Research Article Life Conflux

The early stage of the COVID-19 Pandemic's Psychological Footprint: A Study on the Surge of Mental Health Concerns in China as Reflected by Baidu Index

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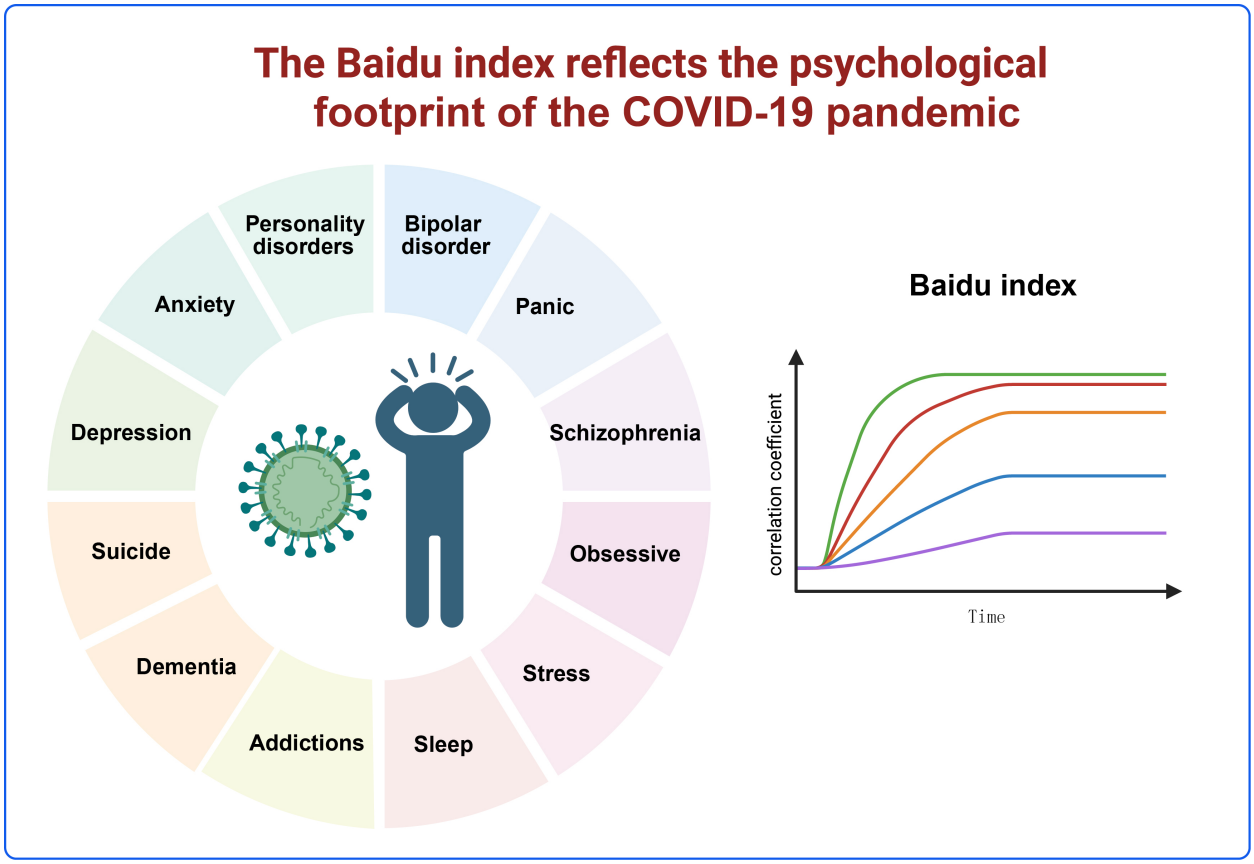
Graphical Abstract



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The early stage of the COVID-19 Pandemic's Psychological Footprint: A Study on the Surge of Mental Health Concerns in China as Reflected by Baidu Index

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Abstract

Background: The outbreak of COVID-19 has posed an enormous threat to the health of people worldwide, both physically and mentally. We aimed to investigate the impact of COVID-19 on Chinese people's mental health via the Baidu Index, especially during the early period of the outbreak.
Methods: We collected people's search data regarding mental illness and COVID-19 from the Baidu index. Spearman's correlation analysis was applied to explore the correlations among mental illness search index values, COVID-19 search index values, and the number of confirmed cases in China. We implemented a dynamic series analysis to show the changing trend of Baidu index search values. Gender, age, and regional distribution of search values were also observed. Internet searches for mental illness increased significantly after the quarantine measures were implemented.
Results: The number of COVID-19 cases were positively correlated to the overall search index values for mental illnesses (r_s=0.766, p=1.041×10^{-12}), and negatively correlated to search index values for COVID-19 (r_s=-0.236, p=0.023). The searches for COVID-19 was positively correlated to the daily growth of cases (r_s=0.861, p=2.310×10^{-18}). No lag pattern exists between Internet searches for mental illness and the number of confirmed cases. Male and people over 50 years old searched less than other groups. Besides, the highest search behaviors appeared in southeastern China. Public search behaviors indicate that since the outbreak of COVID-19, the psychological problems of the Chinese people have been extremely prominent.
Conclusion: Baidu Index offers a valuable tool for guiding effective intervention and prevention efforts aimed at mitigating psychological stress. Its ability to reflect public search behaviors allows for the timely provision of mental health support during the COVID-19 pandemic and could serve as a model for responding to the mental health challenges posed by future large-scale infectious disease outbreaks.
Keywords: COVID-19; Mental illness; Psychological stress; Baidu index.

