	0.000
	[-0.96, -0.43]	[0.00, 0.00]	[-0.78, -0.31]	[0.00, 0.00]	[-0.95, 0.60]	[0.00, 0.00]
Own home (1 = yes, 0 = no)	-1.328[c]	-1.391[c]	-0.899[c]	-0.957[c]	-2.985[c]	-3.338[c]
	[-1.44, -1.22]	[-1.51, -1.27]	[-1.00, -0.80]	[-1.06, -0.85]	[-3.32, -2.65]	[-3.69, -2.99]
Vulnerable according to government category and require shielding (1 = yes, 0 = no)	1.355[c]	1.393[c]	1.083[c]	1.124[c]	3.932[c]	3.929[c]
	[1.25, 1.46]	[1.28, 1.51]	[0.99, 1.18]	[1.02, 1.23]	[3.61, 4.26]	[3.59, 4.27]
Experienced coronavirus (1 = yes, 0 = no)	0.747[c]	0.715[c]	0.566[c]	0.535[c]	2.601[c]	2.398[c]
	[0.64, 0.85]	[0.61, 0.82]	[0.47, 0.66]	[0.44, 0.63]	[2.30, 2.91]	[2.08, 2.71]
Pre-existing mental health condition (1 = yes, 0 = no)	2.808[c]	2.745[c]	2.278[c]	2.266[c]	7.150[c]	7.160[c]
	[2.62, 2.99]	[2.55, 2.94]	[2.11, 2.44]	[2.10, 2.44]	[6.60, 7.70]	[6.60, 7.73]
Drinking alcohol (1 = yes, 0 = no)	2.300[c]	2.506[c]	1.714[c]	1.875[c]	5.976[c]	6.400[c]
	[2.17, 2.43]	[2.36, 2.65]	[1.60, 1.83]	[1.75, 2.00]	[5.59, 6.37]	[5.98, 6.82]
Taking drug (1 = yes, 0 = no)	1.232[c]	1.359[c]	0.539[c]	0.562[c]	3.126[c]	3.270[c]
	[1.01, 1.46]	[1.10, 1.62]	[0.34, 0.74]	[0.33, 0.79]	[2.46, 3.79]	[2.51, 4.03]
Ever experienced suicidal thoughts (1 = yes, 0 = no)	4.405[c]	4.379[c]	2.749[c]	2.716[c]	9.625[c]	9.747[c]

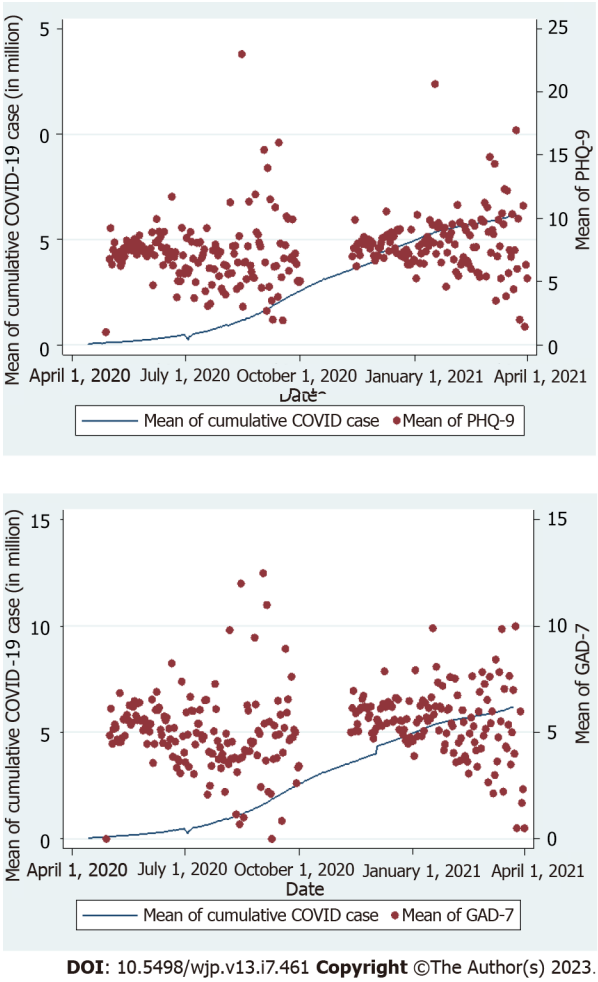
	[4.29, 4.52]	[4.26, 4.49]	[2.65, 2.85]	[2.61, 2.82]	[9.30, 9.95]	[9.41, 10.09]
Mental health support from (base: No support)						
Health service provider	0.322[c]	0.342[c]	-0.024	-0.051	-0.124	-0.288
	[0.10, 0.55]	[0.11, 0.57]	[-0.22, 0.17]	[-0.26, 0.15]	[-0.79, 0.54]	[-0.97, 0.39]
Other	1.041[c]	1.300[c]	0.686[c]	0.854[c]	2.979[c]	3.572[c]
	[0.78, 1.31]	[1.02, 1.58]	[0.45, 0.92]	[0.61, 1.10]	[2.20, 3.76]	[2.75, 4.40]
Constant	8.201[c]	8.292[c]	6.023[c]	5.496[c]	17.577[c]	16.168[c]
	[7.98, 8.42]	[7.84, 8.74]	[5.83, 6.22]	[5.10, 5.90]	[16.94, 18.21]	[14.84, 17.50]
Observations	62938	57985	63545	58547	58966	54202
Adjusted R^2	0.315	0.318	0.228	0.230	0.222	0.228

