Mental Health, Health Experiences, and Health Perceptions of University Students Using E-learning in China During the COVID-19 Pandemic: Cross-Sectional Questionnaire

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Table of Contents

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Abstract

Background: Digital health-the use of mobile health (mHealth) and electronic health (eHealth), has facilitated the widespread surveillance of health for young adults. Regardless of the increasing use of digital health as an instrument of health enhancement, limited research has explored the use of digital health, and how this has impacted the mental health, health experiences, and health perceptions of university students who are regularly accessing online education through digital technologies during the COVID-19 pandemic.

Objective: The major aim of this study was to assess the frequency of digital health use among university students in China, the influence on their mental health, health considerations, and experiences of health-relative behaviors at a point when the shutdown of universities was in progress and e-learning (i.e., online education) was taken as the routine substitute for conventional face-to-face education during the COVID-19 epidemic.

Methods: Full-time undergraduate or graduate students aged 18 to 26 from internet economics and business major of a technology university in China were recruited to participate in an anonymous and cross-sectional online survey to collect data on their utilization of digital health, the association with mental health, their perceptions and experiences of health. Of the 200 surveyed eligible university students who were guided to the online website, 165 (82.5%) students responded effectively to the questionnaire and thus were included in the analysis. Median values and frequency analyses were performed for major variables such as mental health and digital health use that were stratified into dichotomous observations. Chi-square test with p?.05 was employed to determine the significant level of associations between the variables.

Results: The average mental health score of the university students was 17.8 out of a total scale 40, which did not vary remarkably across gender, education, and other sociodemographic attributes. Statistically significant associations between digital health use and mental health (p=.003), the willingness of sharing health information with acquaintances (p=.017), control of health-relative behaviors (i.e., smoking, drinking and dieting, p=.001), communication with physicians (p=.029), and physical activity(p=.016) were identified for young students. During the COVID-19 pandemic, low digital health use among university students was significantly associated with good mental health and high digital health use the reverse. In contrast, digital health use was not associated significantly with components such as the concerns on health-relative topics, concerns on social media, and the decision-making on health treatment.

Conclusions: The average mental health score of the university students was 17.8 out of a total scale 40, which did not vary remarkably across gender, education, and other sociodemographic attributes. Statistically significant associations between digital health use and mental health (p=.003), the willingness of sharing health information with acquaintances (p=.017), control of health-relative behaviors (i.e., smoking, drinking and dieting, p=.001), communication with physicians (p=.029), and physical activity(p=.016) were identified for young students. During the COVID-19 pandemic, low digital health use among university students was significantly associated with good mental health and high digital health use the reverse. In contrast, digital health

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Results: The average mental health score of the university students was 17.8 out of a total scale 40, which did not vary remarkably across gender, education, and other sociodemographic attributes. Statistically significant associations

between digital health use and mental health (p=.003), the willingness of sharing health information with acquaintances (p=.017), control of health-relative behaviors (i.e., smoking, drinking and dieting, p=.001), communication with physicians (p=.029), and physical activity(p=.016) were identified for young students. During the COVID-19 pandemic, low digital health use among university students was significantly associated with good mental health and high digital health use the reverse. In contrast, digital health use was not associated significantly with components such as the concerns on health-relative topics, concerns on social media, and the decision-making on health treatment.

Conclusions: COVID-19 pandemic has increased the digital technologies (e.g., smartphones, computers, and tablets) use for full-time university students who are undergoing school closure and are taking e-learning instead as the routine way of education in China. The continuous use of digital technologies has deteriorated mental health and impacted the health experiences and perceptions of university students. Digital health hinges on digital technologies to fulfill the functionality of health surveillance and intervention, which reversely affects the choice of digital health use for young adults. Students tended to use less digital health to avoid the deterioration of mental health or alleviate the distress accumulated in the online education case in which digital technology was integrated with routine e-learning. Future research is expected to investigate the duration and dynamics of the associations that can provide insights on solving long-term and cyclical public health crisis for university settings.