Introduction

The emergence of the coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has unveiled a global health crisis that has not only posed an immediate threat to physical well-being but also cast a long shadow over mental health [1]. The pandemic has resulted in a surge of infections and fatalities, with the numbers continuing to rise and reshape our understanding of global health [2]. The psychological impact of COVID-19 is equally pervasive, ranging from heightened anxiety and depression to post-traumatic stress disorder, with the early stages of the outbreak being particularly distressing due to the novel nature and severity of the virus [1]. Despite the growing recognition of the pandemic's psychological impact, few studies have focused on the early weeks of the outbreak, a period critical for understanding how the public's mental health was affected and for identifying the most vulnerable populations in need of immediate intervention. While several studies have been published on the acute effects and features of COVID-19, few have focused on the psychological effects on the public [3, 4]. Since the timely treatment of psychological stress would enhance public resilience and strength [5], understanding the epidemiological characteristics of psychological problems caused by COVID-19 is of great importance.
To interrupt the transmission of the epidemic, the Chinese government has put in place strong quarantine measures, which also influence the routinely psychological counseling procedure. Thus, it is difficult to get data on public mental disorders during the epidemic from the hospital. Since the epidemiologi-

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cal data on mental illness is missing, the best way to deal with these challenges keeps unknown [6]. Today, social media and medical forums have been an essential medium for public access to information [7]. Almost eighty percent of Internet users have used the Internet as the source of health-related information. It is becoming increasingly clear that using an Internet search engine to gather and conduct the data of users' search behavior can improve the surveillance of epidemics and public interest in health topics [7, 8]. In China, people are more likely to retrieve the diagnosis and treatment information through the Internet compared with the past [9]. Baidu, as a search tool with the largest consumers in China, public search terms through this engine could represent their interest in the topics concerned, especially in places with a high Internet penetration [10]. Several examinations had used Baidu Index to explore people's search behavior in the health-related field, including HIV/AIDS [10], dengue fever [11], and H7N9 virus [12]. Besides, a positive correlation was observed between these search behaviors and epidemics.

Our study leverages Baidu Index data to scrutinize the psychological responses among the Chinese population during the nascent stages of the COVID-19 outbreak, from January 10, 2020, to March 9, 2020. The choice of this early period is deliberate and significant for several reasons. First, the initial shock of the pandemic led to a surge in public anxiety and a scramble for information, which is often reflected in online search behaviors. Second, by analyzing these search trends, we can detect the early signs of psychological distress and the specific mental health concerns that were most prevalent. This approach allows us to provide insights into the psychological impact of COVID-19 that can inform targeted interventions to mitigate long-term mental health consequences. Our study contributes to the existing literature by highlighting the importance of early psychological surveillance during pandemics. It underscores the need for a proactive approach to mental health support, particularly during the initial stages of a health crisis when public anxiety is at its peak [13]. Based on the hypothesis that Internet query data can reflect the epidemics of psychological stress during the outbreak (such as the types of mental illness with higher concern, the gender, age, and regional distribution of the vulnerable population), data from Baidu search engines could help the nation to face the challenges of public mental illness with more timely and effective ways. By identifying the early psychological repercussions of COVID-19 through Baidu Index data, our study aims to inform public health strategies that address not only the physical health threats but also the mental health challenges posed by such pandemics.

Methods

Baidu Index

As the major Internet search engine in China, Baidu's market share has exceeded eighty percent [14]. Moreover, 92.1% of search engine users conducted their searches by Baidu [15]. By analyzing and calculating the weighted sum of the search times of the entering queries, Baidu users can view the characteristics of their searching behaviors [15]. In the current study, we collected the daily number of cases confirmed with COVID-19 data from the National Health Commission of People's Republic of China [16]. Since the National Health Commission has reported the number of new people daily since January 10,2020, we retrieved daily search metrics data between 2020/1/10 to 2020/3/9 from the Baidu index.

Keywords of Screening

As a Chinese search engine, search queries are all entered as Chinese characters and can be expressed with various related keywords among populations. Thus, the point for Internet surveillance is how to recognize these keywords. To analyze the psychological impact of COVID-19 during the outbreak, we selected the Chinese search terms, which were highly correlated to "COVID-19" and "SARS-CoV-2" in the study based on the function of the keyword analysis provided by Baidu Index. First, we entered the official Chinese names of "COVID-19" and "SARS-CoV-2" as keywords. Then, the keyword analysis function generated a series of related keywords automatically, ranging from high to low by the search volumes related to our topics. Different terms can be combined with the sign (+), which means "OR" to represent the multiple terms. According to prior research that analysis Spanish students' use of the Internet as the source of mental health information, the keywords that reflect public psychological stress can be defined as follows: "Depression", "Bipolar disorder", "Anxiety", "Obsessive", "Panic", "Suicide", "Schizophrenia", "Stress", "Dementia", "Personality disorders", "Addictions", "Post-natal depression" and "Eating disorder" [17]. Since the Baidu index did not provide adequate search data for "Eating disorder," we could not include this term in our study. Besides, we did not include the keyword of "Post-natal depression" because of its low correlation with our study. Eventually, seven COVID-19-related and 44 mental health-related keywords were selected for our analysis (Table S1). To analyze the overall characteristics of public psychological stress, we added up together each keyword of mental illness to get an aggregate daily data to perform our research. Furthermore, gender, age, and regional distributions of users who conducted mental illness searches were examined in our study.

Statistical analysis

Using software SPSS 23.0, we performed the correlation analysis to examine the correlations among the daily number of confirmed cases in China, the daily Baidu Index values for COVID-19, and the daily Baidu Index values for psychological stress. We also performed a lag Spearman correlation to analyze the lag pattern of the relationship between the number of COVID-19 cases and internet searches for mental disorders. $P < 0.05$ was set for statistical significance between variables (two-sided test). Besides, we used software GraphPad Prism 8.2 and ArcGIS 10.6 to create figures.

Dynamic series analysis

We applied a dynamic series analysis to describe the dynamic change in Baidu index search values for the entered queries. Since public awareness to COVID-19 was not high until Wuhan (China) had suspended the transportation (23 January 2020) [6], we conducted the dynamic series analysis between 24 January 2020 to 9 March 2020 to better reflect the mental impact of COVID-19 on Chinese people. We provided the daily development rate and increase rate of the search values as the statistical indicators. The ratio of fixed base and link-rel-

ative was also adopted to investigate the dynamic change of our object. Comparing the search index values in a given time with the baseline, we get the daily development of a fixed base rate, which can indicate the general development direction and speed of the search index values in a given time. While the daily development rate of link-relative was defined to describe the day by day growth rate of the search index values by making a comparison between a day's search values and the previous day's search index values. Moreover, we also calculated an average development rate (the geometric mean of the link-relative development) to compare the development speed of people's search behaviors for our observing topics. Besides, by decreasing the development by 100%, we get the increase rate.