[b]$P < 0.05$.

[c]$P < 0.01$.

[1]See Table 3 for dates of first lock down period.

95% confidence intervals are in brackets. PHQ-9: Patient health questionnaire-9; IES-R: Impact of Events Scale-Revised; GAD-7: Generalized anxiety disorder-7; COVID-19: Coronavirus disease 2019.



DOI: 10.5498/wjp.v13.i7.461

Figure 3 The association between mental health scores and coronavirus disease 2019 case. A: Mean of patient health questionnaire-9; B: Mean of impact of events scale-revised; C: Mean of generalized anxiety disorder-7. PHQ-9: Patient health questionnaire-9; IES-R: Impact of Events Scale-Revised; GAD-7: Generalized anxiety disorder-7; COVID-19: Coronavirus disease 2019.

three mental health scale indices: Depression, anxiety, and trauma. Ordinary least squares regression results with RDD specification to control for lockdown effects confirms the results. The results are dominated by data in the United Kingdom, which has the largest number of respondents with wider distribution over time. The study findings imply that

participants' mental health worsened with high cumulative COVID-19 cases. Daily cases did not show any impact on mental health scores of participants. The study also highlights other important demographic information and differences due to impact of the COVID-19 pandemic on different countries' participants.

These findings are understandable, considering the significant impact of COVID-19 pandemic on the lives of people across the globe and similar results from other data. Evidence from the Centre for Disease Control and Prevention has shown that fear and stress related to the COVID-19 has led to symptomatology, including change in sleep and eating patterns, worsening of premorbid psychiatric conditions, and increased use of substances (*e.g.*, alcohol, tobacco, drugs), which add to the mental health burden[21]. Quadros *et al*[22] conducted a scoping review and concluded that females, younger adults, urban residents, divorcees, healthcare workers, those in quarantine settings, those in suspicion of being infected, and those with mental health problems, were found to be at an increased risk of COVID-19-related fear[22].

High cumulative COVID-19 cases not only presented a fear of infection and mortality, especially in vulnerable groups, but also impacted on education, jobs, ability to socialize, relationships, loneliness, and other socio-cultural and socioeconomic variables. Most studies have shown an impact on young people's mental health as does this study and the same study in United Kingdom participants has shown an increase in suicidal thoughts[23,24]. High cumulative cases additionally meant the implementation of public health interventions and lockdowns restricting activities. Our findings from the United Kingdom data of the same study demonstrate the positive association of lockdown relaxation and face covering policies on the mental health of participants evidencing the impact of these interventions on mental health of populations as also demonstrated by the international data in this study[9].

These results add to existing global evidence of the psychological impact of the COVID-19 pandemic and previous studies that have demonstrated the adverse impact of population shocks on population mental health[25-27]. A systematic review of data published between January 2020 to January 2021 during the COVID-19 pandemic found that daily SARS-CoV-2 infection rates and reductions in human mobility were associated with increased prevalence of major depressive disorder[28]. These findings have been confirmed by the WHO[3].

In our study, participants from Hong Kong, India and Ukraine had lower mental health scores than other countries' participants. It is not possible to make conclusions on these findings as the number of participants were small and there would be an element of time of participation in the survey.

Different countries had their case number surges and lockdowns at different times during the pandemic. Similarly different countries followed a different trajectory depending on their populations, readiness to respond, political, cultural, financial, and technical landscape. As an example, Ukraine underwent change in ministers three times during the pandemic. There were other determinants of response to the pandemic including levels of awareness, stigma, fear in the early phases of pandemic and attributions to the illness based on cultural explanations[11].