KEYWORDS
mHealth; digital health; digital technology; eHealth; mental health; health experiences; health perceptions; e-learning; online education; university students

Introduction

Mobile- and electronics-based psychological interventions, or digital health interventions, are increasingly being employed to help individuals suffering health-relative issues [1]. Digital health typically integrates the knowledge of digital technologies and that of healthcare expertise. Although it is a major source of instruments in response to health problems, debates cast on whether the association presents heterogeneous trajectory during a public health emergency [2,3], as adolescents and young adults are more vulnerable to stressful and unexpected exterior events and thus more likely to contract a variety of health issues when such shocks emerge. And the relation might be complicated by confounding factors that correlate with the concerned major variables [4].

Prior research has identified the potential effectiveness of digital health on health improvement such as reduction of self-reported anxiety and depression at university settings when accounting for the specific contexts in which it is implemented [4-7]. Low level of social support such as direct material aid, social networks, and community participation indicates higher risks of mental health issues for students [8]. In contrast, some other studies find that the use of digital health does not imply a substantial association with health-relative behaviors for university students [9,10]. There are still inclusive debates remaining to be resolved. University students face potentially more severe mental health risks during the pandemic as it has altered the routine way of education that is familiar to the cohort, and the exposure to COVID-19 is associated with a higher prevalence of depression and anxiety [8] that can impact directly on the subsequent health and health behaviors [4]. The spread of COVID-19 has incurred unprecedented impacts on the health of university students [9].

Since the first cases were identified in December 2019, China has employed a variety of measures including the closure of schools, inclusive of other educational institutions, and places with large gatherings to counteract the spread of COVID-19. By late July 2020, China has gained meaningful containment of the first-wave outbreak. A growing number of universities in China have either postponed or canceled the opening of campuses, instead, online education or e-learning requesting students to access educational resources through smartphones or personal computers is employed by the administration as the routine substitute nationwide [11]. Online education increases the use of digital technologies and screen time for students in China. The transition to online education has raised concerns for the students regarding their reduced physical activity and deteriorated mental health [12]. For each student, he or she has to take a certain level of courses in a single semester to qualify the conditions of passing or graduation, which increases the time spent online by using electronic devices. This raises the concern that mental health would deteriorate and the likelihood of participating in physical activity would drop, which may lead to unfavorable effects on the health of students [13,14].

Although the acceptability of digital health interventions for health problems appears to be relatively high, its impact on mental health, health experiences, and health perceptions for full-time university students during a global health crisis have yet to be identified. The closure of schools was long-lasting in China, which was started in Jan 2020 and extended to late Aug 2020. The increased accessibility to, adoption of, and dependence on digital technologies could have a long-term negative impact on the development of students. Hence, how university students respond to and perceive the shocks are of critical concern. To facilitate implementing effective strategies and interventions of digital health for university settings during a public health crisis, this study aims to explore the utilization of digital health, the experiences, and perceptions of university students in China, extending extant literate with updated knowledge on the

COVID-19 pandemic through mobile- or electronics-based health.

Methods

Study Population and Recruitment

This cross-sectional study was conducted from early June to late July 2020 as an exploratory questionnaire in a sample of full-time undergraduate and graduate students who majored in internet economics and business at the Fujian University of Technology. An online questionnaire was distributed through two widely used apps termed WeChat and QQ in China by instructors to 300 young students, who were guided to the most popular online survey-star platform, and no reward was disseminated at the time of completion. The participants were provided with informed consent to participate in the questionnaire and the responses were voluntary and anonymous. The eligible students were both Chinese- and English-speaking and aged 18-26 years old. The time of administration and completion of the survey was approximate 10 min, accounting for the factors that potentially complicate the mental health of students due to the overuse of digital technology. This study was approved by the Ethics Board at the Fujian University of Technology.