Results

Correlation analysis among search index values of mental illness, search index values of COVID-19, and number of cases in China

Table 1 shows the correlation among the overall search index values of mental illness, the search index values of COVID-19, and the daily number of cases confirmed with COVID-19 in China. Table 1 also presents the correlations between the daily number of confirmed cases in China and the search index values of each topic regarding mental illness. We observed a strong positive correlation between the number of cases and the relative Baidu index values for "Anxiety" (r_s=0.879, p=2.42×10^{-20}), "Addiction" (r_s=0.555, p=4.23×10^{-6}), "Suicide" (r_s=0.849, p=1.132×10^{-17}), "Schizophrenia" (r_s=0.774, p=4.218×10^{-13}), "Panic" (r_s=0.946, p=4.984×10^{-30}), "Obsessive" (r_s=0.839, p=5.811×10^{-17}), "Stress" (r_s=0.895, p=5.856×10^{-22}), "Dementia" (r_s=0.772, p=4.896×10^{-13}), "Personality disorders" (r_s=0.790, p=5.865×10^{-14}), and "Sleep" (r_s=0.778, p=2.499×10^{-13}) ("Depression" and "Bipolar disorder" presented with slightly positive correlations, r_s=0.261, p=0.044, and r_s=0.394, p=0.002, respectively).

As for the correlations between the search index values of each topic regarding mental illness and the index values of COVID-19. We observed negative correlations between relative search index of COVID-19 and search index for nine of twelve mental illnesses: "Depression" (r_s=-0.862, p=1.219×10^{-28}), "Anxiety" (r_s=-0.207, p=0.046), "Addiction" (r_s=-0.596, p=2.844×10^{-10}), "Suicide" (r_s=-0.272, p=0.008), "Schizophrenia" (r_s=-0.495, p=4.458×10^{-7}), "Obsessive" (r_s=-0.262, p=0.011), "Stress" (r_s=-0.352, p=0.001) ("Dementia", "Personality disorders" and "Sleep" did not show such correlations, r_s=-0.014, p=0.894, r_s=0.042, p=0.691, and r_s=0.078, p=0.458, respectively, "Panic" presented with positively correlation: r_s=0.538, p=2.742×10^{-8}). The correlations between the number of confirmed cases in China, the daily growth of cases in China, and search values of COVID-19 were shown in Figure1A-C.

In our analysis, we observed a robust positive correlation be-

Table 1. Correlation among search index values of mental illness, number of cases, and search index values of COVID-19

Keywords/Overall	Search index values of mental health and number of cases		Search index values of mental health and values of COVID-19	
	r_s	*p* value	r_s	*p* value
Overall	0.766	1.041×10^{-12}	-0.236	0.023
Depression	0.261	0.044	-0.862	1.219×10^{-28}
Anxiety	0.879	2.42×10^{-20}	-0.207	0.046
Addiction	0.555	4.234×10^{-6}	-0.596	2.844×10^{-10}
Suicide	0.849	1.132×10^{-17}	-0.272	0.008
Schizophrenia	0.774	4.218×10^{-13}	-0.495	4.458×10^{-7}
Panic	0.946	4.984×10^{-30}	0.538	2.742×10^{-8}
Obsessive	0.839	5.811×10^{-17}	-0.262	0.011
Stress	0.895	5.856×10^{-22}	-0.352	0.001
Dementia	0.772	4.896×10^{-13}	-0.014	0.894
Personality disorders	0.790	5.865×10^{-14}	0.042	0.691
Sleep	0.778	2.499×10^{-13}	0.078	0.458
Bipolar disorder	0.394	0.002	-0.642	4.232×10^{-12}

tween the frequency of COVID-19-related searches and the daily increase in confirmed cases in China (Figure 1a, r_s=0.861, p=2.310×10 $^{-18}$). This suggests that public interest in COVID-19 was closely aligned with the early surge in case numbers. However, we did not detect a significant correlation between the volume of COVID-19 searches and the cumulative number of confirmed cases (Figure 1b, r_s=-0.006, p=0.966). Despite the continuous rise in confirmed cases throughout our study period, the frequency of COVID-19-related searches exhibited a decline, indicating a waning public interest and sensitivity towards the pandemic. This trend may reflect a decrease in public concern and attention as the outbreak progressed during the early outbreak of COVID-19.

We observed an intriguing negative correlation between search indices for mental illness and COVID-19, with a Spearman's rho of -0.236 (Figure 1c, p=0.023). This inverse relationship suggests that as the immediate threat of the pandemic receded from public focus, attention shifted towards the enduring psychological impacts of the crisis. Significantly, we identified a sustained rise in searches related to mental health, concomitant with increasing cumulative COVID-19 cases during the same timeframe (Figure 1d, r_s=0.766, p=1.041×10^{-12}). This pattern of search behavior indicates that while the direct attention on COVID-19 waned, there was an escalating awareness and concern regarding mental health issues-potentially a secondary repercussion of the pandemic's influence on daily life and overall well-being. This evolution highlights the critical need to address not only the direct health impacts of COVID-19 but also its indirect psychological ramifications for the broader population.

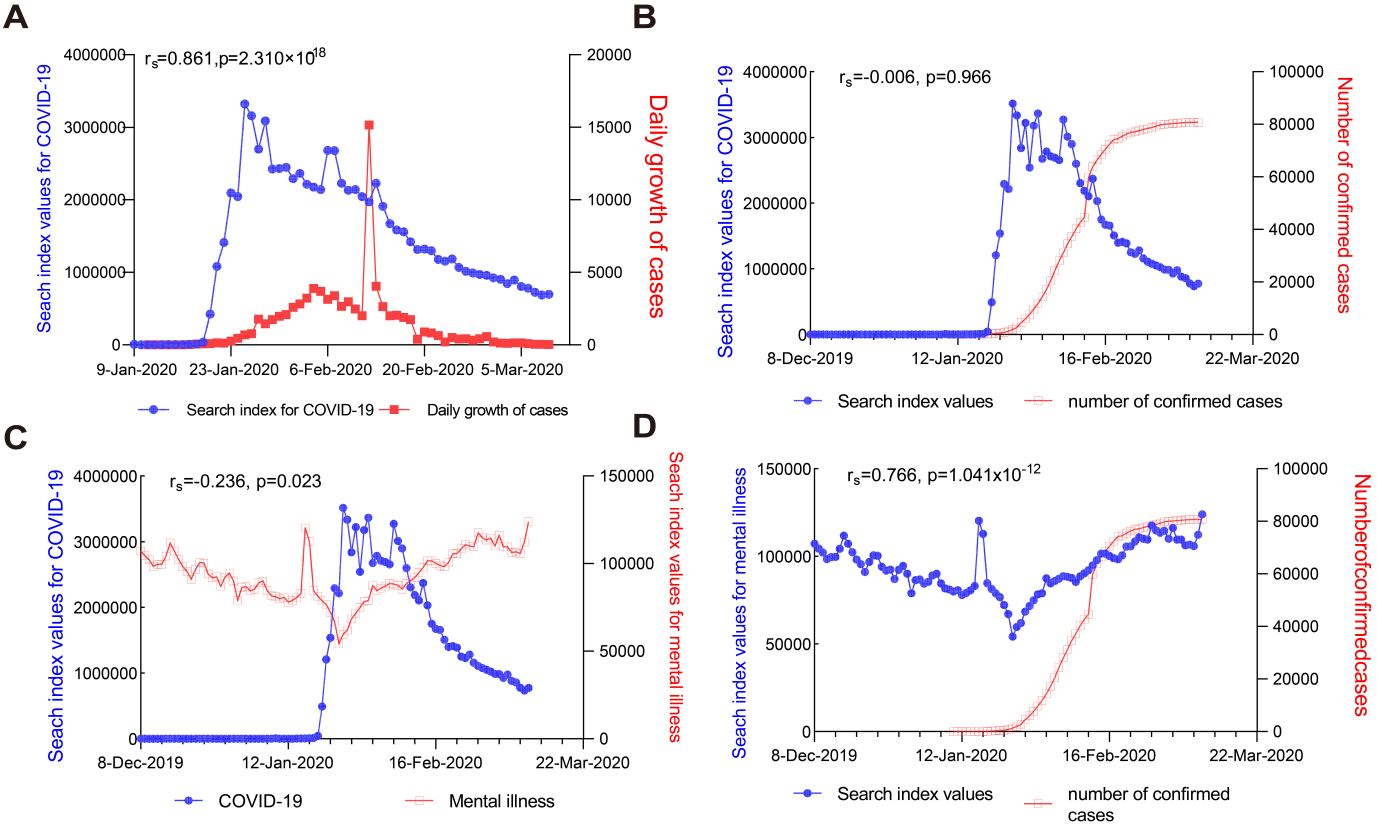
Lag correlation between the number of confirmed cases and search index values of mental illness