Since the COVID-19 pandemic, the need for mental health support services has increased significantly[29]. This has been particularly difficult due to isolation and distancing measures, causing a physical barrier to help-seeking and treatment implementation[29,30]. Mental health rehabilitation interventions aim to increase social skills and teach coping strategies through training and increased social interactions[29]. This can help individuals with various mental health conditions but is especially useful for those with anxiety or depression[30]. Social and peer support is an integral part of mental health rehabilitation, yet the isolating protection measures of the COVID-19 pandemic pose a barrier[30].

Measures, such as regular testing or online programmes, are some actions which help to overcome these unprecedented circumstances[30,31]. Many organisations and facilities moved their services online in order to provide continuous psychological support for their clients[30,31]. This will ensure that services can continue to operate whilst controlling the spread of the pandemic[31]. The United Kingdom government has published a COVID-19 Mental Health and Wellbeing Recovery Action Plan to accommodate for mental health interventions throughout and post-pandemic [32]. The plan outlines various measures including support for young people, assistance within the employment sector, and accessible and widely available support for frontline healthcare workers[32]. Whilst mental health has always been a pressing matter, the pandemic has amplified its prevalence and affects across all demographic groups[32]. As there were rigid isolation regulations in place, this made the imple-mentation of support difficult so organisations had to be innovative with the ways in which they would continue to assist clients[33]. Likewise, the pandemic also helped to highlight vulnerable groups, leading to the implementation of better support strategies and frameworks for these groups [33].

The results of this study should be interpreted considering its limitations. The timing of the study was such that most countries were in different phases of the pandemic. To conduct a study in that unusual environment meant that some may not consider this a cross sectional study in the epidemiological sense, and it could be difficult to judge the true population prevalence and make international comparisons. For this reason, we have explained the landscape of the different countries separately. This limitation could not have been avoided given the unpredictable nature of the spread of virus, even if confined parameters had been used. Additionally, where many cultural adaptations were made to account for the differences in the countries, it may still be difficult to draw conclusions about the differences in these populations which might be attributable to COVID as the measures are all taken after the onset of the pandemic. Another limitation concerning cumulative cases is that in many low and middle income countries, public health infrastructures and disease notification are very different to those used in high income countries, meaning that the potential for under-ascertainment of cases is much higher. The study has a high number of missing cases and non-random selection of participants are further limitations. In some participating centres the numbers are small. Many surveys were in circulation during this time in all the participating countries, especially during the second round, which may have affected the participation in the survey. Most studies of similar kind have reported small numbers.

CONCLUSION

The results from the current study add to developing evidence of the psychological impact of COVID-19, especially daily cumulative cases on three mental health indices. Building a database of evidence will allow for future planning of pandemics, particularly the impact on mental health of populations and the cultural differences.

ARTICLE HIGHLIGHTS

Research background

The coronavirus disease 2019 (COVID-19) pandemic had a huge effect on mental health across the globe. As the pandemic developed over time, international rates of mental health conditions increased. It would be insightful to explore how the increasing cases of COVID-19 impacted mental health throughout the pandemic.

Research motivation

Exploring the impacts of COVID-19 on mental health with help construct a better understanding of the current mental health situation across the globe. It will also help to inform pandemic preparedness policies around mental health services.

Research objectives

This study aimed to explore the psychological implications of the increasing COVID-19 case throughout the pandemic across various countries.

Research methods

A repeated, cross-sectional online international survey of adults was carried out in 10 countries. Five standardised psychological measures were included to explore the psychological impact of cumulative COVID-19 cases. This was carried out at two timepoints in all countries, aside from the United Kingdom which collected data at 3 timepoints.

Research results

There were two rounds of the online survey in eight country groups with 42866 participants recruited in Round 1 and 92260 recruited in Round 2. This study found that the daily cumulative COVID-19 cases had a statistically significant effect on three depression, anxiety, and trauma. Trauma scores were higher across all countries compared to those for anxiety and depression. All scores increased in Round 2 in all countries.

Research conclusions

Considering the significant impact of COVID-19, understanding the effects will enable for adequate services and support to be put in place. This evidence dataset will also help inform the policies and strategies for pandemic preparedness.

Research perspectives

COVID-19 has had enduring effects in all aspects of life including physical and mental health.

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FOOTNOTES

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