Survey Instrument

The questionnaire was designed by a team of three researchers in health economics, information technology, and business, following a four-step collaborative process. According to this methodology, the team (1) collaboratively identified the topics of research by performing comprehensive literature ; (2) reviewed the items of the extant survey; (3) designed a new survey and merged existing measures of mental health used in other applied research; and (4) refined the draft providing a final version. During steps 1-3, the team reevaluated the feasibility of the survey, eliminating items that were time-consuming accounting for the factor that students had to take routine online courses. As lengthy use of smartphones or computers to respond to the questionnaire might incur additional anxiety or depression on the students. After the school closure on Jan 2020, Fujian University of Technology followed the nationwide strategy of online education. Ever since the university provided over 300 online classes daily, and around 21,000 students were formally registered at the university by July 2020. Although heterogeneity existed in the schedule of accessibility to the online courses, students on average had to participate in multiple e-lectures each week. Engagement in online learning

and exposure to digital technologies was impressively high during the COVID-19 outbreak with a large part of academic participation daily. Of the 200 participants, 91.5% (183/200) and 7.3% (15/200) answered that using smartphones and personal computers to access the online courses respectively.

The final questionnaire was divided into 4 sections:

- Sociodemographic characteristics: gender, age, education (4 items: freshman/sophomore/junior/senior), marital status (3 items: partnered/single/married), age, current residency (2 items: urban/rural), number of siblings (4 items: 0/1/2/3 or more).
- Questions on digital health use: frequency of digital health use during the past month (everyday/nearly per day/one to two times per week/less than once per week/no use at all), whether ever searched health-relative topics (2 items: yes/no), when searching health-related topics which option is the first priority (6 items: internet/family/friends/books or news/physicians /others), the purpose in the latest search of health-relative topics (for own/for others/both), whether used the internet to send/receive e-mails(yes/ no), when using the internet what is mostly used tool (cell phone/computer/ other/no phone or computer), whether installed health- or medical-relative apps (yes/no), whether digital health has helped in the control of smoking, drinking, dieting or physical exercise, whether digital health has helped in decision-making of health relative issue(yes/no), whether digital health has helped communication with physicians(yes/no) , whether used digital health to track health status in the past month (yes/no).
- Likert-scale questions on mental health: comprised of Spielberger State-Trait Anxiety Inventory State (STAIS) and Spielberger State-Trait Anxiety Inventory Trait (STAIT) scale. Each scale had five questions respectively and the responses included 4 items each: not at all/ somewhat / moderately so / very much so.
- Likert-scale questions on health experiences and perceptions: whether it took great effort to obtain health information(4 items: completely agree/generally agree/not agree/completely not agree), whether it was frustrating in the information search (4 items: completely agree/generally agree/not agree/completely not agree), level of confidence to obtain health-relative information (5 items: completely confident/generally confident /confident / a little bit confident /completely not confident), credibility of the health information obtained through physician/family or friends/internet (completely credible/generally credible/a little bit credible /completely not credible), whether willing to share information with family or friends (willing/ not willing), the frequency to access social media (more during the COVID-19 outbreak/ more after the COVID-19 outbreak), the frequency of physical activity (more during the COVID-19 outbreak/ more after the COVID-19

outbreak),concerns on health-relative topics (more during the COVID-19 outbreak/ more after the COVID-19 outbreak).

Statistical Analysis

Statistical analysis was performed using SPSS (V24; IBM Institute Inc, USA). Descriptive statistics (e.g., frequency and percentage) were summarized in the initial data analysis. Chi-square and corresponding levels of significance were used to identify the associations between digital health use, self-rated mental health, health experiences, and health perceptions of the participants. The level of statistical significance was set at *p*-value <.05. The total scores of mental health (sum of STAIS-5 and STAIT-5) were redefined to a range from 10 to 40, with higher scores representing higher levels of anxiety and thus indicating lower levels of mental health. We divided mental health into dichotomous categories (i.e., good or bad) relative to the median group value (median score was 17.8), which complied with what has been conducted in previous studies [10,11].

Results

Participants

A total of 200 students were approached to answer the survey, of whom 165 chose to participate in the study with a response rate of 82.5%. All of the students majored in internet economics and business and completed the online survey with effective responses. The sociodemographic attributes of participants are summarized in Table 1. The mean age of the whole sample was 20.6 years old with the minimum age of 18 and the maximum 26, of which 69.9% (115/166) were females. The population consisted of 28.5% (47/165) freshmen, 28.5% (47/165) sophomore, 26.7% (44/165) junior and 16.4% (27/165) senior students respectively. 80% (132/165) of the participants were single and 20% (33/165) had partnered with girlfriends or boyfriends. Almost one-half (80/165, 48.5%) lived in rural areas. Of all the participants, 19.4% (32/165) were the only child in the family, in contrast, 13.9% (23/165) had three or more siblings. There were no missing values for the data on sociodemographic characteristics.