Figure 2 and Table S2 presents the lag correlation between the number of confirmed cases and search index values of mental illness. Generally, we observed a declined trend of correlation coefficient with the increasing lag of time. We found the highest correlation with the Baidu searches for “Depression” (r_s=0.261), “Bipolar disorder” (r_s=0.394), “Anxiety” (r_s=0.879), “Obsessive” (r_s=0.839), “Suicide” (r_s=0.849), “Schizophrenia” (r_s=0.774), “Stress” (r_s=0.895), and “Dementia” (r_s=0.772) 0 days earlier for the number of COVID-19 cases (Table 1). As for other search topics of mental illness, the results of time lag correlation showed that the highest correlation between Baidu searches for “Panic”, “Personality disorders”, “Addictions” and the number of reported COVID-19 cases 2 days, 2 days, and 11 days earlier with the correlation coefficient as 0.949, 0.802, and 0.772, respectively (Table S2) (p<0.05 for all).

Search trends in Web-based data of mental illness

The top five searched topics were "Depression" (with the ratio of 33.15%), "Addiction" (12.91%), "Anxiety" (12.23%), "Suicide" (8.87%), and "Schizophrenia" (7.28%) (Figure S1). Figure 3 shows the search trend of the 12 search topics regarding psychological stress in China during the outbreak of COVID-19. The overall search trends of index values for “Depression”,

Figure 1. Analysis of Search Trends During the COVID-19 Pandemic in China. **A.** Correlation between COVID-19-related search frequency and daily increase in confirmed cases in China; **B.** Correlation between COVID-19 search volume and cumulative confirmed cases in China; **C.** Correlation between search indices for mental illness and COVID-19; **D.** Correlation between search indices for mental illness and the cases of cumulative COVID-19 in China.



"Addictions", "Anxiety", "Suicide", "Schizophrenia", and other seven search topics declined in the earlier period of observing time combined with a little of fluctuation. Then the trend increased around 24 January 2020 and kept at a higher level. The dynamic series of the overall and top five search index values for topics regarding mental illness is presented in Table 2, Table S3. A steady increase trend was observed for all the topics contained with the average increase rate of 52.11% for "Depression", 154.33% for "Addictions", 112.66% for "Anxiety", 66.96% for "Suicide", and 42.77% for "Schizophrenia" (Figure S2).

Gender distribution of public search behaviors

For all the search topics on mental illness in our study, women searched more than men, especially for "Depression" (nearly female: 72%, male: 28%) and "Addictions" (nearly female: 79%, male: 21%) (Figure 3).

Figure 2. Lag correlations between the number of confirmed cases and each/overall search topics of mental illnesses.

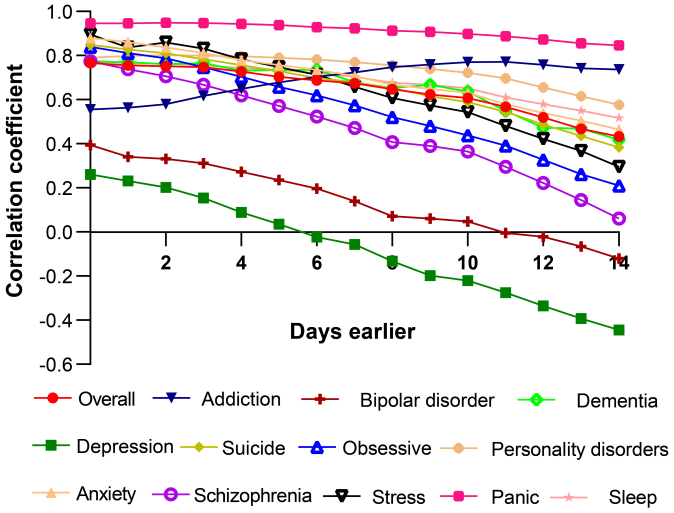
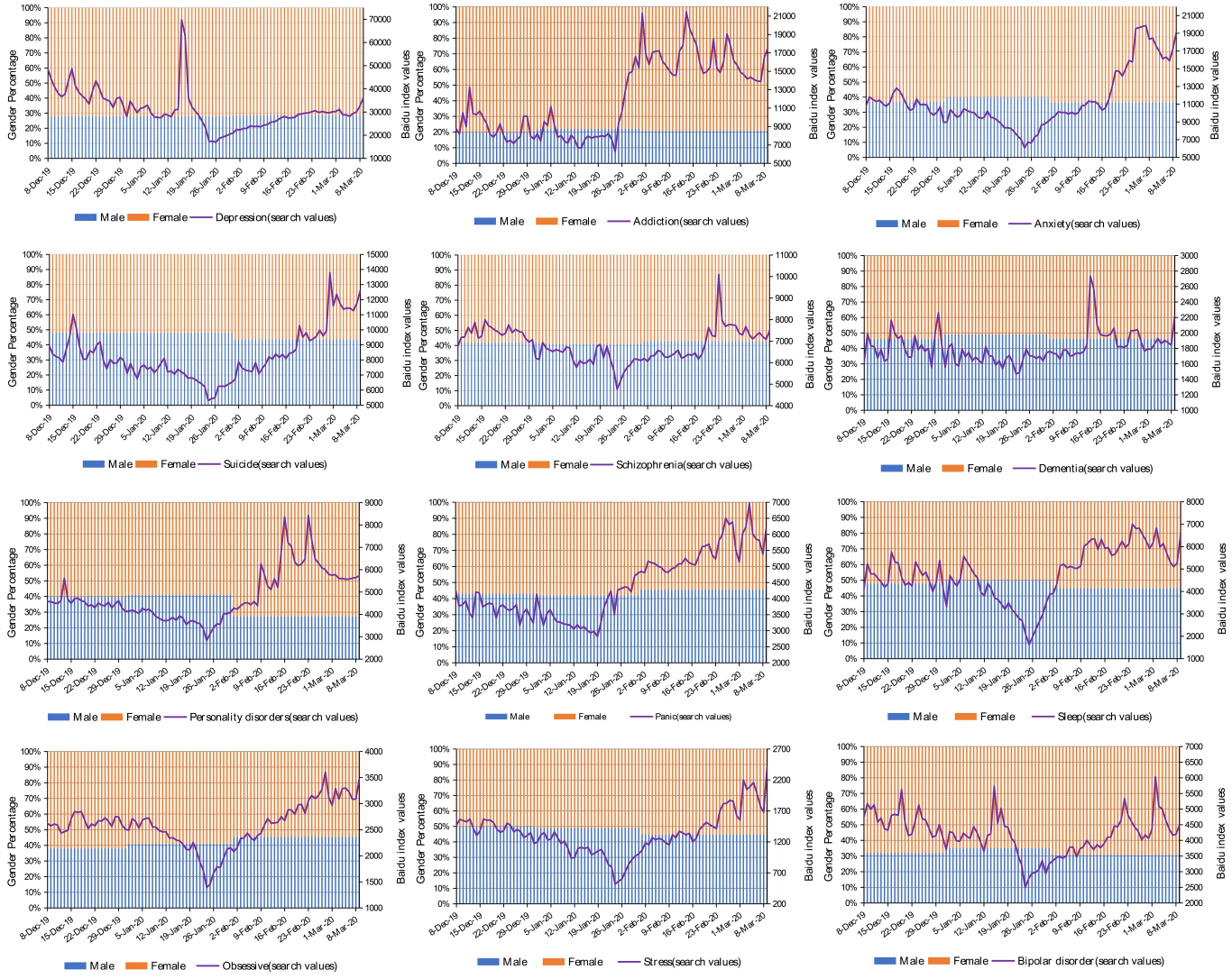


Figure 3. Gender distribution and time series of search index values for the 12 search queries on mental illness from 8 December 2019 to 9 March 2020.



Age distribution of public search behaviors

Figure 4 presents the age distribution for mental illness-related searches between 8 December 2019 to 9 March 2020, in China. Generally, people aged between 20-49 presented higher search behaviors for each topic regarding mental illness, while the group with people aged over 50 years old had the lowest search behaviors.

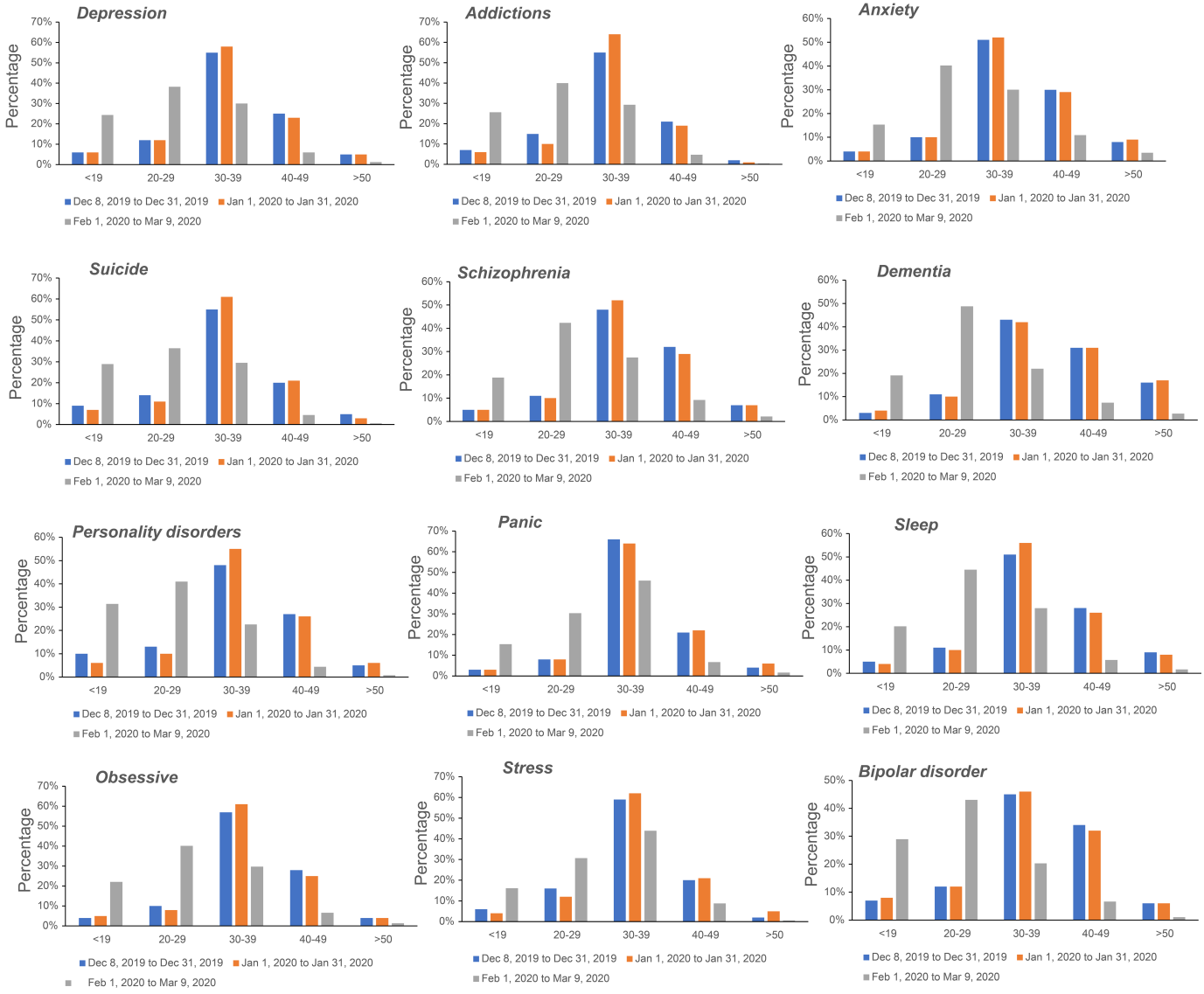
Regional distribution of public search behaviors