Table 1. Sociodemographic characteristics of university students (N=165).

measures		n (%)
Gender		
	Male	49(29.7%)
	Female	116(70.3%)
Education		
	Freshman	47(28.5%)
	Sophomore	47(28.5%)
	Junior	44(26.7%)
	Senio r	27(16.4%)
Marital Status		
	Single	132(80%)
	Partnered	33(20%)
Current Residency		
	Urban	85(51.5%)
	Rural	80(48.5%)
Number of Siblings		
	None	32(19.4%)
	One	51(30.9%)
	Two	59(35.8%)
	Three or more	23(13.9%)

Measure of Digital Health Use

Students (N=165) were asked of the frequency of digital health use to dynamically track the status of health during the previous month, of whom 18.8% (31/165) declared everyday use of digital health, 15.8% (26/165) of the participants responded almost every day, 12.7% (21/165) answered one to two

times per week, 9.1% (15/165) of the participants responded less than once per week and the remaining 43.6% (72/165) replied no experience of digital health use at all during the previous month. We redefined the variable into a dichotomized category, with high use of digital health termed as those using at least one time per week and low use of digital health otherwise.

Measure of Mental Health

Spielberger State-Trait Anxiety Inventory (STAI), which is manifested with outstanding reliability and validity regarding psychometric attributes, is employed to measure the STAIS and STAIT characteristics of anxiety respectively [17]. Higher scores of STAI indicate more severe levels of anxiety or equivalently worse levels of mental health. Individuals with higher values in STAI scales are more likely to suffer anxiety issues and thus be more vulnerable to anxiety disorders. It is a measure of self-rated mental health on a Likert scale (4 items each: not at all/somewhat/ moderately so /very much so) with a one-point unit of increment. To account for the factor that completion of the questions requests lengthy responses complicating the measure of mental health of the students, we employed STAIS-5 and STAIT-5, the five-item short forms of the stratified STAI scales, to measure the levels of mental health for students. Prior research has identified the reliability [18] and consistency [19] of both forms. We merged STAIS-5 and STAIT-5 to generate a new measure of mental health. For all of the short-form STAIS items, less than 1.8% (3/165) of participants reply with a high level of anxiety (i.e., response of very much so). In contrast, the ratios of individuals answering no anxiety (i.e., response of not at all) consist of 38.8% (64/165), 55.8% (92/165), 46.1% (76/165), 48.5% (80/165), and 36.4% (60/165) respectively. The ratios of individuals who consider at least somewhat levels of anxiety are 61.2% (101/165), 44.2% (73/165), 53.9% (89/165), 51.5% (85/165), and 63.6% (105/165) respectively. Comparatively, in the case of short-form STAIT items, these ratios are 45.5% (75/165), 37.6% (62/165), 25.5% (42/165), 20% (33/165) and 20.6% (34/165) for anxiety-free case respectively. Of all the individuals, 54.5% (90/165), 62.4% (103/165), 74.5% (113/165), 80% (132/165) and 79.4% (141/165) reply with somewhat or higher levels of anxiety. The average mental health score was 17.8, which did not vary remarkably across gender, education, and other sociodemographic attributes. Based on the median score of mental health, the participants were stratified into two dichotomous groups: the first group with scores higher than the median anxiety score (71/165, 43.1%) while the second group had scored lower than the median (94/165, 56.9%). The mental health statistics on how students evaluated the two forms of STAIS and STAIT are presented in Table 2.

Table 2. Measure of mental health.