Figure 5 performs the regional distribution of the online searches for mental illness and the cases of COVID-19 in 34 provinces and autonomous regions in China. We observed that populations in Guangdong Province searched most while people in Macao and Taiwan searched least compared with the population in other places. For the top five keywords related to mental illness, the population in southeastern China (Guangdong Province, Shandong Province, Jiangsu Province, Hebei Province, Zhejiang Province, Henan Province) and Sichuan Province had the highest search values for mental illness. While search values in northwestern China (Tibet, Ningxia Hui autonomous region, and Qinghai Province) as well as in Hongkong and Taiwan were the lowest. Besides, followed by central, northeast, south, north, and west China ranked second to sixth regarding search index for mental health. Similar results were also found in the regional distribution of confirmed cases. The public in southeastern China showed the highest search behaviors (Figure 5).

Discussion

Our study contributes to the existing literature by highlighting the importance of early psychological surveillance during pandemics. It underscores the need for a proactive approach to mental health support, particularly during the initial stages of a health crisis when public anxiety is at its peak. Based on the hypothesis that Internet query data can reflect the epidemics of psychological stress during the outbreak, data from Baidu search engines could help the nation to face the challenges of public mental illness with more timely and effective ways. By

Figure 4. Age distribution of the searches for 12 topics regarding mental illness from 8 December 2019 to 9 March 2020.



identifying the early psychological repercussions of COVID-19 through Baidu Index data, our study aims to inform public health strategies that address not only the physical health threats but also the mental health challenges posed by such pandemics, providing valuable insights for future infectious disease outbreaks as well.

Our results suggest that public Baidu index search values for mental illness were significantly positively correlated to the number of confirmed cases in China and slightly negatively correlated to the Baidu index search values for COVID-19. Internet searches for topics of mental illness increased significantly after the quarantine measures were implemented. For most Internet searches of mental disorders, there is no lag pattern of the relationship between the number of COVID-19 cases and internet search for most kinds of mental illnesses. We also observed that women searched more about mental health-related information via Baidu than men, and people over 50 years old had the least search behaviors. Besides, people in southeastern China searched for information related to mental illness via Baidu more than in other places.

The results suggest that when real-time information is missing (e.g., routinely face-to-face psychological counseling process cannot proceed), search engine data can serve as a useful method for investigating the epidemiological characteristics of psychological stress. Each topic related to mental illness presented positive correlations for the Baidu index with the number of confirmed cases in China, which shows that with the confirmed cases soaring, public interest to mental problems is increasing as well. At the same time, the Baidu index for COVID-19 was positively correlated to the daily growth of COVID-19. An explanation could be that with the robust surveillance and quarantine measures taken by the Chinese government and the joint efforts of all walks of life, the COVID-19 epidemic in China have been gradually controlled. Therefore, with the daily increase of cases decreasing, the public's concern about this novel virus declined as well. Instead, the searches

Table 2. Dynamic series analysis of the overall search index values for the topic regarding mental illness in China

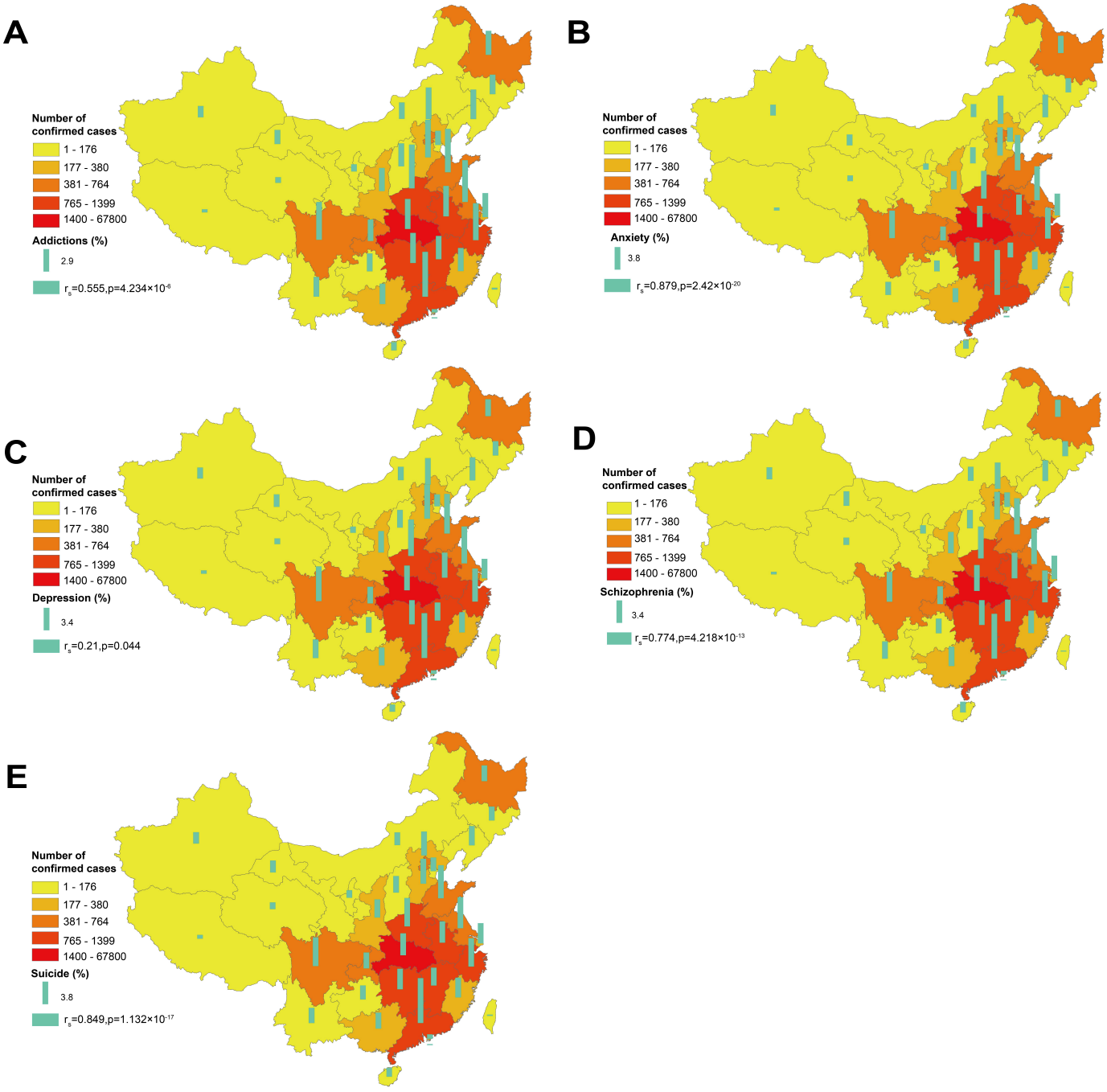
Date	Search index values	Absolute increment		Development rate(%)		Increment rate(%)	
		Cumulative	Day on day	Fixed base ratio	Link relative ratio	Fixed base ratio	Link relative ratio
24-Jan	54202	_	_	100.0	100.0	_	_
25-Jan	59693	5491	5491	110.1	110.1	10.1	10.1
26-Jan	61899	7697	2206	114.2	103.7	14.2	3.7
27-Jan	68379	14177	6480	126.2	110.5	26.2	10.5
28-Jan	71648	17446	3269	132.2	104.8	32.2	4.8
29-Jan	74948	20746	3300	138.3	104.6	38.3	4.6
30-Jan	78297	24095	3349	144.5	104.5	44.5	4.5
31-Jan	78901	24699	604	145.6	100.8	45.6	0.8
1-Feb	87395	33193	8494	161.2	110.8	61.2	10.8
2-Feb	84621	30419	-2774	156.1	96.8	56.1	-3.2
3-Feb	85957	31755	1336	158.6	101.6	58.6	1.6
4-Feb	87246	33044	1289	161.0	101.5	61.0	1.5
5-Feb	88745	34543	1499	163.7	101.7	63.7	1.7
6-Feb	88274	34072	-471	162.9	99.5	62.9	-0.5
7-Feb	87706	33504	-568	161.8	99.4	61.8	-0.6
8-Feb	85408	31206	-2298	157.6	97.4	57.6	-2.6
9-Feb	88530	34328	3122	163.3	103.7	63.3	3.7

10-Feb	90371	36169	1841	166.7	102.1	66.7	2.1
11-Feb	92003	37801	1632	169.7	101.8	69.7	1.8
12-Feb	94788	40586	2785	174.9	103.0	74.9	3.0
13-Feb	97757	43555	2969	180.4	103.1	80.4	3.1
14-Feb	101543	47341	3786	187.3	103.9	87.3	3.9
15-Feb	101580	47378	37	187.4	100.0	87.4	0.0
16-Feb	100170	45968	-1410	184.8	98.6	84.8	-1.4
17-Feb	98902	44700	-1268	182.5	98.7	82.5	-1.3
18-Feb	98363	44161	-539	181.5	99.5	81.5	-0.5
19-Feb	100615	46413	2252	185.6	102.3	85.6	2.3
20-Feb	105560	51358	4945	194.8	104.9	94.8	4.9
21-Feb	105632	51430	72	194.9	100.1	94.9	0.1
22-Feb	108496	54294	2864	200.2	102.7	100.2	2.7
23-Feb	110842	56640	2346	204.5	102.2	104.5	2.2
24-Feb	110075	55873	-767	203.1	99.3	103.1	-0.7
25-Feb	109541	55339	-534	202.1	99.5	102.1	-0.5
26-Feb	117519	63317	7978	216.8	107.3	116.8	7.3
27-Feb	114798	60596	-2721	211.8	97.7	111.8	-2.3
28-Feb	113430	59228	-1368	209.3	98.8	109.3	-1.2
29-Feb	114608	60406	1178	211.4	101.0	111.4	1.0
1-Mar	110069	55867	-4539	203.1	96.0	103.1	-4.0
2-Mar	116200	61998	6131	214.4	105.6	114.4	5.6
3-Mar	109532	55330	-6668	202.1	94.3	102.1	-5.7
4-Mar	109584	55382	52	202.2	100.0	102.2	0.0
5-Mar	106313	52111	-3271	196.1	97.0	96.1	-3.0
6-Mar	106640	52438	327	196.7	100.3	96.7	0.3
7-Mar	105794	51592	-846	195.2	99.2	95.2	-0.8
8-Mar	112299	58097	6505	207.2	106.1	107.2	6.1
9-Mar	123929	69727	11630	228.6	110.4	128.6	10.4

for COVID-19 was negatively correlated to searches for most of the mental health-related disorders, which suggests the public's interest in mental problems is increasing even though the concern to COVID-19 is decreasing. Especially for "Depression", the Baidu index for this topic showed the strongest negative correlation with the Baidu index for COVID-19. In addition, since the gradual control of the epidemic, public interest to COVID declined, and people's fearless declined as well. Besides, for most search topics of mental illness, there was no lag time between the number of cases and the Baidu searches data of mental health-related disorders, which imply that the impact of such heal-emergencies on the public's mental health is immediate. Thus, when reporting the epidemic situation of COVID-19, the government must take into account the impact of these data on public mental health so as to make appropriate guidance and intervention to protect the public's mental health.

Adhered to previous studies, when suffering from health emergencies, fear and anxiety appeared quickly and did not last for too long, while depression lasts for a long time [18, 19]. According to several prior studies about the mental-related symptoms after the outbreak of SARS in 2003, 17.3% of the workers

Figure 5. Graph map and correlation for the top five most commonly searched topics regarding mental health and the number of confirmed cases in China (A-E, the height of the straight bar in various regions represents the search values of various mental disorders, the higher the bar, the higher the values).



served in the health-care system showed mental symptoms after the epidemic of SASR was controlled, and there were still 15.4% of them presented with mental symptoms one year after [20]. Thus, the mental disorders caused by heal-emergencies on the public tend to be a long-term and continuous process. As a result, although people's interest in COVID-19 declined, the searches for mental-illness information on the Internet increased instead. Such research may also be an explanation for results that search trends for topics regarding mental illness kept at a higher level compared with the earlier observing time [20, 21]. To control the further spread of COVID-19, Wuhan had suspended public transportation since 23 January 2020, indefinitely, and pronounced that citizens should not leave Wuhan without special reasons [22].