Item	Content	Not at all	Somewhat	Moderately so	Very much so
STAIS-1	I feel upset.	64(38.8%)	84(50.9%)	15(9.1%)	2(1.2%)
STAIS-2	I feel frightened.	92(55.8%)	63(38.2%)	8(4.8%)	2(1.2%)
STAIS-3	I feel nervous.	76(46.1%)	78(47.3%)	9(5.5%)	2(1.2%)
STAIS-4	I am jittery.	80(48.5%)	67(40.6%)	16(9.7%)	2(1.2%)
STAIS-5	I feel confused.	60(36.4%)	82(49.7%)	20(12.1%)	3(1.8%)
STAIT-1	I feel that difficulties are piling up so that I cannot overcome them.	75(45.5%)	69(41.8%)	19(11.5%)	2(1.2%)
STAIT-2	I worry too much over something that really does not matter.	62(37.6%)	78(47.3%)	22(13.3%)	3(1.8%)
STAIT-3	Some unimportant thoughts run through my mind and bother me.	42(25.5%)	99(60%)	21(12.7%)	3(1.8%)
STAIT-4	I take disappointments so keenly that I cannot put them out of my mind.	33(20%)	94(57%)	29(17.6%)	9(5.5%)
STAIT-5	I get in a state of tension or turmoil as I think over my recent	34(20.6%)	96(58.2%)	28(17%)	7(4.2%)

	concerns and interests.				

Associations Between Digital Health Use, Mental Health, Health Experiences and Health Perceptions

There are significant associations between digital health use and mental health(p=.003), willingness to share health information with family or friends (p=.017), whether digital health helped the communication with physicians (p=.029), whether digital health helped control of smoking, drinking and dieting(p=.001) and physical activity (p=.016) (see Table 3). In contrast, no remarkable associations are observed between digital health use and concerns on health- or medical-related topics, concerns on social media, and whether digital health helped decision-making on health treatment. For university students who are using digital technologies to participate in routine online education, the low use of digital health is significantly correlated with good mental health (62.8% (59/165) versus 37.2% (35/165)). In contrast, the high use of digital health is significantly correlated with bad mental health (60.6% (43/165) versus 39.4% (28/165)). Participants willing to share health information with acquaintances use digital health more frequently (54.3% (57/165) versus 45.7% (48/165)). For students with high use of digital health, more agree that digital health has helped the communication with physicians (57.1%(40/165) versus 42.9%(30/165)), control of health behaviors such as smoking, drinking and dieting (58.3%(56/165) versus 41.7%(40/165)), and more physical activity when the spread of COVID-19 is less severe (59.4% (41/165) versus 40.6% (28/165)).

Table 3. Associations between digital health use, mental health, health experiences, and health perceptions of university students.

	Value, n (%)		*p*-value
	Low Use of Digital Health	High Use of Digital Health	

Mental Health				0.003
	Good mental health	59(62.8%)	35(37.2%)	
	Bad mental health	28(39.4%)	43(60.6%)	
Concerns on health- or medical-related topics				0.159
	More when the spread of COVID-19 is severe	78(54.9%)	64(45.1%)	
	More when the spread of COVID-19 is less severe	9(39.1%)	14(60.9%)	
Concerns on social media				0.456
	More when the spread of COVID-19 is severe	79(53.7%)	68(46.3%)	
	More when the spread of COVID-19 is less severe	8(44.4%)	10(55.6%)	
Willingness to share health information with family or friends				0.017
	Yes	48(45.7%)	57(54.3%)	
	No	39(65%)	21(35%)	
Whether digital health helped communication with physicians				0.029
	Yes	30(42.9%)	40(57.1%)	
	No	57(60%)	38(40%)	
Whether digital health helped decision-making on health treatment				0.131
	Yes	48(48%)	52(52%)	
	No	39(60%)	26(40%)	
Whether digital health helped control of smoking, drinking, and dieting				0.001
	Yes	40(41.7%)	56(58.3%)	
	No	47(68.1%)	22(31.9%)	
Physical Activity				0.008
	More when the spread of COVID-19 is severe	59(61.5%)	37(38.5%)	
	More when the spread of COVID-	28(40.6%)	41(59.4%)	