On the one hand, such quarantine measures could result in several outcomes, including the absence of interpersonal communication and the usual psychological counseling process [23]. On the other hand, with quarantine, people were required to stay at home. Consequently, they had more time to surf the Internet. Because of the increase of people's online activities, they were more vulnerable to the impact of the news about the COVID-19 epidemic on the Internet, which would also lead to an increase in psychological pressure. This may explain why the increasing turning point started around 24 January 2020, with the average increase rate of overall search values for mental illness as 78.95% since then.

Interestingly, public search behaviors for addictions presented with the fastest increase speed. Moreover, the lag pattern of the relationship between Baidu searches for "addiction", and the number of confirmed cases indicated that such addictive behaviors did not appear immediately. An explanation could be that when facing with the negative emotions caused by COVID-19 and those compulsory isolation measures, people tend to adopt some habitual ways to deal with it, which could result in the increase of various addictive behaviors, including smoking, drinking, and gambling, and it would take several days before people realize that they were addicted.

In terms of gender differences, some reasons may contribute to the phenomenon that women searched more than men. On the one hand, the utilizes of smartphones in women is higher among men, and when facing the crush of psychological stress and mental disorders, they were more likely to look for mental-related information as a form of help[24, 25]. On the other hand, even though under high mental pressure, men were not willing to seek help because of the idea of "collective face-saving," which was linked to the characteristics of masculinity, confidence, and robustness in East Asian culture [24]. Thus, a man would be embarrassed if his soft side was presented. Thus, even though the female is more prone to suffering from psychological stress, additional attention should be paid to the male group to help them to face such challenges.

There are more than 177 million order adults beyond 60 years in China consisted of the largest aging population in the world, and a large number of them are suffering from disabilities, mental health problems, and loneliness [26]. The remarkable transmission speed and high death rate of COVID-19 would aggravate the possibilities of getting mental problems, harsh their existing symptoms, and even damage to their cognitive function. Since the elders have limited access to Internet-based information for help, the mental health-protection initiatives should care more about this age group to provide them with high-quality and timely psychological services. We also found that the distribution of online search behaviors was different across regions. The overall regional distribution of online searches for mental illness was consistent with the regional distribution of confirmed cases in China, with the highest search behavior that appeared in southeastern China. Besides, the spatial heterogeneity, demographical, economical, and educational medical disparities may also contribute to the regional differences of online search behaviors for mental illness.

Interestingly, similar results were also found in a study of public online search behaviors of cancer in China by Xu et al [27]. They observed that people in places with dense population and developed economic (e.g., cities in eastern China) had more access to the Internet and higher awareness of health-related information Compared with people in cities with sparsely population and developing economies, they were more likely to look for health-related information on the Internet. Thus, local authorities need to put in place robust measures to ensure that people nationwide have enough access to Web-based information, especially for places with an underdeveloped economy.

Given the difficulty of retrieving public mental-related data because of the quarantine and isolation strategies during the outbreak of COVID-19, the characteristics of public mental problems and psychiatric morbidity remained unavailable. Establishing timely and efficient mental illness- control methods has become an essential part of the overall victory against the epidemic of COVID-19. As an Internet search toll with the largest consumers in China, gathering data of public real-time search behaviors from Baidu engines can be the source of information that supports mental illness prevention and control. People's attention to topics related to mental illness, as well as the population characteristics, can help the authorities to take prevention and intervention measures in a more targeted way, so as to lower the loss of public mental health caused by COVID-19. Besides, the epidemic of COVID-19 in China has been initially controlled due to the series of strong measures (e.g., quarantine, isolation, and social distancing) taken by the government). Thus, other countries where the epidemic is beginning to spread are encouraged to put in place similar strategies to control the transmission of the epidemic. Therefore, the characteristics of public psychological stress and mental disorders in those countries may also be similar to the characteristics in China. Our results can also help the authorities in those countries to make timely and effective measures to prevent and control the mental catastrophe.

As the first of exploring the psychological characteristics of the public during the outbreak of COVID-19 in China using the Baidu Index, some limitations need to bear in mind. For instance, we only applied the Baidu engine to retrieve public search behavior data, so the data that people who were suffering from mental disorders and did not seek help from Baidu is missing. Besides, only people with access to the Internet can perform those searches. So, it is insufficient to extrapolate our conclusion to the whole population. Finally, this study focused on the early phase of the COVID-19 pandemic (January–March 2020), and thus does not capture potential long-term psychological adaptations or clinically diagnosed mental health outcomes. Future research should extend the observation period to evaluate whether public sentiment stabilized or required sustained intervention.

Conclusions

Our study has demonstrated that the early stages of the COVID-19 pandemic were associated with a significant increase in online searches related to mental health among the Chinese population. This correlation underscores the immediate impact of the pandemic on mental well-being and the need for targeted interventions. Looking ahead, our findings suggest that monitoring online search trends could serve as an effective tool for detecting psychological distress during future pandemics, aiding in the development of timely and responsive public health strategies to address mental health needs. This approach could provide valuable insights into the psychological implications of major infectious disease outbreaks and inform preparedness plans to mitigate their mental health impacts. While our findings highlight the acute psychological distress during the initial outbreak, further research is needed to determine whether these effects were transient or required sustained intervention. Monitoring search trends can serve as an early warning system, but policy responses should be calibrated to avoid unnecessary panic.

Abbreviations

Severe Acute Respiratory Syndrome Coronavirus 2: SARS-CoV-2;

Author Contributions

Nana Meng: Conceptualization, Methodology, Data curation, Writing - Original Draft, Writing - Review & Editing. Yuan Chen: Data collection, Formal analysis, Validation, Writing - Review & Editing. Danna Zhao: Supervision, Writing - Review & Editing. Dingtao Hu: Supervision, Project administration, Writing - Review & Editing. All authors read and approved the final manuscript.

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Ethics Approval and Consent to Participate

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Competing Interests

The authors declare that they have no existing or potential commercial or financial relationships that could create a conflict of interest at the time of conducting this study.

Data Availability

Not Applicable.

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