	19 is less severe			

Discussion

Principal findings

Our results confirmed the relatively low penetration of digital health use among university students who were participating in online education during the COVID-19 epidemic, with a mere one-half of all participants (78/165, 47.3%) using digital health in the previous month. This is in line with the recent surveys on the general population showing that young adults represent the highest consumers of mHealth or eHealth, ranging from 30% to 60% of the overall interviewed populations [13]. For the remaining one-half, the main reasons for not using digital health could be multiple, including concerns about negative health impact, fatigue, and anxiety resulting from continuous use of digital technologies to access online education, electromagnetic waves emission, privacy risks, and the operating costs. One or several of these factors might be attributable to the low use of digital health. A few studies have been conducted in college students, focusing on the views and experiences on health behavior change [14], and fitness apps at non-emergent situations [15]. However, survey metrics about the use of digital health and health responses in university settings worldwide during the COVID-19 are scarcely documented. Results from our survey reinforce previous studies concerning students' characteristics of digital health use. These findings can be interpreted in that future effective and successful digital health interventions should account for factors that are specific to the contexts and could be time-sensitive. Future research should monitor the dynamics and duration of such digital health use to assist a better understanding of the long-term effectiveness of health interventions.

Without other confounders, prolonged use of digital-based distance learning

itself can incur mental health issues such as boredom, nervousness, and tension for students [23]. Further, due to the widespread COVID-19, the closure of schools can cause anxiety for university students and some might even suffer the problem of severe distress [24]. Online education is considerably different from traditional face-to-face learning settings because of using diverse tools of digital technologies and the way of interactions between teachers and students [25]. Without direct and close interactions between students and instructors, online learning is not effective. Students are at high risk to develop anxiety or even suicidality in severe cases during the COVID-19 outbreak [26]. COVID-19 outbreak has caused a significant psychosocial impact on adolescents and young adults. Findings of current levels of anxiety and depression highlight the need to address emotional distress for this population during the epidemic [27]. Research finds that around 70% of learners were involved in e-learning, most of whom used mobiles, computers, or tablets for attending online classes. Students were facing a variety of problems related to depression and anxiety, poor internet connectivity, and unfavorable study environment at local sites [28]. Almost 600 million learners are affected globally due to the closure of educational institutions. The outbreak of COVID-19 results in the widespread use of digital technologies in the higher education system through online lectures, teleconferencing, digital open books, online examination, and interactions via virtual environments. Concerns regarding COVID-19 was positively correlated with the occurrence of somatic and psychiatric symptoms. These symptoms were more likely among university students expressing greater concerns regarding the threat to health posed by COVID-19, and the efficacy of prevention, treatment, and control measures [29]. The behaviors of university students changed substantially since the COVID-19 outbreak established, leading to increased risks of isolation from their social and academic communities, and potentially all domains of their lives were affected. It was found that many students were stressed owing to COVID-19, hence, it is of essence to surveil the mental health sequelae of COVID-19 for this cohort both in the short-term and in the long-term [29,30]. Prior research has found that more than one-third of the surveyed students agreed with being confronted with COVID-19-related anxiety. Participants were concerned about COVID-19's health implications for their families and the communities, as well as educational implications for themselves [30]. Increased digital screen time was found to be correlated with myopia issues and could potentially be aggravated during and beyond the COVID-19 pandemic. While school closures may be intermittent, increased dependence on digital devices could have a long-term negative influence on the development of students [31]. This has potentially changed the routine leaning habits of students and pushed them to online services, and the way of releasing accumulated pressure and distress. Digital technologies, combined with commitments and expertise by health providers worldwide, could be used to generate an unprecedented digital health surveillance network to identify the next pandemic and resurgences of existing contagious diseases. Mobility data collected through the use of digital devices and apps reported have been a vital input into the efforts to track the drivers of the pandemic in plenty of countries [32]. The increased availability and use of digital technology during the pandemic has also enabled public authorities and private investors to develop critical COVID-19 tracking systems, where smartphone apps and digital

technologies have been exploited extensively to control the spread of the pathogen [33]. Given the lower use of mHealth or eHealth apps compared with the high concerns for health experiences and health perceptions, our results suggest that future digital health interventions should be based on integrating the latest outbreak information that is easily available to and attractive to young adults and can solve their mental health concerns. Contingent on these findings, future digital health interventions could address these topics to meet the urgent demands of health concerns for university students.

Proactive physical activity has been effective in the prevention and treatment of health issues [34,35]. However, our study implies the opposite trend compared with prior research, indicating a significant reduction of physical activity for the university students who have low use of digital health during the COVID–19 pandemic [34]. Reasons can be the concerns on being infected by COVID-19, mental pressure resulting from continued participation in online education, fatigue, and other potential confounders [36,37]. E-learning has been employed as the routine substitute of traditional education for university students during the COVID-19 epidemic, and significant associations between good mental health, low physical activity, and low use of digital health are observed. This provides meaningful insight that interventions of digital health should account for the specific conditions that students are facing in practice.

Limitations

First, the convenience sample recruited from one university and one major is a lack of diversity, and the studied environment might not be similar to other university settings. Hence, future studies can be extended to diverse populations and different settings for generalizability. Second, the number of individuals with severely bad mental health is relatively low, hence it requests caveat when applied in the empirical explanation. Third, the methodology used in the online survey may represent an implicit limitation, as questionnaires requesting the use of either digital technologies were disseminated to the participants during the progression of online education. This might complicate the mental health of the students although we accounted for the factors that impact the students to complete the survey within reasonable time slots. The study might still have introduced bias due to the increased use of digital devices or apps other than from e-learning. Attributable to this, participants might not have been completely at ease when answering the questionnaire. Fourth, our study hinges on data by a small cohort of university students

undergoing school closure, resulting in a sample of analysis in specific variable categories (e.g., concerns on health-related topics and self-reported mental health). This potentially has compromised the explanatory strength of our analysis and introduced a margin of disturbance concerning the associations. Future research including more widespread and representative participants would enhance the strength of findings by examining the duration and dynamics of digital health use for university students during a high-impact public health crisis. The definition of digital health use could also be extended or redefined in future studies by exploring a broader range of scenarios with the advancement in digital technologies.

Implications

Our analysis can provide meaningful insights for implementing digital health interventions in young university students during a public health crisis albeit the generalizability of the study was limited. First, we categorized the health-relative concerns for university students, suggesting new potential fields of interventions for digital health and digital technology. Second, we confirmed that university students used less digital health during the COVID-19 pandemic to keep up with good mental health, which was different from the findings in other studies concentrating on the scenarios of non-crisis cases. Third, our findings suggested that not only mental health but also health experiences and health perceptions of university students could be impacted remarkedly during the outbreak. Finally, the questionnaire we employed could be improved and applied in other academic settings to facilitate better effectiveness of digital health interventions. Conducting a survey to collect data on university students' experiences and perceptions with regards to digital health can provide initial evidence that can be used to guide general digital health strategy at university settings. Similar surveys, also combined with both in-depth quantitative and qualitative studies, would allow universities to obtain more insights on how to design customized and effective digital health interventions applicable for specific settings and how to disseminate these

resources according to heterogeneous scenarios with different students.

Conclusions

Although digital health is an important intervention contributing to enhance the mental health and health experiences of university students, to generalize its applicability to other scenarios multiple factors have to be taken into account. This is especially meaningful when students are disconnected from their conventional style of education, instead, the online education substitute using digital technology is employed as their routine way of learning. E-learning has changed the original viewpoints on digital technology captured by this young cohort. And the dynamics need to be closely observed yet tends to be neglected. We examined the scenarios of concurrent use of digital health, health experiences, and health perceptions of university students in China during the global COVID-19 public crisis. We aimed to provide meaningful insights into the development of future digital health interventions addressed to this specific population when public shocks emerge unpreparedly. With the widespread of internet and advancement of technologies such as 5G, artificial intelligence, and big data, digital health will definitely be redefined dynamically [38]. The interventions based on digital health will help university settings cope with public crises more effectively.

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Authors' Contributions

IN designed the study and questionnaire. WQZ analyzed the data and synthesized results. IN and WQZ drafted the manuscript and supervised the data analysis. All authors contributed to the final writing and submission of the manuscript.

Conflicts of Interest

None declared.

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Abbreviations

COVID-19: coronavirus disease

eHealth: electronic health

mHealth: mobile health

STAI: Spielberger State-Trait Anxiety Inventory

STAIS: Spielberger State-Trait Anxiety Inventory State

STAIS-5: short term of Spielberger State-Trait Anxiety Inventory State

STAIT: Spielberger State-Trait Anxiety Inventory Trait

STAIT-5: short term of Spielberger State-Trait Anxiety Inventory Trait